

The Spatial Pattern of Fraudulence Risk in Legal Metrology and Its Socio-Economic Drivers: A Case Study Of Bandung, Indonesia

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Abstract

This study develops a fraudulence risk in the legal metrology model, gaining insight into urban spatial characteristics as contextual variables that may cause a risk of fraud. The model uses Geographically Weighted Regression on the Metrological Consumer Index data of Bandung, West Java, Indonesia. The findings indicate a wide distribution of recorded fraudulence risk in legal metrology across Bandung, with a spatially clustered pattern based on spatial and context of varying neighbourhood attributes. The findings also demonstrate an increase in the fraudulence risk in legal metrology in the central business district of Bandung. Such phenomena could be attributed to the residents who trade and are involved in the measurement practice. The findings also suggested that the areas with more senior residents were more likely to have a high fraudulence risk in legal metrology. On the other hand, areas with a high proportion of poor and lesser-educated people exhibit low risk. These findings are helpful for legal metrology authorities seeking to establish appropriate strategies to mitigate adverse impacts of fraudulence risk in legal metrology practice on communities. It can also help identify high fraudulence risk in legal metrology areas to geo-target when and where to disseminate information to increase awareness of the dangers.

Keywords— Fraudulence Risk, Legal Metrology, Geographically Weighted Regression, Routine Theory, Consumer Protection

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I. Introduction

Legal metrology activity comprises metrological control measures that include the verifications and surveillance of measuring instruments before and after being released (OIML, 2011). The checking error conducted is intended to enforce trust in the measurements to reduce unfair competition and ensures trade consistency. Much of the existing published researches (Rifan Ardianto, 2012; Birch, 2003; Bruno A Rodrigues Filho & Gonçalves, 2016) had ascertained that legal metrology activity benefits the society and economy when the legal metrology can increase confidence in measurement instruments. In the field of economy, numerous studies have investigated the impact of legal metrology through analyzing the capital involved in measurements. For instance, Indonesian oil and gas imports and exports were worth USD 118.7 billion (Indonesia, 2018). Similarly, the aggregate values of the transactions of commodities from the point of production to final sale, including freight and taxes, exceed 52.6 percent of the gross national product of Indonesia in the same year (Rifan Ardianto, 2012).

In the social aspect, the risk revolving around this issue is concerning consumer protection. Consumers are vulnerable when they purchase goods with a measurement-based value if they cannot evaluate the number of goods traded (Rifan Ardianto, 2012). Nevertheless, the inadequate use of measuring instruments can result in incorrect measurement (Birch, 2003; Kochsiek & Odin, 2001). In most developed countries such as Australia, legal metrology also contributes to the security field. It helps mitigate the number of accidental deaths and injuries by using measuring instruments as a means of regulation, such as radar speed devices and breath analyzers.

Fraudulence risk in legal metrology, in general, is the likelihood of fraud-loss measurement in trade transactions and its potential consequences (e.g., financial losses and or social problems). Exposure to the source of metrological fraud such as faulty measuring instruments, the use of illegal measurement instruments during a transaction, and improper use of measuring instruments contributes directly to fraudulence risk in legal metrology (OIML, 2005, 2011). In general, risk depends on an individual's perception of fraudulence risk in legal metrology, personal behaviors such as their awareness of measurement, accuracy, and habits or culture towards unfair transaction based on measuring instrument (R Ardianto, 2013; OIML, 2020).

Kadushin (2004) suggested that the risk perception might depend on the spatial distinction of the socio-economic characteristics. The perception is also unevenly distributed across areas. Factors such as socio-economic status are identified as the critical drivers of fraudulence risk in legal metrology as they affect, if not control, social interactions, local learning, and the propagation of risk-related information. The situated context of fraudulence risk in legal metrology is vital for theory building and critical to addressing key

policy questions. Legal metrology authorities need to know the likely impact of space on fraudulence risk in legal metrology (OIML, 2011, 2020). They would benefit from them to mitigate the risk. This augmented information would also help in the planning and implementing education programs in the areas in need. There is currently limited empirical evidence which estimates the effect of space on fraudulence risk in legal metrology. This article aims to contribute to the current literature by delving into environmental criminology theory in order to comprehend the spatial distribution of fraudulence risk in legal metrology. This paper aims to bridge the gap between the investigation of fraudulence risk in legal metrology occurrences and the understanding of how this information links to the theory by exploring spatial patterns of fraudulence risk in legal metrology within a theoretical context.

