On mathematical model approach to competition dynamic of shipping companies in Surabaya

by Windarto Windarto

Submission date: 22-Feb-2023 12:37PM (UTC+0800)
Submission ID: 2020202334
File name: ach_to_competition_dynamic_of_shipping_companies_in_Surabaya.pdf (919.09K)
Word count: 3205
Character count: 17728

On mathematical model approach to competition dynamic of shipping companies in Surabaya

Cite as: AIP Conference Proceedings **2329**, 040009 (2021); https://doi.org/10.1063/5.0042176
Published Online: 26 February 2021

Windarto, Fatmawati, and Nadiyah Nurlaily Nuzulia

On Mathematical Model Approach to Competition Dynamic of Shipping Companies in Surabaya

Windarto[a)], Fatmawati and Nadiyah Nurlaily Nuzulia

Department of Mathematics, Faculty of Science and Technology, Universitas Airlangga, Indonesia

[a)]Corresponding author email: windarto@fst.unair.ac.id

Abstract. Indonesia has a vast sea area and consists of many islands, so shipping companies are very beneficial for Indonesia's people. This study aims to estimate parameters and analyze mathematical models of shipping company competition between three shipping companies in Surabaya. This model is a differential equation and uses the Lotka-Volterra mathematical model. In this study, the estimation of model parameters is done using the genetic algorithm method based on the number of container production transported by shipping companies. The mathematical model is then analyzed by finding the equilibrium point and checking its stability by substituting the parameter value from the estimation results. The results of this mathematical simulation model show that the three companies exist in the future, and competition between the three companies still occurs.

INTRODUCTION

Shipping companies are one type of business that provides services in the form of shipping goods between islands using ships [1]. Indonesia has a vast sea area and consists of thousands of islands. Therefore, the presence of a shipping company is beneficial for the Indonesian people in the inter-island shipping business. Some parties consider that shipping services via sea shipping are more desirable than through aviation business because of the lower shipping rates [2].

The Port of Tanjung Perak Surabaya is one of the centers of shipping activities in Indonesia. There are various shipping companies that service inter-island shipping in Indonesia. Delivery of goods is carried out through containers transported using ships. Surabaya's Tanjung Perak Harbor consists of several terminals. Each terminal at the Port of Tanjung Perak Surabaya has a function to support the activities of shipping companies engaged in domestic goods shipping services [3].

Pelindo III is a state-owned company engaged in port services, showing a definite increase in work. According to Pelindo III, most of the activities at the Port of Tanjung Perak Surabaya experienced an increase, whereas Pelindo III had the highest increase in container loading and unloading activities. Based on Pelindo III data, the number of container flows in 2018 increased by 8.5 percent compared to the previous period in 2017. Furthermore, the increase in container shipments in the first semester of 2019 doubled compared to the same period last year [4]. Increased container loading and unloading activities at the Tanjung Perak Port Surabaya terminal show that there is also an increase in performance at various shipping companies in Surabaya. Each shipping company will compete for customers.

The competition of several shipping companies can be modeled using the Lotka-Volterra competition model application. The Lotka-Volterra competition model is a model that describes the competition of two species for food sources [5]. The model has also applied to describe the Korean stock market competition [6], competition of retail industry in Taiwan [7], retailing formats competition [8], and bank competition in Indonesia [9].

The application of mathematical models can be interpreted in real problems if the model's parameter values can be known. In this research, we apply the Lotka-Volterra competition model to describe the competition dynamics of shipping companies in Surabaya. We also perform parameter estimation on the proposed model using genetic algorithm method. Moreover, we carried out stability analysis on the model by substituting the parameter values

International Conference on Mathematics, Computational Sciences and Statistics 2020
AIP Conf. Proc. 2329, 040009-1–040009-9; https://doi.org/10.1063/5.0042176
Published by AIP Publishing. 978-0-7354-4073-9/$30.00

obtained from the estimation results and finding the equilibrium point of the model. We perform the stability analysis of every equilibrium of the model, and we simulate the model to study the competitive conditions of the three companies in the future.

