GIS-Based Spatial Mapping of Vocational Schools in Construction and Building Engineering

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Abstract. This study aims to analyze the spatial distribution patterns of Vocational High Schools (SMK) specializing in Construction and Building Engineering in North Sumatra Province using Geographic Information Systems (GIS). This quantitative research involved a sample of 37 vocational schools distributed across various regions. The expertise programs offered in North Sumatra include: (1) Construction and Property Engineering, (2) Building Modeling and Information Design, and (3) Furniture Engineering. Data were collected through topographic maps (raster data), field surveys to obtain the geographical coordinates of each school, and attribute data comprising detailed school information. Descriptive analysis was conducted using ArcGIS 10.8 software to map school locations, along with Nearest Neighbor Analysis to determine the spatial distribution pattern. The results show a T-value of 0.867, which falls into the category of random distribution. This finding indicates that there is no significant concentration or clustering of SMK locations within this field of expertise. The results of this study can serve as a reference for spatially-based vocational education development planning to support equitable access and improve the quality of vocational education in North Sumatra Province.

Keywords: SMK, Vocational School, Spatial Distribution, Construction and Building Engineering, GIS.

1 Introduction

Geographic Information Systems (GIS) have emerged as a powerful technological framework for capturing, storing, analyzing, and visualizing spatially referenced data. Unlike conventional information systems, GIS is uniquely designed to integrate spatial and non-spatial data, thereby providing comprehensive insights into phenomena occurring both on the surface and beneath the Earth [1]. The ability of GIS to represent information through cartographic visualization such as maps, plans, and spatial models enables users to interpret complex data in a more intuitive and decision-oriented manner. One of the distinctive features of GIS is its capability to combine statistical analysis with spatial visualization, which allows for the exploration of geographic patterns, prediction of future events, and the development of evidence-based

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strategic planning. GIS has been widely recognized as an indispensable tool for organizations seeking to understand spatial relationships, monitor dynamic changes, and optimize resource allocation [2]. By associating data with geographic coordinates, GIS not only facilitates efficient organization of information but also enhances the ability to uncover new insights from existing datasets. This spatially enabled approach contributes to improved decision-making, more effective communication of information, and the potential generation of innovative solutions to complex geographical and socio-economic problems.

The rapid acceleration of globalization has intensified competition among nations, particularly in the domains of industrialization and information technology. This global rivalry is characterized by swift advancements in science and technology, which simultaneously present both opportunities and challenges. On one hand, such developments create significant potential to accelerate national and regional development. On the other hand, they pose substantial demands for the enhancement of human resource quality to ensure competitiveness in a dynamic global landscape [3]. Effective resource management is not only crucial for sustaining development but also for fostering resilience in the face of technological disruption and shifting labor market demands [4]. Within this framework, education plays a pivotal role in bridging the gap between rapid technological change and the preparedness of society. Vocational education, particularly through the establishment of vocational high schools (SMK), has been positioned as a strategic response to these global and regional challenges. Such institutions are designed to equip students with practical skills and competencies aligned with industrial needs, while simultaneously improving the overall standard of living of the communities they serve.

Table 1. Indonesia's Unemployment Rate by Education 2022-2024

Level of education	Unemployment Rate		
	2022	2023	2024
SD	3,59	2,56	2,32
SMP	5,95	4,78	4,11
SMA	8,57	8,15	7,05
SMK	9,42	9,31	9,01
Diploma	4,59	4,79	4,83
Bachelor	4,80	5,18	5,25

According to data released by the Central Bureau of Statistics (BPS) in **Table 1** [5], the unemployment rate among vocational high school (Sekolah Menengah Kejuruan/SMK) graduates remains the highest compared to other levels of education. This persistent phenomenon raises critical concerns about the effectiveness of vocational education in preparing graduates for the labor market. Although SMK is intended to provide students with industry-oriented skills and practical competencies, the expected outcomes in terms of employability have not been fully realized. Several factors contribute to this high unemployment rate among SMK graduates. One of the key issues lies in the limited promotional efforts undertaken by vocational schools, which often fail to adequately showcase their graduates' competencies to potential employers. In addition, many vocational institutions struggle to adapt their curricula and training systems to the rapid advancement of technology and the evolving demands of the labor market [6]. This misalignment between the skills provided by schools and those required by industries creates a significant gap that directly impacts the employability of graduates. The situation underscores the urgent need for a more dynamic and responsive vocational education system that is able to anticipate and align with industrial transformation.

