Techno-economic Analysis in the Development of Smart Sluice Gate Systems

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Abstract. The agricultural irrigation system is a water supply system in agriculture and one of the determining factors is the used sluice gate that needs developing. However, the development of technological tools or instruments requires further economic analysis in the form of a techno-economic analysis. The development of a smart sluice gate was carried out at the Pusat Inovasi Agroteknologi (PIAT) Universitas Gadjah Mada, Kalitirto, Berbah, Sleman, Yogyakarta. Furthermore, research has achieved many things that can affect the financial calculations of a project or activity, prices, taxes, and grants. Techno-economic calculations were made according to different investment criteria. Based on investments including NPV (Net Present Value), IRR (Internal Rate of Return), and BCR (Benefit Cost Ratio), to collect data using Input parameters from CAPEX and also OPEX, this techno-economic feasibility analysis was expected to be able to meet the Payback Period within 5 years.

Keywords: smart sluice gate, techno-economy, finance, NPV, IRR, BCR

1. Introduction

Most of the waters in Indonesia is still in a condition without the pressure of water shortage. Despite this, several river basins of Java fall in the category of absolute scarcity as there are scarcity and pressures. This causes conditions that are susceptible to water crises.

Water supply and water need management. Smart irrigation encourages automated/smart management of agricultural water supplies. As such, smart irrigation must apply water reliably based on pre-determined performance objectives and/or water use efficiency. To date, much of the effort in data-driven irrigation programming has focused on automatic irrigation control rather than accurate control [1]. Smart irrigation decision support systems should examine the water supply of crops promptly and establish the crucial relationship between irrigation processes and results. In other words, with successful smart irrigation, water applications can be programmed according to achieve performance goals and/or effective water use.

Applying intelligent systems based on artificial intelligence (AI) to agriculture will generate extraordinary digital innovations and have several advantages, such as increased efficiency, a reduced effect on the environment, and a reduction of occupational accidents. Smart systems in agriculture have been applied to various aspects, from seeding and planting to harvesting and post-harvesting, from spraying to managing livestock, and so on. The IoT monitoring system can be regarded as efficient for various parameters that affect plant growth and development. It is very important in the design of efficient irrigation control systems for increasing food production with a minimum of water loss.

A major objective of water management is to balance water demand and availability through appropriate water allocation arrangements. In general, within watersheds and sub-watersheds, there have been numerous conflicts related to water use, including irrigation, domestic use in urban areas, domestic use in rural areas, farming, livestock, as well as industrial and commercial uses.
One of the developments in modern irrigation has been an IoT-based irrigation system, such as a smart sluice gate system, an intelligent smart sluice gate in agriculture that should optimize water distribution and minimize water loss both in farming and nature. The assessor was used as an IoT component which was then connected in the microcontroller interconnection, then combined in the internet network so that it was able to work in real-time and be adjusted to needs in planning smart sluice gates. The type of sensor must be considered according to the desired needs in the smart sluice output.

Technologically using IoT-based technology by the use of Arduino (controller) combined with sensors that have been adapted to the needs of irrigation and plants in addition to the energy supply can be used photovoltaic as energy to produce electricity in automated irrigation.

However, the cost estimate is one of the constraints based on a study that does not include an economic study of smart sluice gate; therefore, this research will concentrate on economic calculations as the feasibility of a smart sluice gate project.

1.1. Formulation of the problem
The formulations of the problem in this study are:

1. Economic feasibility analysis using techno-economic computing methods on IoT-based smart sluice gates. Not much has been done so that an economic feasibility analysis needs to be done.
2. The obligation for a feasibility study using techno-economy specifically for sustainability in the development of smart sluice products.

1.2. Research objectives
The objectives of the feasibility analysis using techno-economics in the development of smart sluice gates are:

1. To provide the complete components of each CAPEX and OPEX instruments in techno-economic analysis on the development of smart sluice gate.
2. To conduct a feasibility analysis of the smart sluice gate using techno-economic calculations (NPV, IRR, PBP, and BCR) of the smart sluice gate.

2. Techno-economy smart sluice gate
The feasibility of a product can be carried out through economic analysis as an activity or a project based on a cash flow comparison between the results of gross sales and the total costs expressed in present value as the eligibility or profit criteria.

