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Urban-specific planning strategies for advancing the Suandok Medical Innovation District: a pathway to sustainable development in Chiang Mai, Thailand

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Abstract. Suandok Medical Innovation District (SMID) serves as a key hub for medical education, services, research centers, schools and medical innovation development, aiming to enhance service delivery efficiency. Especially since the COVID-19 pandemic, there has been rapidly growing interest in urban policy in SMID and the town of Chiang Mai. However, the institutional environment may not fully address the evolving needs of SMID. To investigate this potential disparity, urban-specific planning emerges as a novel approach that promotes collaborative infrastructure use, accessibility, and enhanced quality of life. Using observation research, this paper aimed to formulate a planning strategy for SMID, employing a place-based approach that uses Kernel Density Estimation (KDE) via Geographic Information System (GIS) and Analytic Hierarchy Process (AHP) to identify key planning factors. The results indicate that, within the SMID framework, medical services hold the highest importance weight (47.10%), followed by environmental development and physical access connectivity (28.84%), and knowledge provision, medical innovation and business promotion (24.06%). Consequently, these insights provide a valuable framework for strategic decision-making fostering the spatial development of innovation-district planning.

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1. Introduction

In the wake of global economic recovery following the COVID-19 pandemic, innovation has become increasingly essential for economic growth and development. It has emerged as a key consideration in policymaking and in designing cities that are environmentally friendly and socially inclusive (Pfotenhauer & Jasanoff, 2017; Fastenrath et al., 2023). In an urban design paradigm, the strategic execution of area-specific planning or specific district planning serves as a structural vehicle to actualize these goals, moving beyond rigid comprehensive zoning toward responsive, localized development frameworks (Cullingworth et al., 2014).

The development of the Suandok Medical Innovation District (SMID) is therefore a crucial factor in disseminating knowledge and innovation, as well as in fostering mechanisms for new forms of urban economy. This initiative focuses on three key innovation areas aligned with local assets: medical innovation (MEDTECH), government innovation (GOVTECH) and urban development innovation (CITYTECH). Recognizing the importance of this initiative, the National Innovation Agency (NIA) emphasized the need for strategic planning in the development of SMID to ensure effective implementation. The city planning strategies are conceptualized and developed with the aim of accomplishing a more vibrant urban life, as they are closely linked to residents' safety, livelihood and well-being (Jacobs, 1961; Braun & Malizia, 2015; Shach-Pinsly, 2019). By incorporating principles of Smart Growth (compact, walkable, mixed-use development served by public transport to improve sustainability) and Mixed-Use Zoning, specific district planning optimizes spatial proximity, thereby facilitating seamless cross-sector knowledge spillover. This facilitates seamless cross-sector knowledge spillovers and collaborative clustering, creating environments where institutions and companies are concentrated and closely connected to startups and incubators (Katz & Wagner, 2014; Pujinda & Sanit, 2022; Kalliomäki, Oinas & Salo, 2024). This will promote collaboration among relevant public- and private-sector stakeholders, aligning with the country's future direction towards a knowledge-based economy.

Chiang Mai University, through its Faculty of Medicine and its affiliated networks, started a memorandum of understanding with NIA in 2019 to collaborate on the development of Innovation Districts in Northern Thailand. The agreement established a framework for co-operation in area-based innovation development, leading to the SMID project for medical innovation planning and city development. The district serves as a center for medical services, research, experimentation and innovation development in the medical field. It is home to major educational institutions and is surrounded by faculties and organizations related to medicine and healthcare, including the Faculties of Medicine, Medical Technology, Nursing, Dentistry, and Pharmacy, and Maharaj Nakorn Chiang Mai Hospital, among others. This area is well suited to developing strategies to promote the shared use of infrastructure and is also supported by public health offices, government and private hospitals, healthcare facilities and various private clinics. Additionally, it hosts a high concentration of people, communities, startups and organizations ready to support the growth of new startup businesses that have the potential to enhance business value and improve quality of life in the district. With specialized personnel and state-of-the-art medical equipment, the district is well equipped to accommodate a wide range of patients. Therefore, SMID can be regarded as an area rich in physical assets, network assets and economic assets (see Fig. 1).

The development of strategies to promote the effective utilization of infrastructure within the SMID represents a key approach to leveraging all three categories of assets. This operational approach aligns with specific planning theories that advocate for institutional density and active infrastructure integration to maximize locational advantages (Healey, 2007). Therefore, SMID holds strong potential to cultivate an innovative ecosystem rooted in the district's unique identity in the Northern Region. It promotes creative thinking in science, technology and innovation by fostering a space that connects creative ideas and serves as a testbed and pilot zone for new technologies. The district enables the systematic utilization of infrastructure and research facilities, while simultaneously benefiting residents and commuters by cultivating a sense of place within the innovation ecosystem. Additionally, the development of support systems for accessing medical services enhances opportunities for the public to gain knowledge and innovation that ultimately contributes to an improved quality of life and community well-being especially when integrated with urban planning (Van den Berg et al., 2015).