Vocational high schools (SMK) play a strategic role in preparing a skilled workforce that meets the demands of national and regional development. Within this framework, the field of Construction and Building Technology represents one of the most crucial areas, given its direct relevance to infrastructure development, urbanization, and industrial growth. Skilled graduates in this sector are expected to contribute significantly to the construction industry, which remains a vital driver of economic progress in developing countries. Despite its strategic importance, the Construction and Building Technology expertise area in vocational schools has received relatively low levels of interest compared to other vocational fields [7]. Enrollment trends indicate that students are more likely to choose programs perceived as modern, such as information technology, business, or hospitality, while construction-related programs are often viewed as less attractive.

Data indicate that there are approximately 640 vocational schools offering construction programs, with a total of only around 30,000 students enrolled. In contrast, nursing programs, which are offered by about 400 vocational schools, attract nearly 100,000 students [8]. This disparity reflects the limited interest among students in pursuing construction-related education, despite the sector's strategic importance to national development and the abundance of available job opportunities. This imbalance highlights a pressing challenge for vocational education in Indonesia. The lack of student interest in construction programs not only risks creating a skills gap in one of the nation's most vital industries but also suggests the need for systemic reforms in how these programs are promoted, structured, and aligned with both industry needs and student aspirations. Strengthening the attractiveness of construction-related vocational education requires a combination of curriculum modernization, industry collaboration, and efforts to reshape public perceptions of construction careers as viable, rewarding, and future-oriented professions.

In North Sumatra, the presence of vocational high schools (SMK) specializing in Construction and Building Technology remains limited, with only institutions offering this expertise area. Despite the construction sector's pivotal role in supporting regional infrastructure and economic development, these programs are relatively under-enrolled, reflecting a lack of student interest and a persistent mismatch between educational supply and labor market demand. This condition raises concerns about the adequacy of skilled human resources to meet the growing needs of the construction industry in the province. To address this gap, a comprehensive mapping effort is required, utilizing Geographic Information Systems (GIS) to spatially analyze the distribution of SMKs in relation to the potential industrial sectors in North Sumatra. Such an approach would not only provide a clearer understanding of the alignment between vocational education and regional economic needs but also serve as a strategic basis for planning, policy formulation, and strengthening school–industry linkages to enhance the attractiveness and relevance of construction-related vocational programs.

2 Method

This study employed a quantitative descriptive research design with spatial analysis to examine the distribution of vocational high schools (SMK) in North Sumatra Province. The analysis was conducted using ArcGIS software, which enables the integration of numerical and spatial approaches in a systematic manner. This method was selected because it allows for the identification of spatial patterns, disparities, and distributional imbalances of educational facilities across different administrative regions. By combining quantitative data with spatial mapping, the study provides a comprehensive representation of how vocational schools specializing in Construction and Building Technology are distributed in relation to regional boundaries and potential industrial demands [9]. The administrative boundaries of North Sumatra Province were used as the base map for the spatial analysis, serving as a reference framework for further interpretation of educational distribution and regional disparities.

