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Availability of Loading and Unloading Equipment, Berthing Docks, Loading and Unloading Speed on Improving Port Operational Performance Through Service Digitalization

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Abstract: This study aims to analyze the effect of the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed on operational performance at Marunda Port, Jakarta, mediated by service digitalization. The background of this research is based on the importance of port operational efficiency in supporting economic growth, primarily through increasing loading and unloading productivity and utilizing digital technology. The research method used is a quantitative method with a linear regression approach. Data was collected by distributing questionnaires to 170 respondents who are users of Marunda Port services. The results showed that the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed significantly affected port operational performance. In addition, service digitization is proven to mediate the influence of these factors on improving operational performance. This study concludes that increasing the availability of equipment and operational efficiency of the dock and loading and unloading speed, supported by service digitalization, significantly improves the operational performance of Marunda Port, Jakarta. Implementing service digitalization is vital in improving port efficiency and competitiveness in the industrial era 4.0.

Keyword: Port Digitalization, Availability of Loading and Unloading Equipment, Ship Docking Docks, Loading and Unloading Speed, Port Operational Performance.

INTRODUCTION

Transportation by sea plays a vital role in national transportation and economic growth, automatically increasing the country's foreign exchange earnings (Fitriani & Imtiyaz, 2023). The quality of transportation infrastructure that is well connected will have implications for the rapid circulation of trade goods, increasing trade volume and economic growth (Harja, 2019). So that the port becomes a vital node to build a solid maritime territory. Ports play a crucial role in the sea transportation system and the national economy, serving as a central point for loading and unloading goods and ship and passenger mobility. The quality of port infrastructure and digitization of services significantly affect ports' operational efficiency and productivity.

Improved facilities such as docks, loading and unloading equipment, and port information systems can speed up the turnover of goods and improve the safety and transparency of services. Thus, a well-managed port supported by modern technology will contribute significantly to economic growth, reduction of logistics costs, and overall efficiency of the transportation and logistics system.

As sea transportation infrastructure, ports have a vital and strategic role in industrial and trade growth. They are a business segment that can contribute to the national economy and development because they are part of the transportation and logistics chain (Putra & Djalante, 2016). Daily, dozens of ships operate at the port, resulting in a dense flow of ship traffic, especially at large ports such as Tanjung Priok Port in Jakarta (Humaira Ninvika & Junitasari, 2023). Port digitization is necessary to encourage improved service and better port competitiveness. The implementation of the logistics ecosystem era has many benefits, including reducing logistics costs, sharing logistics capacity, growing the digital economy, increasing service transparency, connecting systems between K / L, lowering logistics chains, no duplication and repetition and eliminating manual processes (Ministry of Transportation of the Republic of Indonesia, 2021).

The primary function of port services is to facilitate intra and intermodal transportation movements as a centre for sea transportation service activities and for the distribution and consolidation of goods (Husen & Baranyanan, 2021). The ship's time in port will significantly affect the vessel's operation (Marzuki & Wair, 2020). The longer the boat is at the port, the more inefficient the ship's operation is because the costs incurred are higher and will harm the parties involved (Rahmayanti & Tirtayadi, 2011). This will affect the productivity of the goods to be loaded and unloaded. Effectiveness is considered a measurement of success in achieving predetermined goals because, as a value of a port's productivity, there is undoubtedly a good time measure so that the loading and unloading process runs optimally. Without well-maintained equipment and reliability, which shows that many tools are in prime condition, loading and unloading activities cannot meet standard output targets.

To improve its service, the company must achieve high productivity. To meet the standards set by the company, it is necessary to make a procedure regarding the loading and unloading process to facilitate and streamline the loading and unloading process at the port. The facility closely related to this is the terminal, the main element. It is a facility where ships dock and carry out loading and unloading activities. The availability of port facilities is designed by the capacity of berthing and mooring service capabilities at the port, including users of the type of equipment to be used. The time of ship visit at the port is highly dependent on the quality of service, which includes the speed of loading and unloading and the provision of facilities such as mooring/berthing, warehouses, and goods stacking fields. All this aims to ensure that shipping navigation takes place safely, orderly and smoothly, thus protecting the safety of ships, people, goods and the environment.

