Cement Supply Chain Model of Palangka Raya Using System Dynamics Method

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Abstract

One of the most strategic material resources in the execution of construction is cement. It is estimated that the demand for cement to support construction activities in Indonesia is approximately 78.66% of national cement consumption, with cement consumption in Indonesia increasing by 14.1% in the first quarter of 2021 to 18.19 million tons. The objective of this research is to understand how the dynamic supply chain model and cement inventory in Kota Palangka Raya will be from 2024 to 2028. In this research procedure, data analysis techniques use the system dynamic method with the Vensim program, utilizing data from interviews with distributors and retail stores scattered in Kota Palangka Raya and supporting research data. The results of the supply chain model for cement include three variables: stock, in, and out. The total inventory of Conch cement in 2024 is 1140555 zak, in 2025 is 1547654 zak, in 2026 is 6192387 zak, in 2027 is 1946944 zak, and in 2028 is 1918412 zak. The total inventory of Gresik cement in 2024 is 548287 zak, in 2025 is 1785559 zak, in 2026 is 1826060 zak, in 2027 is 1849395 zak, and in 2028 is 1838869 zak. The total inventory of Tiga Roda cement in 2024 is 42763390 zak, in 2025 is 250804 zak, in 2026 is 177705 zak, in 2027 is 321805 zak, and in 2028 is 183585 zak.

Keywords: *Supply Chain, Cement, System Dynamics*

I. Introduction

One of the most valuable strategic resource materials in conducting construction activities is cement. The usage of cement is utilized on a large scale in developments like public infrastructure construction and building constructions, as well as community-led developments [1]. It is estimated that the need for cement to support construction project activities in Indonesia accounts for approximately 78.66% of cement consumption. The growth in cement consumption in Indonesia increased by 14.1% in Q1-2021 to reach 18.19 million tons [2]. Palangkaraya City had housing development realization data totaling 657 units in 2020, 683 units in 2021, and 755 units in 2022 [3]. As the number of residential developments in Palangkaraya increases, the demand for cement in construction projects also rises.

Cement functions to bind aggregate particles together to form a solid structure and allows for the unification of air voids present in the aggregate particles [4] . The role of cement is crucial for concrete work, which must adhere to technical specifications and predetermined proportions. Concrete work constitutes a significant item that affects the total building cost by approximately 13-39% and is a critical component of construction projects [5]. This underscores the important role of cement in construction project activities.

The cement distribution system from producers to consumers consists of various levels (chains), starting from factories, distributors, and retail stores. The supply chain is a series of activities or processes involved in delivering products, such as raw materials, to customers from the sources of these materials, including parts manufacturing, assembly, warehousing, inventory tracking, order management, distribution across channels, shipping, and the information systems necessary to monitor all activities [6]. The supply chain network consists of relationships between producers, suppliers, consumers, logistics companies, and collaborative partners working together to facilitate the supply chain [7].

System Dynamics is a method for analyzing the behavior of a complex system over time by transforming the entire system into a series of interconnected stocks and flows that influence each other through feedback loops [8].System dynamics represents a mental model that illustrates the components within a complex system by depicting interactions among feedback, information flows, time delays, components, and non-linearity within subsystems [9].

In fact, global cement demand is projected to rise in the future, driven by population growth and urbanization, and is expected to increase by 12–23% by 2030 based on business scenarios typical of IEA[10]. The purpose of this study is to determine the dynamic model of the cement supply chain and stockpile for Palangka Raya city from 2024 to 2028. Research was conducted in the area of Palangka Raya city with respondents being companies distributing and retail stores spread throughout Palangka Raya.

II. Methods

The method used in this research is System Dynamics. The stages of the research are presented in Figure 1. The first stage involves literature study and model conceptualization to understand the initial concepts of the model that will be developed.

The second phase of the research involves collecting data through interviews using purposive sampling, where the questions are not rigidly structured so as to gain insight into the flow of the cement supply chain. This method ensures that supporting data for the research can be directly obtained from the source.

The third phase includes creating a dynamic model consisting of both Causal Loop Diagrams (CLD) and Stock Flow Diagrams (SFD). These models incorporate the collected data from distributors and retailers, allowing for an integrated representation of the cement supply chain dynamics.

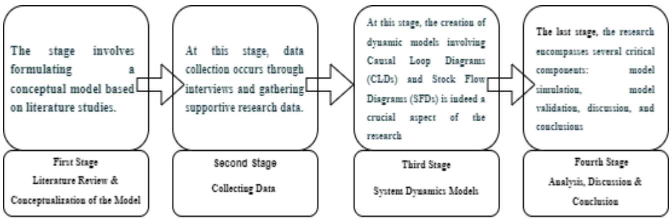

Figure 1. Study Stage

The fourth stage involves simulation, model validation, analysis, and conclusions. In this phase, the simulation produces graphs and tables, and validation is conducted through three stages:

1. Materials and methods should come after the Construction Validation aims to determine whether the model structure aligns with the actual system's model construction.
2. Construction Validation aims to determine whether the model structure aligns with the actual system's model construction.
3. Construction Validation aims to determine whether the model structure aligns with the actual system's model construction.

