

The Effect of PJU Quality, Environmental Security, Infrastructure Accessibility On Income Through Digital Innovation of MSMEs in Balikpapan

Yusri¹, Ety Soesilowati², Hadi Sumarsono³

¹⁻³⁾ Department of Development Economics, Postgraduate Program, Universitas Negeri Malang

E-mail: ¹⁾ yusri.2404328@students.um.ac.id, ²⁾ ettysoesilowati.fe@um.ac.id,
³⁾ hadi.sumarsono.fe@um.ac.id

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Abstract

This study aims to analyze the effect of Public Street Lighting (PSL) Quality, Environmental Safety, and Infrastructure Accessibility on MSME Income through Digital Innovation in Balikpapan City. A quantitative approach with an explanatory research method was used on a sample of 100 MSME actors selected using purposive sampling. The data were analyzed using Structural Equation Modeling based on Partial Least Squares (SEM-PLS). The results of the study prove that Digital Innovation plays a significant mediating role. The quality of PJU, Environmental Safety, and Infrastructure Accessibility have a positive and significant effect on Digital Innovation, which in turn directly increases MSME Income. These findings underscore that improvements in physical infrastructure and environmental safety create an ecosystem conducive to the adoption of digital technology by MSMEs, which is a major catalyst for improving their economic performance. The implications of this study suggest the need for integrated policies that combine the development of smart public infrastructure (smart street lighting) with digital literacy and access programs for MSMEs in order to promote inclusive and sustainable local economic growth.

Keywords: MSMEs, Digital Innovation, Infrastructure, Environmental Safety, MSME Income

1. INTRODUCTION

The development of Micro, Small, and Medium Enterprises (MSMEs) in large cities like Balikpapan faces both opportunities and obstacles. Public infrastructure, such as street lighting (PJU), infrastructure accessibility, and environmental safety, are crucial factors influencing nighttime economic activity, consumer mobility, and business actors' perceptions of risk. Good street lighting not only improves road user comfort but also strengthens nighttime economic activity by creating a sense of security and attracting more consumers (Gordic et al., 2021). This demonstrates the close relationship between public infrastructure and the dynamics of economic activity, particularly for MSMEs in urban areas.

The availability of physical and digital infrastructure also determines the operational efficiency of MSMEs. Good transportation infrastructure and road access enable faster distribution of goods and expand market reach. Centurião et al. (2024) showed that investment in transportation infrastructure has a significant impact on increasing regional economic output by improving inter-regional connectivity. In the context of Balikpapan, where the logistics and energy sectors are key economic drivers, improved infrastructure accessibility is expected to strengthen the productivity base of MSMEs, which play a role in supporting the local supply chain.

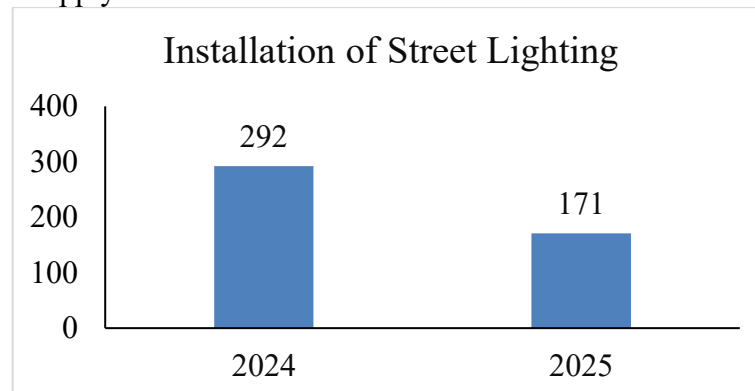


Figure 1. Data on the Addition of Solar-Powered Street Lights in Balikpapan City
 Source: Balikpapan City Transportation and Public Works Agency (2026)

Figure 1.1 shows that the number of additional solar-powered Street Lighting (PJU) in Balikpapan City decreased from 292 points in 2024 to 171 points in 2025. Although this appears to be a decrease, this condition does not necessarily indicate a decrease in the city government's commitment to lighting infrastructure. Based on information from the Balikpapan City Transportation and Public Works Department (2025), the decrease occurred because the Balikpapan Terang program was still in the implementation stage until the end of 2025, so that some PJU installation projects had not been fully recorded in the current year's data.