THE COMPETITIVE MATHEMATICAL MODEL

The competitive dynamics model of shipping companies in Surabaya uses the Lotka-Volterra competition model. The mathematical model of shipping company competition in Surabaya consists of three compartments, namely x_1, x_2, and x_3. Here x_1, x_2, and x_3 are the number of first company, second company and the third company container production respectively. The model is built on the following assumptions:

(1) There are only three competing shipping companies.
(2) Competition between the three selected shipping companies and other shipping companies can be ignored. This is due to the amount of container production from the three companies is far greater when compared to the production of containers from other shipping companies.
(3) The number of container production of each shipping company grows logistically.
(4) Promotion effect of every company could be represented into logistic growth model.
(5) Every company does not need to rent some ships from other companies.

The mathematical model of the competition dynamics of shipping companies in Surabaya consists of twelve parameters. Table 1 presents a description of the parameters used in the model.

TABLE 1. Parameters description of the shipping companies' competition mathematical model

Notation	Description	Unit
K_1	Maximum production volume of the first container company	box
K_2	Maximum production volume of the second container company	box
K_3	Maximum production volume of the third container company	box
a_1	The production volume growth rate of the first company	$\frac{1}{month}$
a_2	The production volume growth rate of the second company	$\frac{1}{month}$
a_3	The production volume growth rate of the third company	$\frac{1}{month}$
$c_{1,2}$	The reduction growth rate of the first company due to competition of the first and second companies	$\frac{1}{month.box}$
$c_{1,3}$	The reduction growth rate of the first company due to competition of the first and third companies	$\frac{1}{month.box}$
$c_{2,1}$	The reduction growth rate of the second company due to competition of the first and second companies	$\frac{1}{month.box}$
$c_{2,3}$	The reduction growth rate of the second company due to competition of the second and third companies	$\frac{1}{month.box}$
$c_{3,1}$	The reduction growth rate of the third company due to competition of the first and third companies	$\frac{1}{month.box}$
$c_{3,2}$	The reduction growth rate of the third company due to competition of the second and third companies	$\frac{1}{month.box}$

The variables x_1, x_2, x_3 represent number of container productions. Hence

$$x_1, x_2, x_3 \geq 0.$$

The parameters $K_1, K_2, K_3, a_1, a_2, a_3, c_{1,2}, c_{1,3}, c_{2,1}, c_{2,3}, c_{3,1}, c_{3,2}$ are quantities that represent rate, so we assume

$$K_1, K_2, K_3, a_1, a_2, a_3, c_{1,2}, c_{1,3}, c_{2,1}, c_{2,3}, c_{3,1}, c_{3,2} > 0.$$

Carrying capacity parameter represents maximum of container production number of each company. Hence, the carrying capacity parameters are not affected by the other shipping company. From the assumptions, the mathematical model of the competition dynamics of shipping companies in Surabaya could be represented in the following ordinary differential equation system:

$$\frac{dx_1}{dt} = a_1x_1\left(1-\frac{x_1}{K_1}\right) - c_{12}x_1x_2 - c_{13}x_1x_3, \quad (1)$$

$$\frac{dx_2}{dt} = a_2x_2\left(1-\frac{x_2}{K_2}\right) - c_{21}x_2x_1 - c_{23}x_2x_3, \quad (2)$$

$$\frac{dx_3}{dt} = a_3x_3\left(1-\frac{x_3}{K_3}\right) - c_{31}x_3x_1 - c_{32}x_3x_2. \quad (3)$$

Equation (1) represents the rate of change in the number of container production from the first company per unit time. The number of container production for the first company increased due to the growth rate in the company's production. On the other hand, the number of container production in the first company decreased due to the competition of the first company with the second and third companies.

Equation (2) describes the dynamics of the number of container production of the second company per unit time. The number of container production for the second company logistically increased due to the growth rate of the company. In contrast, the number of container production in the second company decreased due to the competition of the second company with the first and third companies.

Equation (3) describes the change rate of the container production number of the third company per unit time. The number of container production for the third company logistically increased due to the growth rate of the company. On the other hand, the number of container production in the third company decreased due to the competition of the third company with the first and second companies.