Absolute Mean Error Formula:

$$AME = \frac{1}{N} \times \sum \left| \frac{S - A}{A} \right| 100\% \quad (1)$$

Where A represents the actual value, S represents the simulated value, and N represents the observation time interval.

III. Results and Discussions

Field data collection resulted in identifying five primary distributors in Palangka Raya. Among the five primary distributors, several retail stores were successfully located. The following is a draft that had been studied, including:

Table 1. List Distributors and Retails

Number	Name	Information
1	PT. IKS	Distributor Gresik
2	PT.SMA	Distributor Gresik
3	CV. CMS	Distributor Conch
4	PT. PMD	Distributor Conch
5	PT. BKS	Distributor Conch
6	TB. NHY	Retail
7	TB. DI	Retail
8	TB. BISA	Retail
9	TB. ABRS	Retail

A. Conceptual Models

At this stage, the model concept can be formed based on the established concepts. The results are derived from direct surveys and interviews with distributors and retails. Below is the sub-model of the cement supply chain based on stock for the city of Palangka Raya.

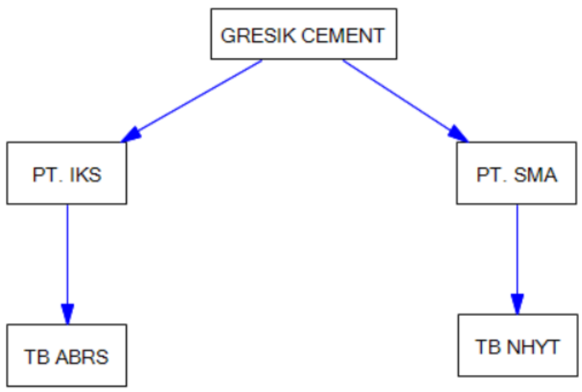

Figure 2. Gresik Cement Supply Chain Sub Model

In the case of Gresik brand cement, there are four stores that sell this product: PT. IKS, PT. SMA, Toko ABRS, and Toko Norhayatie. PT. IKS and PT. SMA are distributors of Gresik cement located in Palangka

Raya, ordering the cement directly from the factory in Tuban, East Java. Toko ABRS orders Gresik cement from PT. IKS, while Toko Norhayatie sources Gresik cement from PT. SMA.

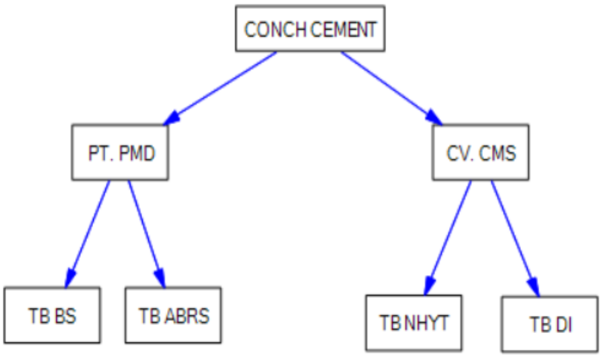

Figure 3. Conch Cement Supply Chain Sub Model

On the Conch brand of cement, there are six stores that sell this product: PT. PMD, CV. CMS, Toko Bina Subur, Toko ABRS, Toko Doa Ibu, and Toko Norhayatie. PT. PMD and CV. CMS are the distributors of Conch cement in Palangka Raya, ordering the cement directly from the factory located in Tanjung Tabalong, South Kalimantan. Meanwhile, Toko Bina Subur and ABRS purchase Conch cement directly from PT. PMD, whereas Toko Norhayatie and Doa Ibu obtain it directly from CV. CMS.

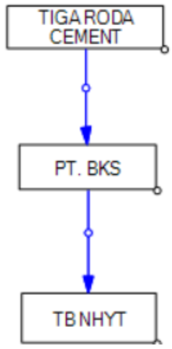

Figure 4. Tiga Roda Cement Supply Chain Sub Model

On the Tiga Roda cement, there are two stores that sell this product: PT. BKS and Toko Norhayatie. PT. BKS is the distributor of Tiga Roda cement in Palangka Raya, purchasing the cement directly from the factory located in South Kalimantan. On the other hand, Toko Norhayatie obtains Tiga Roda cement directly from PT. BKS.

Causal Loop Diagram

A Causal Loop Diagram (CLD) is used to create a mental model and show connections and feedback processes within a system. All dynamics originate from interactions between two types of feedback loops: positive loops that reinforce or amplify whatever happens in the system and negative loops that balance out the system [9].