This phenomenon illustrates that lighting infrastructure development remains a strategic priority in efforts to improve security and nighttime economic activity in urban areas. This aligns with research by Kurniawan and Kurniawan (2022), which states that improving the quality and availability of street lighting directly contributes to increased public comfort, energy efficiency, and supports the growth of the urban nighttime economy. Therefore, analyzing the impact of street lighting quality on MSME revenue is crucial, given the broad social and economic impact of lighting infrastructure in Balikpapan City.

Environmental security also plays a crucial role in the sustainability of community economic activity. Good security will increase consumer confidence in transactions, reduce business risks, and expand the operating hours of MSMEs. Fitriyyah and Pramana (2025) found that the level of environmental security is positively related to the intensity of economic activity in urban areas, while increased crime risk negatively affects the number of visitors and informal sector income. Therefore, environmental security in business areas is a crucial determinant in analyzing MSME revenue in Balikpapan City.

In addition to physical infrastructure and security, digital transformation is a crucial element in increasing MSME competitiveness. The implementation of digital innovations, such as the use of online platforms, social media, and digital payment systems, has been shown to improve operational efficiency and expand markets. Radicic and Petković (2023) emphasized that digitalization enables MSMEs to optimize product innovation and business processes, oriented towards cost efficiency and increased added value. In the Balikpapan context, digitalization can be a determining factor strengthening the relationship between infrastructure and increased MSME revenue.

However, the digitalization process for MSMEs cannot run optimally without the support of a conducive business environment and policies. Melo et al. (2023) stated that the success of MSME digitalization is highly dependent on the readiness of digital infrastructure, the digital literacy level of business actors, and adaptive regulatory support. In Indonesia, many MSMEs face obstacles in accessing technology, limited digital competency, and low internet penetration in certain areas. Therefore, the success of digital innovation as a mediating variable in increasing MSME revenues requires synergy between physical infrastructure and the socio-economic environment.

From a technical perspective, the quality of public street lighting (PJU) has an indirect impact on MSME revenues, particularly those operating at night. Adequate street lighting can create a sense of security, increase social activity, and strengthen the potential of the nighttime economy. Kurniawan and Kurniawan (2022) showed that improving street lighting systems at the city level can increase energy efficiency by up to 69 percent and expand economic activity in communities surrounding well-lit areas. Thus, the quality of PJU not only plays a role in the technical aspects of lighting, but also contributes to improving the local economy through increasing the intensity of business activities.

Based on the above description, it can be concluded that street lighting quality, environmental safety, and infrastructure accessibility are important external factors that have the potential to influence MSME income in Balikpapan City. However, this relationship is suspected to be indirect, but rather mediated by the digital innovation capabilities of MSME actors. Therefore, this study is relevant to analyze the influence of street lighting quality, environmental safety, and infrastructure accessibility on MSME income through digital innovation as a mediating variable in Balikpapan City. The results of this study are expected to contribute to the development of theories and policies for infrastructure- and digitalization-based MSME empowerment in Indonesia.

2. RESEARCH METHOD

This study uses a quantitative approach with the aim of testing the relationship between variables through inferential statistical analysis. The quantitative approach was chosen because this study seeks to explain the direct and indirect influences between numerically measured variables, as well as to test the mediation model of digital innovation on the relationship between infrastructure and MSME income. This method is in accordance with the positivistic paradigm, where the researcher acts as an objective observer who measures economic phenomena based on empirical data from respondents. The type of research used is explanatory research, because it aims to explain the causal relationship between variables

that have been established in the research model. Explanatory research allows researchers to test the direct and indirect (mediation) effects between Street Lighting Quality (X_1), Environmental Security (X_2), and Infrastructure Accessibility (X_3) on Income (Y) through MSME Digital Innovation (Z). The population in this study were MSMEs active in Balikpapan City and registered with the Balikpapan City Cooperatives, MSMEs, and Industry Office in the year of the study. The sample in this study was determined using a purposive sampling technique. Respondents were selected based on the criteria (1) Having a permanent place of business, (2) Having run their business for at least one year, (3) Willing to provide information for research needs. The number of samples in this study was calculated using the G Power application as described in the following image.