This paper is organized into six sections. The next section discusses a theoretical context that examines the role of space in shaping fraudulence risk in legal metrology. The research methodology applied in this paper is described in Section 3, followed by the case study conducted in Bandung, Indonesia, in Section 4. Section 5 discusses the policy contribution of the main findings. Conclusion and agenda of future research are drawn in the final section.

II. Literature Review

The fraudulence risk in legal metrology is the likelihood of a measurement fraud in a trade transaction and the potential consequences of financial losses and social problems (Aven, 2012; OIML, 2020). It denotes the change of unfair transaction ignition due to the presence of a causative agent, such as inappropriate use of measuring instruments and non-compliance to the existing law and legislation on metrology. From this point of view, the risk could be quantified using a range of measures such as counting fraud measuring instruments per unit, the number of consumers' complaints, and the probability of the occurrence of an unfair transaction.

From the theoretical perspective, metrological fraud in trading has many causes, ranging from faulty measuring instruments to improper measuring instruments (OIML, 2005, 2011). A large proportion of metrological fraud occurs due to daily activities, mainly when trading at the sale point. In the absence of a legal metrology authority, metrological fraud results from the convergence of an offender and an appropriate target in space and time (Brantingham & Brantingham, 1993).

The routine activity theory, introduced by Cohen and Felson (1979), has served as a foundation to explain the geographical clustering of fraudulence risk in legal metrology. There are three critical elements of the routine activity theory: an offender, a target, and the lack of qualified supervisor (Cohen & Felson, 1979; Messner & Tardiff, 1985). The sequence of events that leads to metrological fraud happens when a motivated offender comes across a target in the absence of a capable supervisor. A common offense that creates fraudulence risk in legal metrology includes, but is not limited to, illegal measuring instruments, noncompliance of measuring instruments, and misuse of measuring instruments.

There are two parallel lines of arguments which can be drawn from this decision. First, the theory reduces the complexity of metrological fraud in point-of-sale trading activities to three core elements that focus on metrological fraud, risk assessment, and prevention strategies. Brantingham and Brantingham (1993) noted that the routine theory explains that crime (e.g., measurement fraud) is the daily operation that impacts the level to which opportunities to deviate arise. In other words, the theory highlights that situational change is likely to be the way to achieve the prevention of metrological fraud. Secondly, the theory focuses on the situated context which ignites the crime event (e.g., measurement fraud), not focusing on the offenders' motivations. Felson and Clarke (1998) noted that the theory assumes that offenders' motivation is unchanged over time.

By adopting the routine activity theory, fraudulence risk in legal metrology can be conceptualized as a function that integrates associated factors to move toward theoretically-driven prevention by focusing on one or more of the three core elements of the theory. Thus, the theory draws fraudulence risk in legal metrology due to the interaction between regular activities at the point of sale (e.g., trading, weighing goods), a potential source of ignition, and the proximity of measuring instruments performance.

