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Integration of Center of Gravity for Natural Disaster Mitigation in Indonesia

Rio Haribowo, Justina Ade Judiarni, Ariesta Heksarini*

Department of Management, Faculty of Economics and Business, Mulawarman University, Samarinda, Indonesia

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Abstract:
No one can predict disasters accurately, but it can minimize the potential for their occurrence through careful planning. At this opportunity, the author's main point is to apply operational management in a disaster centered in the capital city of Indonesia (Jakarta), divided into seven scattered locations, requiring accurate disaster management in only one week. Therefore, this study emphasizes disaster mitigation on a national scale based on prediction and planning with high data accuracy. The center-of-gravity method is applied to get various relevant data with optimal points so that they are easy to reach in one area by including demographic aspects at coordinate points such as districts. Seven disaster-prone areas classified as 'severe' spread across Central Java, North Sumatra, West Nusa Tenggara, Central Kalimantan, Maluku, Papua, and South Sulawesi. The areas in question are Pekalongan (-6.965400313, 109.6069198), Sarulla (1.913274421, 99.19588061), Jereweh (-8.8571919, 116.9659885), Muara Teweh (-1.132188612, 114.1819521), the Obi Islands (-1.526250821, 127.9035781), Sawai (-1.769803368, 137.548692), and Palopo (-3.131001243, 120.5336565). The practical implications illustrate that strategic efforts are continuously being pushed by BNPB, the Republic of Indonesia, which plays a very important role in the rapid response to help victims of natural disasters. Important theoretical contributions in research to implement disaster mitigation programs in Indonesia structured, based on local potential, institutionalized, and sustainable. Ideally, the implications will continue to be pursued through the design of modeling on data at a smaller scope, such as the Regency and City areas.

Keywords: center of gravity, logistics, disaster mitigation, Indonesia.

印度尼西亚减轻自然灾害重心的整合

摘要：

Corresponding Author: Ariesta Heksarini, Department of Management, Faculty of Economics and Business, Mulawarman University, Samarinda, Indonesia; email: ariesta.heksarini@feb.unmul.ac.id

没有人能够准确地预测灾害，但可以通过精心规划将其发生的可能性降至最低。借此机会，笔者的主要观点是在以印度尼西亚首都（雅加达）为中心的灾难中应用运营管理，该灾难分为七个分散的地点，需要在一周内进行准确的灾难管理。因此，本研究强调基于具有高数据准确性的预测和规划在全国范围内减灾。重心方法用于获取具有最佳点的各种相关数据，以便通过在坐标点（例如地区）包括人口统计方面的内容，使它们易于在一个区域内到达。七个被列为“严重”的灾害易发地区分布在中爪哇、北苏门答腊、西努沙登加拉、中加里曼丹、马鲁古、巴布亚和南苏拉威西。有问题的地区是北加浪岸（-6.965400313，109.6069198），萨鲁拉（1.913274421，99.19588061），杰瑞威（-8.8571919，116.9659885），穆阿拉特威（-1.132188612，114.1819521），奥比岛（-1.526250821，127.9035781），泽井（-1.769803368、137.548692)和帕洛波(-3.131001243、120.5336565)。实际意义表明，印度尼西亚共和国法国国家银行正在不断推动战略努力，在快速响应以帮助自然灾害受害者方面发挥着非常重要的作用。在印度尼西亚实施减灾计划的研究中的重要理论贡献是基于当地潜力、制度化和可持续的。理想情况下，将继续通过在较小范围内（例如摄政区和城市地区）设计数据建模来追求影响。

关键词：重心，物流，减灾，印度尼西亚。

1. Introduction

Indonesia is an area that is very prone to natural disasters (Muzani, 2020). In the last decade, there have been great turbulence and very large material losses (Sutikno, 2007) because the dominant archipelago in Indonesia is in an active tectonic plate zone, active mountain paths, and a tropical climate. This makes this area vulnerable to natural disasters such as volcanic eruptions, floods, landslides, forest fires, and droughts (Setiadi, 2014; Rifai et al., 2018).

Regarding disaster mitigation, the allowed government agency is the National Disaster Management Agency (BNPB). It has the major task of assisting the President of the Republic of Indonesia under the mandate of Law of the Republic of Indonesia Number 24 of 2007 (Manurung & Siahaan, 2016). Fahlevi et al. (2019), Sudirman and Putra (2018) confirm that the government, agencies, and local communities have carried out the aid distribution to natural disaster posts. However, unfortunately, they are often experiencing a slow reaction to help (Quayle, 1998). Meanwhile, there are still many victims who need immediate help. The logistical help distribution delay (Rossum & Krukkert, 2010) and the urgent need to arrive at the location were because of the dependence on Jakarta (Amin et al., 2021).