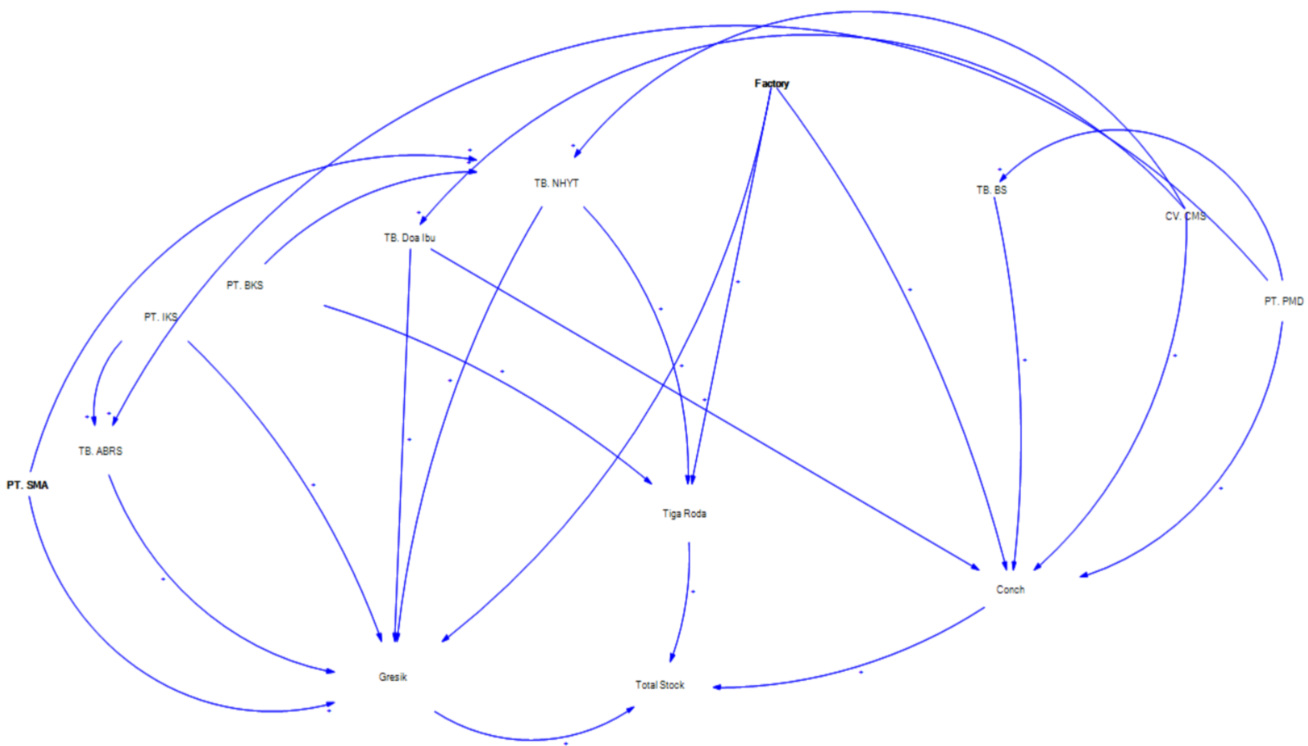

Figure 5. Causal Loop Diagram Supply Chain of cement

The following is an explanation of the Causal Loop Diagram of the cement supply chain:

1. The Causal Loop Diagram (CLD) for Semen Gresik states that the cement distribution flow is caused by customer orders. From these orders, it is possible to see how many units have been ordered from the existing stock. Because of these orders, the amount of stock continuously increases. Semen Gresik distributes its cement through PT. IKS and PT. SMA as distributors, while TB. Norhayatie and TB. ABRS serve as retail customers/toe retail stores.
2. The Causal Loop Diagram (CLD) for Semen Conch states that the cement distribution flow is caused by customer orders. From these orders, it is possible to see how many units have been ordered from the existing stock. Because of these orders, the amount of stock continuously increases. Semen Gresik distributes its cement through PT. PMD and PT. CMS as distributors, while TB. Norhayatie, TB Bina Subur, TB Doa Ibu and TB. ABRS serve as retail customers/toe retail stores.
3. The Causal Loop Diagram (CLD) for Semen Conch states that the cement distribution flow is caused by customer orders. From these orders, it is possible to see how many units have been ordered from the existing stock. Because of these orders, the amount of stock continuously increases. Semen Gresik distributes its cement through PT. BKS as distributors, while TB. Norhayatie, serves as retail customers/toe retail stores.