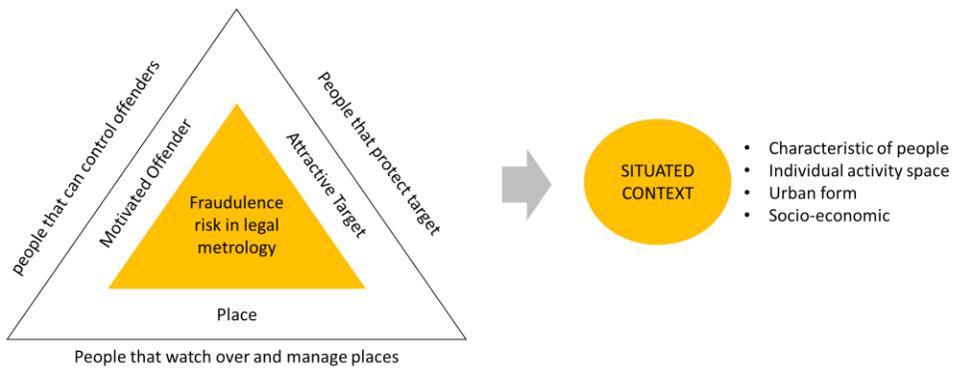


Figure 1. Fraudulence risk in legal metrology triangle

Figure 1 illustrates as follows: First, the legal metrology authority keeps targets (for example, measuring instruments' users, consumers) from fraudulence risk in measuring instrument. The engagement of community-based educational and metrology campaigns can help consumers or society to assist the legal metrology authority as capable guardians also. The next step is the identification of offenders or fraud sources. Handlers are influential in maintaining potential sources of measurement fraud, namely certified measurers, inspectors, and verification officers. Here, handlers can mitigate fraudulence risk in legal metrology through ensuring proper maintenance and care of measuring instruments and their result outcome is a fair measurement. Finally, places are taken into consideration. Place managers have a significant role in preventing fraud by controlling the presence or absence of potential sources and targets. They also can regulate or control activities that take place. There are several forms of place managers at multiple levels (at community, at the marketplace, local government boundary, or across a province and the nation). Verification and metrological supervision are examples of forms of fraudulence risk in legal metrology control. Local area place managers can prevent fraud by implementing planning policies that stipulate regular

supervision. The application of routine activity theory and the prevention triangle demonstrates a potential solution for controlling fraudulence risk in legal metrology and preventing fraud events. Most importantly, ordinary residents can play the role as guardian, handler and manager. They can employ prevention methods stemming from this theoretical perspective, which are relatively low cost and easy to implement.

Modeling metrological fraud risk is theoretically sophisticated and methodologically challenging. A limited study still develops the definition and theoretical frameworks of metrological fraud risk (Bruno A Rodrigues Filho & Gonçalves, 2016; Bruno Amado Rodrigues Filho, Nonato, & Carvalho, 2018; Bruno A Rodrigues Filho, Silva, Fogazzi, Araújo, & Gonçalves, 2015). For instance, Bruno A Rodrigues Filho and Gonçalves (2016), for example, employ an input and output model to determine the economic distortion impact of metrological fraud risk in Brazil's trade metrology. They indicate that the effect of metrological fraud increases the distortion of uncertainty toward consumers' losses, creating a significant asymmetry in trading activities. Bruno Amado Rodrigues Filho et al. (2018) applied a risk analysis approach to analyze the impact of field surveillance in utility meters in Sao Paolo, Brazil. They identify and map the measuring instrument manufacturers with a geographically higher risk. The findings claimed to optimize the resources in legal metrology in areas that present a higher risk to both social and economic context.

This paper employs a Geographically Weighted Regression-based framework as an exploratory tool to comprehensively examine neighbourhood variations that determine the level of fraudulence risk in legal metrology, which is a research gap addressed in this study. Geographically Weighted Regression (GWR) is an extended variation of traditional regression modeling, which considers the spatial heterogeneity by incorporating the spatial location of data. With the conventional regression model, the parameters derived are usually applied as global parameters across the geographic area over which measurements are taken. However, local variations within a geographic area of interest require local analysis, accommodating within GWR.

III. Research Methodology

3.1 Study Area

The study context for this research is Bandung, one of Indonesia's most densely populated cities. Over the two decades, the city has seen significant developments mainly in the city's heart and surrounding areas through urban consolidation. According to Indonesia (2018), the estimated population in Bandung was about 2.49 million residents. Compared with the total population in West Java, the city accounts for around 5.1 percent of residents. In terms of population density, Bojongloa Kaler has had the most significant population density of 39.7 residents per square km, followed by Andir with 26.3 residents per square km and Sukajadi with 25.2 residents per square km. This condition has led to a change of the population center to the suburb of Bojong Kaler (see Figure 1). The principal reasons for choosing Bandung for this study are, firstly, the geography of Bandung has been significantly changed in terms of both the infrastructures and socio-economy cultural diversity. It has led to significant changes in the social characteristics and the design of urban

activities.