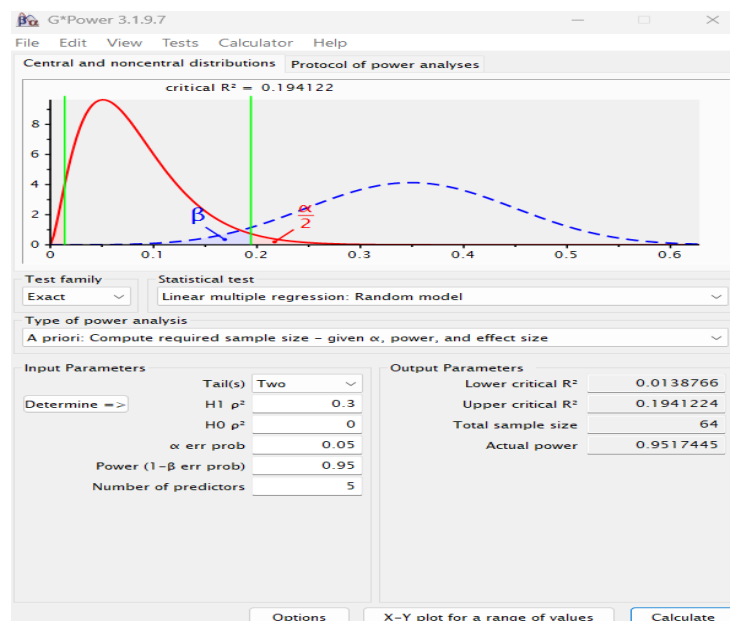


Figure 2. Minimum Sample Calculation with the G Power application

Referring to the minimum sample with the G Power application in the image above, it is known that the minimum sample required is 64 MSME business actors, but because for data supply if it is necessary to drop out respondents who are not suitable, the number of samples will be attempted to reach 100 MSME business actors. Research Variables where the Independent Variable (X_1) is the Quality of Public Street Lighting, Independent Variable (X_2) Environmental Security, Independent Variable (X_3) Infrastructure Accessibility, Mediating Variable (Z) is MSME Digital Innovation. And, the dependent variable of the research (Y) is MSME Income. The data used in this study are primary data and secondary data. Primary data was obtained directly from MSME actors, government officials related to the MSME Service or Public Works Service, and other Stakeholders PLN and Infrastructure construction service providers. Secondary data was obtained from official documents such as reports on the development of MSMEs in Balikpapan City, infrastructure development plans, regional statistical data, regional regulations, BPS publications, and reports on the Balikpapan City Bright program issued by relevant government agencies or private

institutions. Data collection techniques used questionnaires, field observations, and documentation. SEM PLS was used for analysis.

3. RESULTS AND DISCUSSION

3.1. Evaluation of Measurement Models

The measurement model used in this study adopts a reflective approach in evaluating a number of variables, such as Street Lighting Quality (X_1), Environmental Security (X_2), Infrastructure Accessibility (X_3), Digital Innovation (Z), and Income (Y). To ensure that the indicators measure the intended variables better than other variables, the researchers also pay attention to outer loadings.