A project. Various factors can affect the financial calculation of a project or activity, including (1) prices; (2) taxes; and (3) subsidies. As far as the assessment of the financial feasibility of a project is concerned, it may be determined based on various investment criteria depending on the investment, among others, the NPV (net present value), the IRR (internal rate of return), and the BCR (cost-benefit relationship).

The CAPEX and OPEX parameters serve as parameters for a project's economic calculation. Capital expenditures are some financial expenditures made by management for a variety of purposes such as goods, factories, and equipment [2]. Economic calculations have been made using the CAPEX parameter instrument in the original capital issued [3].

In the interim, operating expenditures are generally incurred to meet operational needs. Input parameters of Operating Expenditure are operator payroll, operation, and maintenance, energy costs, annual capital costs (raw materials, marketing, administration), and revenue. Research carried out by Mytilinou V and Kolios A J (2019) [4] made use of OPEX parameters, including operation and maintenance costs.
3. Research method

The latest sustainability model is no longer a pillar (seeing the economy, social, and environment separately) or a triple bottom line (seeing an intersection between the three), but a nested model (looking at the relationship of the three comprehensively: the economy is part of the social, and the social part is of the environment). It means that sustainability sees that there are no distinct objectives, much less contradictory aspects of sustainability. This article is a continuation of the research on the sustainability of smart sluice gate development in the economic viability as part of sustainability that has previously investigated the social and environmental sustainability of smart sluice gate products.

This study assesses several CAPEX and OPEX instruments. CAPEX is an expense to add asset value and is not always in budgeting, while OPEX is an expense to maintain asset sustainability and is regular so that it is always in the budgeting. Techno-economic instruments can be seen in Table 1 as follows:

Table 1. Smart Sluice Techno-economic Instruments

| No. | Parameter | Output Indicator |
|-----|-----------|------------------|
| 1   | CAPEX     | NPV, IRR, PBP, and BCR |
|     | 1. The depreciable total cost of investment, | |
|     | 2. Product manufacturing costs | |
| 2   | OPEX     | |
|     | 1. Operator payroll, | |
|     | 2. Operations and maintenance, | |
|     | 3. Energy Installation Costs | |
|     | 4. Annual capital costs (raw materials, marketing, administration) | |

Several factors can affect the financial calculation of a project or activity, such as (1) price and (2) tax. As far as assessing the financial feasibility of a project is concerned, it may be identified in different investment criteria, according to the investments, such as NPV (Net Present Value), IRR (Internal Rate of Return) with an assumed discount rate of 12%, PBP (Pay Back Period), and BCR (B/C Ratio)

3.1. Calculation of the NPV

One aspect of the techno-economic calculations is the calculation of the NPV. It can be done by the following formula:

\[
NPV = (C1 / 1 + r) + (C2 / (1 + r)^2) + (C3 / (1 + r)^3) + \ldots + (Ct / (1 + r)^t) - C0
\]  

(1)

With a description

- NPV = Net Present Value (in IDR)
- Ct = Cash Flow per Year in Period t
- C0 = Initial investment value in year 0 (in IDR)
- r = Interest rate or discount rate (in \%)

The calculation of the NPV value obtained can be made by the following decisions:

- NPV > 0, feasible or can provide benefits
- NPV < 0, was not feasible or gives a loss
3.2. Determination of the IRR
IRR is the value of the rate of return on investment when the discount rate is equal to 0, which means that the rate of return and risk of the total investment at this time is the same as the rate of return and risk from the market [5]. The IRR is calculated as follows:

\[ IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} (i_2 - i_1) \]  

With a description:
- \( i_1 \) = Discount rate that produces NPV +
- \( i_2 \) = Discount Rate that produces NPV-
- NPV1 = Net Present Value was positive
- NPV2 = Net Present Value was negative

The calculation of the IRR value obtained can be taken as follows:
- If IRR > i, meaning the investment was worth making
- If IRR = i, meaning that the investment breaks even
- If IRR < i, meaning that the investment was not worth making

3.3. Computation of the PBP
The PBP corresponds to all the investment costs that will be reimbursed within a few years following the creation of the business or the time needed to recover the capital or investment that has been invested. The PBP can be computed by using the following formula:

\[ PBP = \frac{Investment Costs}{Annual Profit} \times Period of Effort \]  

