Research paper

Value increase of jetty project based on system dynamics

Agung Prihantoro[1], Albert Eddy Husin[2]

Abstract: Waste or additional costs in infrastructure projects such as jetty projects are often caused by rework. Besides having an impact on costs, rework is also a very significant contributor to waste or adding time which causes delays in the completion schedule of the project. A lot of research on rework has been carried out on both building and road construction projects, but there is no jetty construction project. This study aims to develop improvement scenarios to minimize the emergence of rework on pier infrastructure projects by modelling and simulating cost performance. The research variables were obtained based on the results of a literature study by asking for opinions from experts who are compatible in their scope. The initial model used the causal loop diagram form which was later developed into a Stock Flow Diagram, after which a repair simulation was carried out using the dynamic system method to determine the effect on cost performance. From the research results obtained 14 factors that affect the cost and time performance on the jetty project, the implementation of a dynamic system can provide the optimum solution with the ability to reduce the percentage of the number of reworks by 24.12% for 12 months.

Keywords: jetty project, rework, system dynamics, cost-efficiency

[1]St., Eng., Universitas Mercu Buana, Department of Civil Engineering, Jakarta Barat 11650, Indonesia, e-mail: agung20153@gmail.com, ORCID: 0000-0001-9738-8176

[2]PhD., Eng., Universitas Mercu Buana, Department of Civil Engineering, Jakarta Barat 11650, Indonesia, e-mail: albert_eddy@merbuana.ac.id, ORCID: 0000-0003-0163-928X

1. Introduction

Rework has a direct and indirect impact on project performance. This is an important factor that contributes to the costs and excess time of construction projects [1]. Waste of costs in transportation infrastructure projects, such as road projects, is often caused by rework [2–4]. The cost of rework on most construction projects is large, ranging from 5% to 20% of the contract value [5, 6]. Apart from having an impact on costs, rework is also a significant contributor to the time wastage and schedule delays of a project [7]. The average rework adds to the time required for project completion by 22% of the planned time [8]. An error during construction was ranked 5th out of the total factors, and it was categorized under contractor-related factors. If the contractor fails to execute the work per the contract or install unapproved material, it may lead to the demolition of the work, and then be reworked. This rework would invariably hinder the progress of work and subsequently result in a cost overrun [9]. Rework has also been indicated as a second cause for loss of worker productivity and is a frequent problem in both design and construction work [10].

To formulate the best solution in reducing the incidence of rework, it is necessary to simulate the model for the first time, according to [11] simulation can estimate system performance under certain conditions and provide the best design alternatives according to the desired specification. By looking at the variables causing the rework, which are always changing with time, such as rain whose characteristics can change every time, then the right type of simulation to use is a continuous simulation with a system dynamics approach.

Urban infrastructure encompasses the essential facilities, services, and social structures that ensure the productivity and well-being of cities and communities [12]. 10 sub-factors that have the most influence on the M-PERT scheduling of a toll road project which is the combination of the project [13], Jetty is one of the infrastructures, implementation of the jetty construction work process with cost innovation using system dynamics can improve project performance in terms of cost in project management. The implementation of system dynamics in construction projects can reduce rework costs by 12.02% [14]. In the industrial world simulation using the System Dynamics are the reliability of product handling, percentage of successful rework, and percentage of the deteriorated product. The simulation results show that the optimistic scenario has the smallest defect of 0% and is followed by a most likely scenario of 1% and a pessimistic scenario of 4% [15]. This research is expected to produce innovative studies as the best alternative recommendations in terms of project cost performance for service providers and service providers. By knowing the key factors in completing the jetty work, this research is expected to become a benchmarking or pilot for jetty projects.

The process of data collection, data processing, using the Analytic Hierarchy Process (AHP) method with the help of Expert Choice software.

