Journal of Engineering Science and Technology
Special Issue on STAAUH, November (2022) 13 - 23

TOWARDS SMART DEVELOPMENT: STUDY AND APPLICATION OF DIJKSTRA ALGORITHM IN PUBLIC SERVICE FACILITY LOCATION OF CHINESE TRADITIONAL VILLAGE

ZENG LIQUN[1,2]*,
TAMILSALVI MARI[1,3], SUJATAVANI GUNASAGARAN[1,3]

[1]School of Architecture, Building and Design, Taylor's University, Taylor's Lakeside Campus, No. 1 Jalan Taylor's, 47500, Subang Jaya, Selangor DE, Malaysia
[2]School of Civil and Architecture Engineering, Liuzhou Institute of Technology, 545616, No.99 of Xinliu Avenue, Yufeng District, Liuzhou, Guangxi, China
[3] Liveable Urban Communities Impact Lab, Taylor's University, Taylor's Lakeside
*Corresponding Author: zengliqun2009@126.com

Abstract

Chinese traditional villages have a long history with rich material and intangible cultural heritage, which are essential objects protected by government departments. Chinese traditional villages are usually located in remote areas, and the public service facilities are relatively backward. With the rapid development of society and economy, the Chinese government has made great efforts to narrow the imbalance and gap between urban and rural development by implementing the Rural Revitalization strategy to coordinate urban and rural development. To protect and revitalise traditional villages, the governments have continuously invested funds to improve and upgrade traditional villages' public service facilities, improving the villagers' convenience and satisfaction. However, when selecting the location for public service facilities, the lack of scientific evidence often leads to unreasonable location selection. It caused the problems of low utilisation rate and waste and could not achieve the expected outcome. Therefore, a scientific method to establish location selection is in urgent need. Using the graph theory, the Dijkstra method was adopted to conceptualise the location issues of public service facilities in traditional villages into a network graph. Using weighted modification to assess villagers' travel intention, it was revealed that the optimal location was the location determined by Dijkstra shortest distance labelling method, which was also the most intended travel destination. The ideal location had the largest number of users and the highest utilisation rate. An empirical study was employed to prove the rationality and feasibility of the modified Dijkstra algorithm by taking the Shengtang village of Weizhou Island in the Beihai City of China as an example. The modified Dijkstra algorithm will provide technical references for the scientific location identifier of public service facilities and the smart development of traditional villages and cities.

Keywords: Chinese traditional village, Dijkstra algorithm, Location of public service facility, Smart development.

1. Introduction

1.1. Traditional village and rural revitalisation in China

Chinese traditional villages hold rich historical information and cultural landscape, the most prominent legacy of the Chinese farming civilisation. Traditional villages preserve a significant original historical evolution of the architectural environment, style and features and unique folk customs that have not changed significantly; the villages remain serving people's needs [1]. Traditional village buildings are distinct from ancient buildings despite their long history. Ancient buildings pertain to the past, whilst traditional village buildings pertain to the present. All the buildings are occupied, constantly repaired and updated. Traditional villages are "cultural protection units" and the most basic units of production, life, social composition, and rural communities. With urbanisation, urban expansion, industrial development, and the new and enhanced lifestyle of urban centres, increasing numbers of farmers, particularly the younger generation, are drawn to work in cities, and many residents, particularly the labour force moved to cities. Most villagers working in cities for an extended period have even settled there. These factors contributed to the emptiness of villages. Since most traditional villages are situated in areas with inconvenient transportation and a lagging economy compared to other villages, traditional villages suffer a more severe hollowing crisis. Should traditional villages reach a particular level of hollowness, they will cease to be traditional [1, 2].