PARAMETER ESTIMATION OF THE COMPETITION MATHEMATICAL MODEL

In this section, we determine the parameter values of the mathematical model for the dynamics of shipping company competition in Surabaya. The parameter is estimated using the genetic algorithm since the exact solution of the model in equations (1)-(3) could not be determined [10, 11]. The data used to estimate the parameters is data on the number of container production or the number of containers by shipping companies every month from October 2018 ($t = 0$) to September 2019 ($t = 11$). The data are presented in Figure 1, Figure 2 and Figure 3, respectively.

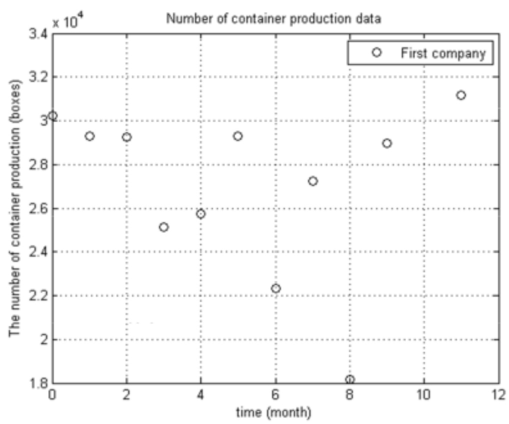

FIGURE 1. Number of container production data of the first company.

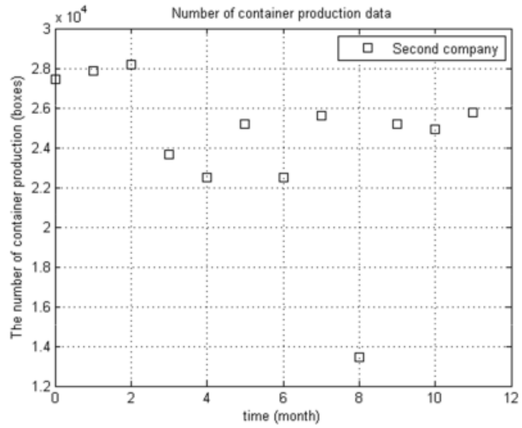

FIGURE 2. Number of container production data of the second company.

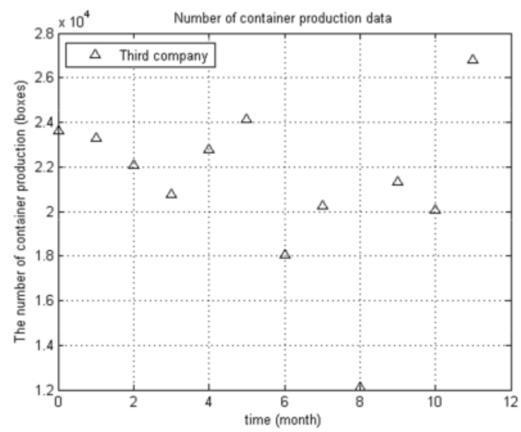

FIGURE 3. Number of container production data of the third company.

The parameter values are selected such that the parameters produce the smallest error value. In this article, we use MAPE (Mean Absolute Percentage Error) as an objective function. MAPE value is given by

$$=\frac{1}{3n}\sum_{i=1}^{n}\left(\left|\frac{x_{1,i}^{*}-x_{1,i}}{x_{1,i}}\right|+\left|\frac{x_{2,i}^{*}-x_{2,i}}{x_{2,i}}\right|+\left|\frac{x_{3,i}^{*}-x_{3,i}}{x_{3,i}}\right|\right).$$

Here is the average of relative error (MAPE), n is the number of data, $x_{1,i}$, $x_{2,i}, x_{3,i}$ are data on the number of container production from the first, second, and third companies at the i-month, respectively. Moreover, $x_{1,i}^{*}, x_{2,i}^{*}, x_{3,i}^{*}$ are the predicted number of container production from the first, second, and third companies at the i-month obtained from the model solution in equations (1)-(3), respectively. Here $i = 1,2,3, \ldots, n$.

The parameter estimation process is done through several trials, where the best objective function value is equal to 0.11994 or 11.994%. The best parameter values of the parameter estimation process are presented in Table 2.

