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RETHINKING THE TACTILE PAVING INSTALLATION SYSTEM BASED ON THE CITY RHYTHM OF VISUALLY IMPAIRED PEDESTRIANS IN URBAN NETWORKS

MEMIKIRKAN ULANG SISTEM INSTALASI UBIN PEMANDU BERDASARKAN RITME KOTA PEJALAN KAKI TUNANETRA DALAM JARINGAN PERKOTAAN

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ABSTRACT
This study was conducted in Bandung, the provincial capital of West Java, to reevaluate the tactile paving installation system based on the movement patterns of visually impaired pedestrians in urban networks. Given the rising global prevalence of low vision and blindness, creating inclusive urban environments has become a critical health and social issue. The research aimed to address the gap in accessibility by focusing on how tactile paving can better align with the daily rhythms and needs of visually impaired individuals. Data collection involved interviews, and data analysis utilized a mixed-methods approach. Findings revealed that the movement patterns of visually impaired pedestrians are intricately connected to their essential activities. The study concludes that a hierarchical approach to tactile paving installation can improve efficiency, particularly in cities with limited funding, thus promoting broader and more effective development of inclusive urban networks. These insights are valuable for both immediate facility improvements and future transit-oriented development planning.
Keywords: *Tactile Paving, Visually Impaired Pedestrians, Inclusive Urban Design, Urban Network Navigation, Transit-Oriented Development*

ABSTRAK
Studi ini dilakukan di Bandung, ibu kota Provinsi Jawa Barat, untuk mengevaluasi ulang sistem instalasi ubin pemandu berdasarkan pola pergerakan pejalan kaki tunanetra dalam jaringan perkotaan. Mengingat meningkatnya prevalensi global gangguan penglihatan dan kebutaan, penciptaan lingkungan perkotaan yang inklusif telah menjadi isu kesehatan dan sosial yang mendesak. Penelitian ini bertujuan untuk mengatasi kesenjangan aksesibilitas dengan berfokus pada bagaimana ubin pemandu dapat lebih selaras dengan ritme harian dan kebutuhan individu tunanetra. Pengumpulan data dilakukan melalui wawancara, dan analisis data menggunakan pendekatan campuran. Temuan menunjukkan bahwa pola pergerakan pejalan kaki tunanetra sangat erat kaitannya dengan aktivitas penting mereka. Studi ini menyimpulkan bahwa pendekatan hierarkis terhadap instalasi tactile paving dapat meningkatkan efisiensi, terutama di kota-kota dengan keterbatasan pendanaan, sehingga mendorong pengembangan jaringan perkotaan inklusif yang lebih luas dan efektif. Wawasan ini sangat berharga baik untuk perbaikan fasilitas jangka pendek maupun perencanaan pengembangan berbasis transit di masa depan.
Kata Kunci: *Ubin pemandu, Pejalan kaki tuna netra, Desain perkotaan inklusif, Navigasi jaringan perkotaan, Pembangunan berorientasi transit*

1. INTRODUCTION

The study focused on tactile-based building technology as an orientation and mobility (OM) system for the visually impaired in urban networks. This technology, known as the "Tenji Block" or more commonly referred to as "Tactile Paving", features a textured design on horizontal surfaces that serves to warn and guide visually impaired individuals. Tactile paving is typically represented by blister and corduroy paving (Ormerod et al., 2015). The study's objective was to rethink the tactile paving installation system, driven by the growing demand for inclusive urban networks in response to global vision health challenges. This is particularly urgent for developing countries, which often face funding constraints. According to the World Health Organization (World Health Organization, 2021), at least 2.2 billion people globally were affected by near or distant vision impairment in 2021, and this number continues to rise each year (Dokainish et al., 2017).

Installing tactile paving is costly (Duncan-Jones, 2015). Incorrect placement can lead to redundancy (Mizuno et al.,, 2008). The author frequently identified four common issues with tactile paving installations. First, the type of indicator used did not align with the environmental conditions and design requirements. Second, it was installed in areas that were inaccessible to the visually impaired. Third, there was insufficient consideration of materials to accommodate geographical conditions. Fourth, there was an overestimation of the community's understanding of how it functions. Ideally, the installation of tactile paving should not be done carelessly or out of mere politeness, but rather with careful observation and evaluation (Padzi et al., 2013).

This paper discussed the efficiency strategy and system for tactile paving installation in the city. That raised two questions: where should tactile paving be applied, and what environmental conditions are good standards for its installation systems? These two questions got integrated into buildings and sidewalks since the theory of OM in public spaces divides indoor & outdoor activities (Long, 1990) and static & dynamic conditions (Knikou & Rymer, 2003). It contributed to developing the first two questions to be more specific: what kind of building needs tactile paving installation the most, and what are the minimum sidewalk standards and criteria to be accessible for the visually impaired as the tactile paving installation spaces. By searching online, people today will find that values related to tactile paving installation systems are widely available and commonly perceived in terms of security, comfort, convenience, aesthetics, safety, humanity, and social interaction for individuals with visual impairments. The values are meant to assist the mobility of visually impaired individuals and enhance their productivity, without sparking debate on how the cost of media procurement can be balanced for spatial and social inclusion planning.

The author chose Bandung as the study location for four reasons. First, social empowerment efforts in Bandung influence the demographic status of visually impaired individuals both in the city and its surrounding areas (Pemerintah Provinsi Jawa Barat, 2016). Second, Bandung is one of the representative cities for urban development models in Indonesia (Chang & Hasanah, 2020). Third, the author observed errors in the installation of tactile paving in various urban networks across Bandung.