Stock Flow Diagram

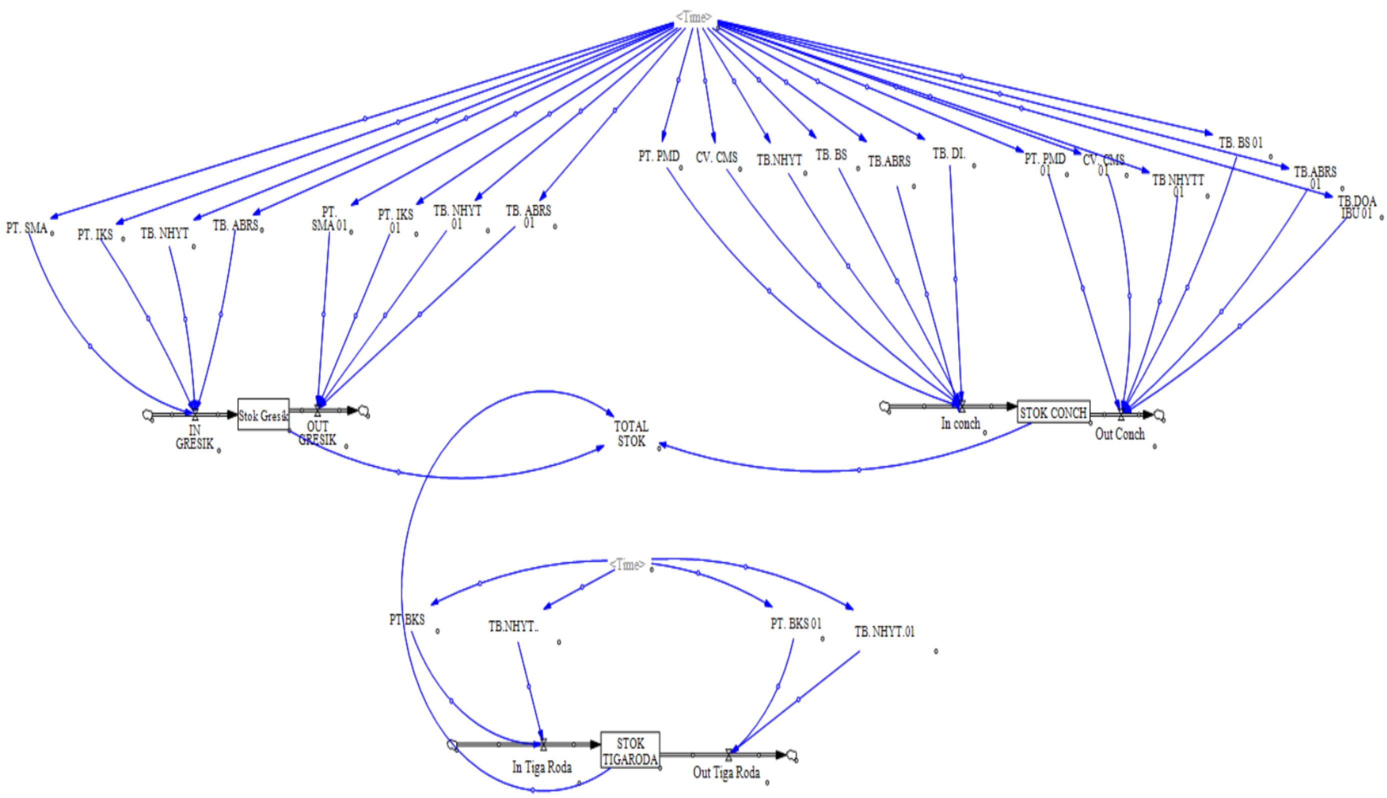

Figure 6. Stock Flod Diagram Supply Chain Oft Cement

Dynamic modeling, simulation, and validation were structured based on the Causal Loop Diagram. Dynamic models were generated after inputting the specified data and assumptions. The dynamic model consists of combinations of sub-models including those for Semen Gresik, Semen Conch, and Semen Tiga Roda. Based on the Stock Flow Diagram, it can be seen that the dynamic model represents the cause-and-effect relationships and feedback loops among the systems of Gresik, Conch, and Tiga Roda. The simulation model illustrating the behavior of the dynamic model is displayed in time graphs and tables once the model has been run using Vensim 10.00 software.

The results of the simulation can be explained as follows:

Cement Gresik Sub Model

In Stock Flow Diagram Figure 6, it is explained that the sub-system of Gresik consists of stock elements functioning as level variables receiving additional inflows from Gresik inputs and reducing from Conch outputs. The input receives information from Gresik Supply, while the output receives information from selling of Gresik. Below follows the simulation results for the Cement Gresik model.

Based on the simulation graph above, it can be explained that the simulation results indicate inventory levels from month 1 to month 30 experience fluctuations (rising and falling). Additionally, the simulation graph shows that from month 34 to month 84, there is a decline in cement stock due to insufficient supply to meet future cement needs. Therefore, it is necessary to increase the supply of cement to prevent stock shortages in the future.