From the results of the survey to respondents regarding the factors that influence cost performance on a jetty project with a system dynamics, the results of the Analytic Hierarchy Process (AHP) with the help of Expert Choice software and opinions from experts or advisors will get the order of the most influential factors (Key Success Factor) and the results of the case study analysis with the cost method using a system dynamics, it will be found whether the implementation of the system dynamics method on the jetty project can optimize the project in terms of costs.

Table 1. Data of case study

Data	Explanation
Location	Sorong, Papua Barat
Jetty	3 segment
Trestle	3 units
Causeway	3 units
Dimension Jetty	299.5×12 m
Dimension Trestle	70×8 m
Dimension Causeway	30×8 m
Owner	Indonesian Navy
Project Costs	IDR 168,586,103,000
Costs of Rework	IDR 8,065,549,000

2. Results and discussion

2.1. Most influencing factors

The Analytic Hierarchy Process (AHP) processing stages with the help of Expert Choice software, after each main factor/criterion, sub-factor / criterion has been obtained then the next step is synthesis to get the overall weight of the existing criteria. Previously, the local priority had to be searched for the global value (global priority) first. The overall global weight value can be seen in Table 2. The data that has been calculated above shows that the overall order of the factors that affect the cost and time performance on the pier project with the following results:

Table 2. The 14 most influential factors

Factor	Weight
Design Change	21.00%
Incompatible Working Methods	12.70%
Lack of supervision	11.70%
Delay in Work	9.70%
Schedule that is too busy	7.70%
Add Work	7.40%
Lack of knowledge of PM and SM	6.40%
Equipment Selection Error	5.60%
Shortage of labor	4.90%
Change in Specifications	3.70%
Lack of Equipment	3.00%
Delayed Material	2.40%
Extreme weather	2.20%
Slow Decision Making	1.60%

2.2. System dynamics

Systems Dynamic Methodology was first introduced by Jay Forrester from MIT (Massachusetts Institute of Technology) in the 1950s [16,17]. In this scope of the study, the system is defined as a collection of elements that continuously interact over time to form a unified whole. In this study, the stages in making a dynamic system model can be seen in Figure 1, the first step is to conceptualize the model. The second step is to create a causal loop diagram (CLD) which is obtained based on the results of questionnaire data collection on the factors that affect the cost performance of the pier project. The third step is to create a stock-flow diagram (SFD) based on the CLD that has been made previously. The fourth step is to determine the formulation of the input values of the variables in the created SFD. The fifth step is to validate the model against the SFD that has been made. The sixth step is to create scenarios and simulations based on the SFD that has been made by adding variables that can reduce rework on the jetty project.
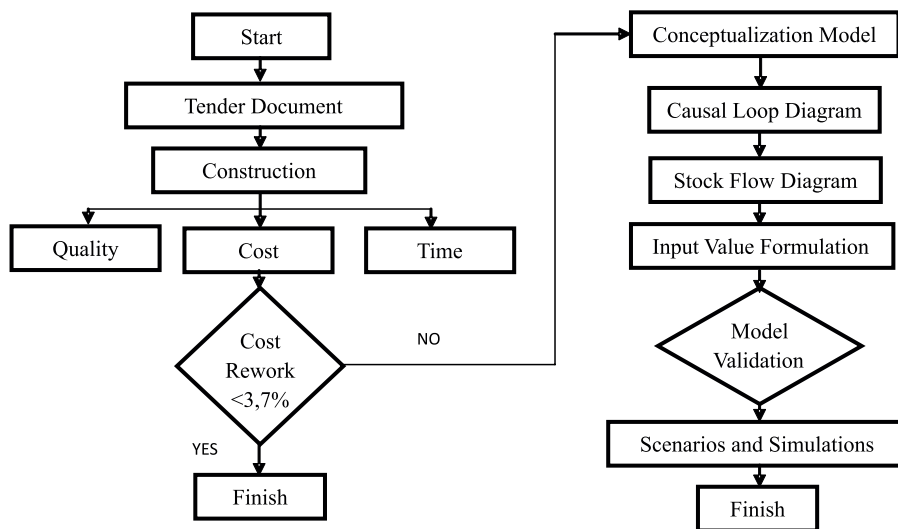