The author proposes a hierarchical approach to the installation of tactile paving in cities. This approach aims to optimize the effectiveness of tactile paving while ensuring budget efficiency. It is implemented by anticipating and assessing installation errors and oversights through a project map based on the city rhythms of visually impaired individuals in urban networks. The author envisions this approach helping cities eliminate architectural barriers without compromising inclusivity. The author employed grounded theory to address the need for qualitative analysis and data collection to bridge the gap. The study offers four integrated potential contributions. First, it provides theoretical confirmation of the effectiveness of tactile paving installations for regional governments. Second, it serves as evaluative material for planning and designing technology-based spatial inclusion in cities. Third, it offers input to enhance public policies that regulate minimum service standards and criteria for sidewalks. Finally, it provides personal insights for future research on developing tactile pictograms or "Tactogram" placemaking strategies— a neuroscientific-based navigation system for all.

A city is not truly inclusive until its technology contributes to improving the quality of life for its citizens (Salha et al., 2020). Furthermore, technology is not inclusive until it meets economic value (Beliz et al., 2019).

2. TACTILE PAVING INSTALLATION

The literature review in this paper refers to previous studies (Pembuain et al., 2020; Putranto & Putri, 2018) and Minister of Public Works Regulation Number 3 (2014), on Guidelines for Planning, Provision, and Utilization of Pedestrian Network Infrastructure and Facilities in Urban Areas.

The relevance of tactile paving installation discussed in this paper refers to criteria outlined in previous research, which asserts that tactile paving is designed to prevent ineffectiveness by addressing four key aspects: 1) the installation must be well-integrated with the surrounding infrastructure, 2) it must support safe and intuitive navigation for users with visual impairments, 3) the tactile features should be easily perceptible to those with limited vision, and 4) the design must accommodate the needs of other mobility-impaired individuals, including wheelchair users and the elderly. Evaluating these aspects is crucial to ensuring that tactile paving installation systems function effectively across various urban settings, thereby contributing to more inclusive and accessible environments.

Minister of Public Works Regulation Number 3 of 2014, on Guidelines for Planning, Provision, and Utilization of Pedestrian Network Infrastructure and Facilities in Urban Areas, serves as a guideline for the quality implementation of these three activities. This regulation encompasses seven principles: security, comfort, convenience, aesthetics, safety, humanity, and social interaction. Chapter 1, section 2 of article 2 states that this Ministerial Regulation aims to create a pedestrian network in urban areas that is safe, comfortable, and humane, thereby encouraging people to walk and use public transportation. Chapter 2 of article 5 specifies that the planning of infrastructure and facilities for pedestrian networks must consider pedestrian sensitivity and the context of the area. The criteria include pedestrian characteristics, environmental characteristics, and the interrelationships between activities and modes of transportation. Additionally, Chapter 2 of article 8 mentions that pedestrian space is measured based on human dimensions while carrying goods or walking with other pedestrians, both statically and dynamically. This article also outlines that pedestrian network infrastructure and facilities planning techniques involve segregation, integration, and separation. Chapter 3 of article 10 indicates that the provision of pedestrian network infrastructure should consider: the characteristics of the transportation system and mode changes, activity centers, road function characteristics and land use, availability of crossings, availability of green lanes, location of pedestrian network infrastructure, and forms of pedestrian network infrastructure. Chapter 4 of article 13 stipulates that the utilization of pedestrian network infrastructure should consider: the type of activity, utilization time, number of users, and applicable technical provisions. The appendix to article 3 states that the provision of pedestrian network infrastructure through the development of transit areas must address twelve considerations, which are:

1. Address aspects of security, comfort, aesthetics, and convenience for all pedestrians, including those with special needs.
2. Apply to a quarter of the road shoulder and be directly accessible to pedestrians.
3. Allow pedestrians to reach a bus stop within a maximum distance of 400 meters or a 10-minute travel time.
4. Include a usage hierarchy based on pedestrian volume.
5. Provide facilities to assist mobility.
6. Connect with other pedestrian network infrastructure.
7. Link to locations where transportation mode changes occur.
8. Be tailored to meet specific needs.
9. Meet the standards for pedestrian network infrastructure services, which vary according to size and dimensions based on pedestrian movement patterns.
10. Consider the typology of the pedestrian path based on space allocation.
11. Provide appropriate signs and markings.
12. Ensure clear visibility in all directions, except in tunnels, and address requirements for pedestrians with special needs in the technical planning of lane widths and specifications.

3. METHODS

Law of the Republic of Indonesia Number 28 on Buildings (2002) categorizes buildings into five types based on their functions: residential, religious, business, social, and cultural, as well as special functions. Table 1 presents the building types.

Table 1. Building Types and Products Based on Law of the Republic of Indonesia Number 28 of 2002 on Buildings

Building Type	Building products
Residential	Single-dwelling houses, row-dwelling houses, flats, and houses.
Religious	Mosques, churches, temples, and monasteries.
Business	Office, trade, industry, hospitality, tourism and recreation, terminal, and storage.
Social	Education, culture, health services, laboratories, and public services.
Special Functions	Nuclear reactors, defense and security installations, and similar buildings as decided by the minister.