Based on observation of the environment and development potential of SMID, it is evident that the area increasingly presents key opportunities for future growth, even amid challenges brought about by rapid physical urban transformations. The main findings indicate that SMID thrives on three interconnected pillars: (1) the district serves as a key medical hub integrated into the development agendas of Chiang Mai Province and Chiang Mai University, (2) the district benefits from strong research infrastructure, specialized human resources, and its role as an academic institution that develops professionals who then form the intellectual core of SMID, and (3) the vision and commitment of

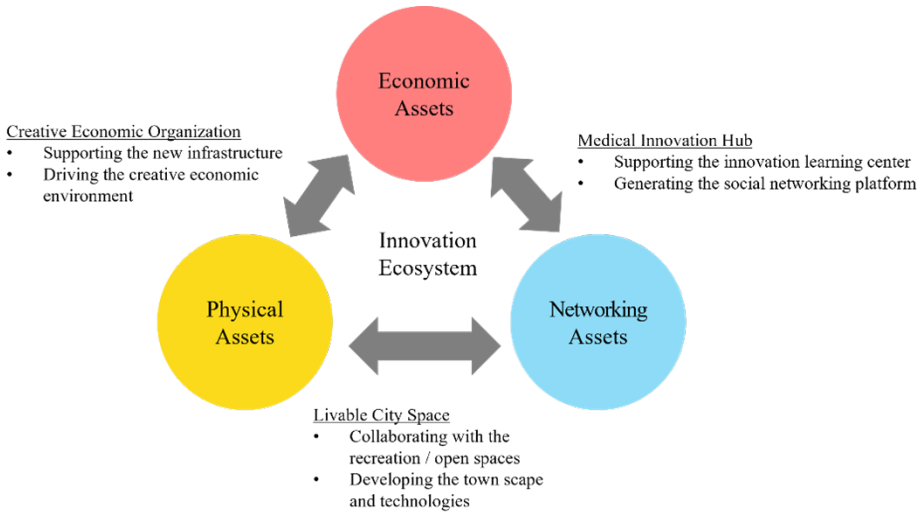


Fig. 1. Physical, network and economic assets of the Suandok Medical Innovation District
Source: Edited from Wagner, Katz & Osha, 2019

local administration organizations in supporting the development of new perspectives in medicine grounded in urban development. The core finding, together with these pillars, strengthens social networks and drives new business opportunities through the comprehensive development and revitalization of medical assets (Chiang Mai Province, 2024). This leads to sustainable urban and community development, along with more efficient income distribution within the city.

However, the literature on innovation districts has paid limited attention to an urban strategic perspective, that is, to how physical environments and spatial planning processes can facilitate interaction with surrounding communities and create social impact in line with sustainable city approaches (Yigitcanlar et al., 2020; Kalliomäki et al., 2024). Therefore, this paper proposes an area scope of 1.64 km² that lies partly within Chiang Mai University and partly in a new commercial area in Nimmanhaemin district. This area was so-defined to cover the zone in which SMID's medical, community and commercial functions interact, so that the strategies can be implemented efficiently. This strategic planning not only aims to improve physical infrastructure and enhance existing service areas in line with the three key dimensions of the innovation ecosystem (see Fig. 2), but also requires an understanding of the increasingly integrated planning and development spheres inherent in SMID. To this end, this study surveys and collects infrastructure data, analyzes spatial potential and identifies opportunities to guide the development of SMID through an urban-specific plan tailored to the district. The results are also expected to raise public recognition of SMID.

2. Methodology

2.1. Kernel Density Estimation via GIS

Kernel Density Estimation (KDE) is a spatial analysis technique used to assess the distribution and intensity of geographic phenomena. This non-parametric method estimates the probability density function of a dataset by smoothing point-based data over a defined spatial extent. When integrated with Geographic Information Systems (GIS), KDE enhances urban planning by identifying spatial hotspots and service gaps, making it a valuable tool for data-driven decision-making. This method is commonly used in statistics to obtain smooth estimates of multivariate probability densities from a sample of observations (Silverman, 1986). Formally, the general form of the kernel density function is estimated as (Borruso & Schoier, 2004):

$$\lambda(s) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{(S-Si)}{\tau}\right)$$

where $\lambda(s)$ is the estimate of the intensity of the spatial point pattern measurement at location S; Si is the observed i^{th} event; k represents the kernel weighting function;τ is the bandwidth.

The kernel density surface was generated in QGIS 3.34 using the Heatmap (Kernel Density Estimation)