TABLE 2. Best parameter values

Parameter	Parameter values
a_1	0.17036
c_{12}	3.96×10^{-7}
K_1	30566
c_{13}	4.58×10^{-7}
a_2	0.56306
c_{21}	5.59×10^{-7}
K_2	26775
c_{23}	6.27×10^{-7}
a_3	0.22156
c_{31}	2.27×10^{-7}
K_3	22296
c_{32}	7.39×10^{-7}

A comparison of model calculation results with real container production data for the first, second, and third companies is presented in Figure 4, Figure 5, and Figure 6, respectively.

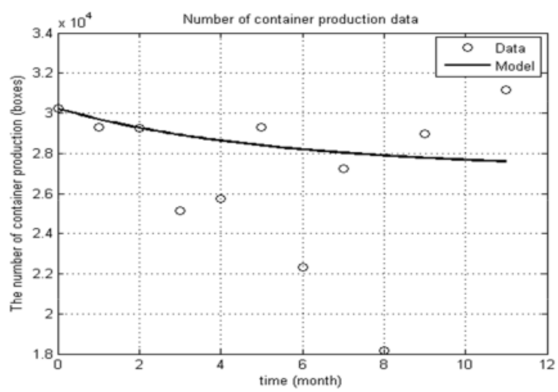

FIGURE 4. Comparison between the data and predicted result of the first company container production number

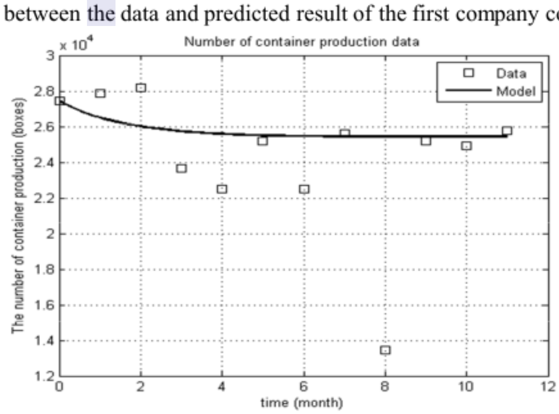

FIGURE 5. Comparison between the data and predicted result of the second company container production number

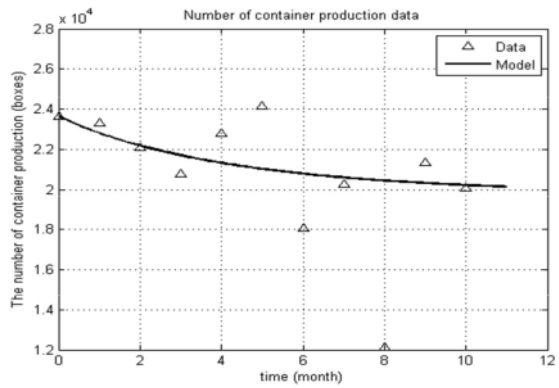

FIGURE 6. Comparison between the data and predicted result of the third company container production number

Figure 4 shows the difference between data and the predicted results of the first company. The predicted results of container production are seen to have decreased around the value of 28,000 boxes. Figure 5 shows in the sixth to the last month between real data and estimated graphs approaching the same value. The predicted results of container production in the second company are seen to have decreased around the value of 26,000 boxes. Figure 6 shows the value of total container production between the real data and the estimation results are quite close to the beginning and end of the data. The predicted results of the third company's container production are also seen to have decreased around the value of 20,000 boxes. Results of the model prediction are much different from the container production data for the three companies in the eighth month (May 2019). May 2019 coincides with Ramadan month (fasting month), where the number of container production of every shipping company in Surabaya was decrease. This decrease in production on Ramadan month (fasting month) is seasonal phenomenon in the port of Tanjung Perak, Surabaya.