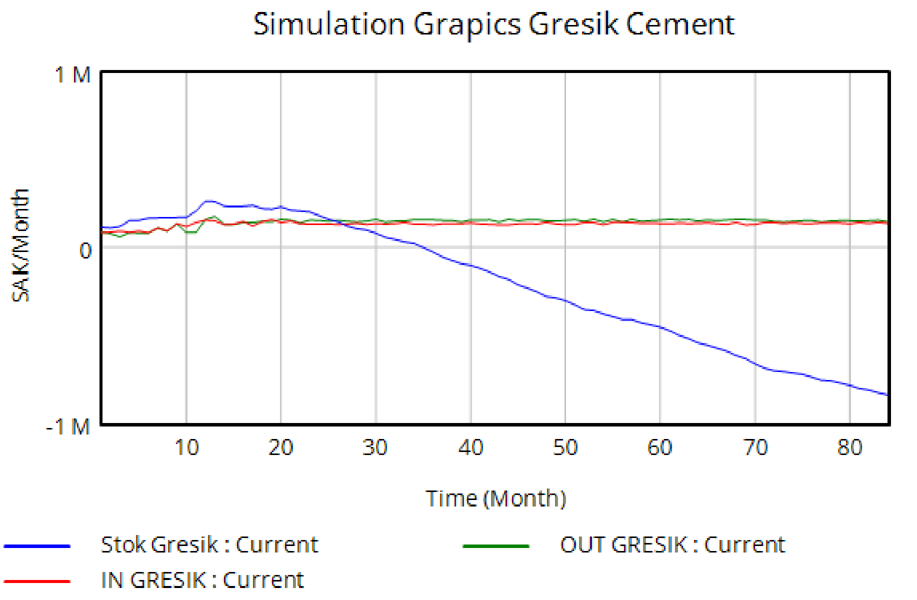

Figure 7. Gresik Cement Simulation Graphics

Table 2. Time Series of Cement Gresik

Month	Availability	Month	Availability	Month	Availability	Month	Availability
1	115515	22	207383	43	-182192	64	-542628
2	110849	23	202724	44	-213538	65	-555824
3	119402	24	181286	45	-231355	66	-572207
4	153096	25	160586	46	-252809	67	-589138
5	154558	26	145563	47	-279002	68	-614017
6	166755	27	121455	48	-286583	69	-631409
7	168285	28	106354	49	-302537	70	-661887
8	169598	29	99013	50	-326174	71	-686375
9	170734	30	80538	51	-353653	72	-700112
10	171195	31	56874	52	-358720	73	-705178
11	206582	32	45618	53	-377494	74	-713914
12	264123	33	31776	54	-392984	75	-720999
13	260961	34	23677	55	-409611	76	-737076
14	234934	35	-624	56	-410558	77	-754639
15	232719	36	-25329	57	-428837	78	-758715
16	234346	37	-53902	58	-439981	79	-771020
17	239686	38	-74219	59	-453355	80	-784321
18	221082	39	-92129	60	-473600	81	-801952
19	218117	40	-101890	61	-499644	82	-810429
20	231026	41	-119035	62	-518431	83	-826548
21	212392	42	-140276	63	-182192	84	-838173

Cement Conch Sub Model

In Stock Flow Diagram Figure 6, it is explained that the sub-system of Conch consists of stock elements functioning as level variables receiving additional inflows from Conch inputs and reducing from Conch outputs. The input receives information from Gresik Supply, while the output receives information from selling of Gresik. Below follows the simulation results for the Cement Conch model.

Based on the simulation graphic forecast above, it can be explained that the simulation results indicate fluctuating stock levels from month 1 to month 84. Consequently, the outcome reveals that the stock for Semen Conch meets the cement demands in Kota Palangka Raya, depending on consumer ordering patterns

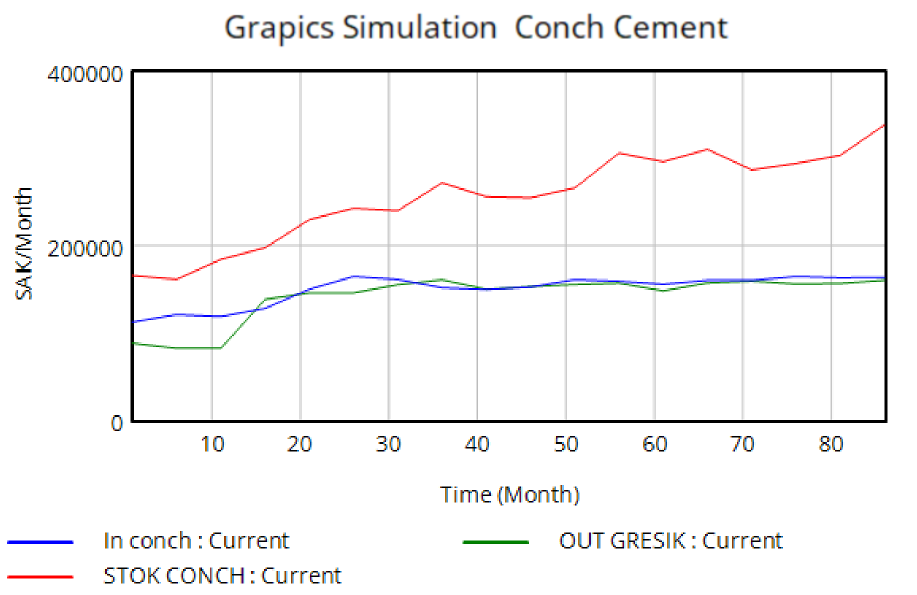

Figure 8. Conch Cement Simulation Graphics

Table 3. Time Series of Cement Conch

Month	Availability	Month	Availability	Month	Availability	Month	Availability
1	58506	22	137519	43	140326	64	162079
2	78255	23	146525	44	138248	65	161158
3	57852	24	113195	45	183991	66	165928
4	81355	25	111504	46	162612	67	155150
5	80184	26	112387	47	165195	68	163756
6	82275	27	107778	48	154294	69	166397
7	104141	28	114557	49	165882	70	166049
8	84162	29	124625	50	156646	71	151237
9	131834	30	122267	51	150861	72	166317
10	80518	31	116260	52	152201	73	163455
11	79511	32	111061	53	163826	74	149996
12	148471	33	99651	54	159204	75	162112
13	175828	34	106921	55	164531	76	153775
14	123166	35	95068	56	167284	77	162054
15	120697	36	91723	57	160123	78	158740
16	133795	37	120410	58	165993	79	166528
17	132160	38	90529	59	160542	80	160763
18	136240	39	126795	60	166555	81	153280
19	141626	40	127997	61	160167	82	154001
20	146502	41	147715	62	160904	83	167391
21	144289	42	142642	63	167564	84	162079

Cement Conch Sub Model

In Stock Flow Diagram Figure 6, it is explained that the sub-system of Tiga Roda consists of stock elements functioning as level variables receiving additional inflows from Tiga Roda inputs and reducing from Tiga Roda outputs. The input receives information from Tiga Roda Supply, while the output receives information from selling of Tiga Roda. Below follows the simulation results for the Cement Tiga Roda model.