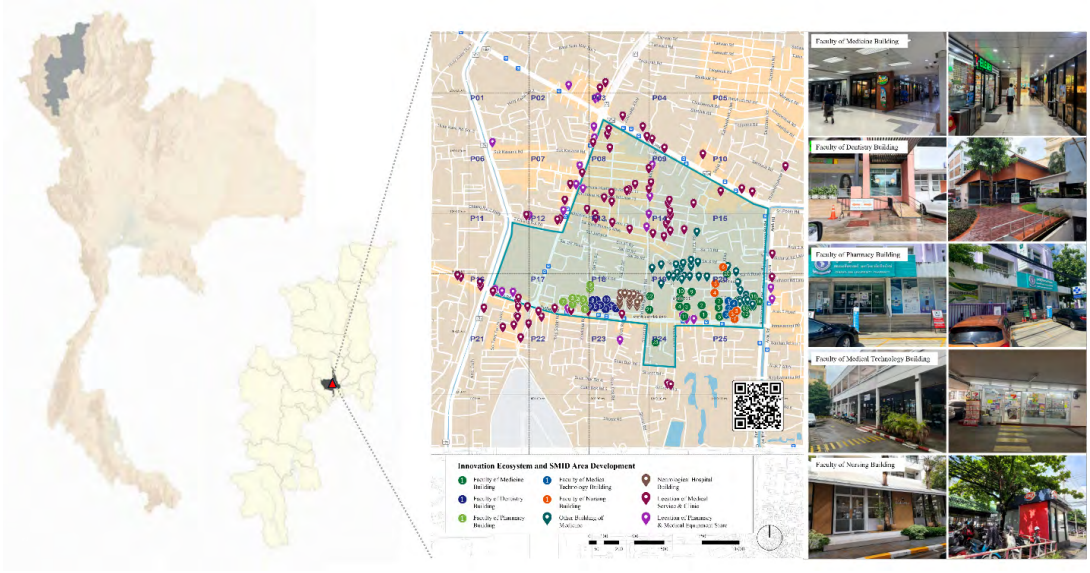


Fig. 2. Location of study area in 2024, showing the innovation ecosystem assets (faculty buildings, hospitals, medical service facilities, clinics and pharmacies) identified through our field observation in 2024. These locations were used to define the SMID planning boundary.
Source: author

tool with a quartic kernel, a search radius (bandwidth) of 300 m and an output raster cell size of 1 m × 1 m. Each junction point contributes a density value to the surrounding raster cells that decreases with distance from the point, so the resulting surface reflects the accumulation of road junctions in a way consistent with spatial modelling frameworks for traffic congestion relative to reference nodes (Andika et al., 2022).

In this study, KDE complements the Analytic Hierarchy Process (AHP) by spatially evaluating road junction density within the Suandok Medical Innovation District (SMID). Rather than assessing healthcare facility locations or landscape quality, this spatial analysis targets road intersections as critical proxies for urban connectivity and mobility demand. These junctions signify movement potential, traffic concentration and spatial accessibility within a high-density medical ecosystem. Integrating KDE with intersection density effectively delineates active urban hubs and informs spatial zoning strategies (Yang et al., 2019). The resulting continuous raster surface identifies urban hotspots and infrastructural pressure zones, guiding decisions on road networks, access nodes and future zoning. The methodology comprises three sequential phases:

Phase 1. Data Collection and Preprocessing: Geospatial datasets were compiled, focusing on recorded junction points throughout the study area. Junction point locations were extracted from OpenStreetMap (OSM) and Google Maps road network data and then processed in QGIS to generate junction points. Junctions located within internal, non-public road networks (e.g., inside hospital compounds, government facilities and temple grounds) were manually identified and removed, since these do not represent publicly accessible urban connectivity relevant to district-level mobility analysis. The remaining junction points were verified through satellite imagery cross-referencing and field observation to confirm accuracy.

Phase 2. Kernel Density Calculation: this analysis was conducted using a 300-meter search radius (bandwidth), producing a smoothed density surface that visualizes high- and low-concentration zones into five intensity levels, ranging from low to high density.

Phase 3. Spatial Interpretation and Strategic Integration: KDE results were interpreted in conjunction with the AHP-derived planning priorities to guide targeted improvements in infrastructure and access. In particular, the clusters are used to identify key nodes for development, walkability enhancement and transit integration within SMID.

This integration of spatial analytics and multi-criterion decision-making bridges quantitative spatial data with participatory qualitative goals, reinforcing evidence-based planning for sustainable innovation districts. Although KDE visualizes spatial concentrations, it does not confirm the statistical significance of these patterns against a random distribution. To address this limitation, a Nearest Neighbor Analysis (NNA), also known as an Average Nearest Neighbor (ANN) test, was conducted based on Clark and Evans (1954). This method evaluates spatial randomness by comparing the observed average distance between nearest-neighbor points against the expected average distance under

a Complete Spatial Randomness (CSR) hypothesis. The resulting Nearest Neighbor Index (R) indicates clustering (R<1), randomness (R=1) or dispersion (R>1). The statistical significance of this deviation is validated via z-scores and corresponding p-values. The NNA was executed in QGIS using the 279 junction points, projected to the World Geodetic System 1984 / Universal Transverse Mercator Zone 47N (WGS 84 / UTM Zone 47N) (EPSG:32647) to ensure metric distance calculation accuracy.

2.2. Analytic hierarchy process

To address complex problems involving multiple criteria, Analytic Hierarchy Process (AHP) decomposes the problem into a hierarchical structure composed of a goal, criteria, sub-criteria and alternatives, allowing both qualitative and quantitative factors to be incorporated systematically (Saaty, 1990; Saaty, 1994; Vargas, 1990).

In this study, AHP is employed to evaluate and prioritize planning strategies for the future development of SMID. The methodology involves three key stages:

1. Problem Structuring: the first step involves defining the decision-making goal and organizing relevant planning criteria and alternatives into a hierarchical framework.
2. Pairwise Comparison and Weight Derivation: each criterion is compared with each other criterion in pairs to assess its relative importance, using Saaty's fundamental scale of importance. This scale ranges from 1 (equal importance) to 9 (extremely more important), with intermediate values for compromise judgments.