Consequently, it is essential to understand the spatial variability of metrological fraud risk across different parts of Bandung. The needs and cost of managing assurance of measurement, mainly involved in trading activities, have increased. This phenomenon necessitates a new approach to public service management to optimize resources and mitigate the city's metrological fraud risk. Investigating the geographical variability helps legal metrology authorities to map and identify areas with high metrological fraud. Further, it helps develop and formulate more effective prevention and intervention initiatives to mitigate the metrological fraud risk within the community.

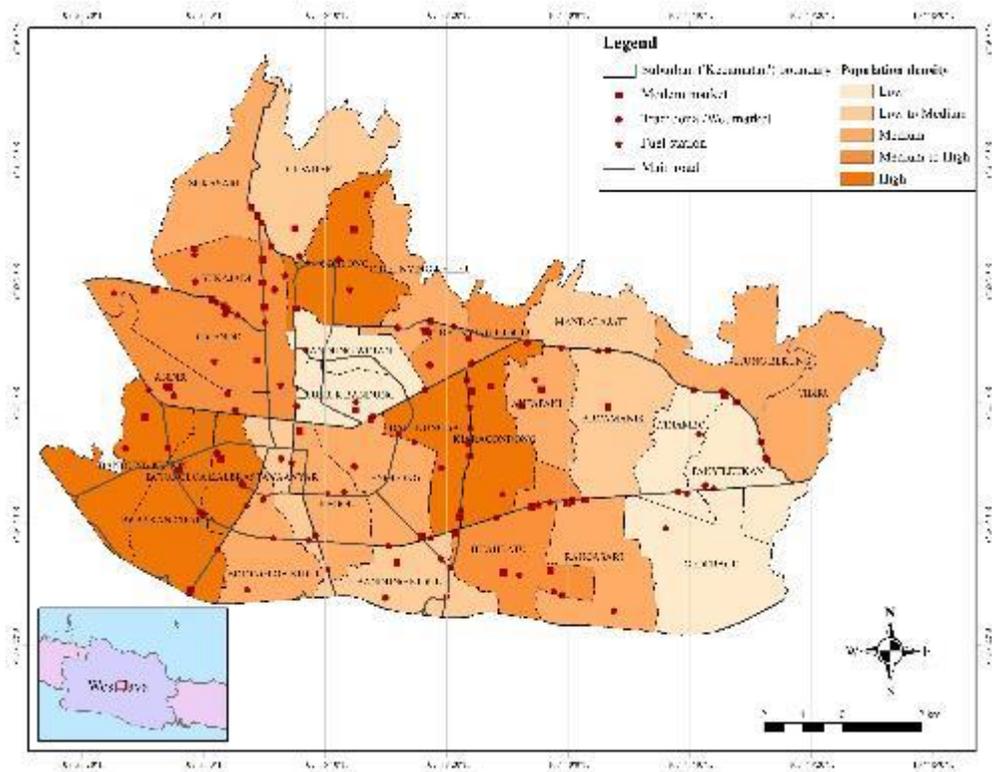


Figure 2. A distribution of traditional market, modern market, and fuel station across Bandung, West Java, Indonesia

3.2 Data

The model described in Section 3 is fitted to the dataset on the Metrological Consumer Index of Bandung, West Java, Indonesia, in 2018. The dataset is gathered from the Directorate of Metrology, Ministry of Trade portal which contain geo-referenced information about the Metrological Consumer Index of residents in Bandung, including location of pump station and traditional markets. The additional information has been added to this database such as education level of residents, employment, and other socio-economic characteristics.

The Metrological consumer index is a tool based on survey done by Directorate of Metrology to measure the level of knowledge and understanding about metrological activities and its role in ensuring a proper measurement involved in the trade. The calculation of index used a total of 59 parameters which are grouped into four categories such as awareness, knowledge, perception, and confidence.