Chinese traditional villages have a long history with rich tangible and intangible cultural heritage protected by the government. The traditional village, unlike other heritages, is a living heritage. Villagers are the guardians and custodians of this living heritage. As a result, if traditional villages become hollow, their tangible and intangible cultural heritage will be threatened, and village protection and inheritance will be challenging. Most traditional villages in China are located in remote areas, lacking public service facilities and modern service facilities [3]. In 2017, China introduced the rural revitalisation strategy [4], which aims to improve the quality of life for rural populations. Enhancing public service facilities is one of the prerequisites for a liveable existence. Therefore, public service facilities have become one of the primary components of rural development and revitalisation planning and building. The location selection of public service facilities in a village is crucial. A smart site selection can attract more villagers to utilise the facilities, increasing the number of villagers it serves, and enhancing the utilisation ratio, resulting in greater user satisfaction.

With the growth of the social economy and the enhancement of people's living standards, the need for public spaces among villagers has increased. In rural revitalisation and development in China, cultural activity centres and other public service facilities are planned and constructed in the villages to improve villagers' quality of life and happiness. These public facilities serve the local villagers as the main service objects. Cultural activity centres include complete public cultural facilities incorporating cultural promotion, party member education, scientific popularisation, legal education, physical fitness, and other services. The cultural activity centre is a facility for the provision of public services. Building the cultural activity centre aims to support the villagers effectively, enrich their lives, and enhance their satisfaction [5]. Therefore, the site selection for the cultural activity centre in the village is crucial. A good site selection can attract more villagers to use it, maximise the number of villagers it serves, improve the utilisation rate, enhance the villagers' sense of gain and happiness, retain more villagers, avoid excessive hollowness, and better protect traditional villages and inherit traditional culture.

1.2. Shengtang village and its public facilities

Shengtang Village, located on China's Weizhou Island, was established over 150 years ago. It was designated a Chinese national traditional village in 2019 and became a government-protected Chinese traditional village [6]. Before construction, there was neither a public space nor reserved land. There are approximately 380 households and more than 1400 people in Shengtang Village [7]; there is a market, primary school, church square, health room, village committee, and other essential public service facilities. However, no cultural activity centre exists as villagers increasingly emphasise the accessibility of public service facilities, such as educational, medical, and entertainment facilities [8]. According to a field survey of 252 households, 85% want public facilities, and 70% believe cultural activity centres are urgently needed.

The Cultural Activities Center was planned to be built in 2021 as part of rural revitalisation and development planning. Travel was restricted, especially during the outbreak. The suitable location of public service facilities will provide local residents with leisure and other activities during an epidemic. Abass et al. [9] suggested good public service facility locations in Australian suburbs improved residents' satisfaction. As Chinese traditional villages are often in remote areas, the placement of public service facilities should be more scientific and reasonable. This is because the distribution of public service facilities in remote areas differs from that in cities, where they are more scattered. Villages have public facilities which only serve the residents who live there. It is difficult for villagers to share facilities outside the village, except for the public facilities [10]. As such, a good location selection for public facilities can offer traditional village residents a sense of belonging and make them happier and want to stay in the village.

1.3. Dijkstra algorithm and its application in the optimal location

The Dijkstra algorithm is one of the best and most well-known techniques for locating the shortest path in a network with positive weights. This algorithm, developed by Dutch scientist Edsger Dijkstra and published in 1959, was initially used to find the shortest path from a starting point to a destination in a graph network [11]. Dijkstra algorithm, a typical shortest path algorithm, searches for the shortest path from the source point to the other points in a weighted network graph [12]. It determines the ideal location for facilities and services such as urban fire stations, emergencies, and schools [13-15]. The Dijkstra algorithm is often employed to resolve the shortest path problem in not-so-large-scale maps such as town or regional scale [16]. The traditional village is one of China's most fundamental administrative entities, and site selection for the cultural activity centre falls within Dijkstra's sphere of expertise. A reasonable site becomes increasingly critical and essential to increase the number of people serviced by public service facilities in traditional villages and to improve villagers' perceptions of gain and satisfaction. The location of public service facilities in traditional villages influences the extent of villagers' willingness to go and the utilisation rate of facilities. Therefore, Dijkstra's shortest path labelling method can determine the ideal location of public service facilities in traditional villages, making them an attraction that locals are interested in and eager to visit. Public service facilities can play a more beneficial function and become a requirement in villagers' daily lives.