Based on the pairwise comparison matrix, priority weights are calculated. The principal eigenvalue of the matrix is then used to assess the consistency of the judgments.

$$\lambda_{max} = \frac{1}{n} + \sum_{i=1}^{n} \frac{(A \cdot W)_i}{W_i}$$

where λ_{max} is the principal eigenvalue of matrix; is the pairwise comparison matrix; W is the priority vector; n is the number of criteria.

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \quad , \quad CR = \frac{CI}{RI}$$

where CI is the Consistency Index; n is the matrix size; RI is the Random Index, based on matrix size. A Consistency Ratio (CR) value ≤ 0.10 indicates acceptable consistency.

3. Consistency Verification and Synthesis: after confirming the consistency of the comparisons, the priority weights from each matrix are aggregated to rank the most important strategies. This step ensures that the decision-making process is both transparent and rational. This study applies AHP to evaluate stakeholder preferences and formulate planning strategies tailored to the place-based area of SMID. By integrating expert judgment with

Table 1. The AHP Fundamental Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Both elements are equally important.
3	Moderate importance	Experience slightly favors one element over the other.
5	Strong importance	Experience strongly favors one element.
7	Very strongly importance	One element is strongly favored, and its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one element is of the highest possible validity.
2, 4, 6, 8	Intermediate values	For cases where a compromise is needed between two judgments.

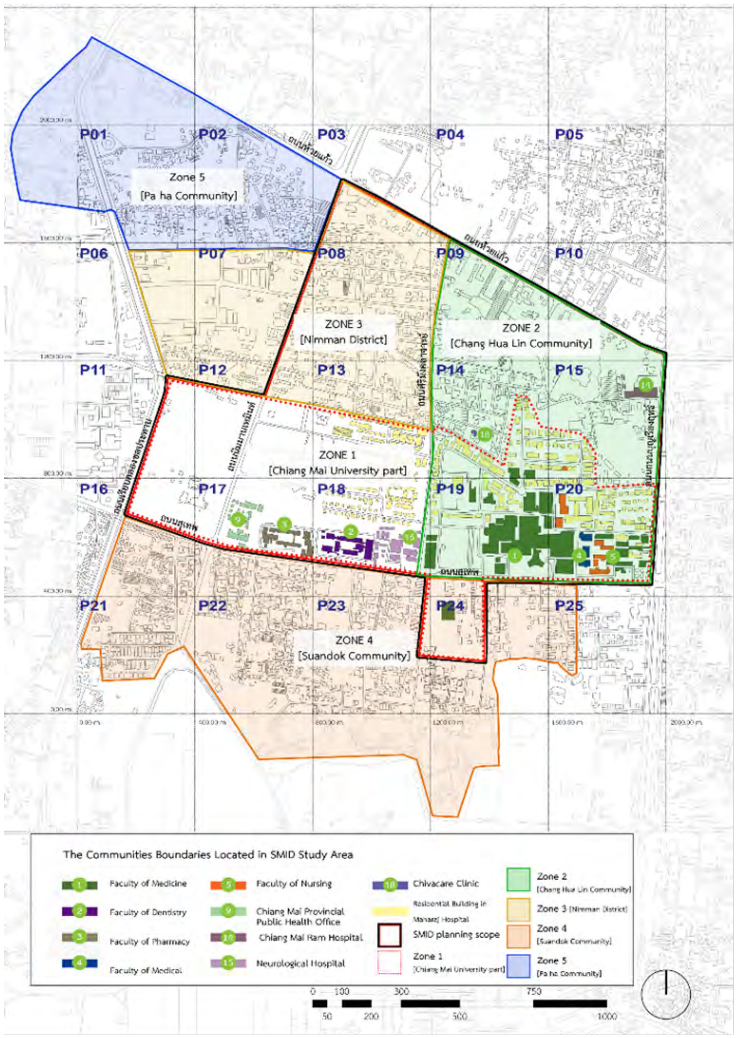
Source: Saaty (1994)

Table 2. Random Index (RI)

n (Matrix size)	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: Saaty (1994)

computational analysis, AHP enhances decision-making transparency and aligns local development with sustainable urban objectives. The multi-criterion framework evaluates indicators across three dimensions: (1) Medical Services (S), (2) Medical Knowledge, Innovation and Business Promotion (K), and (3) Environmental Development and Accessibility (E). The indicators were selected on the basis of a literature review and open-ended questions answered by 400 residents and service users in Zones 1–5 (Yang et al., 2016). Geographically situated in the western sector of Chiang Mai Municipality, the SMID planning framework intersects five functional zones (see Fig. 3). This spatial network encompasses the core institutional hub (Zone 1) and four adjacent districts comprising three local communities and one commercial district zone: Chang Hua Lin Community (Zone 2), Nimman District (Zone 3), Suandok Community (Zone 4) and Pa Ha Community (Zone 5). Demographic data from Chiang Mai Municipality (2024) and Chiang Mai University (2024) indicate a resident population of ~5,900 across Zones 2–5. When integrated with the medical personnel and students operating within Zone 1, the total active stakeholder population exceeds 20,000. To achieve statistical representation within this ecosystem, a sample size of n=400 participants was selected for the AHP evaluation.