3.3 Method

A typical model used in the geographical analysis is Ordinary Least Square (OLS) model. In this technique, the dependent variable is a function of a set of independent explanatory variables, as follows:

$$y(s) = \beta_0 + \sum_{k=1}^n \beta_k x_k(s) + \epsilon(s) \quad (1)$$

where $y(s)$ is the observed risk at suburb s , $x_k(s)$ represents the observation at suburb s of the k th independent variable, and the $\epsilon(s)$ are independent, normally distributed error terms with zero means. The term β_k refers to the coefficient related to the k th independent variable. The least-squares method is typically used to estimate the β_k s. By using matrix notation, this may be expressed as follows:

$$\hat{\beta} = (X^t X)^{-1} X^t Y \quad (2)$$

The independent observations are the columns of X , and the dependent observations are the single column vector Y . The vector $\hat{\beta}$ contains the coefficient estimates.

The Geographically Weighted Regression (GWR) is a multivariate regression that estimates the relationship between a dependent variable (i.e., Metrological Consumer Index) and independent variables (e.g., geographical characteristics) at the local level (Fotheringham et al., 2003). Brunsdon, Fotheringham, and Charlton (1998) noted the advantage of using the GWR, which is its capability to capture variations at the local level. The GWR produces a set of parameters for every location across the study area. While, the OLS model only can produce one parameter used at a global level (Faye, 1993; Fotheringham, Brunsdon, & Charlton, 2003; Fotheringham, Charlton, & Brunsdon, 1997; Fotheringham, Charlton, & Brunsdon, 1998). The GWR model formula is as follows:

$$y(s) = \beta_0(s) + \sum_{k=1}^n \beta_k(s) x_k(s) + \epsilon(s) \quad (3)$$

$\beta_k(s)$ represents the value of the k th parameter at location s . Note that equation (3) can be seen as a special case of (1) in which all of the parameters are constants across the study area. Thus, the parameters of β_k , thus, can be mapped to have a picture of spatial variations in the relationship between the predictor variable and explanatory variables across the region. The parameters mapping helps to understand the complex association between the predicted variable and its explanatory variables over the space. This study examines the relationship between metrological fraud risk and its socio-economic variables across Bandung.

IV. Result and Key Findings

The geographic variability of fraudulence risk in legal metrology has been examined using the Metrological Consumer Index measures. The index is used as a proxy to measure the fraudulence risk in legal metrology. A person who is more knowledgeable about metrological fraud is more likely to avoid these fraud practices. Consequently, such awareness may mitigate the fraudulence risk in legal metrology. Figure 3 shows the map of the fraudulence risk in legal metrology across Bandung. The risk exhibits substantial geographical variability. The most significant metrological fraud risk occurs in the inner city, particularly in the central business district of Bandung city. The finding is a reflection of the socio-economic status and also the routine activity factor of the residents. The suburbs in high risk are Sumur Bandung, Sukajadi, Astanaanyar, Bandung Wetan and Cineuying Kidul. On the other hand, suburbs such as Regol, Kengkong, Bandung Kidul, Coblong, Cibeuuying Kaler, and Cidadap are among those with low fraudulence risk in legal metrology.