Marunda Port is a multipurpose logistics port in North Jakarta, DKI Jakarta Province. At the Marunda port, the digitalization of port services has not been maximized, the a lack of utilization of loading and unloading equipment, and the condition of the dock area is not sterile because there is still hoarding, which causes the dock area to become dusty, which has an impact on the satisfaction of Marunda Port users as a place for loading and unloading.

In line with research (Suryantoro & Punama, 2020), which shows an increase in labour variables, lift on/off loading and unloading equipment, and the effectiveness of the stacking field, the productivity of loading and unloading containers will also increase. Research conducted (Kanellopoulos & Kostovasili, 2023) shows that Short sea shipping can play an essential role in the deployment of the physical internet, as it can provide an efficient and cost-effective mode of transportation of goods between nearby ports and innovative and automated components of MOSES along with the use of Logistics Matchmaking Platforms can help reduce congestion on roads and highways, lower carbon emissions, and improve overall transportation efficiency, all of which are the main goals of the physical internet. Then, according to (Dalaklis & Christodoulou, 2022), The results showed that implementing a broad portfolio of digital initiatives by the port under discussion has optimized its operations and is strongly linked to sustainable development.

The purpose of this study is to evaluate how the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed affect the improvement of the operational performance of Marunda Port in Jakarta, as well as to analyze the role of port service digitization as a mediator in the relationship. This research aims to provide an in-depth understanding of how physical factors and digital technology interact to improve the efficiency and effectiveness of port operations.

This research is expected to provide in-depth insight into the effect of the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed on the operational performance of Marunda Port, as well as understanding how the digitalization of port services can mediate the relationship. The results of this study are expected to be used as a basis for improving operational strategies, efficiency, and effectiveness of services at the port, as well as providing practical recommendations for implementing digital technology to support the development and modernization of port facilities.

This research is expected to add to the literature on the influence of physical factors and digital technologies on port operational performance and significantly contribute to the understanding and best practices in port management. In addition, this research is expected to be a reference for future research and assist policymakers and related parties in formulating strategies to improve the efficiency and effectiveness of Port services.

METHOD

This study aims to explore and analyze the influence of the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed on improving the operational performance of Marunda Port in Jakarta. In addition, this study also aims to assess the role of port service digitization as a mediator that can influence the relationship between these factors and port operational performance. Thus, this study aims to provide an in-depth understanding of how integrating physical factors and digital technology can improve the efficiency and effectiveness of port operations. This research utilizes a quantitative method, namely Path analysis. This approach was chosen because path analysis allows the modelling and analysis of the complex relationships between independent, intervening (or mediating) variables and dependent variables in a study.

This study uses a quantitative survey to collect data from respondents directly and then analyze it to find out how the variables impact. Data was collected through questionnaires distributed to customers who use Marunda Port services. For this study, a purposive sampling method was used, which means that respondents were selected based on criteria relevant to the research. The number of samples used for this study was 170 respondents. This is according to the Hair jr formula in Hidayatullah & Alvianna, (2023), namely (5 to 10) x Indicator. 10 x 17 = 170 research samples. Data was collected through questionnaires distributed online through the Google Forms platform. Respondents who met the research criteria received the questionnaire via email and social media. Data collection was conducted over two months to ensure that the sample was representative.

Before the data was further processed, validity and reliability tests were conducted to ensure that the instruments used in this study were valid and reliable. The validity test was conducted by comparing the calculated r-value with the r-table value for the degree of freedom (df) = n-2-1 with alpha 0.05. If the r count is greater than the r table and the r value is positive, then the item or question is a valid and reliable test. If the Cronbach's Alpha coefficient is ≥ 0.6 $\rightarrow$ then Cronbach's Alpha is acceptable (construct reliable). If Cronbach's Alpha < 0.6 $\rightarrow$ then Cronbach's Alpha is poorly acceptable (construct unreliable).

