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Improved Performance of Toll Road Projects Based on System Dynamics Integrated Life Cycle Cost Analysis Green Retrofitting

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Abstract The increasing number of infrastructure development efforts, one of which is toll roads, of course has a coordinated impact on natural damage because it causes emissions, pollution, and environmental damage. Green road rankings can be an instrument for the degree of implementation of green infrastructure and the level of reforestation in toll road development efforts. Guidelines for green road ranking SE Minister of PUPR. Number: 04/SE/M/2018 is one of the efforts to encourage the implementation of sustainable construction in infrastructure implementation. Furthermore, these green road points can be implemented on existing toll roads and meet the sustainability criteria. This study aims in the innovation of Dynamic Model Implementation and Life Cycle Cost Analysis on Green Infrastructure-based Toll Road works which will result in Cost Efficiency and add value to Toll Roads. For data processing, we used SPSS (Statistical Package for the Social Sciences), a statistical analysis obtained from a questionnaire filled out by experts. From this process, we got the 10 best factors which are: 1. Authority to administer toll roads; 2. Reduction of air/dust pollution; 3. Greening; 4. Provision of access and public transportation facilities; 5. Recycle construction waste; 6. Renewable energy and application of innovation; 7. Renewable energy street lighting; 8. Modeling of dynamic systems; 9. Initial Retrofitting Costs; 10. Period of analysis. From the green retrofitting implementation scenarios, the optimistic scenario shows the highest rating score and the fastest return on investment in 3.92 years, with the toll road retrofitting cost of IDR 378,700,000,000.

Keywords Toll Road, Green Road, Retrofitting, System Dynamic, Life Cycle Cost Analysis

1. Introduction

Transportation infrastructure, such as roads and railroads, is an important factor capable of promoting modern economic growth, improving the health of citizens and strengthening national and inter-national social and cultural relationships. However, these development benefits are often detrimental to the environment, as interactions between transport infrastructure and the surrounding landscape are unavoidable, and likely to be negative [1]. The architecture, engineering, and construction (AEC) industry is frequently chastised for its negative environmental impact, which includes pollution, energy waste, and biodiversity loss [2].

The focus of the Indonesian government in paying attention to infrastructure was seen when it increased the infrastructure budget by 4.9 percent from IDR 399.7 trillion to IDR 419.2 trillion in the 2020 State Budget Plan (RAPBN). Infrastructure development in 2020 includes road construction, construction of bridges, construction of railway lines, and construction of airports. Of these sectors, road construction increased significantly in the 2020

RAPBN [3]. Based on the World Economic Forum's World Competitiveness Index (CGI) in 2019, Indonesia's infrastructure development status is 72nd out of 141 countries surveyed, 67.7 out of 100. In this survey, Indonesia is ranked in the top five ASEAN countries and Brunei Darussalam is ranked third [4]. In the Government Policy in the Implementation of Goods Transportation, which was submitted by the Director General of Highways in January 2021, it summarized the condition of the country of Indonesia compared to other ASEAN countries based on the report from the Global Competitiveness Index Report, 2010 - 2019. One of the parameters of road quality is how a road project still pays attention to environmental and sustainable conditions, namely Green Infrastructure.

As of January 2021, the toll roads that have been operating in Indonesia are 2,342.42 km and are targeted to reach 4,630.25 km in 2024 [5]. Of the existing toll roads, only 3 toll roads with a length of 60.18 km already have a Green Road Certificate, namely Gempol - Pandaan Toll Road with a Silver plus level of 13 km, Pandaan - Malang Toll Road with a four-star level along 34.48 km and Bali - Mandara Toll Road is 12.7 km long. This study is the first study that utilizes Green Retrofitting and System Dynamics based on Life Cycle Cost Analysis which is expected to optimize the performance of retrofitting costs on existing toll roads.

2. Literature Review

In this study, it uses literature related to Green Infrastructure, Life Cycle Cost Analysis and System Dynamics.

2.1. Green Infrastructure

Intelligent Transport Systems represents a scientific and technological field that means integrating the latest information and communication technology into transportation infrastructure and vehicles [6]. As a result, smart solutions, one of which has proven to be green infrastructure, have applications in this area. Green infrastructure (GI) refers to natural or semi-natural areas that have been meticulously managed to minimize development's environmental impact while still providing ecosystem services such as habitat, new, flood control, lower temperatures, and better air and water quality. Cities use green infrastructure (GIs) such as public parks and green spaces to reduce the loss of intact natural habitats, reduce urban heat islands, and improve biodiversity and species mobility transfer. GI could aid in the preservation and restoration of ecosystems by teaching developers how to balance infrastructure and protect animal habitat [1]. Other benefits of Green Infrastructure (GI) include water management and regulation [7], climate change mitigation, and improvement of community health and welfare [8].

Investments in infrastructure reduce the country's growth barriers, and contribute to meeting urbanization needs and meeting development, inclusion, and environmental goals. A green infrastructure framework encourages the creation of a dynamic urban growth vision. Connected high-quality green areas in urban areas provide habitats and corridors that improve quality of life, support the green economy, contribute to biodiversity conservation, and provide ecosystem services [9]. Sustainable road development, in addition to satisfying the demands of the environment and natural resources, provides community transportation alternatives such as access (not just mobility), movement of people and products (not just cars), and safety. Social concerns such as security should be focused on. Convenient routes for walking, cycling and transit" (FHWA, 2016). The declining revitalization of American green infrastructure is having a major impact on the city's economy. Researchers at the University of Florida and the University of Tennessee have discovered that the new tree infrastructure can increase the value of real estate in cities by 3-7% in huge numbers and by 5% perceived to 11% [10]. Toll road retrofitting plans are designed to help construction projects run on budget. This study is the first study to improve retrofitting performance costs using retrofitting and system dynamics based on lifecycle cost analysis. Greenroads is a collection of sustainable best practices for designing and building roads. For each road project, including planning, design, construction, operations, and maintenance, the Project Requirements (PRs) are meant to capture some of the most important sustainability concepts, such as: Making decisions that are both environmentally and economically responsible, public participation, designing for long-term environmental performance, planning for construction, and preparing for lifetime monitoring and maintenance [11]. Green Road as part of green infrastructure certainly requires additional costs to make it happen. However, improving the quality of the toll road as a Green Road will certainly make its life cycle better and this can be reviewed with a Life Cycle Cost Analysis to find out how it is financed. Generally, a high-cost increase appears in the post of green infrastructure project design costs which can reach 5% higher than conventional project designs [12]. In addition to design costs, setup-related costs including management costs, human resources, ratings, and even commissioning eligibility costs such as green ratings also have the potential to arise. These costs are at least influenced by several things, sector regulations, lender requirements (including the fulfillment of environmental & social management framework/ESMF aspects), and the availability of experts [3].