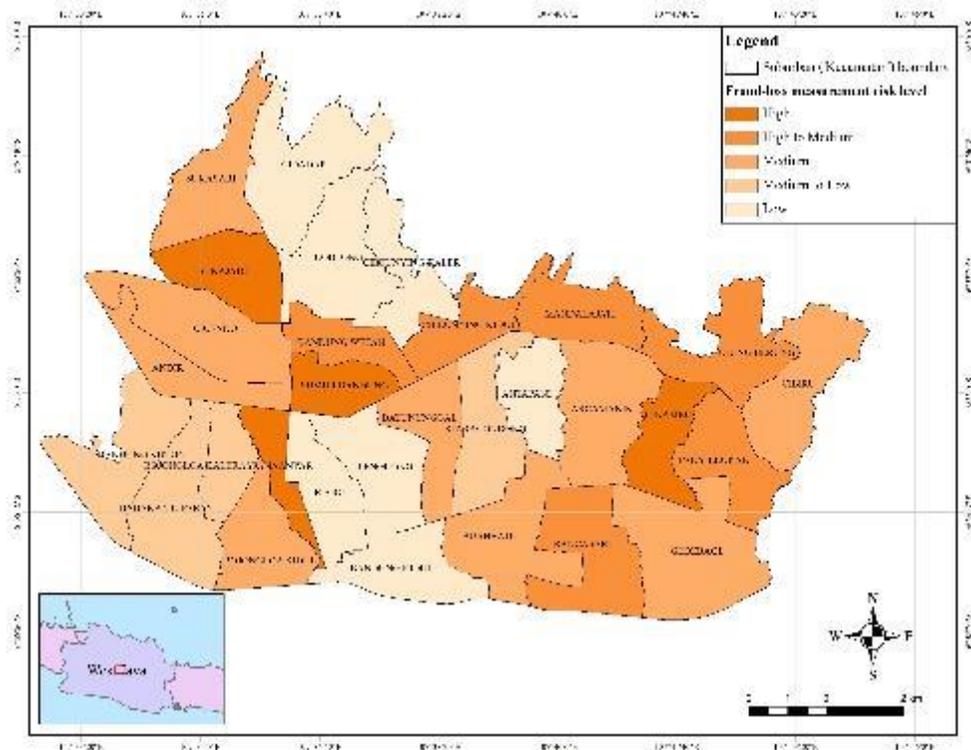


Figure 3. Fraudulence risk in legal metrology level across Bandung

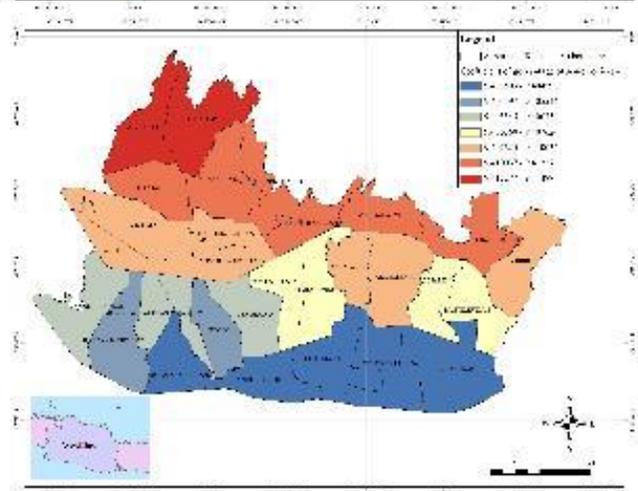
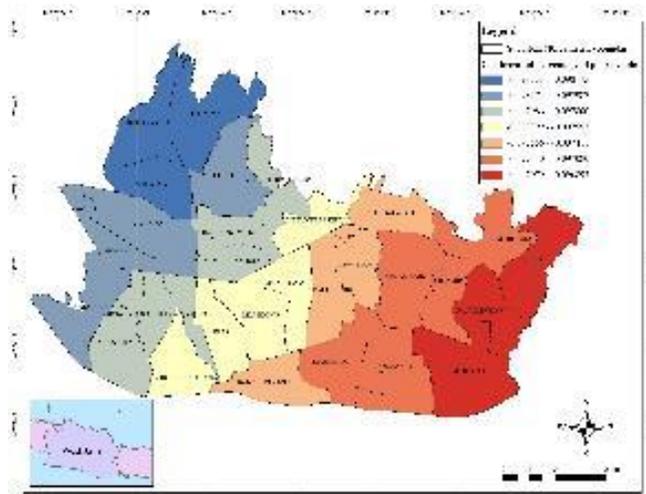
Figure 4 shows the local coefficient estimates for each explanatory variable across the study area with the color ramp indicating the influence of particular variables on risk. The light shade indicates the area with a weak or low impact on the risk, while the dark shade represents the area with a strong influence on metrological fraud. Figure 4(a) shows the impact of the percentage of poor people. The map indicates areas of high negative values in the northern part of the city. The higher percentage of poor people, the lower is the level

of fraudulence risk in legal metrology. This indication exemplifies that poor people seem to have fewer activities in trading, making them lesser prone to being targeted in fraud-loss measurement practices. Overall, the map shows that more disadvantaged areas are not likely to increase the metrological fraud, particularly in northern areas substantially. The scale of this effect reduces with the easterly direction.