Based on the simulation graphic forecast above, it can be explained that the simulation results indicate fluctuating stock levels from month 1 to month 84. Consequently, the outcome reveals that the stock for Semen Conch meets the cement demands in Kota Palangka Raya, depending on consumer ordering patterns

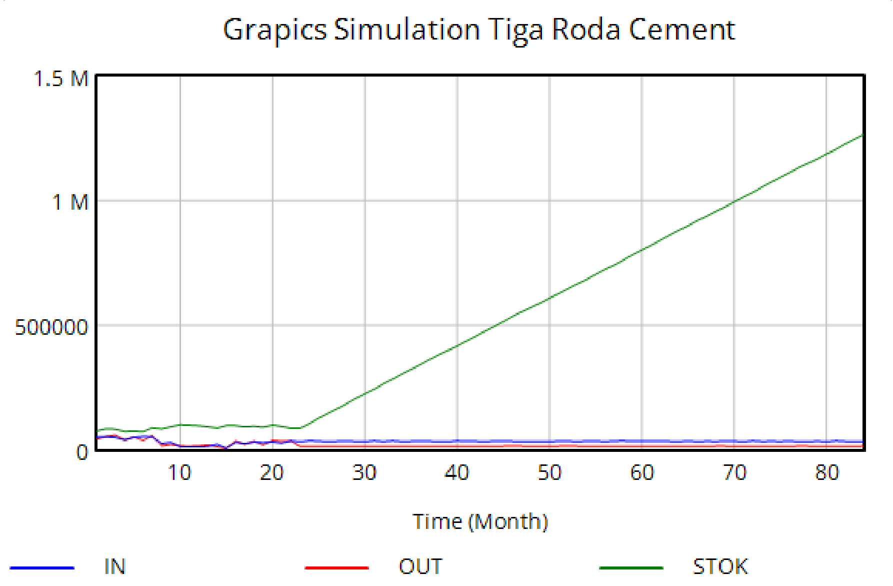

Figure 8. Conch Simulation Grapics

Table 4. Time Series of Cement Tiga Roda

Month	Availability	Month	Availability	Month	Availability	Month	Availability
1	40364	22	13975	43	22464	64	14282
2	50864	23	16129	44	15932	65	15266
3	54327	24	20150	45	15265	66	14662
4	38206	25	12430	46	16592	67	15111
5	51749	26	7457	47	20210	68	14397
6	38241	27	34187	48	13506	69	15604
7	51804	28	22863	49	315	70	15136
8	15160	29	32494	50	35334	71	15344
9	22281	30	20944	51	22776	72	15233
10	14567	31	38140	52	35213	73	15164
11	13975	32	32816	53	20547	74	15715
12	40364	33	34253	54	37787	75	15390
13	50864	34	14499	55	34633	76	14436
14	54327	35	42378	56	35708	77	14592
15	38206	36	53794	57	15043	78	144078
16	51749	37	59236	58	14944	79	15541
17	38241	38	38877	59	152610	80	15510
18	51804	39	51865	60	14506	81	15606
19	15160	40	38127	61	14416	82	15000
20	22281	41	56658	62	14383	83	15043
21	14567	42	16446	63	14681	84	14574

B. Validity Test

1. Construction Validity

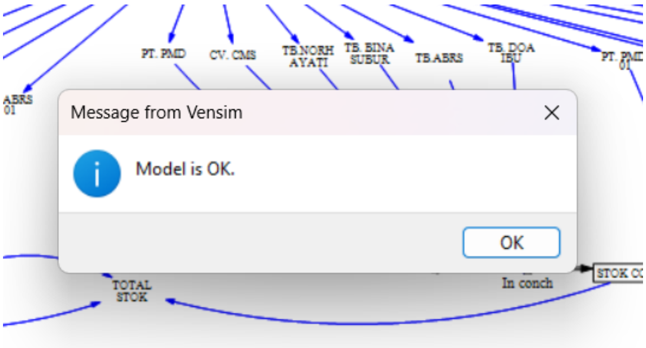

Figure 9. Construct Validity of Model in Vensim Software

2. Structure Validity

The structural validity test aims to test the stability of the structure or behavioral values between the model and the real system. This test can be done by looking at two interrelated variables, namely comparing the actual logic and simulation results. The following are the results of the Gresik, Conch and Tiga Roda cement structure validity test:

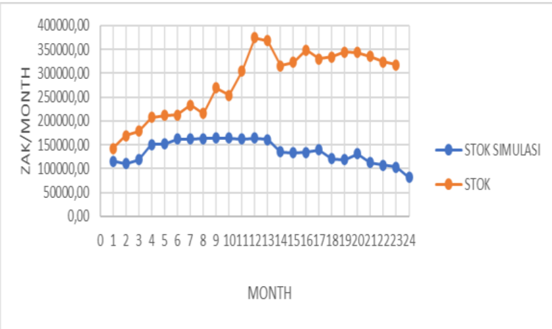

Figure 10. Actual Data and Simulation Results of Gresik Cement Variable Stock

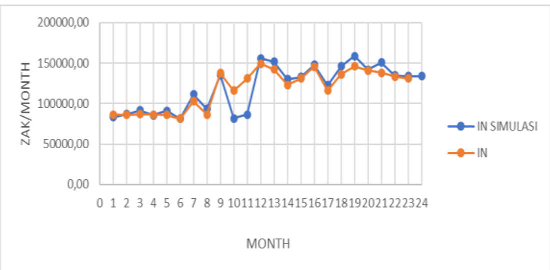

Figure 11. Actual Data and Simulation Results of Gresik Cement Variable In

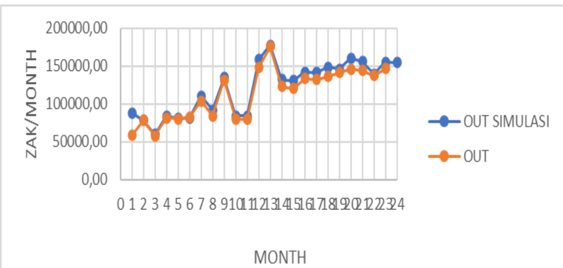

Figure 12. Actual Data and Simulation Results of Gresik Cement Variable

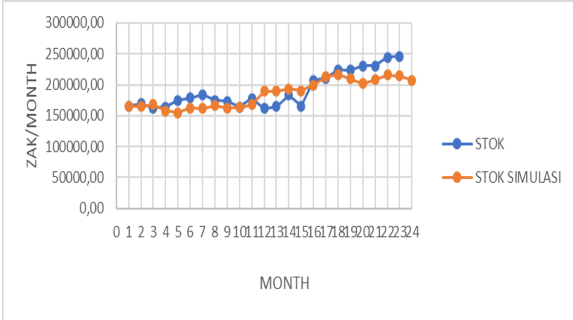

Figure 13. Actual Data and Simulation Results of Conch Cement Variable Stock

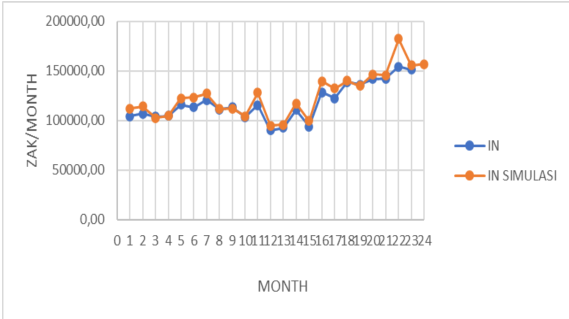

Figure 14. Actual Data and Simulation Results of Conch Cement Variable In

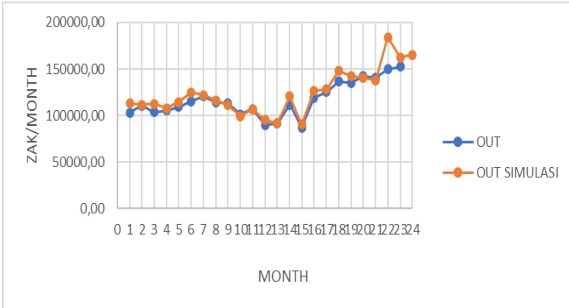

Figure 15. Actual Data and Simulation Results of Conch Cement Variable Out

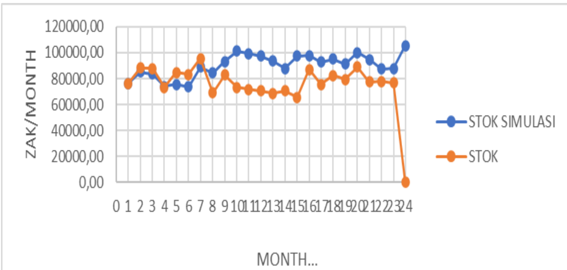

Figure 16. Actual Data and Simulation Results of Tiga Roda Cement Variable Stock.

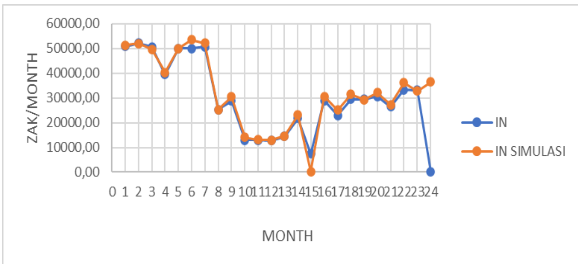

Figure 17. Actual Data and Simulation Results of Tiga Roda Cement Variable In.