Fig. 1. Flow of the research framework

2.2.1. Causal loop diagram

Causal loop diagrams must be finished before making a model so that the model maker has a first picture of the concept of the model to be made. The causal loop diagram as shown in Figure 2 shows the causal relationship which is connected utilizing arrows. Causal loop diagrams are useful for describing the relationship between variables involved in a system. The positive arrows indicate that the relationship is directly proportional, where the addition of value to the variable will cause an additional value to the variable it affects. Meanwhile, the arrow which is marked negative shows an inversely proportional relationship, where the addition of the value to this variable will cause a decrease in the value of the variable it affects.

From the CLD that has been made, it can be seen that each variable is interrelated, for example, the construction cost factor and the rework factor. The greater the construction cost,
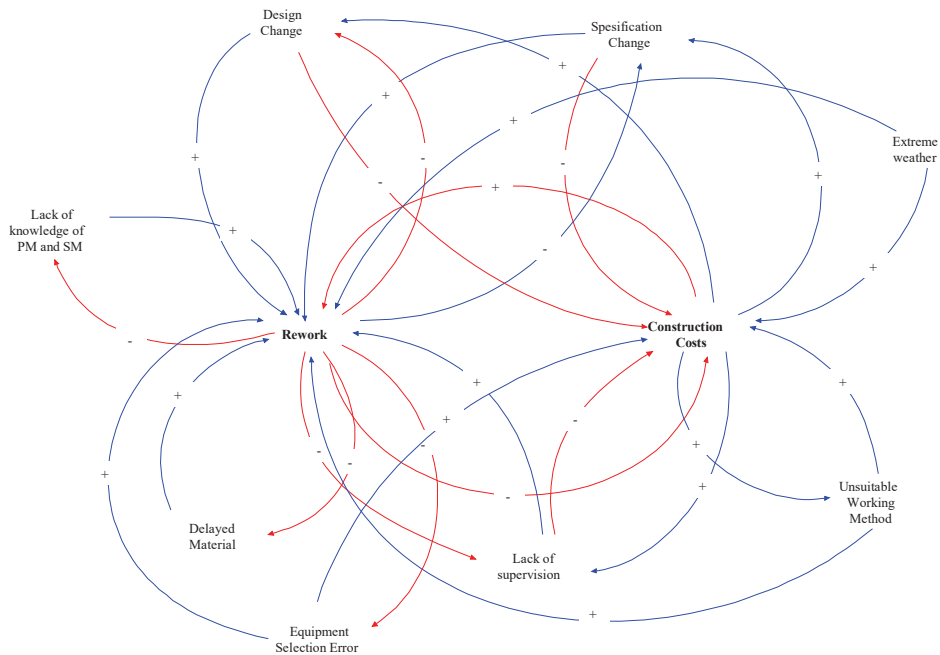
Fig. 2. Causal loop diagram for rework in jetty construction

the more likely rework will occur, conversely, the smaller the construction cost, the less likely rework will occur. CLD describes the factors that affect the cost performance of the jetty project which are interrelated so that from the CLD results, SFD can be formed which will later become a model as a basis for scenario creation.

2.2.2. Causal loop diagram

SFD based on the most influencing factors on the pier project can be seen in Figure 3.

The following Table 3 is the value of each variable that affects the variable occurrence of rework on the jetty project obtained by using the weighting normalization technique obtained from the results of the expert choice software output using the analytical hierarchical process (ahp) method, which later these values entered into the powersim program with the system dynamic method.