Table 1. Green Road Indonesian Category

Category		Criteria	Points
Water, Air and Nature Environmental Conservation	01	Environmental Awareness Training	2.67
	02	Disaster mitigation	4.20
	03	Reduction of air/dust pollution	1.98
	04	Environmental Management System Certificate	1.98
	05	Greening	3.96
	06	Protection and avoidance of habitat loss	3.03
	07	Provision of road drainage system	5.64
	08	Street lighting restrictions	1.26
	09	Noise reduction	1.96
Transportation and Society	10	Arrangement of ornaments and street landscape	0.97
	11	Provision of stop facilities	0.78
	12	Provision of access and facilities for public transport users	2.69
	13	Geometric design and road equipment facilities	2.42
	14	Conduct road safety audit	1.71
	15	Provision of pedestrian access and facilities	2.50
	16	Community participation in planning	0.93
	17	Provision of access and facilities for cyclists	1.73
Construction Implementation Activities	18	Use of recycled materials	2.30
	19	Use of construction methods or equipment	2.30
	20	Water usage monitoring/recording	2.28
	21	Use of construction equipment that meets the threshold	2.10
	22	Use of fossil fuels	1.99
	23	Implementation of the coordination of the design team and construction implementers	1.93
	24	Contractor has SMM certificate	1.72
	25	Construction implementation quality assurance	1.64
	26	Use of renewable energy and application of innovation	2.06
	27	Prepare investment documents	0.98
Materials and natural resources	28	Use of demolition materials	5.64
	29	Reuse of demolition materials	4.68
	30	Use of local materials	3.60
	31	Minimum use of 90% excavated soil material	2.77
	32	Use of demolition materials	1.71
	33	Street lighting using renewable energy	1.69
Pavement Construction	34	Pavement Planning Age Planning	5.88
	35	Use of cold mix for flexible pavement	4.04
	36	Use of porous pavement	3.94
	37	Designing a noise-reducing pavement surface	3.29
	38	Designing warm asphalt mix	3.05
Total Points			**100.00**

Green roads contribute to the sustainability of the highway system because their objects and criteria can enhance “natural laws” and “human values”. The purpose of nature is to protect and improve the quality of ecosystems and the environment as well as resource efficiency, while the purpose of humans is to improve the quality of social life or benefits without energy. Performance indicators or categories can be measured from energy efficiency, ecological protection, and environmental quality within the scope of natural law, while the performance of human values consists of accessibility, safety and mobility, and economy. Several nations throughout the world have implemented a green road score system, such as the inclusion of Green LESES in New York and Green Roads in Washington in the United States, as well as financing from the Sustainability National Roads Administration (SUNRA) in the United Kingdom [13]. The Australian Infrastructure Sustainability Council developed a technical infrastructure sustainability assessment system to assess the level of sustainability of existing and new infrastructure by including roads and highways. South Korea is another country that has adopted sustainable road building technology and tactics. To combat environmental issues such as climate change and global warming, the South Korean government has adopted the Korea Carbon Green Growth Policy [14]. The green rating tool may be used to assess the performance of indicators in establishing the amount of greenery, as well as to assess sustainable practices and stimulate decision making in the road building business. According to previous studies, adopting green construction on highway projects involves several problems connected to materials, equipment, regulations and standards, financial, regulatory, and cultural concerns [15]. The Presidential Regulation of the Republic of Indonesia No. 61 of 2011 on the National Action Plan for Reducing Greenhouse Gas Emissions was issued in order to reach the 2020 GHG emission reduction objective [16]. Furthermore, the Ministry of Public Works in Indonesia has integrated green practices into the road construction industry by enacting relevant laws and regulations under Law Number 13/PRT/M/2015.

Green roads in Indonesia are voluntary evaluations of road construction that seek to apply green criteria at the design and construction stages to achieve road sustainability. The development of green road criteria was adopted from international sustainable rating tools, such as Green Road, INVEST and ILAST which focus on project development on design and construction. The focus in Indonesia's Green Toll Road covers five indicators, including: energy and water efficiency, Transportation and Society, environment, regional cooperation, materials, and construction shown in Table 1.

These indicators have objectives as stated in the Sustainable Development Goals (SDGs). United Nations. Meanwhile, the green road rating is carried out at the design and construction implementation stages of a road project. The road ranking is based on the SE Minister of PUPR. Number: 04/SE/M/2018. Date: March 23, 2018, there are 4 levels as shown in Table 2.

Table 2. Green Road Rating in Indonesia

Rating	Value Rating Green
★★★★	The value of implementing the green road ≥45
★★★	The value of implementing the green road 20,01-44,59
★★	The value of implementing the green road ≤20
★	Roads that have met road technical requirements, have Life Cycle Cost analysis, and environmental documents

2.2. Life Cycle Cost Analysis

Efforts have been undertaken over the last decade to assess the environmental impact of building projects using the LCCA technique. LCCA is an analytical method for determining the environmental impact of product systems (ISO 2006). The life cycle cost analysis (LCCA) technique is used to calculate the expenses associated with each phase of the life cycle of a building. ASTM E917 - 15 (ASTM 2015) and ISO 2000) are two commonly used standards for LCCA development. Both standards advocate for the incorporation of four life cycle phases: construction, operation, maintenance, and displacement. The results of the LCC calculation will show a more cost-effective alternative, not the total estimated cost during the construction period [17].

Many parties are involved in a building's life cycle, from construction through destruction. While building tenants and owners are concerned about energy and maintenance expenses throughout the operating phase, builders and investors are concerned about the original investment (construction costs). The life cycle cost analysis (LCCA) method was used to examine the costs associated with each phase of the building's life cycle and provide clarity on how costs are distributed among stakeholders. Given the many facets of sustainable development and the need to maximize benefits in relation to resources spent, LCCAs have the potential to make a significant contribution to building sustainability [18].

For building owners, the initial cost of a retrofitting project is critical. Life Cycle Cost considers all costs associated with a retrofitting project. Depending on the circumstances, higher-cost retrofitting packages may result in better LCC performance due to higher cost savings. Road retrofitting such as sewer replacement or road redevelopment in existing urban areas can provide good opportunities to apply low impact development (LID) technologies [19]. Retrofitting existing is usually more expensive than integrating in new construction. The cost of upgrading conventional infrastructure to Green Infrastructure ranges from 14-27% of the initial cost [20].

LCCA is a technical and economic optimization method

whose primary purpose is to identify and select the solution with the lowest life cycle cost, that is, the lowest life cycle cost [21]. The initial cost of a retrofitting project is an important consideration for building owners. Life Cycle Cost takes into account all cost elements associated with retrofitting projects. Depending on the circumstances, retrofitting packages with a higher initial cost may result in better LCCA performance due to higher cost savings.

Life cycle cost analysis (LCCA) is generally considered a method of financial evaluation for existing assets or potential investments. LCCA considers both immediate and long-term expenses. LCC is "the cost of an asset or its parts over its life cycle while meeting performance requirements". From an environmental perspective, a combined gray and green system can result in a higher environmental impact than a gray system in the construction phase. From an economic perspective, the economic benefits resulting from the gray and green paired system operation stage can make the total payback time of the economic costs within 4.0 years. The external economic costs and benefits of combined gray and green systems exert a high influence on the analysis of the total economic costs and benefits, especially for the costs and benefits of ecological restoration [22].