To overcome the problems of crucial disasters, they needed a special pattern strategy that focuses on the accuracy of the right supply chain. The objectivity of this study has the ambition to analyze the warehouse location determination system in disaster logistics management based on the center-of-gravity method, which aims to classify the potential of provinces in Indonesia that are prone to disasters. The flow of the paper comprises five parts (introduction, review of literature, methods, analysis and discussion, then conclusions).

2. Literature Review

2.1. Disaster Mitigation

Until now, the term 'disaster' has been an ongoing debate. Does nature or humans cause the concept of 'disaster'? Academics and practitioners understood the meaning differently depending on the era (Ejeta et al., 2015). However, 'disaster' is defined according to the purpose or status of its use by the national government (Kim & Sohn, 2018).

McGowran and Donovan (2021) linked the various collection theories dealing with disaster risk to propose the idea of ’disaster risk management’ in two ways. It based the first approach on a comprehensive analysis to identify disaster risk. Meanwhile, the second approach conceptualizes 'disaster risk management' as the focus of the study. With accurate data, a reference base will be created, followed by an exploration of ideas to be applied empirically.

Although disasters can disrupt economic performance, social determinants and endanger society and the physical environment (Mustafa & Padli, 2019), very little literature focuses on proactive discussions to bring management policymakers to concentrate on disaster management (Mojtahedi & Oo, 2014). There need to be reactive characteristics that are more sensitive to include elements of the built environment, government, and local communities in an emergency agency or disaster management organization at disaster-prone points (Pimentel et al., 2020; Rustian et al., 2021).

2.2. Logistics Management

In the theory of 'contemporary logistics,' there is often a misperception in the meaning of logistics and 'supply chain management' (SCM). It is important to distinguish between the two because SCM only focuses on distribution and logistics flows, and logistics focuses more on coordination and strategy, including production and marketing (Clifford Defee et al., 2010). Specifically, Nilsson (2006) revealed that these two theories grew out of scientific disciplines and developed from actual theories. The social, organizational, and human dimensions play an important role in logistical efforts. They derive empirical arguments from complex 'logistics theory' (Swanson et al., 2017).

Given disasters, logistics cost management and control can be carried out with efficient construction. Logistics management is an absolute requirement to oversee transportation, material control, and adequate logistics procurement, cooperation as harmonization involving shops, transportation, and portage (Wang et al., 2008).

2.3. Operational Management

The priority of operational management is not just discussing the theory but how it contributes to analyzing the strategic service position (Meirelles & Klement, 2013). Economic theory has combined operational management and strategic services in one container. Operations vision describes production capacity and standardization with client contacts. Here, integration emphasizes the professionalism of information and physical goods to maintain good relationships with clients. Although operational management has been criticized for its lack of theoretical foundations, its organizing under certain conditions and situations produces theories or productive advantages over the 'natural science' theories that have existed for a long time. Of the three well-known theories such as 'Even Slow,' 'Performance Frontiers,' and 'Swift' (Schmenner & Swink, 1998), the most complex one discussing the various dimensions of cumulative integration is the 'Performance Frontiers,' where the productivity of factory performance has been tested.

Further investigation by Gupta and Boyd (2008) stated that the theory of 'operations management' was born from the 'constraint theory,' which is useful for investigating the relationship between the two. The integration uses examples from the literature with an important and useful potential for the future.

3. Methodology

The quantitative approach is the basis of this research, where the database is secondary (Johnston, 2017; MacInnes, 2020). We collected data from BNPB, the Republic of Indonesia, which has released publications or disaster reports in 2020. The method is applied by determining the center of gravity. There are four steps, but first, the focus is on designing a 'grid area' map, then, identifying the coordinate points of supply and demand, determining the quantity at each coordinate point, and calculating the center of gravity (Boonmee et al., 2017; Wang et al., 2019; Mareiniss et al., 2009). The formula for the center of gravity is:

$$Cx = \frac{\sum dix\ Vi}{\sum Vi}$$

$$Cy = \frac{\sum diy\ Vi}{\sum Vi} \quad (1)$$

where Cx - X coordinates, Cy - Y coordinates, dix - X coordinates at location i, diy - Y coordinates at location I, and Vi - number of villages/kelurahan affected by the disaster.