Before creating a scenario, first validation of the initial model that has been made based on the causal loop diagram (CLD), validation testing is carried out utilizing the average comparison test and amplitude variation comparison test. It is said to be valid if the mean comparison value is < 5% and the amplitude variation comparison value is < 30%.

$$(2.1) \qquad E_1 = \frac{|S - A|}{A} = \frac{|75.44 - 73.52|}{73.52} = 2.61\%,$$

where E_1 is the Mean Comparison, S is the average value of the simulation results and A is the the average value of the data. The model is considered valid if $E_1 \leq 5\%$.
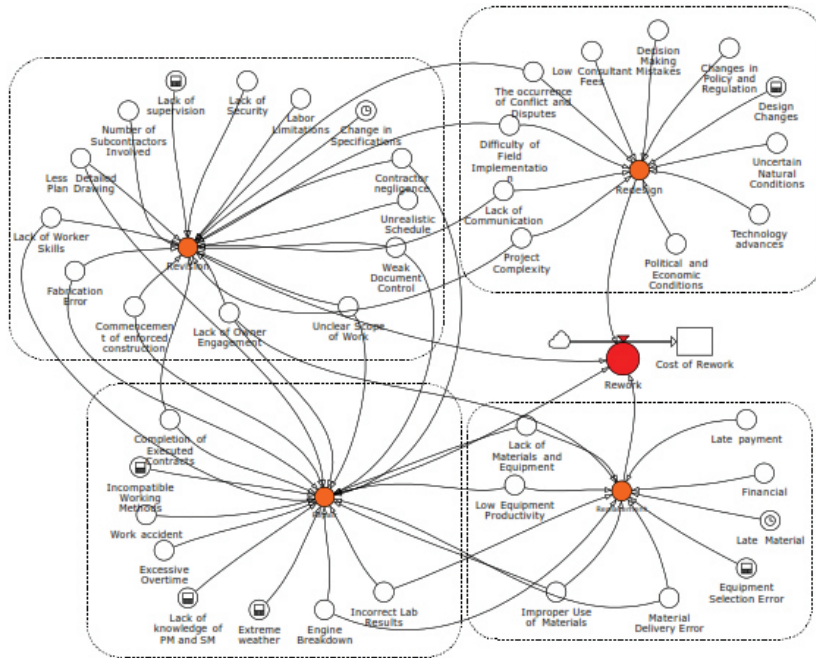
Fig. 3. Stock flow diagram for rework in jetty construction

Table 3. Weighted value on variables

Factor	Explanation
Design Change	Design changes occurred during the initial 3 months of project implementation, due to differences in the results of sondir boring by the Planning Consultant which resulted in changes in pile length.
Incompatible Working Methods	As a result of errors in equipment selection and PM's lack of knowledge, the work method was not following specifications.
Lack of supervision	During project implementation, the supervisory team from the Supervision Consultant only assigns 1 (one) personnel.
Lack of knowledge of PM and SM	Lack of PM and SM's knowledge of the jetty work that occurred during the construction project.
Equipment Selection Error	The main equipment is equipment for erection work that is not following specifications, so the Contractor brings back the main equipment which takes up to 3 months.
Change in Specifications	Changes in specifications occur during the implementation of the construction project (12 months), which is caused by requests from the owner or due to adjusting to field conditions.
Delayed Material	Material delays occurred for 3 months, due to design changes due to differences in design results with existing conditions.
Extreme weather	The occurrence of high tides so that it disturbs construction work, plus a high enough wave during the construction work.

Table 4. Percentage of total reworks

Month	Simulation (%)	Actual (%)
1	22.83	26.33
2	45.67	46.74
3	68.50	67.14
4	72.47	70.80
5	75.33	73.35
6	79.30	77.01
7	81.60	78.99
8	85.00	82.08
9	87.30	84.07
10	91.90	88.35
11	95.40	91.54
12	100.00	95.83

$$(2.2) \qquad E_2 = \frac{|S_s - S_a|}{S_a} = \frac{|21.89 - 19.68|}{19.68} = 11.19\%,$$

where E_2 is the comparison of variations in amplitude, S_s is the standard deviation of the model and S_a is the standard deviation of data. The model is considered valid if $E_2 \leq 30\%$.