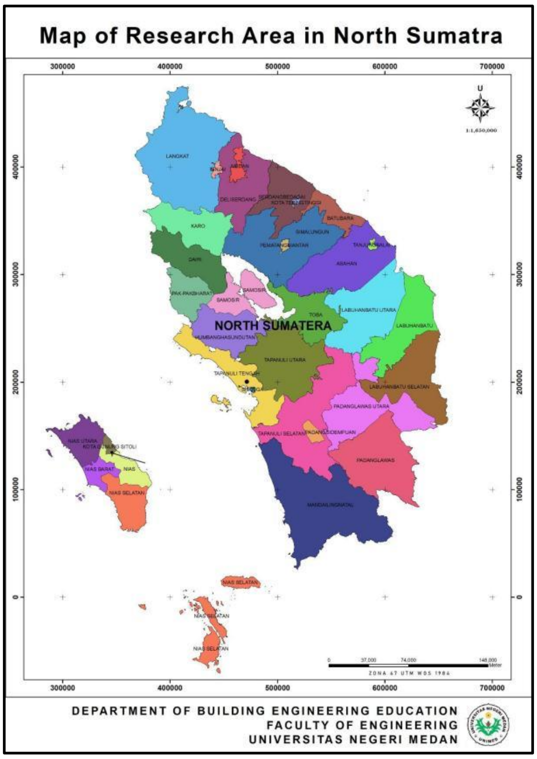

Fig. 1. Research Location Map (Source: spatial mapping results)

Figure 1 shows the population in this study refers to the generalized area encompassing objects or subjects with specific characteristics determined by the researcher for investigation, so that the results can be used to draw valid conclusions [10]. The population in this research consisted of all vocational high schools (SMK) specializing in Construction and Property Technology in North Sumatra Province. The selection of this population was based on the research objective of analyzing the spatial distribution of vocational schools within this expertise area.

Data collection in this study relied on secondary data obtained from official and reliable sources. Information regarding the number of public vocational high schools (SMK) was retrieved from the Basic and Secondary Education Data Center, complemented by data from the Provincial Education Office of North Sumatra. These datasets provided comprehensive details on the distribution and characteristics of vocational schools within the province. The data were processed through spatial analysis using ArcGIS, with a specific focus on examining the distribution patterns of SMK. The Average Nearest Neighbour (ANN) method was employed to identify the spatial tendencies of the schools' locations, determining whether their distribution exhibited clustered, random, or uniform patterns [11]. The ANN technique calculates the ratio between the observed average distance of each feature to its nearest neighbor and the expected mean distance in a random distribution. The resulting ANN index value serves as the basis for interpreting spatial patterns, where values less than 1 indicate clustering, values near 1 suggest randomness, and values greater than 1 reflect a dispersed distribution. This methodological approach enabled a systematic evaluation of the spatial configuration of vocational schools in North Sumatra. The ANN value is calculated using the following formula:

$$T = \frac{Ju}{Jh} \quad (1)$$

Information:

T : Nearest neighbor distribution index
Ju : The average distance from one point to its nearest neighbor
Jh : Rata-rata jarak yang diharapkan apabila pola titik tersebar secara acak

To obtain the average expected distance if the point pattern is randomly distributed, use the following formula.

$$Jh = \frac{1}{2\sqrt{p}} \quad (2)$$

Information:

p : The density of points per square kilometer is obtained by dividing the number of points (N) by the area of the region.

3 Results and Discussion

3.1 Results

The spatial analysis began with the visualization of the distribution of vocational high schools (SMK) specializing in Construction and Building Technology across North Sumatra Province. Figure 2 presents the geographic locations of the 37 SMKs that formed the population of this study, mapped according to their administrative boundaries. This spatial representation provides an overview of how these institutions are distributed throughout the province and serves as the basis for further analysis of spatial patterns and their alignment with regional development needs. The map not only illustrates the concentration of schools in certain districts but also highlights areas with limited access to construction-related vocational education. Such visualization is essential for identifying potential disparities and assessing the adequacy of educational infrastructure in supporting the construction industry within the region.