The use of path analysis in research data analysis is based on several Sugiyono assumptions (Djafar et al., 2024) as follows; The relationship between the variables to be analyzed is linear, additive, and causal; Residual variables are not correlated with the variables that precede them or with other variables; The variable relationship model has only a unidirectional causal path; The data for each analyzed variable is interval data and comes from the same source.

The six-month research included preparation, data collection, data analysis, and report writing. The data was collected online and focused on respondents living in Jabodetabek. This study has some limitations, one of which is that its scope is limited to the Greater Jakarta area. As a result, the results may not be generalizable to other Ports in Indonesia. In addition, it is possible that the respondents are not truly representative of the broader population due to the survey method used.

RESULTS AND DISCUSSION

The data for this study came from questionnaires distributed to 170 respondents. Validity and reliability tests are carried out to ensure the research instruments are valid and reliable. The validity test compares the calculated r-value with the r-table value for the degree of freedom (df) = n-2-1 with alpha 0.05. Suppose the r count is greater than the r table and the r value is positive. In that case, the item or question is said to be valid, and the reliability test is if Cronbach's Alpha coefficient $\geq 0.6 \rightarrow$ then Cronbach's Alpha is acceptable (construct reliable). If Cronbach's Alpha $< 0.6 \rightarrow$ then Cronbach's Alpha is poorly acceptable (construct unreliable).

Table 1 Validity Test

Item No.	R count	R table	Description
X1.1	0,77	0,151	Valid
X1.2	0,911	0,151	Valid
X1.3	0,904	0,151	Valid
X2.1	0,811	0,151	Valid
X2.2	0,834	0,151	Valid
X2.3	0,724	0,151	Valid
X3.1	0,781	0,151	Valid
X3.2	0,904	0,151	Valid
X3.3	0,919	0,151	Valid
Y.1	0,706	0,151	Valid
Y.2	0,873	0,151	Valid
Y.3	0,856	0,151	Valid
Z.1	0,732	0,151	Valid
Z.2	0,861	0,151	Valid
Z.3	0,848	0,151	Valid
Z.4	0,73	0,151	Valid

Source: Data that the author has processed

The table above shows that all variable indicators measured have a value> 0.151; it canbe concluded that all variable indicators in this study have a valid value.

Table 2. Reliability Test

	Cronbach'sAlpha
Availability of L/U Equipment (X_1)	0.822
Ship Berthing Dock (X_2)	0.699
Loading Unloadin Speed (X_3)	0.829
Port Operational Performance (Y)	0.737
Service digitization (Z)	0.738

Source: Data that the author has processed

Based on the Reliability Test above, the Cronbach's Alpha value of X_1 is 0.822, X_2 is 0.699, X_3 is 0.829, Z is 0.738, and Y is 0.737, this means that the questions that constitute the factor dimensions (X_1, X_2, X_3, Z and Y) are reliable. It is declared reliable because the number on Cronbach's Alpha is > 0.60. Based on the results of the reliability test above, respondents showed high stability and consistency when answering questionnaire questions about the variable dimensions of the Availability of Loading and Unloading Equipment (X_1), Ship Docking Docks (X_2), Service Digitalization (Z), and Port Operational Performance (Y). In a rare path analysis, the first is to test sub-structure one and 2.

Table 3. Substructure 1 Effect of Variable X_1, X_2, X_3 on Y
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.952	.736		6.726	.000
	Availability ofL/U tools	.442	.066	.489	4.158	.032
	Ship BerthingDoc	.343	.051	.339	3.037	.010
	L/U Speed	.649	.063	.505	10.234	.000

a. Dependent Variable: Operational Performance

Source: Data that the author has processed

Based on the output of Sub Structure Model I, it can be seen that the significance valueof the two variables, namely Availability of Loading and Unloading Equipment (X_1) = 0.032,Ship Landing Dock (X_2) = 0.010 is smaller than 0.05 and Speed of Loading and Unloading (X_3) = 0.010. These results provide the conclusion that Sub Structure Model I, namely the variable Availability of Loading and Unloading Equipment (X_1), Vessel Dock (X_2) and Loading and Unloading Speed (X_3) have a significant effect on port Operational Performance(Y).