People use maps to search for a route from a starting point to a destination point, and the result typically recommends the "shortest way" [16] due to the development of technology and the proliferation of the internet. The Dijkstra algorithm can be included in urban planning and design software as a set of tools to assist planners and designers in locating a scientific and ideal location for public service facilities and infrastructure. Using the Internet of Things and a mobile app, villagers can check the number of people served by public service facilities at any time and make good plans and arrangements for the use of public service facilities, thereby improving the utilisation rate of facilities and the satisfaction of villagers. It assists in the smart development of villages and encourages locals to continue living in traditional villages to prevent hollowing.

2. Methodology

Dijkstra's shortest path labelling method is a method to search for the shortest path in the weighted map. To use this method to find the ideal location of the cultural activity centre, it is necessary to convert Shengtang Village into a weighted map. The ideal location is intended to increase the number of locals who visit the cultural activity centre. After optimal location searches using Dijkstra's shortest path labelling approach, it is thus essential to evaluate the travel intention of the location. The specific steps are as follows.

2.1. Steps to form the weighed graph

The planned construction of a cultural activity centre in Shengtang Village will be responsible for cultural publicity, party member education, science popularisation, and law popularisation. It will also be an important venue for meetings, leisure sports, cultural reading, and other village activities. Villagers may visit cultural activity centres after dinner or when they are free to engage in recreational activities; it becomes an essential place for the daily activities of villagers. To determine the ideal site selection for the cultural activity centre in Shengtang Village, it is necessary to convert Shengtang Village into a weighed map using the Dijkstra labelling method's calculation criteria [17-19]. The following two steps are used to transform it into a weighting chart.

(1) In Shengtang Village, the cultural activity centre is a service station; the villagers are the service objects. Roads connect the service objects to the service station. At the moment, most villages are made up of courtyard-style and group dwellings, so it is possible to represent a courtyard or a group living unit as a point (as shown in Fig. 1). The service station (the cultural activity centre, Li) and the service object (the residential courtyard, V_j) are both shown as points. A line represents the road between the service object and the service station. As shown in Fig. 2, connecting the points and lines makes a network-weighted diagram [20]. The number of people who live in each residential yard is marked on the top or bottom of the vertex V_j, and the same is true for the unit in person.

(2) As illustrated in Fig. 2, the line length between the connection sites varies. The distance (d_{ij}) between each point is measured in metres because the service object typically walks to the service station. The data shown on each line in Fig. 2 represents the distance between two connection locations as determined by topographic mapping and measurement.

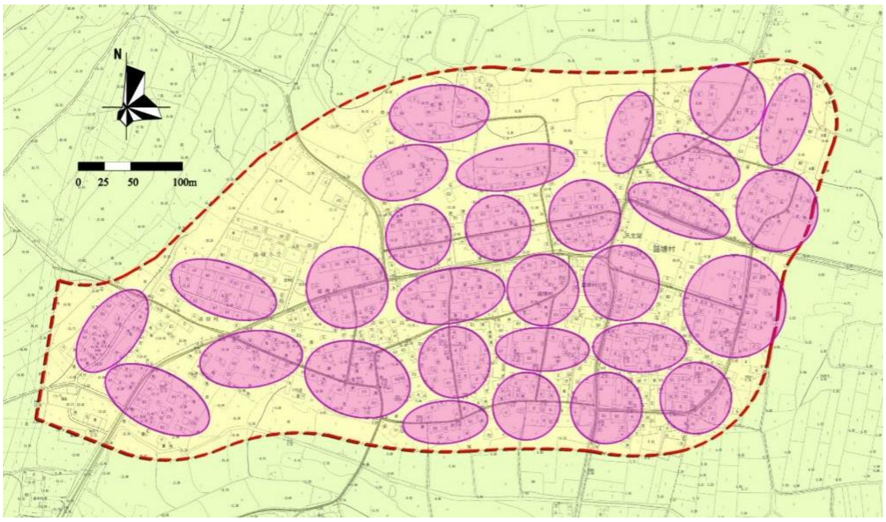

Fig. 1. Division of Shengtang Village courtyard-style and group-style dwellings units.