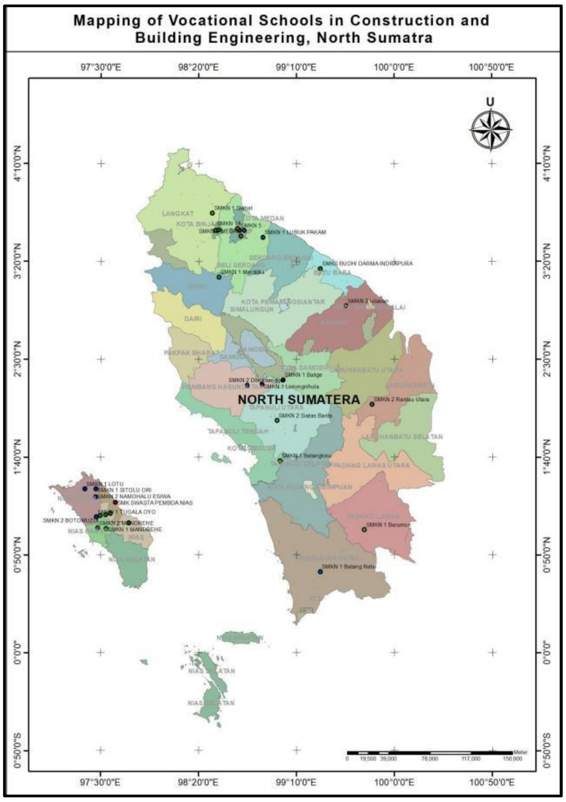

Fig. 2. Map of the Distribution of Vocational Schools in North Sumatra Province (Source: spatial mapping results)

Figure 2 describes to complement the spatial visualization, the distribution of vocational high schools (SMK) specializing in Construction and Building Technology in North Sumatra Province was further presented in tabular form. **Table 2** lists 37 SMKs along with their respective names, district locations, and geographic coordinates. This detailed compilation provides an explicit overview of the institutional landscape, enabling a more precise understanding of the spatial positioning of each school. The inclusion of geographic coordinates is particularly important, as it facilitates integration with spatial analysis tools for examining proximity, accessibility, and alignment with industrial zones. By presenting the data in this format, the study offers a transparent basis for assessing potential disparities in the availability of construction-related vocational education across different districts within the province.

Table 2. Data on names, addresses, coordinates of State Vocational Schools in North Sumatra Province

No	School Name	Regency/City	Coordinate	
			x	y
1	SMKN 1 Balige	Toba	505784.890	257086.948
2	SMKN 2 Siatas Barita	Tapanuli Utara	500110.629	218721.100
3	SMKN 1 Batangtoru	Tapanuli Selatan	502827.014	180757.162
4	SMK Swasta GKPS 2 Pematang Siantar	Simalungun	508685.067	327525.867

No	School Name	Regency/City	Coordinate	
			x	y
5	SMKN 2 Sibolga	Sibolga	475845.029	193262.597
6	SMKN 3 Sibolga	Sibolga	481301.302	188232.529
7	SMKN 1 Palipi	Samosir	478188.691	272648.488
8	SMKN 1 Siempat Rube	Phakpak Barat	429945.018	285865.744
9	SMKN 2 Pematangsiantar	Pematang Siantar	509731.094	327393.944
10	SMKN 2 Padang Sidimpuan	Padang Sidimpuan	528717.908	153952.865
11	SMKN 1 Barumun	Padang Lawas	582824.325	115799.334
12	SMKN 1 Sitolu Ori	Nias Utara	328642.631	154441.923
13	SMKN 1 Lotu	Nias Utara	318111.713	154253.588
14	SMKN 1 Tugala Oyo	Nias Utara	328784.846	127865.279
15	SMKN 2 Namohalu Esiwa	Nias Utara	328205.129	146833.714
16	SMKN 1 Mandrehe	Nias Selatan	338103.548	116901.818
17	SMKN 2 Mandrehe	Nias Selatan	330277.013	117326.787
18	SMKN 1 Botomuzoi	Nias	337632.511	129906.195
19	SMKN 1 Hiliserangkai	Nias	342152.613	130996.109
20	SMKN 1 Sogaeadu	Nias	359614.946	122122.715
21	SMKN 2 Botomuzoi	Nias	332844.001	129198.401
22	SMKN 2 Medan	Medan	465787.178	392466.488
23	SMKN 5 Medan	Medan	464362.542	397927.929
24	SMKN 14 Medan	Medan	462659.810	399711.765
25	SMKN 1 Batang Natal	Mandailing Natal	541166.810	76334.300
26	SMKN 1 Stabat	Langkat	438941.655	414212.505
27	SMKN 2 Rantau Utara	Labuhan Batu	590036.735	233982.338
28	SMKN 1 Merdeka	Karo	445038.362	353861.655
29	SMKN 1 Lintongnihuta	Humbang Hasundutan	485657.739	252953.833
30	SMKN 2 Doloksanggul	Humbang Hasundutan	471783.432	251968.284
31	SMK Swasta Pembda Nias	Gunung Sitoli	347100.062	141676.996
32	SMKN 1 Lubuk Pakam	Deli Serdang	486646.852	391432.284
33	SMKN 1 Percut Sei Tuan	Deli Serdang	469015.660	398038.510
34	SMKN 2 Binjai	Binjai	444802.843	398287.889
35	SMKS Putra Anda Binjai	Binjai	442093.452	397986.951
36	SMKS Budi Darma Indrapura	Batu Bara	541134.059	361839.044
37	SMKN 2 Kisaran	Asahan	565492.929	326790.935