Andresen & Bouldin (2021) proposed that disability research should be integrated with data and surveillance. Grounded theory, as a selected research strategy, incorporates empirical checks into the analytical process and prompts researchers to explore all possible theoretical explanations for their empirical findings (Bryant & Charmaz, 2010). Addressing the urgency of physical accessibility is fundamental to eliminating architectural barriers (Chia-Hsin, 2020). The author aims to inspire adaptive perspectives for readers based on architectural data through a pragmatic assessment model, modular design method, and visionary plan. The study comprised four stages: data collection, data analysis, system design, and simulation.

Table 2. Profile of Respondents

Variable	Frequency	
	N°	%
Gender		
Male	31	62
Female	19	38
Age		
Adolescene (13-18 years)	9	18
Adult (19-59 years)	34	68
Senior Adult (60 years and above)	7	14
Condition		
Low Vision		
Wild (acuity 6/12 to 6/18)	4	8
Moderate (acuity 6/18 to 6/60)	28	56
Severe (acuity 6/60 to 3/60)	7	14
Totally Blind (acuity worse than 3/60)	11	22
Blindness Cause History		
Congenitally	46	92
Disease	3	6
Accident	1	2
Education		
Primary School	22	44
Bachelor	27	54
Doctor	1	2
Domicile		
Bandung	47	94
Other	3	6

Variable	Frequency	
	N°	%
Job		
Work	37	74
Self Employed	4	8
Student	9	18
Monthly Income		
Above Minimum Wage	3	7,31
Minimum Wage	4	9,74
Below Minimum Wage	33	80.48

Table 3. Questions for Interviews

Question for Interviews	1	2	3	4	5
Which building type and product do you often access?					
In which building type and product needs tactile paving installations the most?					
What are the most important sidewalk standards to be accessible for you as the tactile paving installation platform?					

The data were divided into two types: primary data, collected through interviews, and secondary data, collected through observation and literature. Interviews were conducted with 50 visually impaired individuals who have daily activities in the City of Bandung. This number aligns with Creswell & Creswell's (2018) recommendation that a minimum of 30 respondents is appropriate for achieving data saturation. The profile of the respondents is presented in Table 2. Interviews were conducted in both individual and group formats. Table 3 presents the research questions. The interviews were structured by introducing the two regulations, asking questions, and receiving feedback. After conducting the interviews, the author scheduled observations at the specified sites.

Data analysis employed various methods. The analysis process was divided into two consecutive stages: quantitative studies and qualitative studies. The quantitative study aimed to reveal the hierarchical significance of data variables through Exploratory Factor Analysis (EFA). The qualitative study, on the other hand, aimed to establish minimum sidewalk standards for the visually impaired, describe their criteria, categorize city rhythms, and determine the location hierarchy for tactile paving installations. The author incorporated sidewalk standards and criteria using seven principles of universal design (Preiser & Smith, 2010): equitable use, flexibility in use, simple and intuitive design, perceptible information, tolerance for error, low physical effort, and size and space for approach and use. The categorization of city rhythms was supported by Gehl's (2011) types of outdoor activities. According to Gehl, outdoor activities in public spaces can be divided into three categories, each placing different demands on the physical environment: necessary activities—those that are more or less compulsory, optional activities—those pursued if desired and if time and place permit, and social activities—those that depend on the presence of others in public spaces.

The Oxford Dictionary (2020) defines hierarchy as a system in which ideas or beliefs can be arranged according to their importance. The design process for the installation system was carried out by integrating space syntax (Hillier, 2007; Hillier et al., 1987; Hillier & Hanson, 1984) with the Minister of Public Works Regulation Number 3 of 2014. The author intended for the design system to address differences in existing architectural conditions within urban networks and to configure socio-spatial networks based on essential activities. Ultimately, the study developed two design systems: the strategic spatial algorithm for configuring urban networks through tactile paving installations and the built-in environmental architecture approach for inclusivity organizations. To better illustrate the application of these systems, the author simulated their use in the discussion section.

4. RESULTS

4.1. Quantitative Analysis

The data collection is presented in the tables below. There are several hierarchical columns marked by numerical structures corresponding to the number of data variables (1-5 & 1-7), with the highest value identified as the most popular response from the respondents (1.00-5.00). The sharpening of data quantification was performed on the variables with the highest value saturation (starting from a value of 2.50). An orange color code was applied to the analysis of the hierarchical data structure, where a darker shade indicates a higher value. The hierarchy formed consists of four structures, where the concentration starts from the mid-range value as the minimum consideration. Additionally, the limitation applied to the hierarchy is the author's intention to develop a tactogram using a neuroscientific approach, aligning with the working memory capacity theory, which suggests that humans can ideally process up to four types of information (Cowan, 2001, 2010; Owen, 2004).

Table 4. The Most Frequently Accessed Building Type by the Visually Impaired

	1	2	3	4	5
Residential	5.00	5.00	5.00	5.00	5.00
Religious	1.22	2.56	1.95	2.00	1.67
Business	4.78	4.33	4.47	2.57	2.67
Social	2.33	2.89	1.00	1.00	2.67
Special Functions	1.00	1.00	1.00	1.00	1.00

Table 5. The Most Frequently Accessed Building Product by the Visually Impaired

	1	2	3	4	5	6	7
Office	4.22	4.57	1.00	1.00	4.67	4.38	4.00
Trade	1.78	2.71	2.00	2.27	2.89	1.50	1.75
Industry	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hospitality	1.00	1.00	1.00	1.00	1.00	1.38	1.25
Tourism and Recreation	1.00	2.00	1.00	1.27	1.11	1.00	2.50
Terminal	4.44	3.00	1.50	3.55	4.89	2.13	4.00
Storage	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 6. Visually Impaired Preference for Tactile Paving Installation in Building Types