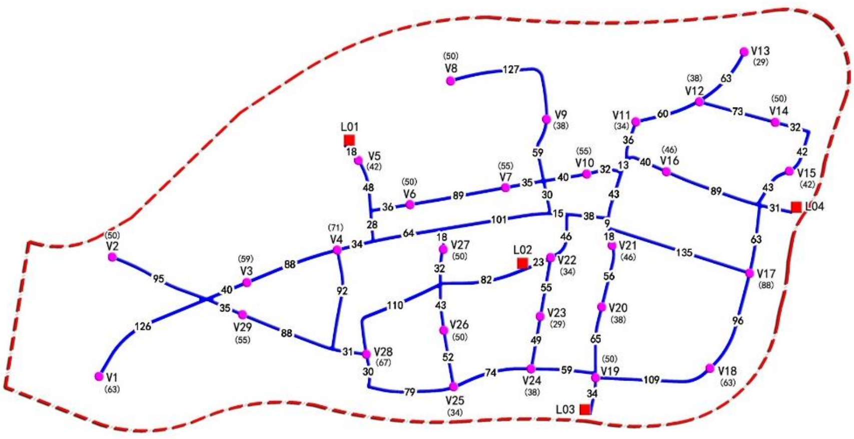

Fig. 2. Weighted network of Shengtang Village.

2.2. Steps to calculate the optimal location

The identification standards of Chinese national traditional villages stipulate that the existing buildings in traditional villages must have a certain degree of permanence, that the level of cultural relics protection units must meet the standards, and that the scale of traditional buildings and existing traditional building groups must have distinctive characteristics.

Traditional villages preserve their original characteristics in terms of site selection and design [1]. Therefore, the planning and construction of cultural activity centres in existing traditional villages cannot disrupt the original planned layout or demolish traditional buildings, and site selection is constrained. In addition, developing the cultural activity centre requires a specific site and transport accessibility. Shengtang Village's cultural activity centre is a venue and facility with multiple functions. According to estimates and guidelines for developing cultural activity centres, the per-person activity area must be greater than 1 square metre. Then, a Shengtang village site must be at least 1,400 m^2 [5]. Therefore, site selection is limited in the constructed villages. L_1, L_2, L_3, and L_4 are potential sites for the proposed building of the cultural activity centre in the context of the current situation in Shengtang Village (as shown in Fig. 2). The calculation steps of the Dijkstra shortest path labelling method must be defined in order to determine how to select the ideal location among the four possible location locations.

(1) Criteria for optimal location

What is the optimal site selection? In other words, this is the criterion for calculation. The criterion for finding the ideal location of service stations, using the Dijkstra shortest distance labelling method, is where the maximum distance between service stations and service objects is the least [19].

(2) Calculation

Utilise the guidelines for calculations in the Dijkstra shortest distance labelling method. First, consider the distance matrix D according to Fig. 1. The element d_{ij} of the matrix is the shortest distance between the *i*th service station and the *j*th service object. From this, the distance matrix D can be found. Then, calculate the maximum Max(*dij*) in each row of elements in matrix D. Finally, the Min (Max*dij*) can be obtained, and the corresponding *i* is the ideal location.

(3) Statistics of the number of people served at the service point

It is challenging to retain communities in traditional villages. The youths may leave their rural village if it cannot provide a comfortable lifestyle. Consequently, hollow are particularly serious in some villages. Young adults have left the elderly and children at home to seek employment in the cities [2]. Due to hollowing, many youths have left the village to find employment or do business. This resulted in the elderly and children living in the village for an extended time as permanent inhabitants, now the literal villagers. Consequently, the number of individuals serviced by the Shengtang Village Cultural Activity Center is based on the number of permanent residents. P_j is the service population of V_j at each vertex, as shown in Fig. 2.