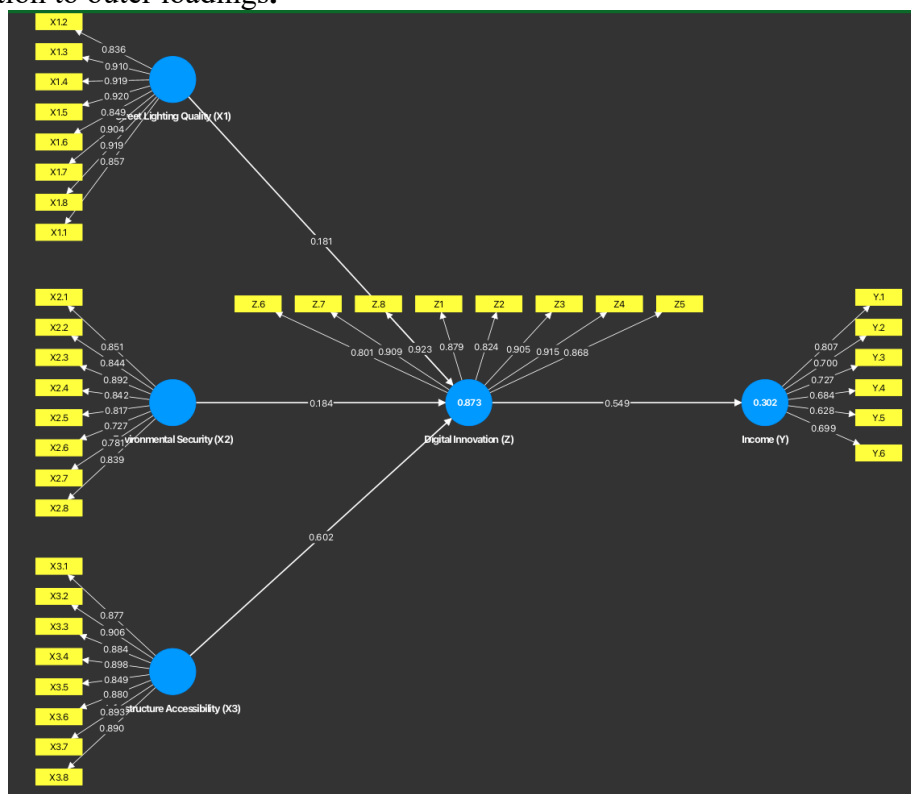


Figure 3. PLS Algorithm Results

Source: Processed data, SMARTPLS 4, 2026

In detail, the results of the convergent validity and discriminant validity tests are presented in Table 1.

Table 1. Convergent Validity Test Results

Variable	Item	Outer Loading	Description
Street Lighting Quality (X_1)	X1.1	0.857	Valid
	X1.2	0.836	Valid
	X1.3	0.910	Valid
	X1.4	0.919	Valid
	X1.5	0.920	Valid
	X1.6	0.849	Valid

	X1.7	0.904	Valid
	X1.8	0.919	Valid
Environmental Security (X ₂)	X2.1	0.851	Valid
	X2.2	0.844	Valid
	X2.3	0.892	Valid
	X2.4	0.842	Valid
	X2.5	0.817	Valid
	X2.6	0.727	Valid
	X2.7	0.781	Valid
	X2.8	0.839	Valid
Infrastructure Accessibility (X ₃)	X3.1	0.877	Valid
	X3.2	0.906	Valid
	X3.3	0.884	Valid
	X3.4	0.898	Valid
	X3.5	0.849	Valid
	X3.6	0.880	Valid
	X3.7	0.893	Valid
	X3.8	0.890	Valid
Digital Innovation (Z)	Z1	0.879	Valid
	Z2	0.824	Valid
	Z3	0.905	Valid
	Z4	0.915	Valid
	Z5	0.868	Valid
	Z6	0.801	Valid
	Z7	0.909	Valid
	Z8	0.923	Valid
Income (Y)	Y1	0.807	Valid
	Y2	0.700	Valid
	Y3	0.727	Valid
	Y4	0.684	Valid
	Y5	0.628	Valid
	Y6	0.699	Valid

Source: From Researchers, SmartPLS 4 2026

3.2.Fornell Lacker Test

Table 2. Discriminant Validity with Fornell Lacker Criteria

	Street Lighting Quality (X ₁)	Environmental Security (X ₂)	Infrastructure Accessibility (X ₃)	Digital Innovation (Z)	Income (Y)
Street Lighting Quality (X ₁)	0.879				
Environmental Security (X ₂)	0.861	0.825			

Infrastructure Accessibility (X ₃)	0.549	0.411	0.710		
Digital Innovation (Z)	0.926	0.883	0.512	0.885	
Income (Y)	0.864	0.797	0.405	0.889	0.890

Source: From Researchers, SmartPLS 4 2026

The diagonal values used for this analysis indicate the square root of the Average Extracted Variance (AVE), while the other values are the results of correlations between variables. To assess discriminant validity, the Fornell and Larcker method was used. The test results show that the Street Lighting Quality variable has discriminant validity that meets the requirements with an AVE root value of 0.879, which indicates a higher correlation value than its correlation with Environmental Security 0.861 and Infrastructure Accessibility 0.549. The AVE root for Environmental Security is 0.825, which is higher than Infrastructure Accessibility (0.41), Digital Innovation (0.883), and Income (0.797). On the other hand, the Infrastructure Accessibility construct shows an AVE root of 0.710, which has a higher correlation than the Digital Innovation variable (0.512) and the Income variable (0.405). Furthermore, the Income construct has an AVE root of 0.889, which has a greater correlation than the Digital Innovation variable of 0.885.

3.3. Structural Model Evaluation

3.3.1. Multicollinearity Test

Table 3. Multicollinearity Test Result

	VIF
Digital Innovation (Z) → Income (Y)	1.000
Environmental Security (X ₂) → Digital Innovation (Z)	4.570
Street Lighting Quality (X ₁) → Digital Innovation (Z)	4.775

Source: From Researchers, SmartPLS 4 2026

Multicollinearity did not occur in the analysis results, because the overall value in the test was below 5. Structural model evaluation is part of testing hypotheses about the influence between variables involved in the study. This structural model is evaluated in three stages. First, we must check whether there is multicollinearity between variables. This can be done by measuring the Inner VIF value, which is below 5, indicating that there is no multicollinearity between variables (Hair et al., 2021).