	1	2	3	4	5
Residential	1.07	1.10	1.40	1.20	1.00
Religious	2.30	1.00	2.40	1.00	4.67
Business	4.81	4.80	5.00	4.80	5.00
Social	2.59	2.60	4.20	4.20	2.00
Special Functions	1.04	1.00	1.00	1.00	1.00

Table 7. Visually Impaired Preference for Tactile Paving Installation in Building Products

	1	2	3	4	5	6	7
Office	2.35	3.25	2.00	2.00	2.40	2.00	2.00
Trade	3.80	2.63	2.50	2.33	2.00	4.50	4.50
Industry	1.05	1.50	2.33	1.00	1.20	1.00	2.33
Hospitality	1.00	1.25	1.17	1.00	1.40	1.00	1.33
Tourism and Recreation	1.65	2.00	1.67	1.00	1.00	1.50	1.33
Terminal	5.00	5.00	4.50	3.33	5.00	3.00	5.00
Storage	1.00	1.00	1.00	1.00	1.00	1.00	1.00

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Table 8. Preferred Sidewalk Standards by Visually Impaired

	1	2	3	4	5	6	7
Security	4.85	4.86	5.00	5.00	4.80	4.90	5.00
Comfort	4.00	3.29	3.00	4.00	4.80	4.00	3.75
Convenience	2.00	3.00	3.00	2.00	2.20	2.30	4.38
Aesthetics	1.15	1.29	4.00	5.00	1.70	1.90	2.13
Safety	4.62	5.00	4.00	5.00	5.00	4.90	4.88
Humane	1.31	1.29	2.00	1.00	1.80	2.70	1.50
Socially Interactive	1.62	3.43	5.00	2.00	4.60	2.30	2.13

The results of the quantification study indicated that the city rhythm experienced by the visually impaired is generally linked to outdoor activities that fulfill basic survival needs, such as conducting business and mobility, which are socio-biological necessities. As shown in Tables 4 and 5, mobility is a consequence of these activities, relying heavily on public transportation for daily living. The bottom-up processes of independence influence the variation in rhythm intensity. The greater the demands, the stronger the need for visually impaired individuals to adapt to routine activities and develop physical abilities on their own. Rhythm intensity is interconnected with economic issues, which can be categorized into two classifications: rhythm based on demographic status and rhythm based on public infrastructure. The first classification relates to social activities with regular patterns, while the second involves the organization of equitable public activities that include various building users.

The study also found that the preferences of the visually impaired are driven more by necessity than by desire. Tables 6 and 7 show that tactile paving installations in more complex spatial environments are essential, especially in facilitating transit activities. Respondents indicated that this level of complexity is influenced by dynamic interactions with other building users, obstacles, variations in spatial information, the use of building tempo, and the availability of guidance. Familiarity with the environment also affects their preference. Respondents noted that tactile paving in buildings they access daily, where there are no extreme threats or where space is organized in a standardized way, is perceived as less significantly useful, regardless of the building's scale, except as a learning tool.

According to Table 8, the author concluded that the standard for preferred sidewalks, particularly tactile paving installations, is adequate but not optimal. Based on data saturation, preferences are still primarily related to physical factors such as security (freedom from crime), safety (protection from hazards), and comfort (ergonomics of environmental conditions). This focus helped the author to examine the use and pattern of streets, as these are connected to the scope of city morphology (Oliveira, 2016). Feedback from respondents revealed that memory and the ability to memorize routes and obstacles are their primary means of coping with non-ideal sidewalks. This finding corroborates the author’s previous research, which identified memory as a fundamental skill for accessing spatial-temporal information among the visually impaired (Fadhlillah, 2020; Fadhlillah, 2021).

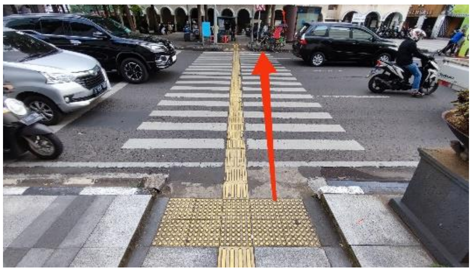
4.2. Qualitative Analysis

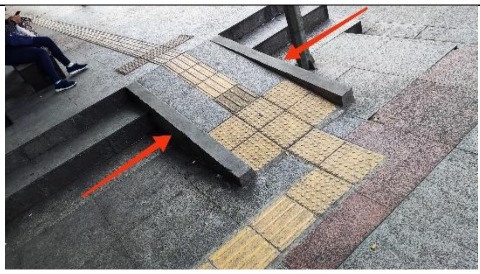
Table 9 presented the author's qualitative analysis map then it was comprehended by Table 10 in visual documentation and comparison.