(4) Evaluation of travel intention to the public service

As a destination-based measurement method of pedestrian travel intention to the public service, travel intention can test the willingness of residents to travel on foot. It can scientifically and effectively reflect the reasonable degree of public service facility location and the possibility of residents using public service facilities. The utilisation rate of public service facilities and the number of people served by public facilities are affected by the distance or walking time between residents and the service facilities [21]. According to Wang et al. [22] and Tang [23], research on the walking accessibility measurement of public service facilities and open spaces serving residents in cities revealed that residents are most willing to walk in under 5 minutes, more willing to walk between 5-10 minutes, willing to walk within 10-15 minutes, reluctant to walk for 15-30 minutes, and unwilling to walk for more than 30 minutes. Therefore, the walking time is weighted, as shown in Table 1. The total travel intention to the site selection of public service was calculated using $Si=\Sigma P_j Ai/\Sigma P_j$, where Ai is the weight corresponding to the walking time from the vertex Vj to the cultural activity centre. To simplify the calculation, walking time is converted into the walking distance to determine the corresponding weight. (as shown in Table 1).

Table 1. Weight of pedestrian travel intention.

Walking time T_i （minute）	**Walking distance d_{ij} （meter）**	**Weight (A_i)**
$T_i \leq 5$	$dij \leq 300$	1.0
$5 < T_i \leq 10$	$300 < dij \leq 500$	0.8
$10 < T_i \leq 15$	$500 < dij \leq 1000$	0.6
$15 < T_i \leq 30$	$1000 < dij \leq 2000$	0.4
$T_i > 30$	$2000 < dij$	0.2

3. Results and Discussion

3.1. Results

According to the calculation rule of the Dijkstra algorithm, d_{ij} is the shortest distance from the ith location point to the jth service point. The distance matrix D was calculated according to Fig. 2. Maxd_{ij} was calculated for the distance matrix D (as shown in Fig. 3). The results are Max$d_{1,j}$=Max$d_{1,18}$=552, Max$d_{2,j}$=Max$d_{2,1}$=484, Max$d_{3,j}$=Max$d_{3,1}$=556, Max$d_{4,j}$=Max$d_{4,1}$=772. Following that determine Min(Maxd_{ij})=484, and the corresponding location L_2 is optimal.

$$D=\begin{pmatrix} d_{1,1} & d_{1,2} & \cdots\cdots & d_{1,29} \\ d_{2,1} & d_{2,2} & \cdots\cdots & d_{2,29} \\ d_{3,1} & d_{3,2} & \cdots\cdots & d_{3,29} \\ d_{4,1} & d_{4,2} & \cdots\cdots & d_{4,29} \end{pmatrix}=\begin{pmatrix} 382 & 351 & \cdots\cdots & 291 \\ 484 & 453 & \cdots\cdots & 311 \\ 556 & 525 & \cdots\cdots & 395 \\ 722 & 691 & \cdots\cdots & 631 \end{pmatrix}$$

Fig. 3. Distance matrix D of Shengtang Village.

According to the actual distance, referring to the weight in Table 1 and the number of people shown in Fig. 2, the corresponding travel intention weight is obtained as shown in Table 2. The corresponding values were substituted into the formula $S_i=\Sigma P_j A_i/\Sigma P_j$. Thus $S_1=(63\times0.8+50\times0.8+\ldots+55\times1)/(63+50+\ldots+55)$, S_1=…… . Then, the outcomes of the calculations are S_1=0.87, S_2=0.95, S_3=0.89, S_4=0.85, and MaxS_i = S_2=0.95. Si is the arithmetic mean value of the travel intention of location i, representing the overall satisfaction and travel intention of the location site [24]. The higher value of travel intention, the higher the utilisation rate of the Village Cultural Activity Center in the future. Therefore it can be concluded that the corresponding location L_2 is optimal.