3.4. Determination of the BCR
The BCR is calculated to determine how much the project will receive net profit for each net expenditure IDR. The BCR will describe the benefits and feasibility of implementation where it has > 1. Meanwhile, if BCR = 1, the project is neither profitable nor wasteful (marginal or poor), it is therefore up to the evaluator to implement the decision. If the BCR is < 1, the business is harmful, then it is preferable not to do so. The BCR methodology indicates that a project must be accepted if the BCR value is greater than 1 [6]; [7]; [8]; [9]; [10]. The BCR can be calculated by using the formula:

\[ BCR = \frac{Total Income}{Investment Costs + Total Production Costs} \]  

With the condition that BCR > 1, the business is declared feasible and viable.

4. Result and discussion
4.1. Investment and operational requirements for the development of smart sluice gates
The budgeting of costs incurred and benefits received was performed based on the unit price using the CAPEX and OPEX instruments on the basis of literature. The investment flow consists of two types of
investment, namely investment in making smart sluice devices based on IoT and investment in the development of corn farming. The amount of investment is determined according to the acreage of irrigated land. The cost of capital has been important in determining economic feasibility, which includes the cost of capital [11].

Investments in tools manufacturing are made once during the life of the project because this investment is also determined by the technical life of the IoT-based smart sluice gate, which is 5 years. The first investment was made during the project's 0 years, while the investment in commodities was only made once in the 0-year project.

Annual operating costs for operating the equipment have been incurred. The value of this cost is derived from the IDR expended on the cost of maintaining the assets and labour it used. In the interim, the operational costs of plant maintenance have been calculated from annual fertilizer, pest control, and labour requirements.

The assumption of this research is the investment flow of the smart sluice gate project from the income of agriculture over the life of the project, which is 5 years.

| Capital Expenditure (CAPEX) |
|-----------------------------|
| Total Expenditure for Sluice Tools | IDR 10.685.000 |
| Expenditure for Consumables | IDR 3.955.000 |
| Installation, 5% Tools | IDR 259.250 |
| Total Equipment Capital | IDR 15.174.250 |
| Total Cost of Plant Capital 4 ha | IDR 11.980.000 |
| TOTAL CAPEX | IDR 27.154.250 |

The cost investment for the CAPEX instrument is in the form of total expenditure for sluice equipment, expenditure for consumables, equipment installation, and a total cost of plant capital covering an area of 4 ha. The total capital cost for plant capital covering an area of 4 hectares is totalled based on the need for plant capital of 1 hectare then multiplied for the need. Four ha of the corn crop and the expenditure for consumables have been calculated by the requirements in 1 year of production, therefore the purchase is not made for the production of smart sluice gate units. The parameter instrument was carried out based on the initial investment or the main capital expenditure at the start of the planning of the smart sluice gate project. The total capital expenditure according to Table 2 is IDR 27.154.250.

Regards OPEX costs in the development needs of the smart sluice gate, these are shown in Table 3.

| Operational Expenditure (OPEX) |
|-------------------------------|
| Total Energy Installation | IDR 1.895.000 |
| Total Travel Expenses | IDR 2.000.000 |
| Total Needs of Sluice Tools | IDR 1.920.500 |
| Total AC Motor Installation | IDR 6.600.500 |
| Total Honorarium Spending | IDR 4.000.000 |
| Maintenance Fee, 5% CAPEX | IDR 1.068.963 |
Based on the OPEX cost components, the parameters calculated as OPEX parameters are total energy installations, total travel costs, total sluice equipment requirements, total AC motor installations, total honorarium spending, OPEX maintenance costs, and total operational agricultural needs with an area of 4 ha. The total operating requirement for agriculture with a 4 ha area of components is calculated based on the need for 1 ha of corn agricultural field and then multiplied by the 4 ha area of needs for corn crops. Investments and operating agriculture expenses are calculated according to the needs of the crop up to the harvest period. Total operating expenses are IDR 29,493,213.

The total cost of the initial investment in the smart sluice gate project is shown in Table 4.