Table 9. Qualitative Analysis Map

Activity	Principle		Building Type	Building Product
	Standard	Criteria		
Necessary	Security Safety Comfort	Equitable Use Low Physical Effort Size & Space for Approach & Use	Business	Terminal Trade Office Tourism and Recreation Industry Hospitality Storage
Optional	Convenience Socially Interactive	- -	Social Religious	-
Social	Humane Aesthetic	- -	Residential Special Functions	-

Table 10. Observation Results

Principle	+	-
Security		
		
		

Principle	+	-
		
Safety		
		
		
		

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Principle	+	-
		
Comfort		

Applying a hierarchical approach involves performing four activities simultaneously: comparing, sorting, limiting, and matching. The author found that the strength of this approach fosters pervasive mindset development, as the performance of multiple users requires similar operational standards. This perspective is based on the correlation between theoretical and organizational analysis. First, the development of three types of leveling systems is encouraged: axis (A) – integrable function, dominant (D) – compulsory connectivity, sub-dominant (S) – supportive connectivity, and tonic (T) – restorative function. Second, these systems define the tolerance for the number of required configurations. Third, universal design principles can serve as tools to translate the arrangement of hierarchical standards for everyone. As inclusive spatial-temporal planning and design modules are rarely discussed in Indonesia, this approach can help the community develop pragmatic problem-solving concepts for creating inclusive environments, rather than relying on semiotic methods or no method.

The findings suggest that creating both livable and productive environments for the visually impaired, through the installation of tactile paving, is a key goal of urban development. To achieve this, there must be a shift from the current paradigm of a walkable city, particularly given the limited sidewalk space in Bandung. Considering the potential consequences and risks, such as costs and land-use disputes, the author proposes that fostering new community transit habits by integrating health and economic values is a more prudent than simply constructing streets. Inclusivity is a shared responsibility and should contribute as an urban catalyst through citizen participation. Therefore, raising public awareness about inclusive technologies like tactile paving, as a purposeful facility for city development, is as important as ensuring its tangible sustainability. In line with this perspective, the author suggests that the Minister of Public Works Regulation Number 3 of 2014 requires clearer parameter descriptions and guidelines for the use of standards and building technologies. These parameters should cover equality measurements for the activities of multiple user groups when using buildings and facilities within the city.

Table 11. Author's Suggestions for Tactile Paving Installation Maintenance Strategy

Theoretical Principle	To Do	Sub-Characteristic
Maximize performance	Determine the minimum standard of product durability based on the analysis of geographical differences.	Stability
Minimize risk	Create a standard operating procedure (SOP) related to supervision during & after the installation process.	Analyzability
Minimize cost	Stimulate community development through participatory-based design.	Modularity
Minimize negative environmental impact	Integrate the issue of tactile paving development with waste management research.	Recyclability
Minimize consumption of matter/energy	Reuse tactile paving in non-ideal locations and low visually impaired intensity rhythm.	Reusability

The discussion of economic value in this study should extend to the issue of maintenance and emphasize environmental consciousness, rather than focusing solely on the initial cost. Barrier-free architecture should ideally be implemented as part of a long-term program. Therefore, comparing product prices is less beneficial if the government does not establish quality standards. The author identified several threats that hinder the successful installation of tactile paving. These include project management—lack of clear definition of roles and responsibilities; human resources—insufficient staff knowledge and experience in understanding the requirements of an inclusive environment and tactile paving installation; and document systems—unclear guideline deliverables, lacking detail, and not systemic. The author evaluated the need for an adaptable maintenance strategy that leverages regional potential to address these issues. From this perspective, the author concurs with the relevance of Chew's (2021) five green maintainability principles in the context of tactile paving installations. Table 11 offers a more comprehensive discussion of this topic.

5. DISCUSSIONS

5.1. Designing System

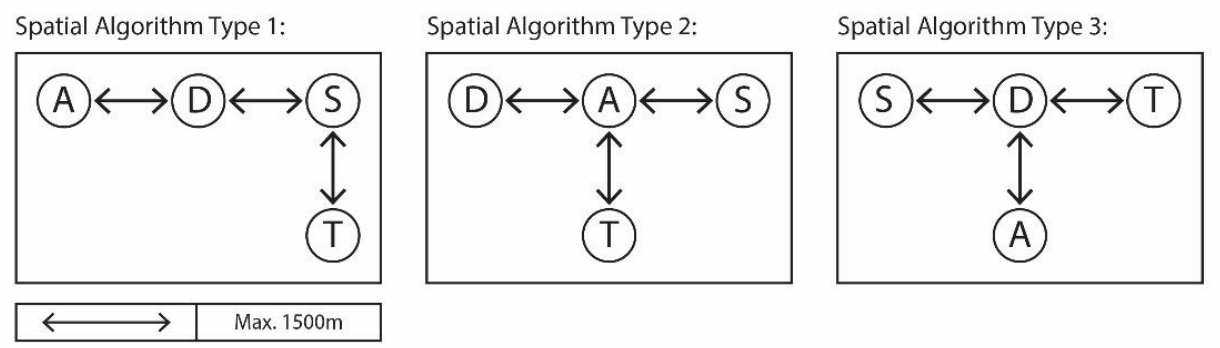

Figure 1. Designed Tactile Paving Installation System by Author

Figure 1 illustrates the designed strategic spatial algorithm as a contribution to evaluative material for planning and designing technology-based spatial inclusion in cities. The positions of spatial configurations can be adjusted, but the axis facilitates transitions between different integrations. By focusing on function and physical characteristics, a route-oriented architectural approach was developed with consideration for socio-biological necessities. This approach aims to assist the government in organizing sites by grouping all components related to travel activities, rather than using a flat structure based solely on component types. The concept of spatial configuration distance was determined by site connectivity rather than just the availability of sidewalk space. The author used an average walking duration of 10 minutes, covering approximately 1,500 meters, to establish the connectivity distance system. This approach considered observation results indicating that it is rare to find accessible sidewalks for more than 400 meters, particularly in Bandung. This consideration aligns with previous studies, which identify the availability of accessible sidewalks as a spatial inclusion issue in developing countries (Choi & Basat, 2022; Han et al., 2019; Putranto & Putri, 2018; Shaaban, 2019; Tanuwidjaja et al., 2018).