By substituting the parameter values in Table 2 into equations (1) - (3), a mathematical model of shipping company competition in Surabaya takes the following form

$$\frac{dx_1}{dt} = 0.17036x_1\left(1 - \frac{x_1}{30566}\right) - 3.9553 * 10^{-7}x_1x_2 - 4.581 * 10^{-7}x_1x_3 \quad (4)$$

$$\frac{dx_2}{dt} = 0.56306x_2\left(1 - \frac{x_2}{26775}\right) - 5.5918 * 10^{-7}x_2x_1 - 6.265 * 10^{-7}x_2x_3 \quad (5)$$

$$\frac{dx_3}{dt} = 0.22156x_3\left(1 - \frac{x_3}{22296}\right) - 2.2739 * 10^{-7}x_3x_1 - 7.387 * 10^{-7}x_3x_2 \quad (6)$$

The mathematical model of the shipping company competition in Surabaya in equation (4) - (6) has eight equilibrium points, namely:

(1) The equilibrium point when all three companies go bankrupt $S_1(x_1, x_2, x_3) = (0,0,0)$.

(2) The equilibrium point is that only the first shipping company has container production, while the second and third companies have experienced bankruptcy $S_2(x_1, x_2, x_3) = (30566, 0, 0)$.

(3) The equilibrium point is when only the second shipping company has container production, while the first and third companies have experienced bankruptcy $S_3(x_1, x_2, x_3) = (0, 26775, 0)$.

(4) The equilibrium point is when only the third shipping company has the amount of container production whereas, the first and second companies have experienced bankruptcy $S_4(x_1, x_2, x_3) = (0, 0, 22296)$.

(5) The equilibrium point when the first and second shipping companies have total container production whereas, the third company has experienced bankruptcy $S_5(x_1, x_2, x_3) = (28720, 26011, 0)$.

(6) The equilibrium point when the first and third shipping companies had total container production, while the second company went bankrupt $S_6(x_1, x_2, x_3) = (28787, 0, 21637)$.

(7) The equilibrium point when the second and third shipping companies have total container production, while the first company went bankrupt $S_7(x_1, x_2, x_3) = (0, 26169, 20351)$.

(8) The equilibrium point when all three shipping companies have total container production $S_8(x_1, x_2, x_3) = (27133, 25464, 19728)$.

By using the eigenvalue approach, the equilibrium points $S_1, S_2, \ldots, S_7$ are unstable while the equilibrium coexistence point S_8 is locally asymptotically stable. Since the coexistence equilibrium S_8 is asymptotically stable, then this coexistence equilibrium will happen in real situation.

Next, we present a numerical simulation to predict the number of container production and the dynamics of competition between the three shipping companies in the future. The simulation is conducted with several different initial values to compare the dynamics of the number of container production of the three shipping companies. This numerical simulation is performed from t = 0 until t = 50 (months). The results of numerical simulations of mathematical models of shipping company competition in Surabaya in equation (4) - (6) using production data in October 2018 as an initial value are presented in Figure 7.

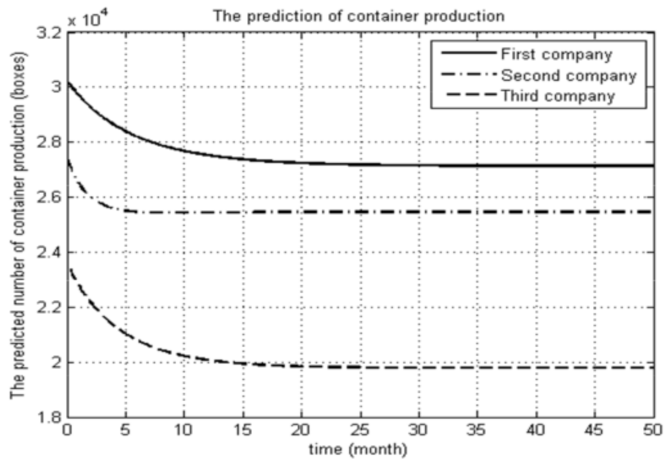

FIGURE 7. Dynamics of the container production of the shipping companies with an initial value of production data in October 2018

Figure 7 uses data on the number of container production in October 2018 as the initial value. The initial value used in the parameter estimation process equal to 30,230 boxes, 27,434 boxes, and 23,632 boxes. The simulation results show that the number of container production from the three shipping companies tends to decrease. Various factors could cause this decrease. One of them is very influential, namely the variation of weather conditions each month. In the simulation results, there was a decrease in container production until the fifth month. However, after these conditions, the amount of container production tends to be constant towards the equilibrium value.