The center of gravity model is a mathematical technique that is useful for finding the location of the distribution center that will minimize distribution costs (Liu et al., 2013). In determining the best location to become a distribution center, this model considers the location of the volume of goods sent to the market, transportation costs, and market location (Heizer & Render, 2014).

4. Findings and Discussion

Referring to Indonesia's disaster data in 2020, Badan Nasional Penanggulangan Bencana – Republic of Indonesia (2020) has released that there are natural disasters that occur in every province in Indonesia. Our investigation is supported by a center of gravity model that classifies each archipelago that can experience severe shaking in every Province in Indonesia. The location of the coordinates on the island of Java, which is well known for its potential for major disasters, is explained by the Google Maps software (Table 1).

Table 1. Total disasters in Java by Province (Estimation using Google Maps)

Provinces	Total	X	Y
DKI Jakarta	60	-6.181479	106.828345
West Java	665	-6.902480	107.618732
Central Java	536	-6.993758	110.420231
DI Yogyakarta	18	-7.794817	110.367312
East Java	410	-7.245745	112.739132
Banten	71	-6.173946	106.156645
	1,760		

Calculations for 'X' coordinates = ((-6.181479*60) + (-6.90248*665) + (-6,993758*536) + (7.794817*18) + (-7.245745*410) + (-6.173946*71)) / 1,760 = -6.965400313. Meanwhile, at the 'Y' coordinate = ((106.828345*60) + (107.618732*665) + (110.420231*536) + (110.367312*18) + (112.739132*410) + (106.156645*71)) / 1,760 = 109.6069198.

Referring to these calculations, we found that the location of the warehouse is suitable for Java, namely the Pekalongan area and bordering near the Bojong toll exit in Central Java Province. For the island of Sumatra, we summarize the ten areas as follows: Aceh = 265 (5.570404, 95.340741), North Sumatera = 92 (3.580716, 98.671949), West Sumatera = 107 (-0.935535, 100.35796), Riau = 11 (0.517789, 101.445775), Riau Islands = 33 (0.876254, 104.445164), South Sumatera = 55 (-2.977067, 104.750518), Jambi = 22 (-1.603922, 103.583551), Bengkulu = 26 (-3.820847, 102.28396), Lampung = 31 (-5.441079, 105.258356), and Bangka Belitung Islands = 11 (-2.153101, 106.157918)

The total disaster on the island of Sumatra is 653 and, from our estimation results, we found the center of gravity at Coordinate X = 1.913274421 and Coordinate Y = 99.19488061.

The suitable warehouse location is Pancumatulu (North Sumatra), but access to infrastructure such as roads is not adequate, so the closest location that meets the criteria is in Sarulla. We explain some important points on the islands of Bali and Nusa Tenggara below: Bali = 38 (-8.667931, 115.234165), West Nusa Tenggara = 55 (-8.581683, 116.109711), and East Nusa Tenggara = 17 (-10.171598, 123.607433).

Thus, the intensity of disasters in Bali and Nusa Tenggara reaches 110. We concluded that the center of gravity is at Coordinate X = -8.8571919 and Coordinate Y = 116.6659885.

The suitable warehouse location is in Matajang (NTB). However, the supporting facilities are not maximized, so it is necessary to look for the closest point with the best access, leading to the Jereweh area.

On the island of Kalimantan, there are five provinces that have been measured in producing disaster estimates, namely: West Kalimantan Barat = 58 (-0.062164, 109.35309), Central Kalimantan = 69 (-2.217107, 113.918746), South Kalimantan = 68 (-3.484284, 114.833803), East Kalimantan = 47 (-0.500981, 117.13932), and North Kalimantan = 36 (2.84208, 117.373982).

The assumptions for the total disaster on the island of Kalimantan are 278 points, where based on the calculation projections, the center of gravity determined: Coordinate X = -1.132188612 and Coordinate Y = 114.1819521.

Thus, it is estimated that a suitable warehouse location for handling disaster mitigation is the anchor area (Central Kalimantan). However, Muara Teweh is an area that meets the criteria because it has adequate infrastructure and facilities.

It is noted that there are two parts of the Maluku Islands with different disaster hazards with the following results: Maluku = 20 (-3.694315, 128.182708) and North Maluku = 19 (0.755922, 127.609758).