3.4. Hypothesis Testing (Direct Effect)

Table 4. Direct Effect

Hypothesis	Path Coefficient	p-value	95% Intervals		f square
			Lower Limit	Upper Limit	
Digital Innovation (Z) → Income (Y)	0,549	0,000	0,571	0,060	0,432
Environmental Security (X ₂) → Digital Innovation (Z)	0,484	0,003	0,183	0,114	0,058
Infrastructure Accessibility (X ₃) → Digital Innovation (Z)	0,602	0,000	0,601	0,122	0,361
Street Lighting Quality (X ₁) → Digital Innovation (Z)	0,329	0,009	0,321	0,107	0,054

Source: From Researchers, SmartPLS 4 2026

1. The first hypothesis (H1) is accepted, namely that there is a significant influence of the Digital Innovation program on the response to Balikpapan City Income with a path coefficient (0.549) and p-value ($0.000 < 0.05$). Every change in Digital Innovation in carrying out innovation will increase the positive impact on Balikpapan City Income. Within a 95% confidence interval, the magnitude of the influence of Digital Innovation in pursuing innovation to boost Balikpapan City Income lies between 0.060 and 0.571. Nevertheless, innovation to increase income has a high influence at the structural level (f square = 0.432). There is a need to maximize creativity in the Digital Innovation program to increase Balikpapan City Income.
2. The second hypothesis (H2) is accepted, namely that there is a significant influence of Environmental Security on the response to Digital Innovation with a path coefficient (0.484) and p-value ($0.000 < 0.05$). Any change in Environmental Security in implementing programs utilizing Digital Innovation will increase positive responses. Within a 95% confidence interval, the influence of Environmental Security in improving the security of Balikpapan City by utilizing Digital Innovation for Balikpapan City Street Lighting is between 0.114 and 0.183. However, the existence of Environmental Security in efforts to improve the security of Balikpapan City by utilizing Digital Innovation for Street Lighting in the City has a moderate influence at the structural level (f square = 0.058). In the context of environmental security, it is necessary to use digital innovation to maximize the implementation of public street

3. The third hypothesis (H3) is accepted, namely that there is a significant influence of the Infrastructure Accessibility program on the response to Digital Innovation to improve existing and developing infrastructure access in Balikpapan City, with a path coefficient of 0.602 and a p-value of $0.000 < 0.05$. Every change in Infrastructure Accessibility in implementing the city infrastructure improvement program with digital innovation carried out on public street lighting in Balikpapan City, within a 95% confidence interval, has a significant effect between 0.122 and 0.601. However, the existence of improvements in Infrastructure Accessibility in Balikpapan City on public street lighting has a high effect at the structural level (f square = 0.361). The need to optimize programs aimed at improving Infrastructure Accessibility for the long term must be balanced with optimizing all aspects involved, so that the designed programs will yield maximum results.
4. The fourth hypothesis (H4) is accepted, namely that there is a significant influence of the Street Lighting Quality program on Digital Innovation with the aim of improving security in access to Balikpapan City infrastructure, with a path coefficient value of (0.329) and a p-value of ($0.000 < 0.05$). Every change in Street Lighting Quality in implementing the program. Within a 95% confidence interval, the influence of Street Lighting Quality on the response of Digital Innovation with the aim of improving security in infrastructure access is between 0.107 and 0.321, and has a low influence at the structural level (f square = 0.054). There is a need to optimize the Street Lighting Quality program by using Digital Innovation as a means to improve security in infrastructure access in Balikpapan City so that the programs designed will yield maximum results and contribute to increasing Balikpapan City's revenue.

3.5. Structural Model Testing

3.5.1. Determination Coefficient Test

Table 5. Coefficient Determination

	R-Square	R-Square Adjusted
Digital Innovation (Z)	0,873	0,896
Income (Y)	0,738	0,756

Source: From Researchers, SmartPLS 4 2026

Based on the results listed in the table, the R-square value for the Digital Innovation variable of 0.873 indicates that 87.3% of the variation in Digital Innovation (Z) can be explained by the independent variables. Thus, only 12.7% of the variation comes from other factors outside the model studied. Meanwhile, the Income (Y) variable has an R-square value of 0.738, which means that the four variables together explain 73.8%, while the remaining 26.4% is influenced by other variables not included in this study.