The fundamental idea in promoting the tactile paving installation system in this paper is not to create a mindset focused on connecting all types of scattered spaces within the urban networks or a comparison of retail prices with variations in product specifications, as is the case due to the common public perception regarding the function of corduroy patterns for navigation. Instead, it is about building an imaginary concept of area and community, aimed at enhancing the value of life through a tool. The author established that the formulation of the design system for tactile paving installation is the solid consistency of connectivity within each regional integration. This consistency encompasses two aspects: building types and the maximum connectivity tolerance. Each integration consists of a maximum of four spatial configurations, with each space allowing up to three connections. In addition, the development of this system needs to be supported by an understanding of the existing architectural conditions and public transportation routes to enhance the cost-effectiveness and efficiency of the installation.

The installation process is not as simple as moving materials from the store and placing them on the streets. Comprehensive thinking regarding aspects of universal design serves as the driving force to enhance the sustainability of the installed tactile paving, including waste conversion and encouraging community participation in the process. Practically, one of the principles of universal design, 'Size and Space for Approach and Use', has the potential to improve personal experiences by informing better installation practices. The Indonesian government aims to ensure spatial and social inclusion in urban networks by detailing technical instructions in the Minister of Public Works Regulation Number 3 of 2014. However, this regulation does not include technical content on installing tactile paving to create inclusive routes for the visually impaired. The appendices primarily discuss concepts such as accessibility, safety, comfort, aesthetics, and ease of interaction, as shown in Table 3.8 of the regulation, with statements like 'Street furniture is located in easily accessible areas', 'Located at safe points away from vehicle traffic', 'Offers high comfort with materials suitable to needs & does not obstruct pedestrian flow', 'Design represents the local character of the environment, thus possessing good aesthetic quality', 'Located at easily reachable points', and 'Located at social interaction points to meet urban social activity needs'. Continuously, the author discusses how the proposed installation system can complement this regulation in three focal areas: first, guidelines for identifying the most beneficial spaces for the visually impaired based on area; second, guidelines for determining the number and types of connected spaces for tactile paving application with clear measurements; and third, guidelines for maintaining the installation of tactile paving that is to be or has been implemented. Thus, this discussion confirms that the government's installation of tactile paving has not been effective, as the technical and practical guidelines are still not comprehensive for the public.

The development mechanism of the tactile paving installation system in this study is generative. More practically, there is a central model consisting of four substitutional variables to respond to spatial conditions and structure route-based spatial syntax. Compared to previous studies (Pembuain et al., 2020; Putranto & Putri, 2018), the characteristics of this generated installation system share similarities in promoting fundamental values for the visually impaired during mobility, namely safety, security, and comfort. This paper also acknowledges that these three aspects are the most crucial for visually impaired users, alongside additional benefits for the elderly. From the abundance of available digital data, two literature references are used, representing the current popular area of tactile paving studies, where evaluations tend to focus solely on justifying observed conditions and assessing user satisfaction. In reality, case studies on the issues surrounding tactile paving installation are a common phenomenon, and the current urgency lies in how this knowledge can be translated into more technical solution proposals. As a distinction, this paper declares the tactile paving installation system as a problem-solving concept, aiming to help the public better understand the inclusivity in urban networks by addressing where and what core values maximize its effectiveness for saving budget.

This study, as part of the tactogram development research initiative, has made significant contributions to the design and evaluation of accessible graphic systems for the visually impaired, particularly in the context of navigation and travel safety. The key findings underscore the importance of ensuring that the shape and style of tactograms are easily interpretable by visually impaired users, regardless of whether they are using mobility aids such as canes. Tactograms should not only serve as navigational tools for defining both outdoor and indoor routes, but they must also facilitate smooth transitions between these environments. By leveraging the concept of episodic memory, tactogram shapes can be structured as architectural graphics that are cohesively connected across horizontal planes, enhancing spatial awareness and orientation for users. Moreover, these designs must stand out distinctly from the textured backgrounds of their installation sites to ensure clarity and usability.

In particular, this analysis suggests that geometric patterns—similar to those used in tactile paving—offer a promising approach for improving tactogram readability and usability. Geometric designs are known for their clear, structured forms, making them ideal for tactile interpretation, especially in environments with varying *textures* and surfaces. Such forms can significantly enhance the effectiveness of tactograms as navigational aids, helping users discern spatial information more intuitively. Further research is required to refine these initial findings, exploring more detailed applications of geometric styles and validating their impact in real-world settings.

5.2. Simulation

The following simulation is provided to offer a more practical illustration of the tactile paving installation system, with a case study focused on the city of Bandung. For Bandung, the author specifies A = terminals and stations, D = markets, S = offices, and T = social and religious buildings. The public transportation modes include buses (Damri, Trans Metro Bandung, Trans Metro Pasundan, Teman Bus), shared taxis (Angkot), and trains. Based on data managed by the central and city governments, there are 25 axis points, comprising 18 terminals and seven train stations. The terminals are categorized into three types: terminal (Leuwipanjang, Cicaheum, Non-bus Leuwipanjang, Non-bus Cicaheum, and Kebon Kalapa), sub-terminal (Ledeng, Ciroyom, St. Hall, Dago, and Ujungberung), and base (I Tegalega, II Sederhana, III Sadang Serang, IV Elang, V Buah Batu, VI Antapani, VII Cibaduyut, and VIII Gedebage). The train stations include Bandung (BD), Ciroyom (CIR), Andir (AND), Cimindi (CMD), Cikudapateuh (CTH), Kiaracondong (KAC), and Gedebage (GDB).