Zone	Community Name	Area (sq.km.)	Population (persons)
1	Zone 1 Chiang Mai University part	0.90	13,800
2	Zone 2 Jang Hua Lin Community	0.74	1,333
3	Zone 3 Nimmanhaemin District	0.57	650
4	Zone 4 Suandok Community	0.74	2,901
5	Zone 5 Pa Ha Community	0.50	1,658

Fig. 3. The boundaries and populations of the communities in the SMID study area
Source: Chiang Mai Municipality (2024); Chiang Mai University (2024)

3. Results

3.1. Spatial concentration patterns and urban gaps

The KDE was conducted using a 300-meter search radius to evaluate the spatial concentration of 279 road junction points across SMID area, and its results were projected to WGS 84 / UTM Zone 47N (EPSG:32647) for accurate distance-based computation. The resulting surface identifies areas of high and low point density, visualized in five gradient classes ranging from low (yellow) to high (red) density zones (see Fig. 4). Density values across the surface ranged from near zero to a maximum of 191.0 junctions/km², with a mean of 57.4 junctions/km² and a standard deviation of 43.8 junctions/km², indicating a spatially uneven distribution consistent with the presence of distinct high- and low-density zones rather than a uniform pattern. These point densities reflect potential connectivity intensity and urban accessibility patterns throughout the district.

To determine whether this spatial pattern reflects statistically meaningful clustering, NNA was conducted on the same 279 junction points. The analysis produced an Observed Mean Distance of 41.57 m against an Expected Mean Distance of 60.25 m under a null hypothesis of spatial randomness, yielding a Nearest Neighbor Index of 0.69 ($z=-9.91$, $p<0.0001$). The results statistically confirm a highly clustered distribution of road junctions within SMID. This clustered morphology reflects an infrastructure development pattern driven by historical land-use intensity and intentional urban design rather than stochastic placement.

This finding confirms the presence of spatial disparities and identifies critical areas of mobility and accessibility within SMID (see Fig. 4). The KDE output helps delineate strategic access nodes such as intersections near hospitals, university zones and key arterial routes, highlighting opportunities for improved infrastructure, pedestrian pathways and multimodal connectivity. Furthermore, the analysis supports the argument that current urban-specific plans may not adequately address the spatial dynamics of SMID. The KDE approach reveals previously underexplored gaps in infrastructure

