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推動行人友善發展的智慧政策研究

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S2017.A7.004.17S

Strategic Public Policy Research Funding Scheme

Final Report

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Strategies for Enhancing Walkability in Hong Kong via Smart Policies
推動行人友善發展的智慧政策研究

Executive summary

(1) Abstract of the research (English version)

The benefits of improving walkability are apparent, such as improved mobility and community livability, better public health, cleaner air due to reduction in vehicular traffic, tourism development, etc. Building a pedestrian-friendly environment and promoting walkability are not only a local priority, as stated in the 2017 Policy Address, but also a global trend in that enhancing walkability is a core element for smart city development.

Existing approaches to walkability have been primarily focused on improving accessibility and connectivity by constructing or retrofitting pedestrian facilities. Despite massive expenditures, ways to improve their effectiveness in enhancing walkability have yet to be more fully developed. Walkability is not only about physical facilities, but also about elements that are linked to community needs and individual characteristics, requiring a broader set of policy instruments for their enhancement. Conducting a systematic analysis is not only critical to understand the effectiveness of existing approaches, but also to develop smart, evidence-based policies to ensure their consistent, widespread implementation.

This project sets out to significantly advance policy thinking towards improving walkability in Hong Kong. The goal of this project was to advance the policy thinking towards improving walkability in Hong Kong by using Kwun Tong and Tsuen Wan as demonstration, which was achieved by the following four objectives:

1. To develop vision statements on walkability and scope of policy interventions for Tsuen Wan and Kwun Tong by surveying community needs, existing policies, and best practices.
2. To develop an integrated BIM-3DGIS (building information modeling-3D geographic information system) platform for network walkability analysis and 3D visualization towards policy applications.
3. To investigate the determinants of walking behavior in Hong Kong and develop walking utility functions for analyzing key policy interventions to promote walkability.
4. To assess policy options for Tsuen Wan and Kwun Tong to enhance and promote walkability via policy modeling, stakeholder analysis, and multi-criteria decision analysis.

The focus on two areas in Hong Kong, Tsuen Wan and Kwun Tong helped illustrate the applicability of the proposed policy framework for formulating concrete policies and solutions, studying their performance based on specific circumstances, and identifying potential barriers and obstacles, and possible rectifications. The results and policy recommendation for the two areas may be specific to the regions, but the developed analytical tools and approaches to generate policy solutions are generic and are applicable for other contexts as well.

(2) Layman summary on policy implications and recommendations

We have successfully completed all four objectives, namely, identified needs of different user groups and issues and barriers for walkability improvement, developed network and choice modeling tools and policy options for the analysis, and came up with eight broad policy implications and recommendations, as listed below:

1. *Appraising pedestrian infrastructure improvement*: this project developed analytical, quantifiable tools with high fidelity for appraising the benefits of both individual projects as well as for conducting walkability assessment. We recommend empowering decision making in walkability enhancement project selection and identifying areas that need improvement through an evidence-based approach, such as through the use of tools developed in this project.
2. *Coordinating street management*: street management is a complicated yet important issue for enhancing walkability. We recommend establishing a single coordination unit or point of contact who is responsible for street management in a holistic manner. With well-defined roles, such a coordination unit can work with different departments and agencies to develop proper processes and procedures for the design, construction and maintenance of walkability facilities, and for streamlining the communications between various government departments and Transport and Traffic Committees of District Councils.
3. *Developing District signature programs*: Signature programs draw attention, increase the profile of walkability, and allow people to experience first-hand the urban environment that is conducive to enjoyable walking. We recommend developing walkability signature programs in each district if possible. Such signature walkability programs shall incorporate cultural, aesthetic, and leisure dimensions, while considering the specific demographics of the District.
4. *Including walkability as part of the formal transport planning process*: We recommend that walking be recognized fully as part of the transport planning process, such that a planning framework can be developed to address the end-to-end transport in a holistic manner.
5. *Modifying Regulations / Guidelines for enhancing walkability*: Planning regulations and guidelines are effective to ensure that all new streets, and old ones to be modified gradually, will fulfill certain updated standards. We recommend that modifications of such regulations and guidelines be duly considered in introducing walkability enhancement.
6. *Providing information to facilitate and encourage walking*: Providing end-to-end walking directions and navigation, via apps, is very useful. The Transport Department has already developed an app called HKeMobility, which as of now is not widely known or used, and it will benefit from more promotion and further improvement to make it more user-friendly.
7. *Specific recommendations for Kwun Tong and Tsuen Wan*: In addition to the above recommendations that are applicable in general, we provided some specific recommendations for these two Districts for further consideration.
8. *Future Thoughts*: The government has embarked on developing the Common Spatial Data Infrastructure (CSDI) and started the new Spatial Data Office. This will be extremely important for upkeeping the pedestrian networks and promoting their use, especially in the development of new pedestrian navigation apps catering to the needs of different user

groups, such as for the elderly, for people with different kinds of disabilities, for different weather conditions, such as different navigational paths for rainy and hot weathers.