Opportunities for spatial access are integrated with three types of markets: traditional markets, supermarkets, and minimarkets. Given the rapid growth of religious buildings in Bandung, the author has classified these structures under the "tonic connectivity" category, aligning them with health services. Details regarding the distribution of axes, along with their identification and settings, are presented in Table 12 and Figure 2.

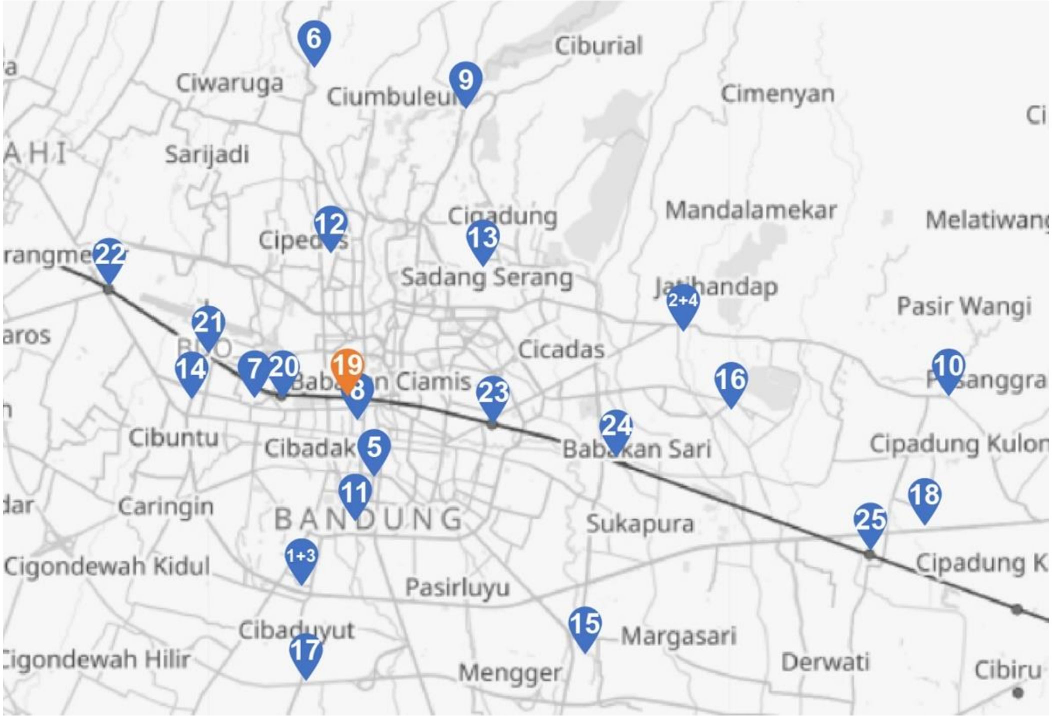

Figure 2. Tactile Paving Installation Planning Map in Bandung

Table 12. Tactile Paving Installation Project Mapping in Bandung

Number	Axis	Connectivity I	Connectivity II	Connectivity III
1	Leuwi Panjang Terminal	Leuwi Panjang Traditonal Market	Bandung Area General Hospital	-
2	Cicaheum Terminal	Cicaheum Traditional Market	Padasuka Public Health Center	-
3	Non-bus Leuwi Panjang Terminal	Leuwi Panjang Traditonal Market	Bandung Area General Hospital	-
4	Non-bus Cicaheum Terminal	Cicaheum Traditional Market	Padasuka Public Health Center	-
5	Kebon Kalapa Terminal	ITC Kebon Kalapa	Pasundan Public Health Center	-
6	Ledeng Sub-terminal	Geger Kalong Traditonal Market	Ledeng Public Health Center	-
7	Ciroyom Sub-terminal	Ciroyom Traditional Market	-	-
8	St. Hall Sub-terminal	Pasar Baru Trade Center	Kebon Jati Hospital	-
9	Dago Sub-terminal	-	-	-
10	Ujungberung Sub-terminal	Ujung Berung Traditional Market	Ujung Berung Hospital	-
11	Base I Tegallega	Tegallega Traditonal Market	Astanaanyar Public Health Center	-
12	Base II Sederhana	Sederhana Traditonal Market	Hasan Sadikin Hospital	-
13	Base III Sadang Serang	Sadang Serang Traditonal Market	Sadang Serang Public Health Center	-

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Number	Axis	Connectivity I	Connectivity II	Connectivity III
14	Base IV Elang	Superindo Rajawali Supermarket	Rajawali Hospital	-
15	Base V Buah Batu	Kordon Kujangsari Traditonal Market	Mayapada Hospital	-
16	Base VI Antapani	Antapani Traditonal Market	Griya Antapani Public Health Center	-
17	Base VII Cibaduyut	Borma Cibaduyut Supermarket	Cibaduyut Kidul or Wetan Public Health Center	
18	Base VIII Gedebage	Gedebage Traditonal Market	Cinambo Public Health Center	
19	Bandung Station	Istana Plaza	Wyata Guna Center	Hasan Sadikin Hospital
20	Ciroyom Station	Ciroyom Traditonal Market	-	-
21	Andir Station	Rajawali Hospital	-	-
22	Cimindi Station	Cimindi Traditional Market	Cibeureum Public Health Center	-
23	Cikudapateuh Station	Kosambi Traditional Market	-	-
24	Kiaracondong Station	Griya Kiaracondong Supermarket	Ibrahim Adjie Public Health Center	-
25	Gedebage Station	Minimarket	Cinambo Public Health Center	-