2.2.3. Scenario

The scenario model aims to improve system performance in overcoming existing problems, the type of scenario that will be carried out is an improvement scenario by adding several improvement scenarios. The following are some of the formulations of improvement scenarios used in this study (Table 5).

Table 5. Scenario

Scenario	Explanation
pessimistic scenario (Figure 4)	Carry out project management training to PM and SM
moderate scenario (Figure 5)	1. Increase the number of supervisors, so that construction is carried out according to the required method. 2. Adding experts, so that problems in the field caused by design changes can be minimized.
Optimistic scenario (Figure 66)	1. Add to the survey the location of boring points, so that the accuracy of boring results does not differ from field conditions. 2. Increase the number of supervisors, so that construction is carried out according to the required method. 3. Adding experts, so that problems in the field caused by design changes can be minimized. 4. Carry out project management training to PM and SM. 5. Carry out regular weekly meetings.

From the scenario discussion above, if applied to a jetty construction project, the value of the savings can be calculated to minimize the rework on a similar pier construction project as in Table 6. The following is a table of alternative scenarios for selecting rework cost savings if applied to similar projects (Figs. 4– 6).
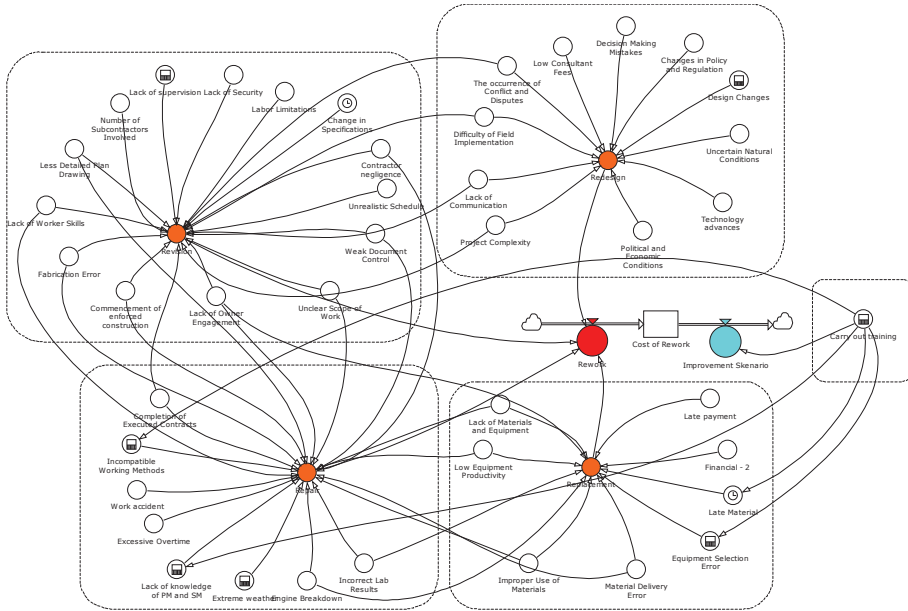