We hope that these recommendations together with the accompanying analytical tools and policy instruments will be able to bring about enhancing walkability for Hong Kong.

行政摘要

一、研究摘要

改善步行環境會帶來許多好處，包括提高城市流動性，營造更宜居的社區環境，改善公共健康，減少車流以改善空氣質素及帶動旅遊業等等。建構一個行人友善的環境不僅是一個地區性的優先發展方向，正如在二零一七年的施政報告上提到，更是一個全球智慧城市發展的趨勢。

現時營造行人友善環境的方法主要通過建設或改善行人設施以提升其暢達性及連接性。但其效果仍有待提升及發揮。行人友善的環境不僅在於基礎設施建設，更需考慮到行人特徵、社區需要等多元的因素，及計劃各種的政策工具。開發一個系統性的分析工具不但能了解現行方法的效率，亦可發展出具智慧及以實證為本的決策過程，使其可適用到不同地方及地區。

本研究著重發展營造及改善香港步行環境的政策，利用觀塘及荃灣兩區作為例子。本研究的目的可以分為四部份：

1. 建立對於觀塘及荃灣的地區願景及政策範疇。透過各種調查及訪問了解地區需要，現行政策及方法；
2. 建立綜合建築信息模型及三維地理信息系統 (BIM-3D GIS) 的平台，以分析行人網絡系統及實現三維可視化；
3. 分析行人步行行為的主要因素及應用經濟學上的隨機效用模型來描述行人步行行為；
4. 透過各種政策模型，持份者分析及多標準分析，評估適用於提升觀塘及荃灣好行的政策方法。

本研究選擇觀塘及荃灣為案例，以闡明其應用，包括建構實際的政策及方法，評估區內的效果，識別可能的限制和障礙及提出解決方法。雖然本研究是建基於觀塘及荃灣的情況，但本研究提出的系統性分析方法及工具，及政策建議可適用於不同區域。

二、研究項目對政策影響和政策建議的摘要

中文摘要：

本研究完成四個設立的目標，識別不同群組在好行環境的需要，問題及障礙，建立行人網絡系統，步行行為模型，政策選項等分析工具，及歸納出以下八項政策建議。

1. 評定行人基建設施改善的效能

本研究建立的精準分析及定量模型，能評定各種單獨項目的利益或進行地區網絡性的好行評估。我們建議使用此客觀及以實證為本的決策方法去訂立改善方案，當中可能包括篩選改善步行環境的方案，或識別需要改善的地區等等。

2. 統籌街道管理

街道管理是複雜但對改善步行環境一個重要議題。我們建議設立一個統籌街道管理的聯絡單位或部門，從而令街道管理有一個整體的管理方式。根據訂立的角色，統籌單位會聯絡有關的政府部門，建立恆常與區議會交通及運輸委員會的溝通渠道，參與統籌步行環境改善事宜。

3. 發展地區性的焦點項目

焦點項目不但引起討論及公眾對步行環境的注視，亦能讓市民親身感受行人友善的環境。我們建議每區可以根據當區特色，引入不同包含文化性，藝術性及休閒等的焦點項目。

4. 涵蓋步行成為交通規劃的一部份

我們建議將步行納入交通規劃的一部份，令交通規劃能整體性處理所有點對點的交通模式。

5. 修改政策及條例以營造好行環境

規劃條例和指引能有效地確保所有新建的街道，或逐漸改造的舊有街道，能滿足隨時代需要而更新的標準。我們建議在營造行人友善的環境時考慮修改相關的政策及條例。

6. 提供數據以促進及鼓勵步行

提供點對點的步行資訊及導航對行人是非常有幫助。運輸署現時雖然有提供一個香港出行易手機應用程式，但此程式的廣泛性及宣傳仍然不足。加強宣傳及優化用戶體驗能有效發揮此應用程式為市民帶來的好處。