### Table 4. Total Initial Investment

| Total Initial Investment |  |
|--------------------------|--|
| **CAPEX + OPEX**         |  |
| **CAPEX**                | IDR 27,154,250 |
| **OPEX**                 | IDR 29,493,213 |
| **TOTAL**                | IDR 56,647,463 |

The overall cost of investing in the IoT-based smart sluice gate project is 56,647,463 IDR. The total investment cost is realized by summing the costs for the CAPEX and OPEX instruments.

### Table 5. Sales calculation

| Sales                                      |
|--------------------------------------------|
| **Smart Sluice Installation**              |
| Production capacity with an area of 6.93 ha| 5 units |
| Production capacity in 1 year              | 120 units/year |
| Production price                           | IDR 20,506,214 |
| Annual Total                               | IDR 2,460,745,650 |
| **TOTAL SALES**                            | IDR 2,460,745,650 |

The ability to produce smart sluice gates in 6.93 ha requires 5 sluice gate units. As a result, the total cost of selling the smart sluice gate installation in 1 year is IDR 2,460,745,650 assuming that up to 120 smart sluice gate units can be installed over one year.

### Table 6. Cash Flow in the Smart Watergate Project

| Cash Flow                                      |
|-----------------------------------------------|
| **TOTAL SALES**                               | IDR 2,460,745,650 |
| **TOTAL OPEX**                                | IDR 29,493,213 |
| Depreciation, 5% Capex                        | IDR 1,357,713 |
| Gross profit                                  | IDR 2,429,894,725 |
Based on the calculations carried out to get cash flow on the smart sluice project, gross profit is obtained from total sales, subtracted by total OPEX and minus CAPEX depreciation by 5%, then gross profit can be obtained and the results of the calculation of gross profit times with tax costs of 10% to obtain Cash flow on the smart sluice gate project. According to Table 6, the cash flow is performed to determine the cash flow from the smart sluice gate project so that the cash flow can be recorded and estimated for the sustainability of the smart sluice project.

### 4.2. Economic feasibility in developing smart gates

| Table 7. Techno-economic Analysis |
|-----------------------------------|
| **Techno-Economic Calculations**  |
| NPV  | IDR 7,826,656,549 |
| IRR  | 54% |
| PBP  | 0.13 |
| BCR  | 38.61 |

The techno-economic calculations are carried out with a discount rate of 12%, and then the value of the NPV over the 5-year project period is IDR 7,826,656,549, so the NPV > 0 is achievable or can provide benefits. The IRR is calculated based on the research method formula and the value is 54% in the IoT-based smart sluice gate project. If the IRR were the same as the existing commercial interest rate, the project would be equal, but if it were larger, it meant that the project is profitable. IRR calculation formula [12]; [13]. The obtained calculation of the IRR value can be taken as IRR > i. In other words, the investment is feasible.

The estimated payback period is obtained at the project age of 1 month and 3 days, so the return on investment funds can be said to have been returned rather quickly from the assumption of a 5-years project.

The benefit-cost ratio is the ratio of the present value benefit divided by the present value cost. The BCR outcome of a project is considered financially achievable if the value of the BCR has exceeded 1 [5]. BCR is declared achievable if BCR > 1, then the enterprise is declared doable and viable. In the results of the calculation, the BCR value is 38.61, which means that BCR > 1 is declared feasible and the project may proceed.

Based on the conditions encountered in the techno-economic calculation, namely the NPV, the IRR, and the BCR, it can be concluded that the smart sluice gate project is feasible.

### 5. Conclusion

Based on the results and discussions on research on the development of IoT-based smart sluice gates, it can be concluded that the total capital cost of an IoT-based smart sluice gate project is IDR 56,647,463. The development of a smart sluice system on corn commodities has an NPV value greater than 0, a BCR value greater than 1, and an IRR greater than 12% of interest rate so it is relatively feasible to implement. The estimated payback period is obtained at the age of 1 month 3 days for the project. The calculation value is BCR > 1 so that the project is declared feasible and can be continued. Given the conditions encountered in the techno-economical calculations, namely NPV, IRR, and BCR, it can be concluded that the smart sluice
project is feasible. Further research is expected to conduct a comparison with the best and least expensive smart sluice gate development tools to obtain different feasibility values.

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