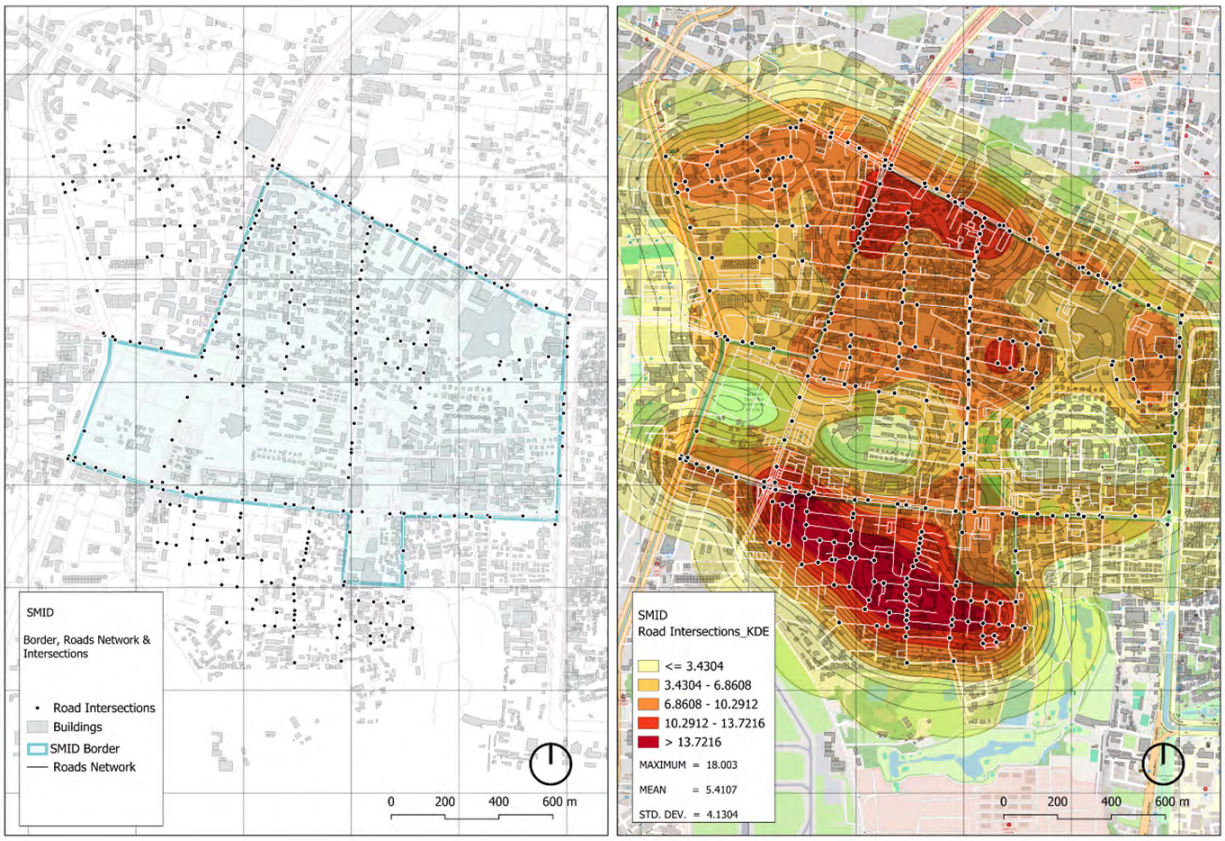


Fig. 4. Road junction points and KDE output (300 m bandwidth) for the SMID study area
Source: author

connectivity and potential congestion points, providing a data-driven basis for refining development strategies.

While KDE alone cannot specify design interventions, it proves valuable when combined with the NNA and AHP prioritization. Together, these methods offer a more comprehensive understanding of spatial conditions and support targeted planning actions for enhancing accessibility and service equity in the district.

3.2. Indicators for SMID development

Following the KDE analysis, a questionnaire on public perceptions of the SMID area and of access to medical services was administered to 400 participants across three communities and one district (Zones 1–5). On this basis, a set of indicators was developed to guide the development and promotion of an innovative ecosystem within SMID and its surrounding communities. Based on a review of existing research on indicator-based evaluation systems, 12 indicators were defined in the following three dimension groups.

1. Medical Services (S): this group emphasizes the development of healthcare services that respond to the needs of the community, particularly areas identified as challenges or concerns during the service experience at medical facilities within the SMID network. It includes four indicators: (S1) Easy access to medical services for all, (S2) Short waiting time for medical services, (S3) Community health check-up services, (S4) Comfortable waiting areas with essential amenities.
2. Medical Knowledge, Innovation and Business Promotion (K): this group focuses on strengthening the relationship between SMID and surrounding communities through public health education, the provision of medical knowledge and innovations and the promotion of a supportive business environment for medical innovation. This is achieved through outreach activities and the incubation of medical innovation businesses. It includes three indicators: (K1) Health education for the community, (K2) Training programs for medical innovation entrepreneurs, (K3) Community-based health co-ordination center.
3. Environmental Development and Accessibility (E): this group highlights the importance of enhancing public spaces, mobility infrastructure and connectivity within the district. The goal is to ensure convenient and efficient travel both for external service users and for staff within the SMID network. These physical and infrastructural developments aim to reinforce the district's identity as a medical innovation hub. It includes five indicators: (E1) Well-maintained and aesthetically pleasing landscape, (E2) Efficient traffic management system, (E3) Comprehensive pedestrian and cycling network, (E4) Accessible public transportation system, (E5) Sufficient parking facilities for users.

For the evaluation process of the development and promotion indicators of the innovation ecosystem within SMID and its surrounding communities, a questionnaire was administered to community representatives. The questionnaire focused on perceptions regarding these indicators, with the aim of conducting a prioritization analysis using the Analytic Hierarchy Process (AHP). This analysis supports the formulation of strategic approaches for enhancing medical services and treatments related to medical innovation, ultimately benefiting the local communities. The evaluation was carried out by 45 representatives from three surrounding communities: Suandok Community, Pa Ha Community and Chang Hua Lin Community. These representatives assessed the relative importance of the development and promotion indicators for the innovation ecosystem within SMID and its surrounding communities.

The participants carried out a pairwise comparison of the three dimensions as part of AHP (Table 3). The matrix was then normalized so that each column sums to 1 (Table 4). The consistency ratio (CR) should be less than 0.1. Subsequently, the average of each row was calculated to determine the weight of each dimension.

4. Discussion

4.1. Weighting of Medical Services (S)

The weights of indicators within each main factor were calculated using the same normalization and weighting procedure described above for the main factors. This process began with the four indicators under the Medical Services category. Table 5 presents the pairwise comparison matrix, and Table 6 presents the resulting normalized weights.

The community representatives evaluated the relative importance of the four sub-indicators under the Medical Services category. Ranked from highest to lowest, “Short waiting time for medical services” (S2) was considered the most important, with a weight of 30.30%, followed by “Easy access to medical services for all” (S1) at 28.53%, “Community health check-up services” (S3) at 23.18%, and “Comfortable waiting areas with essential amenities” (S4) at 17.99%. The Consistency Ratio (CR) for this evaluation was 0.049, within an acceptable range.