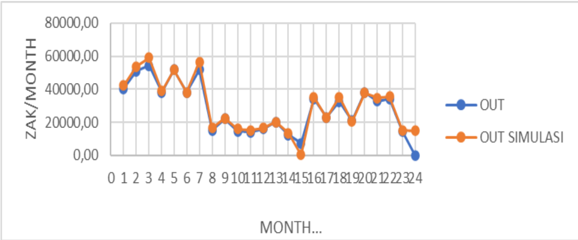

Figure 18. Actual Data and Simulation Results of Tiga Roda Cement Variable Out

Based on Figures 10 to 18, it is shown that the simulated and actual customer data from the 1st to the 24th month have behavioral conformity or similarity and are suitable as a basis for simulation for long-term policies.

C. Performance Test

The next validity is to conduct a statistical test to see the deviation between the simulation output and the actual data by calculating the Absolute Mean Error (AME). The following are the test results with the AME formula:

Table 5. Validation Test with Absolute Mean Error

Brand	AME Result
IN GRESIK	0,21210
STOK GRESIK	0,13518
OUT GRESIK	0,21210
IN CONCH	0,078424
STOK CONCH	0,113135
OUT CONCH	0,113135
IN TIGA RODA	0,185736
STOK TIGA RODA	0,076541
OUT TIGA RODA	0,084957

From the results of table 5, it shows that the Absolute Mean Error (AME) value is below the acceptable deviation limit of 5-10% [11].

IV. Conclusions

Based on the result of the making of the cement supply chaincement supply there are 3 supply chain variables, namely stock, in and out on cement brands, namely Gresik, Conch and Tiga Roda and Simulation of Conch cement inventory from 2024 to 2028 obtained Cement inventory in Palangka Raya City for Total Conch Cement Inventory in 2024: 1140555 Zak, in 2025: 1547654 Zak. In 20261921387 Zak. In 2027: 1946944 Zak. In 2028: 1918412 Zak. Total Gresik Cement Inventory in 2024: 548287 Zak, in 2025: 1785559 Zak. In 2026: 1826060 Zak. In 2027: 1849395 Zak. Year 2028: 1838869 Zak. Total Inventory of Tiga Roda Cement Year 2024: 427634 Zak, Year 2025: 250804 Zak. Year 2026: 177705 Zak. Year 2027: 321805 Zak. Year 2028: 183586 Zak. It is necessary to increase the stock of cement in distributors and retail stores so that the development needs in the construction sector of Palangka Raya City can be met and do not experience a shortage of stock and further research is needed so that the supply results can be known from distributors to construction projects and retail to construction projects.Appendices appear after the conclusions and before the acknowledgment, if needed.

V. References

[1] Nauri Wardhani, "Analisis Rantai Pasok Semen di Kota Palangka Raya," Universitas Palangka Raya, Palangka Raya, 2017.

[2] Asosiasi Semen Indonesia, "Produksi Semen Tergerus Konstruksi di Triwulan I-2021," Asosiasi Semen Indonesia.

[3] Badan Pusat Statistik 2023, "Provinsi Kalimantan Tengah Dalam Angka 2023".

[4] Nuah Kalawa, Fatma Sarie, and Mohammad Ikhwan Yani, "Pengaruh Penambahan Semen Portland, Abu Sekam dan Fly Ash Terhadap Nilai Daya Dukung Tanah Lempung Sebagai Subgrade Perkerasan Jalan," *Jurnal Keilmuan Teknik Sipil*, vol. 4, no. 1, pp. 1–10, 2021.

[5] Pandiangan H. A, "Komponen Biaya Signifikan Yang Mempengaruhi Biaya Konstruksi Pada Proyek Gedung di Kota Palangka Raya," Universitas Palangka Raya, Kota Palangka Raya, 2016.

[6] Lukman, *Suppy Chain Management*, vol. 1. Sulawesi Selatan: CV. Cahaya Bintang Gemerlang, 2021.

[7] M. A. Bellamy, S. Ghosh, and M. Hora, "The influence of supply network structure on firm innovation," *Journal of Operations Management*, vol. 32, no. 6, pp. 357–373, Sep. 2014, doi: 10.1016/j.jom.2014.06.004.

[8] M. Zomorodian, S. H. Lai, M. Homayounfar, S. Ibrahim, S. E. Fatemi, and A. El-Shafie, "The state-of-the-art system dynamics application in integrated water resources modeling," *J Environ Manage*, vol. 227, pp. 294–304, Dec. 2018, doi: 10.1016/j.jenvman.2018.08.097.

[9] M. A. Wibowo and R. Waluyo, "A System Dynamics Modeling for Knowledge Management, Culture and Performance (KMCP): Case study in Indonesian Construction Firm."

[10] IEA, "Global cement production in the Net Zero Scenario, 2010-2030."

[11] I. Nabillah and I. Ranggadara, "Mean Absolute Percentage Error untuk Evaluasi Hasil Prediksi Komoditas Laut," *JOINS (Journal of Information System)*, vol. 5, no. 2, pp. 250–255, Nov. 2020, doi: 10.33633/joins.v5i2.3900.