Table 2. Weight of pedestrian travel intention in Shengtang village.

Vertex (V_i)	Number of population (P_j)	$d_{i,1}$: Distance from V_i to L_1 (meter)	weight (A_i)	$d_{i,2}$: Distance from V_i to L_2 (meter)	weight (A_i)	$d_{i,3}$: Distance from V_i to L_3 (meter)	weight (A_i)	$d_{i,4}$: Distance from V_i to L_4 (meter)	weight (A_i)
V_1	63	382	0.8	484	0.8	556	0.6	722	0.6
V_2	50	351	0.8	453	0.8	525	0.6	691	0.6
V_3	59	216	1	318	0.8	470	0.8	556	0.6
V_4	71	128	1	230	1	399	0.8	467	0.8
V_5	42	18	1	272	1	452	0.8	453	0.8
V_6	50	102	1	238	1	389	0.8	369	0.8
V_7	55	191	1	149	1	300	1	280	1
V_8	50	412	0.8	300	1	451	0.8	431	0.8
V_9	38	285	1	173	1	324	0.8	304	0.8
V_{10}	55	266	1	154	1	257	1	205	1
V_{11}	34	347	0.8	199	1	274	1	196	1
V_{12}	38	407	0.8	259	1	334	0.8	221	1
V_{13}	29	470	0.8	322	0.8	397	0.8	284	1
V_{14}	50	480	0.8	332	0.8	407	0.8	148	1
V_{15}	42	483	0.8	335	0.8	410	0.8	74	1
V_{16}	46	351	0.8	203	1	278	1	120	1
V_{17}	88	456	0.8	228	1	239	1	94	1
V_{18}	63	552	0.6	295	1	143	1	190	1
V_{19}	50	436	0.8	186	1	34	1	299	1
V_{20}	38	395	0.8	189	1	99	1	303	0.8
V_{21}	46	339	0.8	133	1	154	1	247	1
V_{22}	34	313	0.8	23	1	197	1	300	1
V_{23}	29	368	0.8	78	1	142	1	355	0.8
V_{24}	38	377	0.8	127	1	93	1	358	0.8
V_{25}	34	303	0.8	177	1	167	1	432	0.8
V_{26}	50	251	1	125	1	219	1	448	0.8
V_{27}	50	176	1	114	1	294	1	388	0.8
V_{28}	67	251	1	192	1	276	1	515	0.6
V_{29}	55	291	1	311	0.8	395	0.8	631	0.6

3.2. Discussion

As the criterion for determining ideal locations, the traditional Dijkstra algorithm minimises the maximum service distance. This optimal location must also satisfy the requirements that public service facilities radiate to all service objects while minimising the distance between the farthest service object and the service station. However, in reality, there may be a small number of service objects with the shortest service distance and a large number of service objects with the longest service distance. While disregarding the number of people and their travel intentions at the service point may result in a low utilisation rate after implementing public service facilities. To avoid this circumstance, it is vital to consider the demographic and travel intentions of the service point's residents, which will further analyse the site selection's rationality.

The weight of travel intent and the number of service points per population provide further quantitative evaluation of the location selection's rationale. This location is optimal if the optimal location determined using the standard Dijkstra method is also the location with the highest travel intent. However, not all of the optimal sites obtained by the conventional Dijkstra algorithm can obtain the maximum travel intent. The conditions can be divided into the following categories.