3.5.2. Model Quality

Table 6. Model Quality

	Estimate Model
SRMR	0,090

Source: From Researchers, SmartPLS 4 2026

As shown by the research estimation results, the developed model has a statistically acceptable level of fit, with an SRMR value of 0.090. Therefore, empirical data can accurately explain the relationship between model variables.

3.6.The Influence of Digital Innovation (Z) in the Aspect of Public Street Lighting (PJU) on Income (Y) of Balikpapan City

In the context of the article titled "The Effect of Street Lighting Quality, Environmental Security, and Infrastructure Accessibility on Income Through Digital Innovation of MSMEs in Balikpapan City," digital innovation (Z) acts as a critical mediating mechanism transforming the impact of street lighting quality, environmental security, and infrastructure accessibility on increasing city revenue. Digital innovation in street lighting encompasses not only the adoption of energy-efficient LED lighting technology but also the integration of intelligent systems such as the Internet of Things (IoT), smart sensors, and centralized data platforms that enable adaptive energy management, real-time monitoring, and improved public safety. Empirical studies show that cities implementing smart lighting experience a significant increase in nighttime economic activity, as demonstrated by Caragliu et al. (2021), which serves as a catalyst for the growth of MSME turnover. Thus, digital innovation functions as an enabler, transforming the physical infrastructure of street lighting into a productive asset that directly and indirectly drives local economic growth.

This mediating mechanism of digital innovation operates through several channels. First, digital-based street lighting extends the operating hours of MSMEs by creating a safe and comfortable environment for nighttime activities, while reducing operational costs through energy efficiency of up to 30–40%, as demonstrated in research by Almeida et al. (2020). Second, integrating street lighting systems with smart city platforms allows businesses to access traffic, security, and energy data for better business decisions. Third, the presence of digitalized public infrastructure increases investment attractiveness and the city's image as a hub for innovative growth, which in turn opens MSMEs access to a broader market, both physically and digitally. In this context, digital innovation is not merely an intermediary variable, but rather an accelerator that magnifies the positive impact of the independent variables on revenue.

Specifically, the strategic implementation of digital innovation in the street lighting sector in Balikpapan City has significant potential to support economic diversification, which has historically relied on the oil and gas sector. Commercial areas such as Sepinggan, KM.5, and Batu Ampar can serve as pilot projects for the implementation of adaptive lighting connected to local MSME clusters. However, challenges such as the digital divide among traditional businesses, budget constraints, and inter-agency coordination still need to be addressed. Statistics Indonesia (BPS) data (2023) shows that MSMEs contribute approximately 8.5% to Balikpapan's GRDP. Therefore, digital-based street lighting

modernization could be a strategic step to boost this figure by increasing productivity, expanding the market, and creating a more competitive business ecosystem.

Therefore, recommended policy implications include adopting a public-private partnership (PPP) scheme for financing, developing an open data platform accessible to MSMEs, and implementing integrated digital literacy training programs. As reported by the World Bank (2023), cities with digitalized public infrastructure tend to experience higher and more inclusive economic growth. Therefore, digital innovation in street lighting not only improves the quality of public services but also serves as the backbone of Balikpapan's economic transformation into a competitive, high-income, smart city, where sustainable increases in community and city incomes can be achieved.

3.7. The Influence of Environmental Security (X₂) on the Aspect of Public Street Lighting (PJU) in Balikpapan City on Digital Innovation (Z)

Environmental Security (X₂), which in this context refers to the level of physical and social environmental safety generated or supported by the presence of street lighting, has a significant causal and conducive influence on the adoption and effectiveness of Digital Innovation (Z) in Balikpapan City. High environmental safety, manifested through low street crime rates, a sense of safety for pedestrians and road users at night, and a minimal risk of traffic accidents, creates a conducive environment for investment and implementation of digital innovation. Conversely, an environment perceived as unsafe can be a major barrier to technology adoption, as residents and businesses are reluctant to use public facilities at night, thus reducing the economic incentive to digitize street lighting. A study by Painter & Farrington (2001) classically demonstrated that improved public lighting correlates with a 20% reduction in crime, which is then a prerequisite for the development of smart city infrastructure.

The relationship between X₂ and Z is reciprocal and mutually reinforcing. On the one hand, good environmental security—partly achieved through adequate conventional street lighting—provides a foundation of trust for the government and the public to invest in more sophisticated street lighting technology, such as adaptive lighting systems with motion sensors and integrated CCTV cameras. On the other hand, digital innovations in street lighting actually enhance environmental security with greater precision and efficiency. For example, a smart street lighting system with video analytics features can detect suspicious behavior in real time and send automatic alerts to a security command center. Thus, a virtuous cycle is established basic security drives technology adoption, and the adopted technology further enhances security.