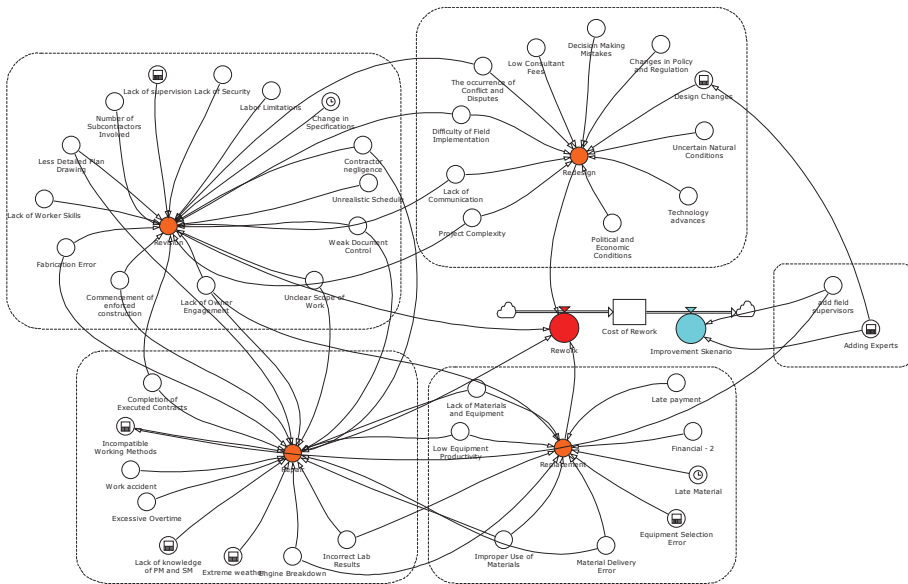Fig. 4. Stock flow diagram for pessimistic scenario
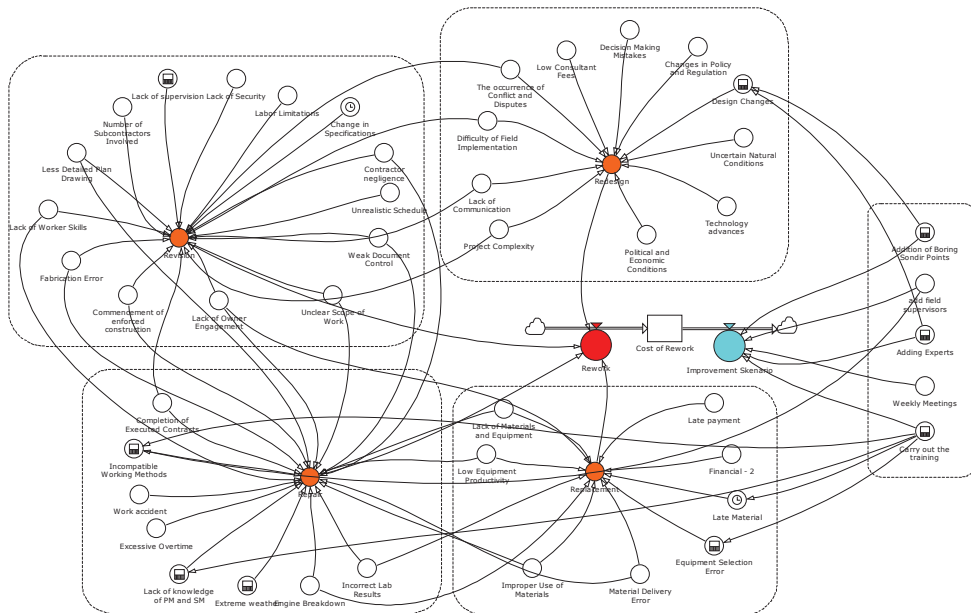

Fig. 5. Stock flow diagram for the moderate scenario

Fig. 6. Stock flow diagram for the optimistic scenario

Table 6. Simulation results of rework improvements

Scenario	Results	Rupiah (Rp.)
Pessimistic scenario	1.73%	IDR 139,534,000
Moderate scenario	12.95%	IDR 1,044,489,000
Optimistic scenario	24.12%	IDR 1,945,411,000

3. Conclusions

Based on the results of research on minimizing rework on the pier project, 14 factors affect the cost performance of the jetty project, namely design changes, inappropriate work methods, lack of supervision, work delays, too-busy schedules, added work, lack of knowledge of PM and SM, selection errors equipment, labor shortages, specification changes, equipment shortages, late materials, extreme weather, slow decision making. From the dynamic system results obtained 3 selected scenarios can minimize rework on the jetty project, namely the pessimistic scenario reduces the rework by 1.73%, the moderate scenario reduces the rework by 12.95% and the optimistic scenario reduces the rework by 24.12%. The limitation of this research is that the scope of work is limited to rework, it would be better if the entire scope of work was discussed.