Table 4. Test Coefficient of Determination X_1, X_2, X_3 on Y
Model Summary[b]

Model	R	R Square	AdjustedR Square	Std. Errorof the Estimate
1	.829[a]	.760	.750	1.19393

a. Predictors: (Constant), Loading Unloadiing speed, ShipBerthing Dock, Availability of L/U equipment
b. Dependent Variable: Port Operational Performance

Source: Data that the author has processed

The magnitude of the R Square value contained in the output results in Table 4 is 0.760; this shows that the contribution of the influence of the Availability of Loading and Unloading Equipment (X_1), Ship Dock (X_2) and Loading and Unloading Speed (X_3) has a significant effect on port Operational Performance (Y) is 76%. In comparison, the remaining 34% is the contribution of other variables. For the value of ε_1 $\sqrt{(1\text{-}0{,}760)}$ = 0,489.

Table 5. Sub Structure 2 Effect of Variable X_1, X_2, X_3 and Y on Z
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.285	.549		7.799	.000
	Availability ofL/U tools	.316	.044	.205	2.821	.000
	Ship BerthingDoc	.279	.043	.175	2.264	.008
	L/U Speed	.193	.054	.142	2.740	.034
	OperationalPerformance	.625	.051	.596	7.482	.003

a. Dependent Variable: Service Digitalization

Source: Data that the author has processed

Based on the output of Sub Structure Model II in Table 15, it can be seen that the significance value of the three variables, namely the Availability of Loading and Unloading Equipment (X_1) = 0,000, Ship Dock (X_2) = 0,008 smaller than 0,05, Loading and Unloading Speed (X_3) = 0,034 smaller than 0.05 and Port Operational Performance (Y) = 0,003 smaller than 0.05. These results provide a conclusion that Sub Structure Model II, namely the variable Availability of Loading and Unloading Equipment (X_1), Ship Dock (X_2), Loading and Unloading Speed (X_3) and Port Operational Performance, have a significant effect on service digitization (Z).

Table 6. Test Coefficient of Determination of Variables X1, X2, X3 and Y on Z
Model Summary[b]

Model	R	R Square	AdjustedR Square	Std. Errorof the Estimate
1	.946[a]	.894	.892	0.78990

a. Predictors: (Constant), Operational Performance, Ship berthing dock, Availability of L/U equipment, Loading andUnloading speed
b. Dependent Variable: Service Digitalization

Source: Data that the author has processed

The magnitude of the R Square value contained in the output results in Table 16 is 0.894; this shows that the contribution of the influence of the Availability of Loading and Unloading Equipment (X_1), Ship Dock (X_2), Loading and Unloading Speed (X_3) and Port Operational Performance (Y) significantly affects the Digitalization of services (Z) is 89.4%. In comparison, the remaining 10.6% is the contribution of other variables. For the value of ε_2 $\sqrt{(1-0,894)}$ = 0,325. Based on the results of the path coefficient in sub-structure I and sub- structure II, it can be described as a whole which illustrates the path analysis diagram of the Effect of the Availability of Loading and Unloading Equipment (X_1), Ship Dock (X_2), Loadingand Unloading Speed (X_3) and Port Operational Performance (Y) through Digitalization of services (Z) can be seen in the following figure:

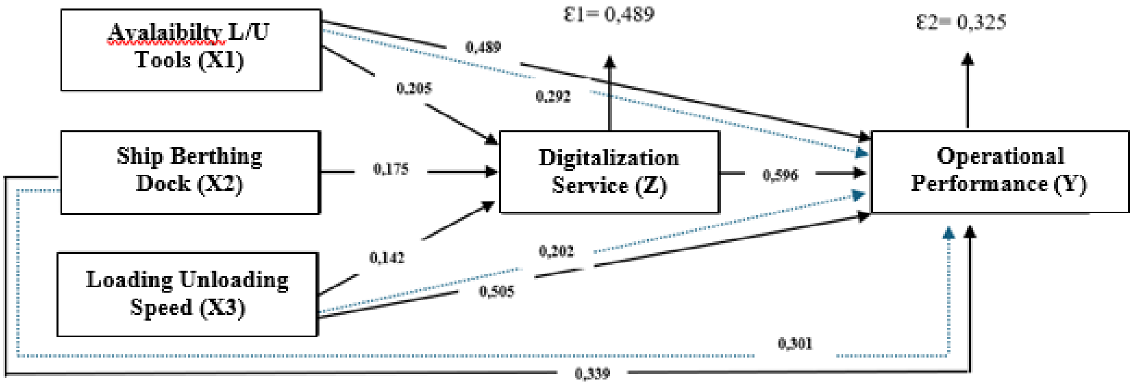

Figure 1. Path Analysis Diagram

The direct effect given by the availability of loading and unloading equipment (X_1) on service digitalization (Z) is 0.205. The indirect impact of the availability of loading and unloading equipment (X_1) through port operational performance (Y) on service digitalization (Z) is the multiplication of the beta value of X_1 against Y with the beta value of Y against Z, namely: 0,489 x 0,596= 0, 292. Based on the results of the above calculations, it is known that the value of the direct effect is smaller than the indirect effect. Namely, these results indicate that indirectly, the availability of loading and unloading equipment (X_1) through port operational performance (Y) has a significant effect on service digitalization (Z).

The direct influence of the Ship Docking Pier (X_2) on the Digitalization of services (Z)is 0.175. The indirect effect of the Ship Dock (X_2) through the port Operational Performance on the Digitalization of services (Z) is the multiplication of the beta value of X_2 against Y with the beta value of Y against Z, namely: 0,339 x 0,596= 0, 202. Based on the results of theabove calculations, it is known that the value of the direct effect is smaller than the indirect effect. Namely, these results indicate that indirectly, the Ship Docking Pier (X_2) through port Operational Performance (Y) has a significant impact on service Digitalization (Z).

The direct effect of B / M Speed (X_3) on service digitalization (Z) is 0.142. The indirect effect of B / M Speed (X3) through port Operational Performance (Y) on service Digitalization (Y) is the multiplication of the beta value of X_2 against Y with the beta value of Y against Z, namely: 0,339 x 0,596= 0, 202. Based on the results of the above calculations, it is known that the value of the direct effect is smaller than the indirect effect. Namely, these results indicate that indirect Loading and Unloading Speed (X_3) through port Operational Performance (Y) has a significant impact on service Digitalization (Z).

Mediation hypothesis testing is done using the sobel test. The Sobel test requires the assumption of a large sample size and a customarily distributed mediation coefficient value. The sobel test is conducted by testing the strength of the indirect effect of X to Y through Z.

Table 7. Sobel Test X1, X2, X3 on Y
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.952	.736		6.726	.000
	Availability ofL/U tools	.442	.066	.489	4.158	.032
	Ship BerthingDoc	.343	.051	.339	3.037	.010
	L/U Speed	.649	.063	.505	10.234	.000

a. Dependent Variable: Operational Performance

Source: Data that the author has processed

Table 8. Sobel Test X_1, X_2, X_3 on Y through Z
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.701	.902		5.209	.000
	Availability ofL/U tools	.408	.151	.063	6.374	.002
	Ship BerthingDoc	.549	.065	.082	7.038	.010
	L/U Speed	.643	.065	.976	9.011	.000
	Service Digitalization	.587	.118	.085	7.824	.004

a. Dependent Variable: OperationalPerformance

Source: Data that the author has processed

The regression results table above shows that the regression coefficient value of the Availability of Loading and Unloading Equipment, Ship Dock and B / M Speed on port Operational Performance is X_1 = 0.442 with a standard error of 0.066 and a significance value of 0.032, X_2 = 0.343 with a standard error of 0.051 and a significance value of 0.010 and X_3 = 0.649 with a standard error of 0.063 and a significance value of 0.000. Then, the service digitization variable gets a coefficient value of 0.587 with a standard error of 0.118 and a significance value of 0.004. So, the Availability of Loading and Unloading Equipment, Ship Docking Blocks and B / M Speed significantly affect port operational performance, and service digitalization has a significant direct effect on port operational performance at Marunda Port Jakarta.