2.3. System Dynamics

System Dynamics (SD) was developed by Forrester in 1956, and since then Industrial Dynamics [Forrester, 1961], Urban Dynamics [Forrester, 1968], World Dynamics [Forrester, 1971] and others have been developed. Correlations can be determined using systems dynamics. Its primary goal is to analyse system feedback and create mathematical models of dynamic reciprocal relationships.

The Dynamic Model Simulation is organized according to the principles:

1) cause-effect (cause-effect),
2) feedback (feedback),
3) delay (delay).

A complete and comprehensive simulation must use these three principles to produce system behaviour that is close to the real world. The Dynamic Model views that a system has a closed loop, and the basic concept of the Dynamic Model is about feedback, so that every variable in the system can have two roles, namely as a cause and as a result. In a closed system, changes in a variable can affect changes in the entire system environment, including the variables themselves.

To illustrate a feedback concept on the structure of the system, the Dynamic Model is known as causal loop diagrams. Causal loop diagrams are excellent for [23]:

1) Capturing quickly a hypothesis about the causes of dynamics.
2) Generating and capturing individual or group mental models.
3) Communication of critical feedback that is believed to be responsible for a problem.

The current index evaluation method using the SD method is applicable to more complex systems and the system can be easily modified and extended [24]. The manufacture, construction, use and maintenance, repair and renewal, dismantling, recycling, and disposal of a product or assembly are all parts of its life cycle. Figure 1 depicts a method for assessing residential LCE and LCCO2 using System Dynamics, which is a technique used to comprehend how all objects in the system interact.

In a previous study, [25] researched on life cycle cost analysis which was integrated with dynamic systems in power grid projects. Regarding the research's impact on the calculation of operation and maintenance costs, it will be approached from four perspectives: material costs, repair costs, employee compensation, and other costs, with the goal of making comparisons before and after changes, such as the impact of accounting for operating and maintenance costs after electricity reform, stock changes, and the resulting increase. The model proposed in this document can simulate long-term behavior and cost changes over the course of a grid project's life cycle. To achieve this goal more precisely, the dynamic causality of LCCs was investigated first. Then, for each stage of the life cycle, we looked at costing models, including modeling ideas and variable selection. LCC costing is categorized into three modules: initial investment, operations and maintenance, and recycling or disposal and treatment of waste. The science of the SD technique examines the composition and operation of system feedback. To manage intricate and dynamic nonlinear systems, it is frequently employed in the social and economic sciences. To evaluate national-level sustainable development in terms of energy, society, and the environment, some academics in China are employing SD models. The SD technique is an established scenario analysis methodology in the macro study of sustainable development at the regional level [26].

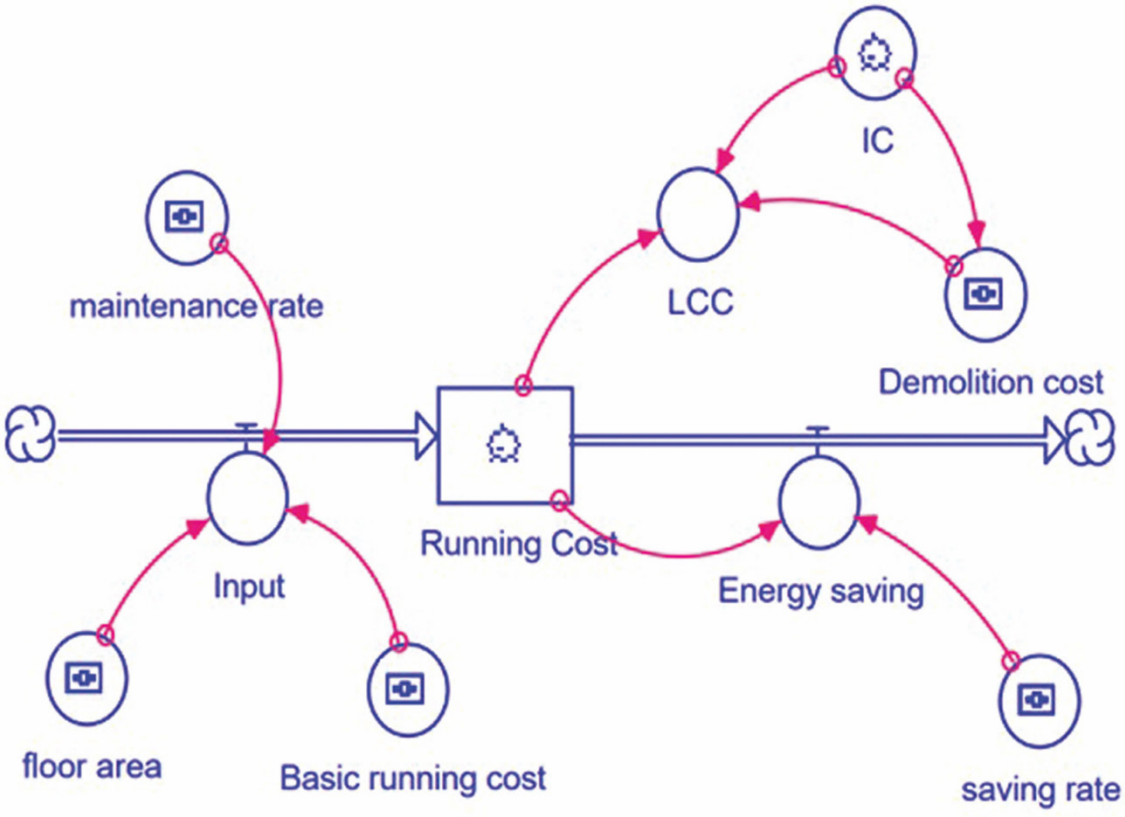

Figure 1. Life Cycle Cost Analysis – System Dynamics Model. source: [24]

3. Methodology

This section discusses the method used in this research by analyzing the implementation of Retrofitting and System Dynamics based on Life Cycle Cost Analysis, as well as their impact on increasing the cost performance of retrofitting toll road projects. This section also discusses the methodology for identifying the critical success factors affecting the successful implementation of retrofitting and system dynamics based on life cycle cost analysis in toll roads retrofitting cost performance.