Table 3. The pairwise comparison matrix of three dimensions

	Medical Services (S)	Medical Knowledge, Innovation and Business Promotion (K)	Environmental Development and Accessibility (E)
Medical Services (S)	1.00	2.81	1.19
Medical Knowledge, Innovation and Business Promotion (K)	0.36	1.00	1.16
Environmental Development and Accessibility (E)	0.84	0.86	1.00

Source: author

Table 4. The normalized matrix and weights of three dimensions

	Main Factor			Weights
	Medical Services (S)	Medical Knowledge, Innovation and Business Promotion (K)	Environmental Development and Accessibility (E)	
Medical Services (S)	0.46	0.60	0.36	47.10%
Medical Knowledge, Innovation and Business Promotion (K)	0.16	0.21	0.35	24.06%
Environmental Development and Accessibility (E)	0.38	0.18	0.30	28.84%
Total	1.00	1.00	1.00	100%
Consistency Ratio (CR) = 0.097				

Source: author

4.2. Weighting of Medical Knowledge, Innovation and Business Promotion (K)

The same procedure was applied to three indicators under the categories of Medical Knowledge, Innovation and Business Promotion. Table 7 presents the pairwise comparison matrix, and Table 8 presents the resulting normalized weights.

The community representatives assessed the relative importance of these three sub-indicators. Ranked from highest to lowest, "Health education for the community" (K1) received the highest weight at 40.97%, followed by "Community-based health coordination center" (K3) at 39.12%, and "Training programs for medical innovation entrepreneurs" (K2) at 19.91%. The Consistency Ratio (CR) for this evaluation was 0.034, i.e. within an acceptable range.

4.3. Weighting of Environmental Development and Accessibility (E)

The same procedure was applied to five indicators under the category of Environmental Development and Accessibility. Table 9 presents the pairwise comparison

Table 5. The pairwise comparison matrix of medical services factors (S)

	S1	S2	S3	S4
S1	1.00	1.45	1.02	1.24
S2	0.69	1.00	2.02	1.64
S3	0.98	0.49	1.00	1.60
S4	0.81	0.61	0.63	1.00

Source: author

Table 6. The normalized matrix and weights of medical services factors (S)

	Medical Services (S)				Weights
	S1	S2	S3	S4	
S1	0.29	0.41	0.22	0.23	28.53%
S2	0.20	0.28	0.43	0.30	30.30%
S3	0.28	0.14	0.21	0.29	23.18%
S4	0.23	0.17	0.13	0.18	17.99%

Source: author

Table 7. The pairwise comparison matrix of medical knowledge, innovation and business promotion factors (K)

	K1	K2	K3
K1	1.00	2.53	0.86
K2	0.40	1.00	0.62
K3	1.16	1.62	1.00

Source: author

matrix, and Table 10 presents the resulting normalized weights.

The community representatives assessed the relative importance of these five sub-indicators. Ranked from highest to lowest, "Accessible public transportation system" (E4) was considered the most important, with a weight of 26.60%, followed by "Sufficient parking facilities for users" (E5) at 24.03%, "Efficient traffic management system" (E2) at 22.14%, "Comprehensive pedestrian and cycling network" (E3) at 15.07%, and "Well-maintained and aesthetically pleasing landscape" (E1) at 12.16%. The Consistency Ratio (CR) for this evaluation was 0.010, i.e., within an acceptable range.

4.4. Weighting of indicators for the development and promotion of innovation ecosystem via SMID and surrounding communities

The final step involved adjusting the weights of all 12 indicators in proportion to the weight of their main factor: Medical Services (S) 47.10%, Medical Knowledge, Innovation and Business Promotion (K) 24.06%, and Environmental Development and Accessibility (E) 28.84% (Table 11). The five highest-ranked indicators overall were: S2 Short waiting time for medical services, S1 Easy access to medical services for all, S3 Community health check-up services, K1 Health education for the community, and K3 Community-based health coordination center. Implementing these priorities will require the communication and collaboration challenges involved in multi-stakeholder implementation (Xie et al., 2021) to be addressed within the SMID strategic plan.

5. Conclusion

In summary, the urban-specific planning strategies provided a strategic framework to guide the enhancement of medical services and healthcare innovation within SMID, using data collected through surveys of infrastructure, medical service centers and community needs both within and around the district.

Table 8. The normalized matrix and weights of medical knowledge, innovation and business promotion factors (K)

	Medical Knowledge, Innovation and Business Promotion (K)			Weights
	K1	K2	K3	
K1	0.39	0.49	0.35	40.97%
K2	0.15	0.19	0.25	19.91%
K3	0.45	0.32	0.40	39.12%
Total	1.00	1.00	1.00	100%
Consistency Ratio (CR) = 0.034				

Source: author

Table 9. The pairwise comparison matrix of environmental development and accessibility factors (E)

	E1	E2	E3	E4	E5
E1	1.00	0.47	0.98	0.44	0.51
E2	2.13	1.00	1.26	0.99	0.76
E3	1.02	0.79	1.00	0.62	0.60
E4	2.26	1.01	1.62	1.00	1.40
E5	1.97	1.32	1.66	0.72	1.00

Source: author

Table 10. The normalized matrix and weights of environmental development and accessibility factors (E)

	Environmental Development and Accessibility (E)					Weights
	E1	E2	E3	E4	E5	
E1	0.12	0.10	0.15	0.12	0.12	12.16%
E2	0.25	0.22	0.19	0.26	0.18	22.14%
E3	0.12	0.17	0.15	0.16	0.14	15.07%
E4	0.27	0.22	0.25	0.27	0.33	26.60%
E5	0.24	0.29	0.26	0.19	0.23	24.03%

Source: author

In this way, the strategies aim to optimize the use of existing physical assets and infrastructure. The AHP results indicate that the innovation ecosystem can be strengthened by ensuring that urban development aligns with community aspirations and the district's strategic potential. This is consistent with emerging research on innovation districts, which emphasizes the new union between strategic spatial planning and innovation (Duan et al., 2024; Kalliomäki et al., 2024), and with studies highlighting the role of area characteristics, especially environmental psychology and place-based social networks, in shaping medical land use within urban development (Leyden et al., 2014; Davis & Wagner, 2025).