- If the ideal location determined by the Dijkstra algorithm is within a 5-minute walking distance (the service radius of public service facilities is within 300 metres) and the resident's willingness to travel is 100%, this location will undoubtedly be the optimal location.
- If the optimal location determined by the Dijkstra algorithm is within the range of walking for more than 5 minutes (the service radius of public service facilities is more than 300 meters), it is necessary to use $Si = \Sigma P_j * Ai / \Sigma P_j$ to evaluate their travel intention. If the travel intention is higher than two-thirds (67%), it can be considered the ideal location. If their satisfaction is lower than two-thirds (67%), the ideal location determined by traditional Dijkstra is not the distance people are willing to travel. This ideal location needs to be reconsidered. Hence if the traditional Dijkstra algorithm is used to determine the ideal location, the travel intent is less than two-thirds (67%) of the population. After the development and full operation of all public service facilities at the location, it is unlikely that inhabitants will be willing to move there. It will result in a relatively low rate of utilisation, which wastes resources and falls short of the original intent and expectations of the construction goal.

4. Conclusion and Recommendation

Based on the calculation results, the optimal location of Shengtang Village Cultural Activity Center is L_2. This location is the optimal location of the traditional Dijkstra algorithm with the highest travel intention. The location of this site encourages villagers to visit, and the utilisation rate will be relatively high, allowing the cultural activity centre to serve the entire community and make villagers happy. In urban and rural planning and construction, particularly the planning and construction of new areas, the location of public service facilities should consider not only the coverage of service facilities but also the willingness of residents to travel to achieve a higher facility utilisation rate and increase resident satisfaction with public service facilities.

The Dijkstra shortest distance labelling method can be combined with the travel intention evaluation to find the optimal location of such public service facilities, and other facilities can also be used. This method can be compiled into a small program and embedded into the design software, which will help improve the rationality of planning and design and the efficiency of planning designers. In the real world, the location may be affected by distance and time and other factors such as traffic patterns and people's lifestyles. This means that the method of location will need to be improved.

In developing smart villages, public service facilities such as cultural activity centres can integrate Internet of Things technology to display the number of users in the cultural activity centre in real-time to minimise long queues caused by many people visiting simultaneously. It can not only improve utilisation but also improve satisfaction.

Acknowledgement

This paper is produced within the 2020 basic scientific research ability improvement project for young and middle-aged teachers in colleges and universities in Guangxi: "the urban renewal design and ecological restoration Project Research on the protection and renewal of old neighbourhoods based on the concept of ‘urban double repair’"(No.2020ky60015) financed by the Guangxi Education Department of China, and scientific research and innovation team project “Guangxi local architecture research and innovation team (2018LSTD03) funded by Liuzhou Institute of Technology, China. The authors are grateful to Ai Xiangren and Zeng Chuyi for their assistance with measuring and the questionnaire.

Nomenclatures

Ai	Weight corresponding to the walking time from the vertex *Vj* to *Li*
d_{ij}	Distance between each point
Li	Service station
P_j	Service population of V_j
Si	Total travel intention to the site selection of public service
V_j	Service object

References

1. Baidu Encyclopedia (2022). Chinese traditional villages. Retrieved September 30, 2022, from https://baike.baidu.com/item/%E4%B8% AD%E5%9B%BD%E4%BC%A0%E7%BB%9F%E6%9D%91%E8%90%BD/660714?fr=aladdin
2. Guangming Daily. (2013). There are only a thousand villages in modern civilisation - the concern about the protection of traditional villages. Retrieved November 2, 2013, from http://www.wenming.cn/wmzh _pd/fw/whyc/zxdt/201311/t20131123_1597314.shtml
3. Zhang, X.; and Zhang, Z. (2020). How do smart villages become a way to achieve sustainable development in rural areas? Smart village planning and practices in China. *Sustainability,* 12(24), 10510.
4. Baidu Encyclopedia. (2022). Rural revitalisation. Retrieved August 30, 2022, from https://baike.baidu.com/item/%E4%B8%AD%E5%9B%BD% E4%BC%A0%E7%BB%9F%E6%9D%91%E8%90%BD/660714?fr=aladdin
5. National standard of the People's Republic of China. (2022). Specification of construction and service for rural cultural activity center. *Beijing: The State Administration of Supervision and Administration, and the National Standardization Administration of China.*
6. Ministry of housing and urban-rural development of the people's Republic of China. (2019). Circular of the ministry of housing and urban-rural development and other departments on publishing the list of the fifth batch of villages included in the list of Chinese traditional villages. Retrieved September 15, 2021, from http://www.mohurd.gov.cn/wjfb/201906/t20190620_240922.html
7. Zhu, X.; Li, H.; and Shi, F. (2012). *Weizhou Island Records*. Nanning: Guangxi People's Publishing House.
8. Lan, F.; Wu, Q.; Zhou, T.; and Da, H. (2018). Spatial effects of public service facilities accessibility on housing prices: A case study of Xi’an, China. *Sustainability*, 10(12), 4503.