This study was constructed using a combination of two research methods: quantitative experimental method and qualitative method combined with statistical analysis. The quantitative empirical method is carried out by simulating the implementation of Retrofit and System Dynamics using the Lifecycle Cost method. Analysis about study is a case study of the implementation object of study, based on performance procedures obtained from literature studies. A system dynamics model was used to capture dynamic pollutant retention/discharge during the use phase of seven different Green Infrastructure types in research on water infrastructure installed at the University of New Hampshire. After that, the system dynamics model is integrated into the LCA framework to perform dynamic assessments of Green Infrastructure performance under various geographic locations, land uses, system sizes, and climate change scenarios [27]. Research for New Zealand's urban areas introduces research in sustainable urban development, with a focus on urban water systems, using a systems dynamics methodology. Systems dynamics models have been proven useful for modeling complex problems and have been shown to yield new insights into urban systems management and policy evaluation [28]. System dynamics has been used to the water distribution system and waste water collection in the cities of Waterloo and Niagara Falls. A decision support tool (15) for integrated asset management of water distribution and wastewater collection systems was created using system dynamics modeling. This work offers a thorough and generalizable strategy to analyze and evaluate diverse Green Infrastructures under various geographical and temporal contexts using integrated system dynamics modeling and life cycle evaluation [29].

The qualitative method is applied by simulation tool in the form of SPSS (Statistical Product and Service Solution) analysis based on the research tool [30]. This SPSS analysis took the form of a questionnaire distributed to selected respondents. With SPSS analysis, the most influential factors for the successful application of Retrofitting and System Dynamics based on Life Cycle Cost Analysis methods in improving toll road retrofitting cost performance.

3.1. Case Study

To provide an in-depth understanding of the application procedural steps followed by the retrofitting scheme and the proposed dynamic system based on life cycle cost analysis, a case study has been conducted using data from toll roads already operating in Medan, Indonesia. Toll road retrofitting is based on the Indonesian Green Road Rating Guidelines, SE Minister of PUPR. Number.: 04/SE/M/2018. Date: March 23rd, 2018. The following toll road study case data can be seen in below Table 3.

Table 3. Data of case study

Data	Explanation
Project Name	Medan - Binjai Toll Road
Location	Medan, Indonesia
Length	16.72 kilometers
Number of sections	3 (three)
Concession period	40 years
Construction cost	IDR 2.4 trillion
Start operating	December 23rd, 2020

3.2. Data Analysis

This research uses two types of data: primary data and secondary data. Primary data were collected from questionnaires and focus group discussions, and secondary data were collected from prior studies, including books, journals, prior studies, and other relevant references related to this study. The questionnaire was distributed to both offline and online respondents. The success of a research questionnaire largely depends on its success in convincing respondents to participate. The following is the procedure for selecting respondents so that they are willing to participate in the research.

a. Respondents' data collection on companies or sectors related to Toll Road and Green Infrastructure.
b. Determine the criteria of respondents who will be asked to participate.
c. Determine the proportion of good respondents who will be asked to participate in terms of age, education, occupation, and experience.
d. Show respondents the importance of participating for them, as well as for their intended audience.
e. Maintain a smooth participation process; participants may feel reluctant to deal with annoying complexities.
f. Give incentives or souvenirs to participating respondents.

Primary data collection carried out in this study was carried out through several stages as follows:

a. The first stage is the construction validation stage as follows: before the questionnaires are distributed to respondents, expert/supervisor validation will be carried out first so that the distributed questionnaires can be understood by respondents and the data obtained is in accordance with the expected research objectives. At this stage, reductions or additions to existing sub-variables are also carried out based on the perceptions of these experts.

The selected experts are at least 3 practitioners who have competence in the field of Toll Roads and Green Infrastructure Roads with 5-10 years of experience.

b. The second stage is the Pilot Survey: at this stage the construction validation questionnaires are distributed to 5 prospective respondents to determine the respondents' level of understanding of the questions or statements in the questionnaire and the level of difficulty of the respondents in answering the questionnaire.
c. The third stage of data collection is done by distributing questionnaires to respondents who are sampled. Respondents who were selected as samples in this questionnaire survey consisting of individuals who were involved in similar projects from Owner, planning consultant, Project Coordinator, Project Manager, Quantity Surveyor Manager, Quantity Surveyor and Site Engineering Manager with more than 5 years' experience with undergraduate education.
d. In this fourth stage, expert validation is carried out on the results of data analysis obtained from the fourth stage. This is intended to ensure the results of the analysis that has been carried out.
e. After the complete data was collected, then a tabulation was made based on the Likert scale in the questionnaire. The simulation process uses the SPSS application for testing of Liner Regression with T-test, and F-test so that the equation for the effect of the independent variable on the dependent variable are found [31].

From the findings of the initial data, a discussion analysis was then carried out to conclude the key success factors of the Green Retrofit Toll Road Project, and then create scenarios and create a model concept by making a causal circle diagram can show causal relationships and interrelationships between variables and they can represent the identified system.

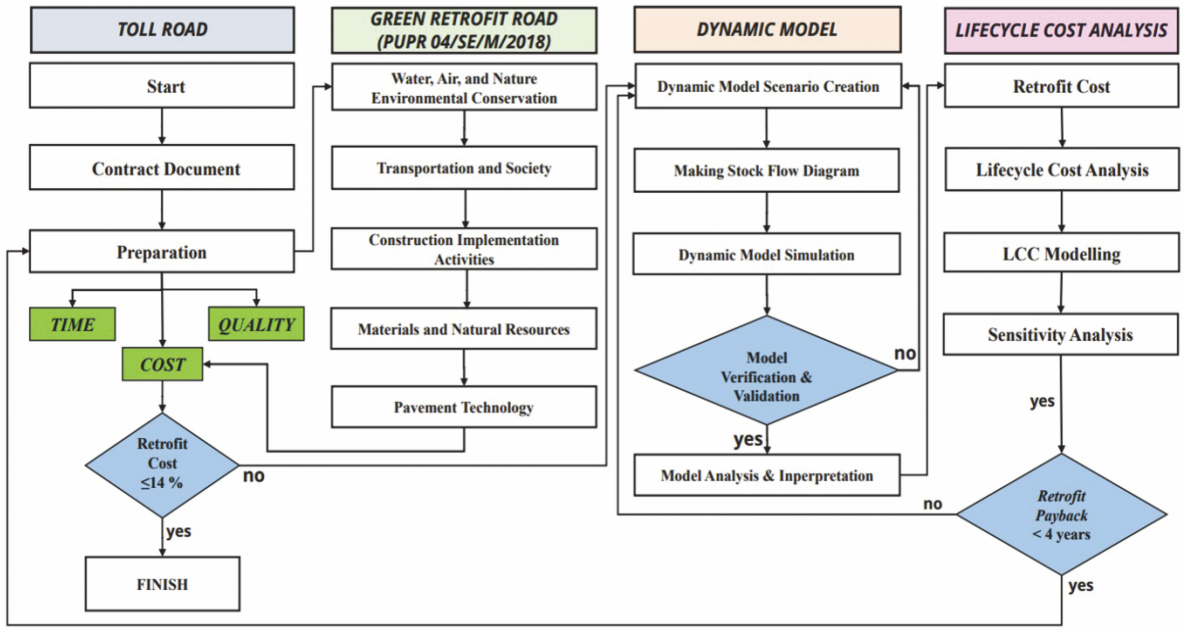

Figure 2. Research flow analysis 3.3. Linear Regression Analysis

Table 4. T -test

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.529	1.500		2.353	.022
Tol Road Existing	.172	.026	.601	3.901	.000
Green Infrastructure	.252	.012	.351	7.309	.000
Integrasi SD Dan LCC	.193	.191	.061	4.259	.037

The process of designing a causal loop diagram is an important step in the use of dynamic systems. This is because this step can significantly affect the results of dynamic system modeling. A causal loop diagram will explain how the system works. The causal loop diagram will show how the relationship between these variables works to form a system that can describe the relationship between toll road variables, Green Retrofitting Infrastructure, and lifecycle costs that affect cost performance on toll road projects and to obtain cost optimization and efficiency [27].