In the specific context of Balikpapan City, the influence of X₂ on Z can be observed in the transformation efforts towards a smart and safe city. Areas with a high security index, such as those around the Balikpapan Super Block or office areas, tend to be the first pilot locations for smart street lighting installation. This is because there is a guarantee that technology investment will yield maximum benefits due to the high intensity of economic activity and a sense of security among the public. Conversely, areas with a reputation for low security may be the ones most in need of such technology, but face obstacles such as low initial investment incentives from the private sector and limited government budgets. Therefore, the policy approach must be proactive and redistributive, allocating digital street

lighting pilot projects to less secure areas to break the cycle of insecurity and technological underdevelopment.

The theoretical implication of this relationship is that Environmental Security (X_2) not only acts as an antecedent condition for Digital Innovation (Z), but also as a moderator in the relationship between street lighting quality and innovation adoption. This means that the impact of improving the quality of physical street lighting on digital technology adoption will be much stronger in neighborhoods that already have adequate levels of basic security. For the Balikpapan City government, this means that efforts to improve neighborhood security—through patrols, urban design improvements, and basic lighting improvements—should be viewed as a critical preliminary investment before launching a large-scale smart street lighting program. Only with a solid security foundation can digital innovation develop optimally and ultimately contribute to increased regional income by strengthening the nighttime economy and attracting investment.

3.8. The Influence of Infrastructure Accessibility (X_3) on the Aspect of Public Street Lighting (PJU) in Balikpapan City on Digital Innovation (Z)

Infrastructure Accessibility (X_3) refers to the ease of physical and digital access to the supporting networks necessary for the operation, maintenance, and development of street lighting systems. In the context of Balikpapan City, infrastructure accessibility—including a stable electricity grid, broadband internet connectivity, and transportation and logistics systems for maintenance—has a direct and significant impact on the implementation and effectiveness of Digital Innovation (Z) in the street lighting sector. Without adequate infrastructure accessibility, smart street lighting technologies such as IoT systems, automatic light sensors, or centralized management platforms cannot operate optimally and may even fail to be adopted altogether. A study by Anthopoulos (2020) shows that the success of smart city projects depends heavily on “invisible supporting infrastructure,” such as fiber-optic networks and reliable energy supplies, which serve as the backbone of the entire digital ecosystem.

The influence of X_3 on Z is multidimensional and creates an interdependent cause-and-effect relationship. First, the accessibility of physical infrastructure—such as an electricity distribution network that reaches all areas of the city—is an absolute prerequisite for the installation and operation of digital-based street lighting. Second, the accessibility of digital infrastructure, particularly high-speed and stable internet connectivity, determines the extent to which advanced features such as real-time monitoring, predictive maintenance, and data integration with other city systems can function. In Balikpapan, the persistent connectivity gap between the city center and peri-urban areas can hinder the equitable implementation of digital street lighting. A 2023 report by the Balikpapan Statistics Agency (BPS) indicates that broadband internet coverage in densely populated residential areas has reached 85%, but in industrial and suburban areas it remains below 60%. This situation has the potential to create a spatial digital divide, which can actually widen the gap in access to better public services.

Furthermore, infrastructure accessibility also influences the complexity and sustainability of implemented digital innovations. Easily accessible and well-integrated infrastructure enables the development of smart street lighting with modular, cost-effective, and easily scalable systems. Conversely, limited access—for example, difficulty reaching street lighting locations for maintenance due to poor road conditions—can increase the total

cost of ownership and discourage government and private investors from adopting more advanced technologies. Therefore, in the context of this research model, Infrastructure Accessibility (X_3) not only acts as an exogenous variable influencing Digital Innovation (Z), but also as a moderating variable that strengthens or weakens the relationship between the quality of physical street lighting and its level of innovation.

The strategic implication for the Balikpapan City Government is the need for a holistic and integrated approach to infrastructure planning. The development of digital street lighting cannot be separated from programs to expand the electricity network, improve road quality, and ensure equitable internet connectivity. A collaborative governance scheme involving PLN (State Electricity Company), internet service providers, and the public works department is key to creating a synergistic infrastructure ecosystem. Furthermore, investment in smart infrastructure should be prioritized in areas with adequate basic accessibility, while also being directed to improve accessibility in underdeveloped areas, so that digital innovation can function as a tool for equitable development. Therefore, strengthening Infrastructure Accessibility (X_3) will accelerate digital transformation in the street lighting sector, ultimately contributing to increased economic productivity and regional income by creating a more conducive environment for MSME growth.