9. Abass, Z.I.; and Tucker, R. (2018). Residential satisfaction in low-density Australian suburbs: The impact of social and physical context on neighbourhood contentment. *Journal of Environmental Psychology*, 56, 36-45.
10. Staricco, L. (2022). 15-, 10- or 5-minute city? A focus on accessibility to services in Turin, Italy. *Journal of Urban Mobility*, 2, 100030.
11. Singal, P.; and Chhillar, R. (2014). Dijkstra shortest path algorithm using global position system. *International Journal of Computer Applications*, 101(6), 12-18.
12. Huang, Y. (2018). Research on the improvement of Dijkstra algorithm in the shortest path calculation. *In 2017 4th International Conference on Machinery, Materials and Computer* (MACMC 2017). Atlantis Press.745-749.
13. Sidabutar, J.A.; and Sinulingga, U. (2022). The implementation of Dijkstra algorithm in searching the shortest path for fire engines in Medan city. *Journal of Mathematics Technology and Education*, 1(2), 160-172.
14. Omomule, T.G.; Durodola, B.L.; and Orimology; S.M. (2019). Shortest route analysis for road accident emergency using Dijkstra algorithm and fuzzy logic. *International Journal of Computer Science and Mobile Computing*, 8(12), 64-73.
15. Zeng, L.; and Shan, G. (2021). The application of improved Dijkstra labelling method in the location selection of primary and secondary schools in urban and rural planning. *Urban Residence*, 28(1), 171-172,175.
16. Rachmawati, D.; and Gustin, L. (2020). Analysis of Dijkstra's algorithm and A* algorithm in shortest path problem. *Journal of Physic*, Conference Series: 1566, (1), 012061.
17. Chen, Y. (2019). *Urban planning system engineering*, Beijing: China Architecture Press.
18. Wang, S.X.; and Wu, Z.X. (2012). Improved Dijkstra shortest path algorithm and its application. *Journal of Computer Science*, 39(05), 223-228.
19. He, B. (2022). Application of Dijkstra algorithm in finding the shortest path. *Journal of Physics*. Conference series 2181(1), 012005.
20. Zeng, L.; and Shan, G. (2015). Site selection of Weizhou Island fire station based on Dijkstra labeling method. *Journal of Fire Science and Technology*, 34(5), 678-680.
21. Tiran, J.; Lakner, M.; and Drobne, S. (2019). Modelling walking accessibility: A case study of Ljubljana, Slovenia. *Moravian Geographical Reports*, 27(4), 194-206.
22. Wang, Z.; Li, H.; and Shang, H. (2021). Convenience analysis of public service facilities in the walking circle of urban housing estates. *Journal of Landscape Research*, 13(4), 1-8, 6.
23. Tang, B.S.; Wong, K.K.; Tang, K.S.; and Wong, S.W. (2021). Walking accessibility to neighbourhood open space in a multi-level urban environment of Hong Kong. *Environment and Planning B: Urban Analytics and City Science*, 48(5), 1340-1356.
24. Chakrabarty, D. (2020). Definition/formulation of average from first principle. *Journal of Environmental Science, Computer Science and Engineering & Technology*, (9), 2278-179.