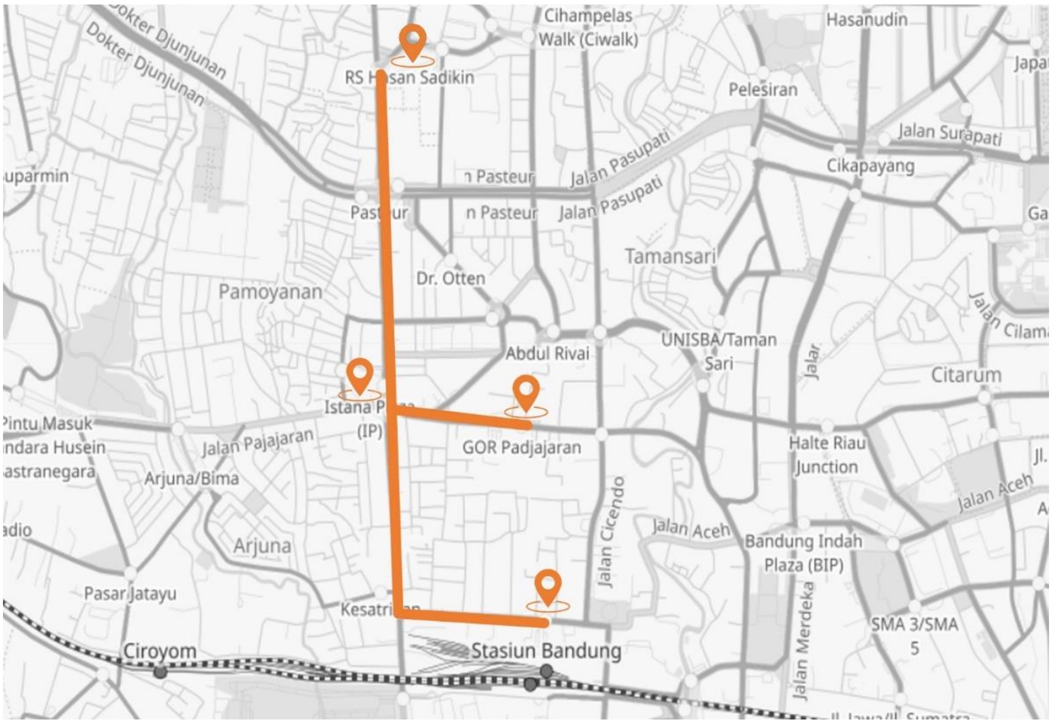

Figure 3. Bandung Station Axis – The Most Representative Tactile Paving Installation Route Map in Bandung

The mapping of axes identifies a representative route that is particularly relevant to on-the-ground needs: the axis extending from Bandung Station–A19 (marked in orange in the table and figure). This analysis highlights the strategic role of Bandung Station in supporting the mobility of the visually impaired within the city, with its connections to buildings that cater to socio-biological necessities. The optimization of pedestrian networks along this route is essential, given the station's connection to Wyata Guna Center–S19, a high-activity area in Bandung due to its historical significance and ongoing social programs closely tied to the visually impaired. Detailing the simulation, as shown in Figure 3, the axis from Bandung Station is connected to two other buildings: Istana Plaza (D19) and Hasan Sadikin Hospital (T19). Additionally, the distance tolerance within the network that remains compatible is the reason why the Bandung Station axis is considered representative.

From this representative route, supported by visual data in Table 10, it becomes evident that inconsistencies remain in the quality of tactile paving installation, particularly at the Bandung Station axis. The 24 additional axes identified serve as secondary recommendations for future tactile paving installation or maintenance efforts. Based on these findings, the author suspects that there are several contributing factors. First, a lack of informative technical guidelines regarding the required tactile paving installation system. Second, insufficient oversight by stakeholders or experts during the project’s on-site implementation. Third, those involved in the project may not possess the necessary knowledge on how to install tactile paving effectively and efficiently.

6. CONCLUSION

Funding challenges for inclusive technologies like tactile paving arise when users do not strategically consider how to overcome limitations. Enhancing spatial inclusion in developing countries by aligning with the rhythms of the visually impaired can foster and sustain partnerships, as their interaction with the environment has significant potential to stimulate tacit knowledge and perceptual systems. Moreover, it offers exposure and political value. Therefore, micro-scale urban design, such as tactile paving, must be integrated with macro-level planning data. If this strategy is adopted, the government should involve experts from project vendors, authorities, and communities, while also addressing the current shortcomings in the tactile paving installation system, which has not yet reached its full potential.

A limitation of this study is that the sample does not fully represent the demographic diversity of visually impaired individuals in Bandung. Nevertheless, this paper serves as a valuable reference for creating a more inclusive city, as most existing studies have yet to bridge theoretical concepts and practical tools for field implementation, often focusing solely on the standards of safety, security, and comfort. Additionally, this paper proposes that tactograms could be a tool for updating tactile paving, without overloading the cognitive processes of visually impaired users navigating pedestrian networks. Future research should focus on two key areas: first, transit-oriented development for cities with limited sidewalk space, and second, refining the standards and criteria for urban products that address both dominant and subdominant activities in Bandung.

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