3.9. The Influence of Street Lighting Quality (X_1) in Balikpapan City on Digital Innovation (Z) in the aspects of Environmental Security and Infrastructure Accessibility

Street Lighting Quality (X_1) is a foundational variable that not only directly impacts Digital Innovation (Z) but also indirectly influences Z through improved Environmental Security (X_2) and Infrastructure Accessibility (X_3). High-quality street lighting, characterized by adequate light intensity, consistent lighting, the use of energy-efficient technologies, and equitable distribution, creates optimal physical environmental conditions as a launching pad for the adoption of digital innovation. In the context of Balikpapan City, high-quality street lighting serves as a "digitalization-ready" foundational infrastructure, as well-managed conventional systems are more easily upgraded with sensors, smart controls, and IoT connectivity. Research by Fotios & Gibbons (2018) confirms that the success of the transition to smart lighting is highly dependent on the underlying condition of existing physical assets; without good foundational quality, digital investments are at high risk of being inefficient or failing.

The effect of X_1 on Z is strongly mediated by Environmental Security (X_2). High-quality street lighting directly improves the perception and reality of neighborhood safety by reducing blind spots and dark areas prone to crime, while increasing visibility for road users. This perceived safety environment then creates social and political demand (political will) for investment in more advanced technology. For example, when the public perceives the safety benefits of conventional street lighting, support for budget upgrades to smart street lighting systems with integrated security features (such as cameras and panic buttons) will grow stronger. In other words, good X_1 reinforces X_2 , and improved X_2 paves the way for broader adoption and public acceptance of Z .

In parallel, Infrastructure Accessibility (X_3) acts as a second critical mediator. High-quality street lighting is essentially part of a city's physical access infrastructure. When functioning optimally, it improves area accessibility at night, supports logistics mobility, and

extends economic operating hours. This condition drives the need for supporting digital infrastructure such as a more stable electricity grid and internet connectivity in the area, which are essential components of Digital Innovation (Z). In Balikpapan, areas with high-quality street lighting, such as Jalan Jenderal Sudirman or the Central Business District, demonstrate better infrastructure accessibility, facilitating integration with digital monitoring systems and smart grids. Conversely, areas with poor street lighting are often associated with limited infrastructure access, creating circular barriers to innovation.

From a policy perspective, these findings highlight the importance of a phased and integrative approach. The Balikpapan City Government cannot jump directly into implementing digital innovation without first ensuring adequate levels of basic street lighting quality, environmental safety, and infrastructure accessibility. Programs such as the complete rehabilitation of the conventional street lighting network should be prioritized before full-scale smart lighting implementation. This strategy aligns with the recommendations of the International Association of Lighting Designers (IALD, 2022), which emphasizes sequential modernization: improving physical quality -> enhancing safety and accessibility -> adopting digital technology. Thus, Street Lighting Quality (X_1) is not simply an independent variable, but rather a strategic catalyst that enables the creation of an ecosystem where Environmental Security (X_2) and Infrastructure Accessibility (X_3) can thrive, ultimately driving sustainable Digital Innovation (Z) with broad economic impact

4. CONCLUSION

Based on the analysis results, it was concluded that PJU Quality (X_1), Environmental Safety (X_2), and Infrastructure Accessibility (X_3) had a positive and significant effect on MSME Income (Y) in Balikpapan City through the full mediation of Digital Innovation (Z). This finding confirms that good public infrastructure and a safe environment serve as a fundamental foundation that enables and accelerates the adoption of digital technology by business actors. Digital Innovation then transforms this potential into increased productivity, cost efficiency, and market expansion, which directly boosts income. This research contributes theoretically by expanding the *Infrastructure-Led Growth Theory* model to include digital innovation as a critical mediating mechanism in the context of urban economies in developing countries. Practically, the Balikpapan City government needs to adopt a holistic and sequential development approach: prioritizing improvements in basic infrastructure quality (street lighting, roads, security), which is then reinforced with inclusive mentoring and digital infrastructure programs for MSMEs. The limitations of this study lie in its geographical scope and sample size. For further research, it is recommended to explore moderating variables such as the digital literacy of MSME owners or government regulatory support in strengthening the proven relationship.

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