7. 針對觀塘及荃灣的建議

除了以上全面整體性的建議，我們針對觀塘及荃灣提出各種建議。

8. 未來願景

政府已成立了空間數據分享平台及建立了新的空間數據辦事處。此舉對維護和管理行人網絡，推廣其使用，及開發新的導航應用程式有重大作用。開發的程式應能滿足老人，殘疾人士等不同群體的特別需要，及根據不同天氣提供對應的路線建議。

我們希望以上的八項建議，及本研究帶出的系統性分析工具和政策選項等，能有效地幫助香港營造行人友善的環境。

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1 Introduction

The benefits of improving walkability are apparent, such as improved mobility and community livability, better public health, cleaner air due to reduction in vehicular traffic, tourism development, etc. Building a pedestrian-friendly environment and promoting walkability are not only a local priority, as stated in the 2017 Policy Address, but also a global trend in that enhancing walkability is a core element for smart city development.

Existing approaches to walkability have been primarily focused on improving accessibility and connectivity by constructing or retrofitting pedestrian facilities. Despite massive expenditures, ways to improve their effectiveness in enhancing walkability have yet to be more fully developed. Walkability is not only about physical facilities, but also about elements that are linked to community needs and individual characteristics, requiring a broader set of policy instruments for their enhancement, such as modifying the building and planning regulations for their consistent implementation, encouraging the formation of public-private partnership in conjunction with the regulations for enhancing their implementation feasibility, provision of information and incentives to encourage and promote walking, etc. Systematic analysis is critical not only to understand the effectiveness of existing approaches, but also to develop smart, evidence-based policies to ensure their consistent, widespread implementation.

This project sets out to significantly advance policy thinking towards improving walkability in Hong Kong. To develop such systematic analysis on walkability, we divided the project into four tasks as shown in **Figure 1**. Firstly, Task 1 aimed to develop vision statements on walkability and scope of policy interventions for Kwun Tong and Tsuen Wan. This was to put emphasis on two districts with distinct pedestrian network characteristics and diverse needs from the local communities and user groups. Existing related policies and good practices on walkability around the world were reviewed. Unique and common features in Hong Kong were identified. Secondly, Task 2 aimed to develop an integrated BIM-3D GIS platform for network walkability analysis and 3D visualization for policy applications. Through the 3D network mapping and data models developed, we established the outdoor and indoor pedestrian networks at ground, below ground and above ground, which have opened up applications to improve the walking environment and connect neighborhoods. Task 3 aimed to investigate the determinants of walking behavior and develop walking utility functions for analyzing key policy interventions to promote walkability. Task 2 and 3 are research and evaluation tools to assess walkability. Through rigorous discrete choice models developed by revealed and stated preference approaches, we investigated the perception of walkability and developed walking utility models, which are instrumental to providing quantitative analysis to support decision and policymaking on walkability. Finally, Task 4 aimed to assess policy options to enhance and promote walkability. In addition to adding and improving the physical infrastructures, the analysis also included policy measures. While some of the results and policy recommendations developed are specific to these two areas, the analytical tools and approaches developed are applicable for other contexts as well.

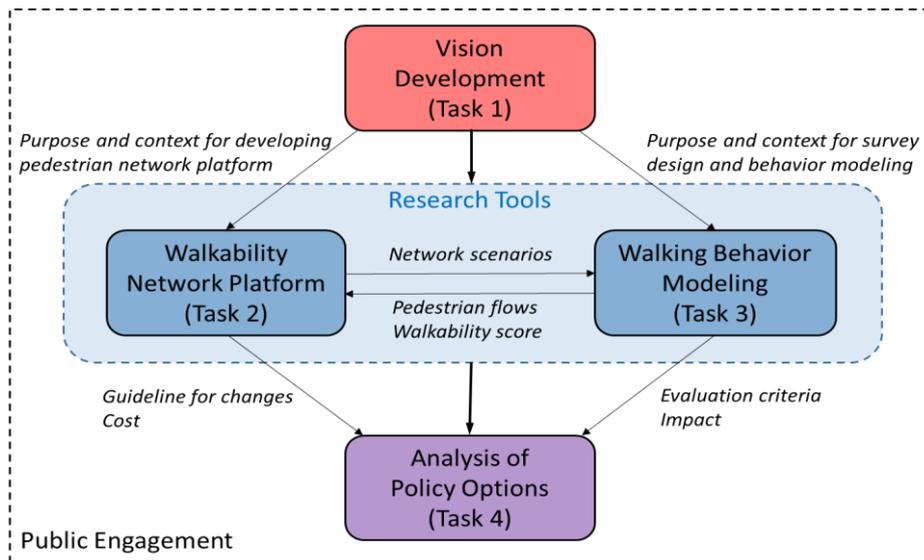


Figure 1. The framework of research tasks

2 Objectives of the study

The objective of this project was to advance the policy thinking towards improving walkability in Hong Kong by using Kwun Tong and Tsuen Wan as demonstration, which was achieved by the following four tasks:

1. To develop vision statements on walkability and scope of policy interventions for Tsuen Wan and Kwun Tong by surveying community needs, existing policies, and best practices.
2. To develop an integrated BIM-3D GIS (building information modeling-3D geographic information system) platform for network walkability analysis and 3D visualization towards policy applications.
3. To investigate the determinants of walking behavior in Hong Kong and develop walking utility functions for analyzing key policy interventions to promote walkability.
4. To assess policy options for Tsuen Wan and Kwun Tong to enhance and promote walkability via policy modeling, stakeholder analysis, and multi-criteria decision analysis.

The focus on two areas in Hong Kong, Tsuen Wan and Kwun Tong helped illustrate the applicability of the proposed policy framework for formulating concrete policies and solutions, studying their performance based on specific circumstances, and identifying potential barriers and obstacles, and possible rectifications. The results and policy recommendation for the two areas may be specific to the regions, but the developed analytical tools and approaches to generate policy solutions are generic and are applicable for other contexts as well.

3 Research methodology

The research methodology will be described by each task.

3.1 Task 1 – Developing vision statements and scope of policy interventions

3.1.1 The vision statements and scope on walkability in other cities

In order to gain experiences from good practices over the world, we compared Hong Kong with five other cities, including London, San Francisco, New York, Singapore, Beijing, to investigate the visions and actions taken by them. Understanding the policies designed and implemented in these cities shed light on the improvement of walkability in Hong Kong.

3.1.1.1 *London*

The responsible government agency to manage walkability in London is the Transport for London (TfL). TfL makes a vision that London should be the world's most walkable city. This means a city where walking is the most obvious, enjoyable and attractive means of travel for all short trips. The aim is to enable more people to walk part or all of their journey, improve the experience of walking in London, and reduce car dependency. Some of the actions implemented by London include: 1) Transform London's streets to reshape the landscape for walking, 2) Deliver the Liveable Neighbourhoods programme to transform walking throughout London, 3) Support pedestrian movement through the management and operation of London's road network. 4) Publish the Strategic Walking Analysis in 2018 to inform planning and decision-making for walking improvements and 5) Support car-free events as catalysts for change and celebrations of walking.

3.1.1.2 *San Francisco*

The San Francisco Municipal Transportation Agency (SFMTA) is the responsible government sector in San Francisco. The SFMTA's vision is to use walking to make San Francisco a more safe, sustainable and equitable city. Underpinning this vision are three key goals: 1) Eliminate pedestrian fatalities and serious injuries; 2) Increase the number of walking trips; 3) Build safer, better streets for people walking. The actions implemented by San Francisco are Sunday Streets, Play Street and Adult School Crossing Guard Program.

3.1.1.3 *New York City*

New York City Department of Transport has implemented some programs to improve walkability. WalkNYC, a way-finding program, aims to install map-based way-finding information in neighbourhoods and at Select Bus Service (SBS) stations across the city. NYC Plaza Program aims to ensure that all New Yorkers live within a 10-minute walk of quality open space. The Summer Streets, which NYC's streets are opened for people to play, run, walk and bike. Summer Streets provides space for healthy recreation and encourages New Yorkers to use more sustainable forms of transportation.

3.1.1.4 *Singapore*

Walkability is jointly managed by the Urban Redevelopment Authority, the Land Transport Authority, the National Parks Board and the Housing Department Board in Singapore. Urban Redevelopment Authority clarifies the vision of walkability in Singapore is to enhance the walking experience across Singapore's towns, estates and the city area to boost overall accessibility. Car-Free Sunday SG program is implemented where roads within the Civic District and parts of the Central Business District (CBD) are closed, transforming the area into a walkable, cyclist-friendly, and activity-filled precinct for families and friends. The Walk2Ride Program has expanded the network of sheltered walkways, allowing more commuters to enjoy convenient connections to our public transport nodes. Where feasible,

walkways have been built to schools, healthcare facilities and other public amenities within a 400-metre radius of MRT stations, and within a 200-metre radius of bus interchanges, LRT stations and selected bus stops with high commuter volumes. Throughout the \$300 million W2R program, LTA worked closely with the local community to prioritize the building of sheltered walkways where they are most needed and to improve the walking experience for all commuters.