In an effort to evaluate the improvement in time and cost performance based on Green Retrofitting and System Dynamics combined with LCCA on the research object, the analysis is carried out in the same order as the implementation flow as shown in Figure 2 for this implementation flowchart.

3.3.1. Partial influence of variable X on Y (T test)

Regression models belong to statistical models that allow you to examine the intensities and dependencies between individual variables. As the basis for the decision from the t-test by comparison t_{count} with t_{table}.

- Variable X1 (Toll Road Existing) has a positive and significant impact on Y. This is indicated by sig. (X1) 0.006 < 0.05, coordinate values t_{table} = t(a/2; nk−1) = t(0.05/2; 61− 3−1) = t(0.025; 57), from table found t_{table} = 2.000; t_{count} = 5.309, value of t_{count} = 5.309 > 2.000, so that H0 is rejected and H1 is accepted.
- Variable X2 (Green Infrastructure) has a positive and significant impact on Y. This is indicated by sig. (X1) 0.006 < 0.05, coordinate values t_{table} = t(a/2; nk−1) = t(0.05/2; 61−3−1) = t(0.025;57), from table found t_{table} = 2.000; t_{count} = 5.309, value of t_{count} = 5.309 > 2.000, so that H0 is rejected and H2 is accepted.
- Variable X3 (Integrated SD LCC) has a positive and significant impact on Y. This is indicated by sig. (X1) 0.006 < 0.05, coordinate values t_{table} = t(a/2; nk−1) = t(0.05/2; 61−3−1) = t(0.025;57), from table found t_{table} = 2.000; t_{count} = 4.901, value of t_{count} = 4.901 > 2.000, so that H0 is rejected and H3 is accepted.

Substitute the numerical coefficients in column B into the equation: Y = 3.529 + 0.172X1 + 0.252X2 + 0.193X3

3.3.2. Simultaneous Effect of Variable X on Y (test F)

Table 5. F -test

Model	*Sum of Squares*	df	*Mean Square*	F	Sig.
Regression	418.647	3	139.549	55.793	.000[b]
Residual	142.567	57	2.501		
Total	561.213	60			

Basis for decision by comparing f_{table} and f_{count}:

- Variables X1, X2, X3 have a positive and significant impact on Y. This is indicated by Sig (F) 0.000 < 0.05
- Coordinate value f_{table} = f(k; nk) = t(3; 61-3) = t(3; 58)

See the table that $f_{table} = 2.75$; $f_{count} = 55.793$. Value $f_{count} = 55.793 > 2.58$, so that H0 is rejected, and Ha is accepted.

3.3.3. Mean and Ranking

From the Mean and Ranking, it is found that the 10 most influential factors in cost performance in the implementation of the Life Cycle Cost Analysis-Based Dynamic Model on Toll Road Retrofitting and they can be seen in Table 6.

Table 6. T -test

Rank		Sub Factor	Mean
1	X1_2	Authority to operate toll roads	4.98
2	X2_3	Reduction of air/dust pollution	4.93
3	X2_5	Reforestation	4.86
4	X3_12	Provision of access and public transportation facilities	4.77
5	X2_18	Use of recycled materials	4.73
6	X2_26	Renewable energy and application of innovation	4.72
7	X2_33	Renewable energy street lighting lamp	4.60
8	X3_1	System dynamic modeling	4.57
9	X3_8	Retrofitting initial cost	4.56
10	X3_13	Period Analysis	4.55

According to this study, the most significant element in toll road strengthening is toll road operation. It is critical to preserve and execute environmental sustainability because of increasing urbanization and the change, transformation, and fragmentation of human land across the world. Implementing retrofitting in the operation of this toll road comprises integrating funding, planning, construction, and operation into a single source, the concessionaire, which helps the accomplishment of an optimal project life-cycle cost. In this sense, one environmentally friendly approach has been discovered as a low-cost, nature-based infrastructure alternative for expanding infrastructure development.

The next step is to reduce air/dust pollution and to green the environment. Wang Chao-hui recommended in 2015 preserving resources, protecting the environment, and decreasing pollution as much as possible throughout the life cycle of the road, as well as offering an ecological urban road with a healthy, comfortable, and efficient usage environment [32]. Easy access from public roads and other highways, transit facilities, parking, construction style, close proximity to air and rail modes, peak traffic volume, and trip generation are just a few of the perks available to users of public transportation. Road construction costs, life cycle costs, and environmental impact may all be decreased by using recycled materials, which are practical, accessible, and cost-effective.

Recycled materials can be used in place of virgin resources in many types of roadway infrastructure (such as pavements, foundation materials, walls, etc.) without affecting the performance of the finished result. Last but not least, this lessens the need for the manufacture of virgin materials, including their extraction, processing, and manufacturing, which lowers associated costs, waste disposal, emissions, and energy use. Given that an important amount of the world's electricity is produced by unsustainable methods, decreased power consumption is a crucial goal in the pursuit of sustainable infrastructure. After construction, roadway lighting systems are generally responsible for the majority of the direct power consumption on roadways.

It is important to assess and monitor the application of environmental sustainability because of accelerating urbanization and global human land change, transformation, and fragmentation. Therefore, many approaches for sustainability-oriented framework conditions have been developed at the project and policy level, seeking to integrate these findings, considering social, economic, and ecological aspects' increase. An important issue in sustainability assessment is the need to identify science-based and policy-based indicators that contribute to sustainable development. In this regard, one of the environmentally friendly roads has been identified as an alternative to nature-based, low-cost infrastructure solutions to improve the sustainability of infrastructure development [32]. The Green Road is defined as an integrated network of natural and semi-natural areas and functions, providing multiple benefits to people and ecosystems.

4. Research Result

According to [23] the stage of developing a dynamic model begins with the definition of the problem (problem identification) posed by the creation of the dynamic model. The second step is to create an initial hypothesis (dynamics hypothesis) with the problems of the first step. The third stage is problem formulation (formulation). The fourth phase is the test phase with different combinations or

policy scenarios (tests). The fifth or final phase is to create and evaluate the best policy from the previous phase. The advantage of the dynamic model is that it has a feedback structure that is interrelated and leads to balance [33].