Figure 4(b) shows the effect of the percentage of senior residents on fraudulence risk in legal metrology. The map depicts high positive values were the decisive influence in the northern part of the city. The high proportion of senior residents seems to elevate the metrological fraud risk in these areas. This finding is in line with the theoretical perspective. Senior residents are an attractive target who routinely visits business centers such as the traditional and modern markets. Overall, the map shows that a higher number of senior residents are likely to affect leveling fraudulence risk in legal metrology substantially. The magnitude of this effect reduces from northern suburbs towards southern suburbs.

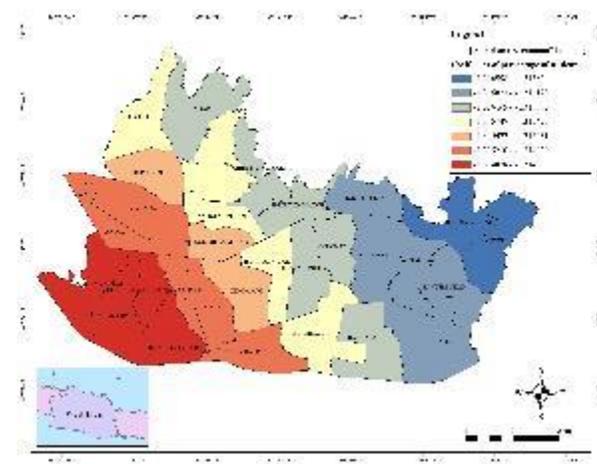
Figure 4(c) shows the spatial variability of students' impact, leading to higher negative values in the eastern suburbs. The high proportion of students is likely to mitigate the fraudulence risk in legal metrology within these areas. Students represent a group of more knowledgeable individuals of the risk, and they are aware of being a target of metrological fraud practice. Overall, the map shows that a higher percentage of students is likely to mitigate the fraudulence risk in legal metrology substantially. The magnitude of the effect reduces from eastern suburbs towards western suburbs.

Figure 4(d) shows the influence of the variable of the proportion of people who had no formal education. People with no formal education have stronger negative values in the south-eastern suburbs and southern suburbs. This value shows that these suburbs with more people with no formal education are likely to decrease metrological fraud risk levels. This phenomenon aligns with the theoretical framework that people with no formal education background are not an attractive target of the metrological fraud environment. Their routine activity is not as a buyer but mainly as a trader. Overall, the map shows that areas with a higher percentage of people with no formal education are likely to have a low level of fraudulence risk in legal metrology, particularly in south-eastern suburbs and southern suburbs. The scale of effect reduces within the northerly direction.



a

b



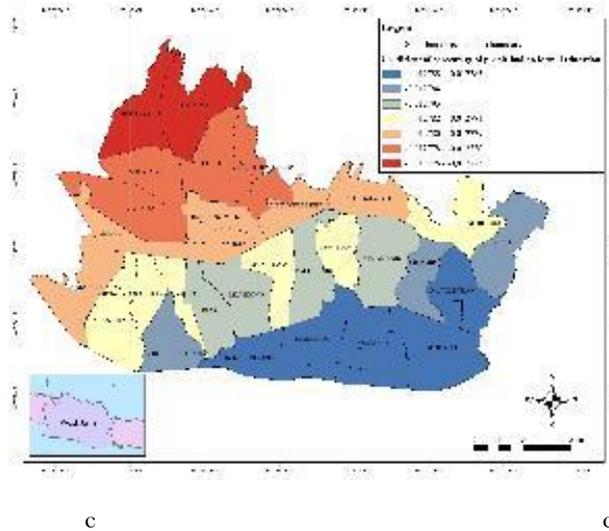


Figure 4. Map of coefficient of the Geographically Weighted Regression indicating the magnitude and direction of the local effect: a) percentage of poor people; b) percentage of senior residents; c) a percentage of a student; and d) a percentage of people with no formal education