The GIS-based spatial mapping identifies 37 Vocational High Schools (SMK) specializing in Construction and Building Engineering across North Sumatra. The distribution illustrates how vocational education in this field is spread across various regencies and cities, encompassing urban centers, rural areas, and island territories. In the Lake Toba region, schools such as SMKN 1 Balige (Toba) and SMKN 2 Siatas Barita (North Tapanuli) are positioned strategically around the lake basin. Further south, SMKN 1 Batangtoru (South Tapanuli) and SMKN 1 Barumun (Padang Lawas) serve as key institutions in the southern corridor of the province. Along the west coast, vocational schools are located in Sibolga (SMKN 2 and SMKN 3), Samosir (SMKN 1 Palipi), and Phakpak Barat (SMKN 1 Siempat Rube), while in the central area, Simalungun and Pematang Siantar host institutions such as SMK Swasta GKPS 2 and SMKN 2 Pematangsiantar, reinforcing the accessibility of vocational education in urban centers. A notable concentration is found in the Nias Islands, where multiple schools exist across North

Nias (SMKN 1 Sitolu Ori, SMKN 1 Lotu, SMKN 1 Tugala Oyo, SMKN 2 Namohalu Esiwa), South Nias (SMKN 1 and 2 Mandrehe), and Nias Regency (SMKN 1 Botomuzoi, SMKN 1 Hiliserangkai, SMKN 1 Sogaeadu, and SMKN 2 Botomuzoi). Gunung Sitoli also accommodates vocational education through SMK Swasta Pembda Nias, highlighting the importance of providing educational access to island communities. In the northeastern urban corridor, the provincial capital Medan has a cluster of schools including SMKN 2, SMKN 5, and SMKN 14, reflecting its role as a central hub of vocational education. Neighboring regions such as Binjai (SMKN 2 and SMKS Putra Anda), Deli Serdang (SMKN 1 Lubuk Pakam and SMKN 1 Percut Sei Tuan), Langkat (SMKN 1 Stabat), and Karo (SMKN 1 Merdeka) further expand the reach of vocational training. On the east coast, the presence of schools in Batu Bara (SMKS Budi Darma Indrapura), Asahan (SMKN 2 Kisaran), and Labuhan Batu (SMKN 2 Rantau Utara) illustrates the integration of vocational education within industrial and agricultural development zones. Overall, the GIS-based spatial mapping demonstrates that vocational schools in Construction and Building Engineering are evenly distributed across North Sumatra, ensuring educational opportunities are accessible to diverse communities across mainland and island regions. This spatial distribution highlights the strategic role of vocational education in supporting local development and addressing regional workforce needs.

The nearest neighbor analysis of 37 vocational schools specializing in Construction and Building Engineering across North Sumatra yielded a mean observed nearest-neighbor distance (Ju) of 19.18 km, while the expected mean distance under a random distribution (Jh) was 22.13 km. This produced a nearest neighbor index (T) of 0.867, indicating that the spatial distribution of schools is more clustered than random. The clustering is most evident in the Medan–Binjai–Deli Serdang corridor, the Pematangsiantar–Simalungun area, and the Nias Islands, reflecting the concentration of educational facilities in major urban and regional centers.

3.2 Discussion

The spatial clustering of vocational schools in Construction and Building Engineering across North Sumatra, as indicated by a nearest neighbor index value of $T = 0.867$, reflects several underlying regional dynamics. First, the concentration of schools in the Medan–Binjai–Deli Serdang corridor corresponds with the province's highest population density and urban development, where demand for technical education and accessibility to infrastructure is greater. Similarly, the Pematangsiantar–Simalungun cluster demonstrates the role of secondary urban centers in providing educational opportunities to surrounding regencies.