Figure 8 presents results of numerical simulations of mathematical models of shipping company competition in Surabaya in equation (4) - (6) using production data in January 2019 as the initial value. Figure 8 uses data on the number of container production in January 2019 as the initial value of 25,235 boxes, 23,684 boxes, and 20,769 boxes. The simulation results show that the number of container production from the first and second companies tends to increase. In contrast, the number of container production of the third company seems to have decreased. This is due to various factors, including economic factors, company internal factors, and weather factors that can affect the amount of container production of each company. From the simulation results, it can be seen that the dynamics of the number of container production of the three companies tend to be constant towards the equilibrium value at a certain time.

Simulation results with different initial values show a changing trend in the number of container production that varies from each shipping company. This result shows that the initial value used in the simulation affects the simulation results. Uncertain conditions every month affect the number of container production of shipping companies so that monthly data is volatile. From the simulation results, the first shipping company tends to have a large amount of container production when compared to the second and third companies. Compared to the first and second companies, the third shipping company tends to have smaller container production.

The simulation results in Figure 7 and Figure 8 show that the graph of the number of container production in Surabaya at a specific time will lead to an equilibrium value of coexistence i.e., the equilibrium point $KS_8(Kx_1, Kx_2, Kx_3) = (27133, 25464K, 19728)$. This condition represents this situation occurs when the three shipping companies continue to survive. Competition between the first, second, and third shipping companies will also continue to occur over time. The three shipping companies must anticipate all possibilities that will occur and must have a new strategy to maintain the existence of the company's shipping activities.

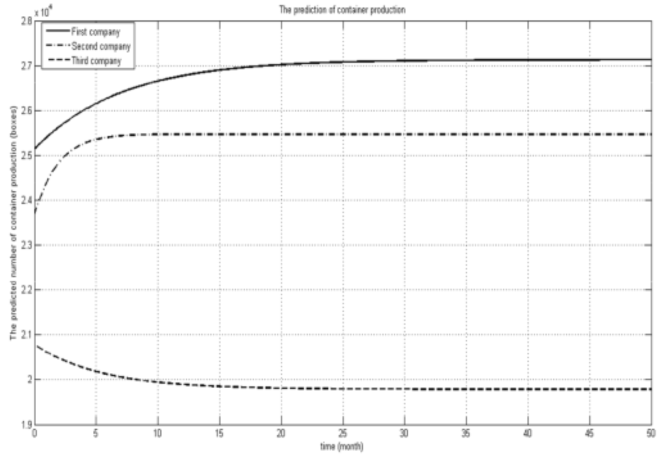

FIGURE 8. Dynamics of the container production of the shipping companies with an initial value of production data in January 2019

CONCLUSIONS

In this article, the mathematical model of the Lotka-Volterra competition has been successfully applied to explain the dynamics of the competition of three shipping companies in Surabaya. Numerical simulation results show that the equilibrium stable asymptotic equilibrium point associated with the three companies still exists, and competition between the three competition of shipping companies will continue to occur.

ACKNOWLEDGMENTS

This research was funded by Directorate of Research and Community Services Development, Ministry of Research and Technology, Republic of Indonesia.

REFERENCES

1. Peraturan Pemerintah Republik Indonesia, *Penyelenggaraan dan Pengusahaan Angkutan Laut No. 17* (text in Indonesian) (1998).
2. Kargo Penyedia Jasa Logistik, *www.kargo.tech*, accesed on 09 December 2019.
3. Kementerian Perhubungan Indonesia, *www.dephub.go.id*, accesed on 16 Desember 2019.
4. PT. Pelabuhan Indonesia III, *www.pelindo.co.id,* accessed on 26 March 2020.
5. Hastings, A., *Population Biology*: Concept and Models, Springer, New York (1997).
6. Lee, S., Lee, D., Oh, H., Technological forecasting at the Korean stock market: A dynamic competition analysis using Lotka-Volterra model, Technological Forecasting and Social Change 72(8): 1044-1057 (2005).
7. Hung, H., Tsai, Y., & Wu, M., A modified Lotka-Volterra model for competition forecasting in Taiwans retail industry, Computers & Industrial Engineering 77:70-79 (2014).
8. Hung, H., Chiu, Y., Huang, H., & Wu, M., An enhanced application of Lotka-Volterra model to forecast the sales of two competing retail formats, Computers & Industrial Engineering 109: 325-334 (2017).
9. Fatmawati, Khan, M.A., Azizah, M., Windarto, & Ullah, S., A fractional model for the dynamics of competition between commercial and rural banks in Indonesia, Chaos, Solitons and Fractals 122:32-46 (2019).