4.1. Model Conceptualization

The model is conceptualized by creating a causal loop diagram that shows the causal relationships and the interrelationships between the variables to represent the identified system. The process of designing a causal diagram is an important step in deploying a dynamic system. A causal loop diagram is a system that can describe how the relationships between these variables work to describe the relationships between toll road variables, green retrofit infrastructure, and life cycle costs that affect the cost performance of toll road projects, which indicates whether to form. The causal relationships between the variables contained in the initial or temporary causal loop diagram are obtained from the results of the previous discussion, namely the factors that have the greatest impact on the toll road project and the literature research conducted.

4.2. Causal Loop Diagram (CLD)

The Dynamic Model Simulation is organized according to the principles: 1. cause-effect (cause-effect), 2. feedback (feedback), and 3. delay (delay). A complete and comprehensive simulation must use these three principles to produce system behavior that is close to the real world. The Dynamic Model views that a system has a closed loop, and the basic concept of the Dynamic Model is about feedback, so that every variable in the system can have two roles, namely as a cause and as a result. In a closed system, changes in a variable can affect changes in the entire system environment, including the variables themselves. To illustrate a feedback concept on the structure of the system, the Dynamic Model is known as causal loop diagrams. Causal loop diagrams are excellent for [23]: 1. Capturing quickly a hypothesis about the causes of dynamics; 2. Generating and capturing individual or group mental models; 3. Communication of critical feedback that is believed to be responsible for a problem.

From the results of the most influential factors in the application of Green Retrofit on Toll Roads, a Causal Loop Diagram is then made which shows the causal relationship of these factors, which is shown in Figure 3.

4.3. Scenario

The scenario model aims to improve system performance to overcome existing problems. The type of scenario that is executed is an improvement scenario by adding multiple improvement scenarios. Figure 4 shows the main program formulation of the LCC integration in SD.

In this study, the scenario aims to determine the maximum acquisition of the Green Infrastructure rating from the retrofitting cost value and to determine the payback time with the discount rate scenario on the Toll Road project with the Green Infrastructure concept. Table 7, table 8 and table 9 show the input values in alternative scenarios, namely pessimistic scenario, moderate scenario and optimistic scenario on the implementation of Green Road on existing toll roads. From each scenario input value, it is entered into the LCC-integrated Dynamic System shown in Figure 4 to obtain the NPV and payback time for retrofitting costs.

Table 7. Input Value Pessimistic Scenario

Description of Toll Road sub-categories and criteria	**Score**	**Cost (IDR)**
1. Toll Road Settings		
Policy Basis - Traffic Management and Safety		3,000,000,000
2. Toll Road Concession		
Toll road operation - Mobilization		5,000,000,000
Environmental Handling		1,500,000,000
Quality management		500,000,000
Description of subcategories and criteria for Green Road	**Score**	**Cost**
1. KL, Water, Air and Nature Environmental Conservation Category		
KL-1 Environmental awareness training	2.67	2,400,000,000
KL-3 Reduction of air/dust pollution during construction/post construction	1.32	90,000,000
KL-4 Certificate of environmental management system and implementation	1.98	1,100,000,000
KL-5 Reforestation	1.32	450,000,000
KL-6 Protection and avoidance of habitat loss	0.3	40,000,000
KL-7 Provision of road drainage system	1.88	2,800,000,000
KL-9 Noise reduction	0.56	8,000,000,000
KL-1 Environmental awareness training	2.67	2,400,000,000
2. TM, Transportation and Society Category		
TM-1 Street ornament and landscaping	0.97	5,500,000,000
TM-3 Provision of access and facilities for public transport users	0.77	20,000,000,000
TM-5 Implementation of road safety audit by an independent party	0.57	500,000,000
TM-7 Involvement of community participation in planning	0.31	300,000,000
3. TM, AK Category, construction implementation activities		
Implementation of the coordination of the design team and construction implementers	1.93	600,000,000
Contractor has a certificate of quality management system (QMS)	1.72	500,000,000
4. MS Category of materials and natural resources		
Street lighting that uses renewable energy resources	1.69	70,200,000,000
Description of subcategories and criteria for Dynamic Model	**Score**	**Cost**
1. Model Usage		
Cost Simulation		250,000,000
Time Simulation		250,000,000
Model Objectivity		300,000,000
2. Making Stock Flow Diagrams		
Use of Dynamic Models		250,000,000
Key Person in Dynamic Model		500,000,000
3. Model Analysis and Interpretation		
Disclaimer by Stakeholders		200,000,000
Difficulty of Dynamic Model Application		200,000,000
Total Green Road Rating	**13.63**	**61,250,000,000**

Table 8. Input Value Moderate Scenario

Description of Toll Road sub-categories and criteria	**Score**	**Cost (IDR)**
1. Toll Road Settings		
Policy Basis - Traffic Management and Safety		3,000,000,000
2. Toll Road Concession		
Toll road operation - Mobilization		5,000,000,000
Environmental Handling		1,500,000,000
Quality management		500,000,000
Description of subcategories and criteria for Green Road	**Score**	**Cost**
1. KL, Water, Air and Nature Environmental Conservation Category		
KL-1 Environmental awareness training	2.67	2,400,000,000
KL-2 Flood mitigation from the environment	4.20	36,800,000,000
KL-3 Reduction of air/dust pollution during construction/post construction	1.32	90,000,000
KL-4 Certificate of environmental management system and implementation	1.98	1,100,000,000
KL-5 Reforestation	1.32	450,000,000
KL-6 Protection and avoidance of habitat loss	0.30	40,000,000
KL-7 Provision of road drainage system	1.88	2,800,000,000
KL-9 Noise reduction	0.56	8,000,000,000
2. TM, Transportation and Society Category		
TM-1 Street ornament and landscaping	0.97	5,500,000,000
TM-3 Provision of access and facilities for public transport users	0.77	20,000,000,000
TM-5 Implementation of road safety audit by an independent party	0.57	500,000,000
TM-7 Involvement of community participation in planning	0.31	300,000,000
3. TM, AK Category, construction implementation activities		
Implementation of the coordination of the design team and construction implementers	1.93	600,000,000
Contractor has a certificate of quality management system (QMS)	1.72	500,000,000
4. MS Category of materials and natural resources		
Street lighting using renewable energy resources	1.69	7,020,000,000
Description of subcategories and criteria for Dynamic Model	**Score**	**Cost**
1. Model Usage		
Cost Simulation		250,000,000
Time Simulation		250,000,000
Model Objectivity		300,000,000
2. Making Stock Flow Diagrams		
Use of Dynamic Models		250,000,000
Key Person in Dynamic Model		500,000,000
3. Model Analysis and Interpretation		
Disclaimer by Stakeholders		200,000,000
Difficulty of Dynamic Model Application		200,000,000
Total Green Road Rating	**21.85**	**98,050,000,000**