Table 11. AHP analysis of SMID development indicator weights

Main Factors		Indicators	Weights (a)	Global Weights (b)	Rank
Medical Services (S)	47.10%	S1 Easy access to medical services for all	28.53%	13.44%	2
		S2 Short waiting time for medical services	30.30%	14.27%	1
		S3 Community health check-up services	23.18%	10.92%	5
		S4 Comfortable waiting areas with essential amenities	17.99%	8.47%	6
Medical Knowledge, Innovation and Business Promotion (K)	28.84%	K1 Health education for the community	40.97%	11.81%	3
		K2 Training programs for medical innovation entrepreneurs	19.91%	5.74%	9
		K3 Community-based health coordination center	39.12%	11.28%	4
Environmental Development and Accessibility (E)	24.06%	E1 Well-maintained and aesthetically pleasing landscape	12.16%	2.93%	12
		E2 Efficient traffic management system	22.14%	5.33%	10
		E3 Comprehensive pedestrian and cycling network	15.07%	3.63%	11
		E4 Accessible public transportation system	26.60%	6.40%	7
		E5 Sufficient parking facilities for users	24.03%	5.78%	8

(a): Weights derived from a calculation of a single main factor group
(b): Global weights obtained by multiplying the weight of the indicator by the weight of main factor
Source: author



Fig. 5. Proposed physical design linking the SMID Core Zone to its urban context to improve accessibility, urban mobility and green-space use
Source: author

Hence, this approach supports inclusive innovation and helps transform the environment into an innovative ecosystem that not only benefits local stakeholders but also positions the district as a key contributor to future urban and regional economic zones. The proposed SMID strategy model extends the Core Zone and connects it to the Future Development Zone (see Fig. 5). It aims to strengthen place-based approaches in the K dimension, combining the characteristics of innovation and urban development for the surrounding community and the wider city. Within this model, the physical design focuses on the spatially actionable indicators: S1 (easy access to medical services for all, ranked 2nd) and the E indicators, E4 (accessible public transportation), E5 (parking), E2 (traffic management), E3 (pedestrian and cycling network) and E1 (landscape) (see Fig. 5). The highest-ranked service indicators (S2, S3, K1 and K3) relate to service delivery and community programs and lie beyond the scope of the physical design strategy proposed here. The study results were used to develop place-based development guidelines, supporting more effective planning strategies through physical structure design:

1. Accessibility Strategy: this plan centers on Node 1 (Green Point; Fig. 5), at the intersection of Suthep Road and Sirimangkalajarn Road, as a strategic development node for the K dimension. This location connects key institutions including the Center of Medical Excellence, Sriphat Outpatient Center, Suandok Park Parking in Faculty of Medicine, Neurological Hospital, Faculty of Dentistry and Suandok Community. While public transport networks are currently limited, integrated development strategies for the Core Zone suggest that the intersection should be developed further, building on its existing parking infrastructure (E5). However, challenges remain in sidewalk coverage, safety and landscape maintenance. If the area is developed according to the environmental indicators, it will enhance mobility, reduce traffic congestion and improve user experience across the district. Secondly,

Node 2 (Green Point; Fig. 5) is the underused connection between Sirimangkalajarn Alley 7 and Boonruangrit Alley 2, which focuses on reconnecting with local communities, improving environmental conditions and enhancing the accessibility of medical services.

2. Core Zone Linkage Strategy: this plan uses three axial lines: (i) the Red Line, which connects the main area of SMID, which is not high-density; (ii) the Pink Line, which reduces the high-density area in the southern part; and (iii) the Blue Line, a future link to areas outside SMID, in order to achieve a suitable land-use configuration and improve the efficiency of Medical Services (S).

These strategies proposed for expansion would be integrated with the new Faculty of Medicine project, establishing a new corridor that links the community, Chiang Mai University, Chiang Mai Ram Hospital, and the Huay Kaew Road and canal area, a zone of mixed residential and commercial use. This would provide alternative circulation paths and improve connectivity between medical and commercial areas bordered by Huay Kaew Road (north), Suthep Road (south), Boonruangrit Road (east) and Sirimangkalajarn Road (west). Although respondents gave relatively low priority to landscape quality (E1) and the pedestrian and cycling network (E3), ranked 12th and 11th in Table 11, these elements are central to the proposed corridor, and realizing its potential requires physical integration and collaboration between communities and district institutions. A coordinated effort involving public agencies, academia, the private sector and local communities is essential, with a focus on inclusive pedestrian and cycling infrastructure and safe, well-structured circulation systems for healthy city planning. Future studies could explore how such coordination can be achieved.

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