10. Windarto, Indratno, S.W., Nuraini, N, & Soewono, E., A comparison of binary and continuous genetic algorithm in parameter estimation of a logistic growth model, AIP Conference Proceedings 1587:139-142 (2014).
11. Windarto, An implementation of continuous genetic algorithm in parameter estimation of predator-prey model, AIP Conference Proceedings 1718, 110005 (2016).

On mathematical model approach to competition dynamic of shipping companies in Surabaya

ORIGINALITY REPORT

12%	8%	8%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	statik.unesa.ac.id Internet Source	2%
2	Submitted to UIN Syarif Hidayatullah Jakarta Student Paper	1%
3	aip.scitation.org Internet Source	1%
4	Žaneta Stasiškienė, Olga Anne, Dovilė Aleknavičiūtė, Tatjana Paulauskienė, Rasa Viederytė, Lilita Abele. "The Analysis of EMAS Efficiency in Industrial Companies: A Case of Lithuania", Environmental Research, Engineering and Management, 2020 Publication	1%
5	Windarto Windarto, Eridani Eridani. "Comparison of particle swarm optimization and firefly algorithm in parameter estimation of Lotka-Volterra", AIP Publishing, 2020 Publication	1%

6 Submitted to Colorado State University Fort Collins
Student Paper
1%

---

7 www.semanticscholar.org
Internet Source
1%

---

8 Hung, Hui-Chih, Yun-San Tsai, and Muh-Cherng Wu. "A modified Lotka–Volterra model for competition forecasting in Taiwan’s retail industry", Computers & Industrial Engineering, 2014.
Publication
1%

---

9 Jiali Shen, Alessandro Bigi, Angela Marinoni, Janne Lampilahti et al. "Emerging Investigator Series: COVID-19 lockdown effects on aerosol particle size distributions in northern Italy", Environmental Science: Atmospheres, 2021
Publication
<1%

---

10 arxiv.org
Internet Source
<1%

---

11 easychair.org
Internet Source
<1%

---

12 mpra.ub.uni-muenchen.de
Internet Source
<1%

---

13 Elih Sutisna Yanto. "Engaging pre-service English teachers in Sheltered Instruction
<1%

Model – mediated content and language learning", Texto Livre, 2022
Publication

14	cesmaa.org Internet Source	<1 %
15	I A Santoso, D G Pratomo, Khomsin. "Identification of a wharf wall condition using an Oblique Side Scan Sonar approach", IOP Conference Series: Earth and Environmental Science, 2021 Publication	<1 %
16	academic-accelerator.com Internet Source	<1 %
17	jglobal.jst.go.jp Internet Source	<1 %
18	Mahmoud H. DarAssi, Muhammad Altaf Khan, Fatmawati, Marei Saeed Alqarni. "Analysis of the Competition System Using Parameterized Fractional Differential Equations: Application to Real Data", Symmetry, 2023 Publication	<1 %
19	Roques, Lionel, and Michel Cristofol. "The inverse problem of determining several coefficients in a nonlinear Lotka–Volterra system", Inverse Problems, 2012. Publication	<1 %

eprints.uad.ac.id

20	Internet Source	<1%
21	Anita T. Kurniawati, Fatmawati, Windarto. "Global analysis of a dengue hemorrhagic fever transmission model with logistics growth in human population", AIP Publishing, 2021 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

On mathematical model approach to competition dynamic of shipping companies in Surabaya

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10