From the results of the calculation of the sobel test, the effect of the availability of loading and unloading equipment (X_1) on port operational performance (Y) through service digitalization (Z), getting a z value of 3.993, the results of the calculation of the sobel test on the effect of ship berth docks (X_2) on port operational performance (Y) through service digitalization (Z), getting a value of 3.999 and the results of the calculation of the sobel test on the effect of Loading and Unloading speed (X_3) on port operational performance (Y) through service digitalization (Z), getting a value of 4.479. Because the z value obtained is 3.993> 1.96, the value of 3.999 > 1.96 and 4.479> 1.96 with a significance level of 5%, it proves that service digitalization (Z) can mediate the relationship between the availability of loading and unloading equipment (X), ship docking docks (X_2) and B / M speed (X_3) on port operational performance (Y) at Marunda Port Jakarta.

CONCLUSION

The availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed are crucial elements in improving the operational performance of Marunda Port Jakarta, and service digitization plays a vital role as a mediator that strengthens the effectiveness of these three factors. Modern and adequate loading and unloading equipment enables fast and efficient loading and unloading processes, while well-designed jetties support safe and efficient ship berthing.

The availability of sufficient loading and unloading equipment and wharves are fundamental factors in ensuring optimal port operational performance. Modern and adequate loading and unloading equipment, such as automatic cranes and reach stackers, speed up moving goods from ship to dock, reducing vessel dwell time and improving operational efficiency. Spacious and well-designed docks allow vessels to dock safely and efficiently, supporting a seamless loading and unloading process.

With enough berth capacity, ports can handle larger volumes of vessels and cargo, increasing throughput and reducing congestion. The availability of adequate facilities in these two aspects directly contributes to lowering vessel berthing time, improving vessel rotation, and optimizing port space and resources. Therefore, investment in state-of-the-art loading and unloading equipment and adequate berths is essential to support smooth port operations, speed up the flow of goods, and improve the overall competitiveness of the port.

High loading and unloading speeds optimize vessel turnaround and cargo handling. Service digitization facilitates system integration and eases real-time monitoring, data management, and operational coordination, improving port efficiency and productivity. By incorporating digital technologies, ports can optimize resource use, reduce downtime, and increase throughput. Building a sustainable port, therefore, requires investment in both state-of-the-art physical infrastructure and the application of digital technology to create more responsive, efficient and competitive port operations in the future.

The availability of adequate and modern loading and unloading equipment is critical to port operational performance. Advanced tools such as automated cranes and reach stackers speed up the loading and unloading process, reduce vessel dwell time, and improve operational efficiency by accelerating vessel turnaround and freight forwarding. Digitalization at ports is essential as it significantly transforms operational efficiency, monitoring, and data management. By implementing digital technology, ports can leverage automation systems to optimize vessel scheduling, loading and unloading, and container management.

Digitalization enables real-time integration of connected systems, facilitating accurate data collection and analysis for better decision-making. This reduces downtime, speeds up logistics processes, and increases operational transparency and accountability. In addition, digital technology enables ports to adapt quickly to changing markets and customer demands, improving competitiveness and reducing operational costs. Thus, digitalization is crucial in creating efficient, responsive and sustainable ports in the modern era.

While this research has provided valuable knowledge on how the availability of loading and unloading equipment, ship berthing docks, and loading and unloading speed affect the improvement of port operational performance mediated by service digitalization at Marunda Port Jakarta, some shortcomings need to be noted. Firstly, the research may be limited to certain aspects of digitization and not fully cover all the latest technologies or digital solutions available. Second, the data used in the study may not include seasonal or situational variability that could affect the results, such as fluctuations in cargo volumes or changes in operational policies. Third, there may be geographical or temporal coverage limitations that restrict the generalizability of the results of this study to other ports with different conditions. Fourth, other aspects such as staff training, equipment maintenance, and external factors such as government policies or the global economy that affect port operational performance may not have been analyzed in depth. Therefore, further studies covering a more comprehensive range of variables and conditions are needed to provide a more thorough and accurate picture of the influence of these factors on port performance.

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