References

[1] B.G. Hwang, et al., "Measuring the impact of rework on construction cost performance". Journal of Construction Engineering and Management, 2009, DOI: 10.1061/(ASCE)0733-9364(2009)135:3(187).

[2] A.E. Husin and I. Siregar, "Multi-Span Bridge work based on line of balance and critical path methods integration in light rapid train". ARPN, Journal of Engineering and Applied Science, vol. 14, no. 17, pp. 3001–3012, 2019.

[3] P. Barber, et. al., "Quality failure costs in civil engineering projects". International Journal of Quality and Reliability Management, 2000. DOI: 10.1108/02656710010298544.

[4] P.E.D. Love, et al., "Overruns in transportation infrastructure projects". Structure and Infrastructure Engineering, 2014, DOI: 10.1080/15732479.2012.715173.

[5] J.L. Burati, J.J. Farrington, and W.B. Ledbetter, "Causes of quality deviations in design and construction". Journal of Construction Engineering and Management, vol. 118, no. 1, pp. 34–49, 1992, DOI: 10.1061/(asce)0733-9364(1992)118:1(34).

[6] P.E.D. Love and A.S. Sohal, "Capturing rework costs in projects". Managerial Auditing Journal, 2003, DOI: 10.1108/02686900310474343.

[7] M.M. Kumaraswamy and D.W.M. Chan, "Contributors to construction delays". Construction Management and Economics, 1998, DOI: 10.1080/014461998372556.

[8] P.E.D. Love, "Influence of project type and procurement method on rework costs in building construction projects". Journal of Construction Engineering and Management, 2002, DOI: 10.1061/(ASCE)0733-9364(2002)128:1(18).

[9] A.M. Kamaruddeen, C.F. Sung, and W. Wahi, "A study on factors causing cost overrun of construction projects in Sarawak, Malaysia". Civil Engineering and Architecture, vol. 8, no. 3, pp. 191–199, 2020, DOI: 10.13189/cea.2020.080301.

[10] P.F. Kaming, et al., "Factors influencing construction time and cost overruns on high-rise projects in Indonesia". Construction Manaement and Economics, 1997, DOI: 10.1080/014461997373132.

[11] S. Erma, "Pemodelan dan Simulasi". Pemodelan dan Simulasi, 2006.

[12] M.A. Berawi, "Managing sustainable infrastructure and urban development: Shaping a better future for Asean". International Journal of Technology, vol. 9, no. 7, pp. 1295–1298, 2018, DOI: 10.14716/ijtech.v9i7.2731.

[13] A.E. Husin, et al., "Research article time performance upgrade on toll road construction project by M-Pert". Journal of Current Research in Life Sciences, vol. 8, no. 1, pp. 3035–3042, 2019.

[14] A.E. Husin, M.A. Berawi, and T. Ilyas, "Forecasting demand on mega infrastructure projects: increasing financial feasibility", no. 10, 2015, DOI: 10.14716/ijtech.v6i1.782.

[15] A. Suwandi, T.Y. Zagloel, and A. Hidayatno, "Risk control failure of iron pipes in finished goods warehouses using dynamic systems". International Journal of Technology, vol. 12, no. 1, p. 15, 2021, DOI: 10.14716/ijtech.v12i1.4068.

[16] A. Hidayatno, I. Rahman and R. Muliadi, "Policy analysis of the Jakarta carbon mitigation plan using system dynamics to support decision making in urban development – options for policymakers". International Journal of Technology, 2015, DOI: 10.14716/ijtech.v6i5.1926.

[17] E. Yuliawati, et al., "System dynamics model for airport characterization in huband- spoke networks". International Journal of Technology, 2015, DOI: 10.14716/ijtech.v6i5.1039.