In the Nias Islands, clustering of schools reflects both geographic constraints and policy efforts to ensure equitable access to vocational education in remote and insular areas. Despite challenging topography and limited transportation networks, the existence of multiple schools in Nias indicates a strategic allocation of resources to reduce educational disparities.

The overall clustered pattern suggests that the distribution of vocational schools is not random but rather shaped by demographic concentration, economic development zones, and regional education planning. While this clustering improves access for students in urban and regional hubs, it also highlights the potential inequality of access for students in sparsely populated or peripheral areas. Therefore, future planning should consider a more balanced spatial distribution by establishing new vocational schools or expanding existing facilities in underserved regions to achieve wider educational equity.

4 Conclusion

The GIS-based spatial mapping and nearest neighbor analysis revealed that vocational schools specializing in Construction and Building Engineering in North Sumatra exhibit a clustered spatial distribution pattern (T = 0.867). This clustering is strongly influenced by population density, urban development, and regional education policies, with major concentrations identified in Medan–Binjai–Deli Serdang, Pematangsiantar–Simalungun, and the Nias Islands.

While such clustering ensures accessibility in key growth areas, it also underscores the need for more equitable distribution to address gaps in rural and peripheral regions. Strategic planning that considers demographic dynamics and geographic constraints is essential to expand opportunities for vocational education, thereby supporting human resource development and regional economic growth across the province.

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References

[1] Ganie, Parvaiz Ahmad, Ravindra Posti, Garima Kunal, Raja Aadil Hussain Bhat, and M. Junaid Sidiq. Principle and applications of Geographic Information System (GIS) in coldwater fisheries development in India. In Aquaculture and conservation of inland coldwater fishes, pp. 469-495. Singapore: Springer Nature Singapore (2024).
[2] Mahmud, Danish. An Iot-Enabled Decision Support System For Circular Economy Business Models: A Review Of Economic Efficiency And Sustainability Outcomes. American Journal of Scholarly Research and Innovation 4, no. 01: 250-286 (2025).
[3] Haiyong, S. Global Science and Technology Governance: Impetus, Challenges, and Prospects. China Quarterly of International Strategic Studies, 7(01), 61-78 (2021).
[4] Agarwal, V., Mathiyazhagan, K., Malhotra, S., & Saikouk, T. Analysis of challenges in sustainable human resource management due to disruptions by Industry 4.0: an emerging economy perspective. International Journal of Manpower, 43(2), 513-541. (2022).
[5] Badan Pusat Statistik (BPS). Tingkat Pengangguran Terbuka Berdasarkan Tingkat Pendidikan. (2024)
[6] Safitri, R. D., & Rezza, M. Membedah Tren Tingginya Angka Pengangguran Terbuka Pada Gen Z Di Indonesia. Jurnal Intelek Insan Cendikia, 2(1), 636-649. (2025).
[7] Adepoju, O. O., & Aigbavboa, C. O. Assessing knowledge and skills gap for construction 4.0 in a developing economy. Journal of Public Affairs, 21(3), e2264. (2021).

[8] Direktur Jenderal Pendidikan Dasar dan Menengah Kementerian Pendidikan dan Kebudayaan (Kemdikbud) (2018)
[9] Ana, A., Dwiyanti, V., Sari, A. R., Saripudin, S., & Muktiarni, M. A Geographical Information System-based Mapping Model for Aligning Vocational High Schools with Industrial Needs. Journal of Technical Education and Training, 17(2), 229-244. (2025).
[10] Jumadi, J., Mardian, M., & Yanti, L. Pengaruh strategi pembelajaran The Power of Two untuk meningkatkan kemampuan membaca teks eksposisi. Journal of Educational Review and Research, 3(1), 59-64. (2020).
[11] Jaslan, R., & Ramadhan, R. Analisis Pola Sebaran Fasilitas Pendidikan Tingkat Sekolah Menengah Atas (SMA) di Kabupaten Agam. Jurnal Pendidikan Tambusai, 8(2). (2024).