In sum, there are three key findings from the outputs of the model. The first finding relates to the spatial fragmentation of fraudulence risk in legal metrology. The fraudulence risk in legal metrology has a spatial pattern influenced by the socio-economic fragmentation of space. The second finding relates to the locally geographic variability of socio-economic characteristics, which have a significant association with fraudulence risk in legal metrology. The result shows that each variable has a different magnitude and direction to increase or decrease fraudulence risk in legal metrology across Bandung. The third finding shows the variables that differentiate areas of high fraudulence risk in legal metrology from those of low risk and the underlying groups underpinning these relationships. The distribution of risk across Bandung exhibited a considerable variation between suburbs, and this variability was partly dependent upon the socio-economic characteristics of the community.

V. Planning Implication

There is new evidence based on the analysis of local variability of metrological fraud risk such that it could address some of the unanswered policy questions. Knowing the importance of socio-economic drivers that influence metrological fraud risk is critical for metrological control planning and consumer protection. Those drivers play a vital role in the success of prevention and intervention initiatives. Effective initiatives require a different solution from the one currently adopted by legal metrology authorities. A new approach would employ a range of integrated variables to address the specific needs groups in the community.

This paper has identified key significant sets of factors that define vulnerability to

fraudulence risk in legal metrology. These factors are, in many respects, a manifestation of a range of resident behaviors in their social and economic situations. The generalized notion of the individual as consumer protection in fair measurement does not necessarily provide insight into the need of high-risk groups. The main task is to understand how individuals or individuals in these high-risk groups perceive the risk in their situation. Similarly, measures to improve protection are unlikely to be accepted and implemented if an individual or a group of individuals concern find them impractical, inappropriate, or irrelevant. If legal metrology authorities are to meet the needs of society, they must first understand those needs.

The traditional focus of legal metrology authorities has been based on providing an efficient service to ensure fair trade in measurement. They focus on the verification and surveillance of measuring instruments, which underestimates the role of the human aspect in contributing to metrological fraud. The legal metrology authorities also diminish the significance of a range of mostly personal and social factors which define vulnerability. Recently, there has been increasing recognition worldwide that verification activities and surveillance represent only one component of managing the legal metrological control in the community. There has been a shift towards a wider acceptance of the principles of legal metrological management. Legal metrological management involves developing a thorough and detailed understanding of the nature of legal metrology faced by the community, developing strategies to reduce the likelihood of fraud, and minimizing consequences when legal metrology crime occurs. It demands that organizations diversify their activities to utilize a range of community intervention, mitigation, and prevention programs to address legal metrological control.

VI. Conclusion

In this paper, the application of Geographically Weighted Regression enriched the modeling fraudulence risk in legal metrology. There are key findings from the analysis of metrological fraud risk for Bandung, West Java, Indonesia. First, the fraudulence risk in legal metrology varies greatly across Bandung, with the most significant case occurring in the inner city. Secondly, different areas have a different situated context which is likely to affect the level of fraudulence risk in legal metrology. The effect of socio-economic characteristics such as the proportion of poor people, number of senior residents, number of students, and number of people with no formal education, on fraudulence risk in legal metrology, tends to vary across Bandung. Areas with a higher proportion of poor people, students, and people with no formal education tend to lower fraudulence risk in legal metrology.

On the other hand, areas with a higher percentage of senior residents are likely to represent the area with higher fraudulence risk in legal metrology. Thirdly, each explanatory variable has a different direction of the substantial magnitude of their effect on fraudulence risk in legal metrology. Overall, the study had demonstrated that areas of varying fraudulence risk in legal metrology could be discriminated by spatial differences in the social and economic characteristics of the community. These socio-spatial ecologies define the spatial structures and patterning of fraudulence risk in legal metrology.

However, because the case study covered the region of Bandung, although the methods are general, the results indicate that the relationship between fraudulence risk in legal metrology and a range of spatial characteristics cannot be generalized. As one needs to consider the different geographical aspects, including socio-economic and demographics.

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