Table 9. Input Value Optimistic Scenario

Description of Toll Road sub-categories and criteria	**Score**	**Cost (IDR)**
1. Toll Road Settings		
Policy Basis - Traffic Management and Safety		3,000,000,000
2. Toll Road Concession		
Toll road operation - Mobilization		5,000,000,000
Environmental Handling		1,500,000,000
Quality management		500,000,000
Description of subcategories and criteria for Green Road	**Score**	**Cost**
1. KL, Water, Air and Nature Environmental Conservation Category		
KL-1 Environmental awareness training	2.67	2,400,000,000
KL-2 Flood mitigation from the environment	4.20	36,800,000,000
KL-3 Reduction of air/dust pollution during construction/post construction	1.32	90,000,000
KL-4 Certificate of environmental management system and implementation	1.98	1,100,000,000
KL-5 Reforestation	1.32	450,000,000
KL-6 Protection and avoidance of habitat loss	0.30	40,000,000
KL-7 Provision of road drainage system	1.88	2,800,000,000
KL-9 Noise reduction	0.56	8,000,000,000
KL-1 Environmental awareness training	2.67	2,400,000,000
2. TM, Transportation and Society Category		
TM-1 Street ornament and landscaping	0.97	5,500,000,000
TM-3 Provision of access and facilities for public transport users	0.77	20,000,000,000
TM-4 Geometric design and road equipment facilities	0.66	86,400,000,000
TM-5 Implementation of road safety audit by an independent party	0.57	500,000,000
TM-7 Involvement of community participation in planning	0.31	300,000,000
3. TM, AK Category, construction implementation activities		
Planning for construction and waste recycling activities	2.30	4,000,000,000
Implementation of the coordination of the design team and construction implementers	1.93	600,000,000
Contractor has a certificate of quality management system (QMS)	1.72	500,000,000
Use of renewable energy and application of innovation	0.98	189,750,000,000
4. MS Category of materials and natural resources		
Use of local materials	2.27	500,000,000
Street lighting using renewable energy resources.	1.69	7,020,000,000
Description of subcategories and criteria for Dynamic Model	**Score**	**Cost**
1. Model Usage		
Cost Simulation		250,000,000
Time Simulation		250,000,000
Model Objectivity		300,000,000
2. Making Stock Flow Diagrams		
Use of Dynamic Models		250,000,000
Key Person in Dynamic Model		500,000,000
3. Model Analysis and Interpretation		
Disclaimer by Stakeholders		200,000,000
Difficulty of Dynamic Model Application		200,000,000
Total Green Road Rating	**28.40**	**378,700,000,000**