Based on calculations, the 39 total disasters in Maluku Island got two points of center of gravity: Coordinate X = -1.526250821 and Coordinate Y = 127.9035785.

Finally, a warehouse location that meets the classification was on Obi Island (South Halmahera, Maluku). Papua Island includes West Papua and Papua, with the centers of gravity being 9 (-0.918266, 134.030492) and 10 (-2.536187, 140.715072), respectively.

There are 19 disaster points on Papua Island, so the center of gravity is at Coordinate X = -1.769803368 and Coordinate Y = 137.548692.

Finally, the determination of a suitable warehouse location was in Sawai (Papua Province). From this finding, it confirmed 6 representative regions of Sulawesi Province: North Sulawesi = 17 (1.469983, 124.844866), Central Sulawesi = 35 (-0.890589, 119.871152), South Sulawesi = 116 (-5.139091, 119.452293), Southeast Sulawesi = 16 (-4.024699, 122.540544), Gorontalo = 24 (0.523985, 123.077471), and West Sulawesi = 11 (-2.664896, 118.852839).

The clues have shown that the total disaster number on Sulawesi Island is 218. The two centers of gravity points are at Coordinate X = -3.131001243 and Coordinate Y = 120.5336565.

The results have also shown that a suitable center for disaster preparation is Palu (Central Sulawesi Province), where these points are in the waters; the closest area is Palopo.

Figure 1. Map of natural disasters in Indonesia (Indonesia-Investments, 2021)

Regulations made by BNPB Number 20 of 2011 in anticipating natural disasters in Indonesia provide guidelines for monitoring and evaluating disaster management logistics. When a disaster occurs, logistics management includes distribution, storage/warehousing, receiving at the destination, transportation, elimination, planning, and inventory of needs (Figure 1) (Tien et al., 2019; Shukla & Sharma, 2015; Li et al., 2014).

The study is very relevant when compared with previous findings that discuss the role of disaster mitigation as a policy consideration and projection. Parameters for disaster vulnerability in Indonesia have become a concern in the next few decades, where this is certainly a lesson about what happened in the past (Tauhid et al., 2017). Here, Gougelet (2016), Boonmee et al. (2017) evaluate the impact of disasters in two ways: disaster risk management (DRM) and disaster risk reduction (DRR). Even though these two terms look the same, they have different goals, where DRM focuses on efforts or handling activities in repairing disasters that often occur. Meanwhile, DRR is more dominant in anticipating natural disaster damage through a series of processes in prevention ethics.

5. Conclusion

The center-of-gravity method is expected to assist the government in accelerating aid distribution to the victims. The seven priority points are Pekalongan (Central Java Province), Sarulla (North Sumatra Province), Jereweh (West Nusa Tenggara Province), Muara Teweh (Central Kalimantan Province), Obi Islands (Maluku Province), Sawai (Papua Province), and Palopo (South Sulawesi Province).

The governance of the distribution of logistics for natural disasters in Indonesia explains it refers to SOPs regarding distribution to victims of natural disasters within a minimum of seven working days (Octavia et al., 2016). Prabowo et al. (2017), Hadi et al. (2020) stated that determining the location of laboratory branches was necessary for monitoring the potential of disasters in several regions in Indonesia.

The management function is the major actor in logistics operations. According to Azmi et al. (2017), Ristovska et al. (2017), logistics management comprises seven dimensions: control, elimination, maintenance, storage and distribution, planning and determination of needs, procurement, and budgeting.

6. Limitations and Future Study

There is no perfect study in this world. We recognize that this study has limitations in its center-of-gravity-based presentation. In addition, the accuracy of the data with Google Maps needs to be evaluated again because the map scale does not detail the current state of the area, especially in 2021.

In addition, extra support also needs to pay attention to the perception of local communities whose areas are prone to disasters. It is about an actual practice that can be extended to identify potential material losses.

Realizing the importance of this, we expected the theoretical policy to develop these findings with various techniques to produce more varied empirical studies. Now and in the future, studies that highlight disaster mitigation are always in the spotlight, so scientific expansion is more striking.

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Authors' Contributions

Mr. R.H and Dr. JAJ contributed 55% to this study, covering idea visualization, literature conceptualization, data validation, and assembling methods. Dr. A.H is responsible for 45% of the work: refining the findings and discussions, conclusions, and references.

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