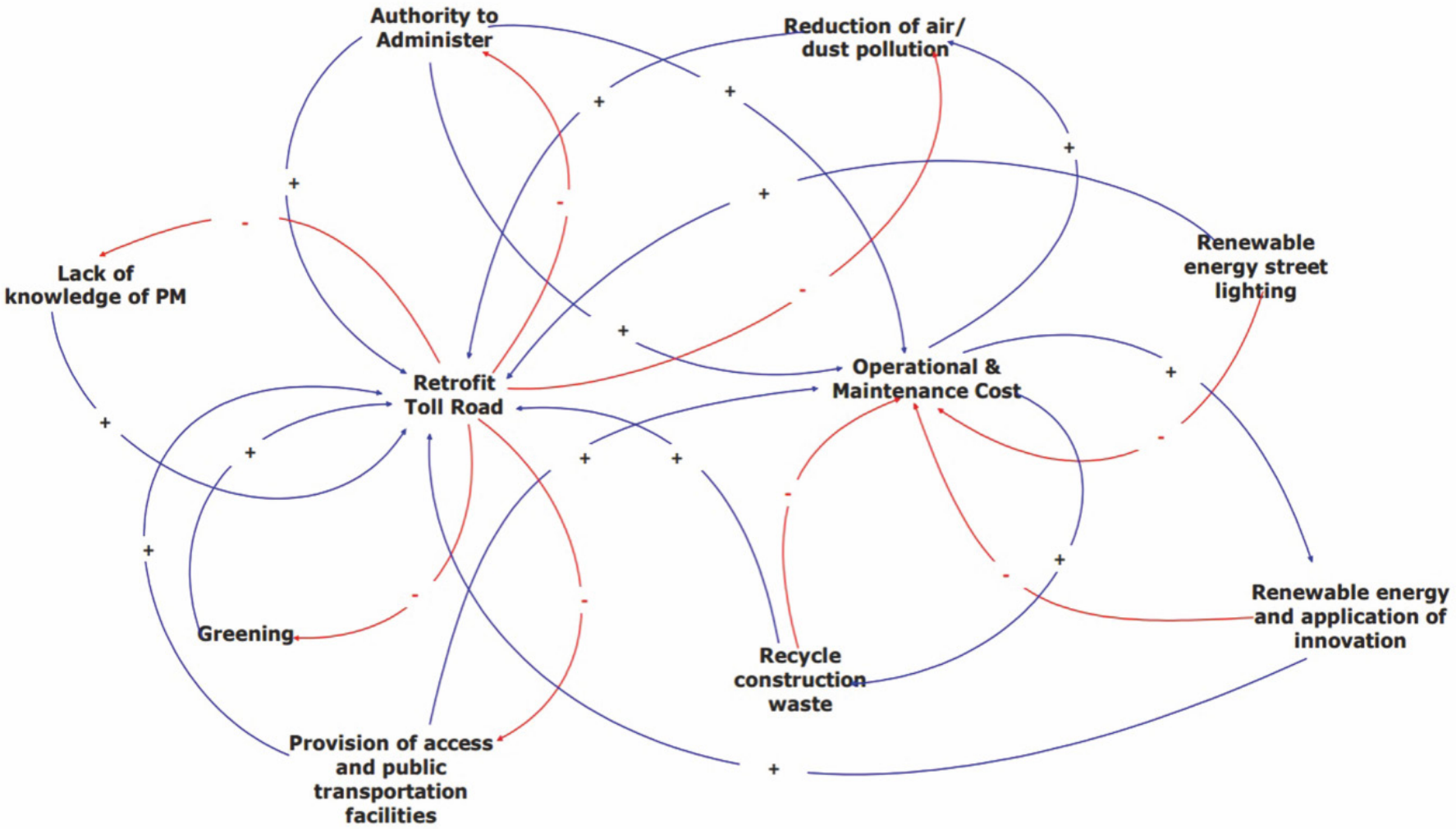

Figure 3. CLD Toll Road

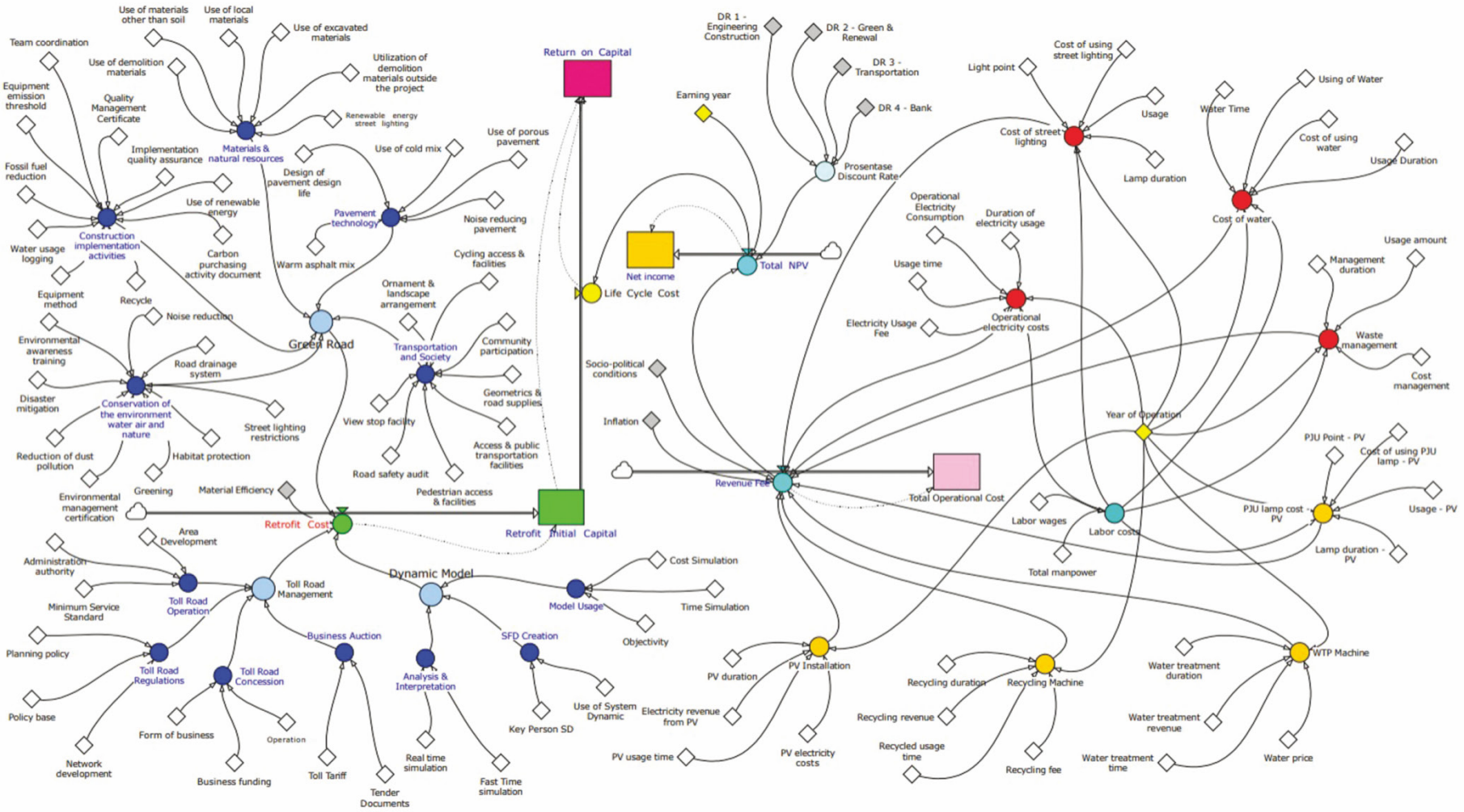

Figure 4. Causal Loop Diagram Retroffiting Toll Road

4.4. Discussion

From the 3 scenarios of implementing Green Road based on SD LCC integration on Toll Roads, the results are shown in the following table 10.

Table 10. Simulation result of Green Retrofitting Road

Scenario	Retrofitting Cost	Green Rating	Payback in
Pessimistic	IDR 61,250,000,000	13.63 ★★	No return
Moderate	IDR 98,050,000,000	21.85 ★★★	14.92 years
Optimistic	IDR 378,700,000,000	28.40 ★★★	3.98 years

The optimistic scenario shows the highest rating score 28.40 and the fastest return on investment in 3.98 years. In this optimistic scenario, it is the innovation of installing flood control and PV installations along toll roads that are the difference with the moderate scenario. The installation of PV along the road and flood control requires the greatest cost in retrofitting toll roads, but from both of these, large savings in operational and maintenance costs are obtained. From installing solar panels along the way, you will get a large amount of electrical energy and can generate a quick return on investment. According to the Washington Department of Transportation: WSDOT, 2008 due to high concern for the impact of flooding on highways, it may be most appropriate to use a combined approach, which may require a combination of LID and conventional methods to meet flood control demands while also maintaining water quality standards. The rainwater management strategy should be considered carefully in terms of its long-term geomorphic implications in addition to flood control and pollutant removal functions because in the event of a flood it will result in transportation interruptions and high losses in road operations. With flood control, a lot of operational & maintenance costs are saved and get a return from water treatment.

Solar panels require unshaded sunlight which makes highways with large open areas an ideal location. Mounted over the road they also provide shade which will reduce the use of air conditioning on sunny days. But also: The high cost of UV degradation of paved expressway surfaces will be drastically reduced. An example of applying solar panels over toll roads is the 24-kilometer Santa Monica freeway between Downtown and the beach. The average width is 40 m. This gives a paved surface of one million m2 or 10 million square feet. It comprises only 5% of the county's freeway system. The Santa Monica freeway can accommodate the equivalent of more than 600,000 domestic market panels 1,6 m2 each. The Santa Monica freeway will become a local power station. Compared to the Ivanpah 500 MW solar complex this expressway can provide a maximum peak effect of 115 MW. That would be enough energy -150 gigawatt hours - to cover the electricity needs of e.g. Venice, CA [34].

Meanwhile, from the installation of PV, large amounts of energy can be obtained and can be utilized on the toll road and can provide income by collaborating with the State Electricity Company (PLN) or the like as a source of electrical energy for the surrounding community.

Toll roads either directly or indirectly stimulate the growth of the surrounding areas. Toll highways linked to inter-city connectivity and ports play a vital role in shortening travel times. Changes in residential areas and inhabitants living near toll highways create social and cultural changes. The growth of infrastructure in the form of toll roads becomes highly significant in economic development since the interstate highway is one of the motors of the economy [3] and supports a country's equitable development [4]. Toll roads can also be used to measure micro and macroeconomic progress. Finally, their presence demonstrates a nation's desire to establish a culture marked by basic yet fast-paced activities.

5. Conclusion

This study aims to identify the factors that have the greatest influence on the performance of the dynamics model based on the life cycle cost analysis of the implementation of green routes over the existing toll roads in Indonesia. Data processing used statistical analysis SPSS (Statistical Package for the Social Sciences), which was obtained from questionnaires filled out by experts. From this processing, the 10 highest factors were obtained, namely 1. Authority to administer toll roads; 2. Reduction of air/dust pollution; 3. Greening; 4. Provision of access and public transportation facilities; 5. Recycle construction waste; 6. Renewable energy and application of innovation; 7. Renewable energy street lighting; 8. Modeling of dynamic systems; 9. Initial Retrofitting Costs; 10. Period of analysis.

From the green retrofitting implementation scenarios, the optimistic scenario's result is 28.40 (★★★) with the toll road retrofitting cost of IDR 378,700,000,000. - fastest return on investment is 3.98 years.

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