3.1.1.5 Beijing

The walkability in Beijing is governed directly by General Office of Beijing People's Government. While various programs are proposed by different agencies to improve walkability at implementation level. The actions taken by Beijing include 2018 Action on Alleviating Traffic Congestion in Beijing City, Car-Free Days, Urban Design Guidelines for Beijing Street Regeneration and Governance, Guideline for Urban Pedestrian and Bicycle Transportation System Planning.

3.1.2 Development of vision statements and scope of policy interventions for Hong Kong

In developing vision statements and scope of policy intervention, face-to-face interviews with community opinion leaders and key informants of different user groups are crucial. The community opinion leaders included government departments, such as Planning Department, Transport Department, Chairs and Members of Traffic and Transport Committees in Kwun Tong and Tsuen Wan District Councils. The user groups included the elderly, people with disabilities, commuters, and way-finders. The community surveys gathered information about the demands as well as supply constraints and regulation barriers on enhancing walkability in each study area. During the project period, we conducted 18 interviews and surveys with community opinion leaders, the elderly, people with disabilities, and residents, commuters and way-finders, as listed in **Table 1**. Through these surveys and interviews, we collected and gathered important features and desired walkability improvements for the two districts, as will be discussed in the Results section.

Table 1: Interviews and surveys conducted in Task 1

	Community opinion leaders
May 04, 2018	Meeting with Chief Town Planner Mr. Liu Kam-ming and representatives from Planning Department, HKSAR.
July 16, 2018	Interview with Mrs. Ann So, Chair of Traffic and Transport Committee, Kwun Tong District Council.
July 20, 2018	Interview with Mr. Peter Lo, Chair of Traffic and Transport Committee, Tsuen Wan District Council
January 30, 2019	Interview with Professor Anthony Cheung Bing-leung, GBS, JP, former Secretary for Transport and Housing Bureau, Hong Kong SAR.
January 30, 2019	Meeting with Walkability Task Force of Transport Department and representatives from Mott Macdonald.

May 2, 2019	Interview with Mr. CHAN Wah-Yu, District Council Member at Kwun Tong
February 09, 2020	Interview with Mr. BUX Sheik Anthony, Chairman of Traffic and Transport Committee, Kwun Tong District Council.
April 2020	Interview with Mr. Wong Ka Wa, Vice Chairman of Traffic and Transport Committee, Tsuen Wan District Council
January 27, 2021	Interview with Mr. CHIU Yan Loy, Chairman of Traffic and Transport Committee, Tsuen Wan District
January 28, 2021	Interview with Mr. BUX Sheik Anthony, Chairman of Traffic and Transport Committee, Kwun Tong District Council
January 29, 2021	Meeting with Walkability Task Force of Transport Department, HKSAR.
	The elderlies
July 05, 2018	Interview with three aged (over 80) persons at St. James' Project Care Neighborhood Elderly Centre
December 28, 2018	Interview with 20 elderlies at Tsuen Wan Social Service Building
February 18, 2019	Interview with 20 elderlies at True Light Villa District Elderly Community Center at Kwun Tong
	People with disabilities
June 28, 2018	Interview with physical disabled (wheel-chaired) person at Hong Kong Society for Rehabilitation (4 person)
April 01, 2019	Interview with Hong Kong Federation of Handicapped Youth (15 responses)
	Residents, commuters and way-finders
April 13 - 26, 2019	Two street surveys were conducted: One at Kwun Tong MTR station and Kwun Tong Promenade; another at the Tsuen Wan Riviera Park, Tsuen Wan Park, Yeung Uk Road, and Tai Ho Road.
February - May 2020	An online questionnaire survey has been conducted and collected data from 140 valid samples.

3.2 Task 2 – Developing integrated BIM-3DGIS platform

Task 2 aimed to develop an integrated BIM-3DGIS platform for network walkability analysis and 3D visualization for policy applications. For the development of the BIM-3DGIS platform key sub-components are:

1. Creation of 3D GIS Outdoor and Indoor Pedestrian Network & barrier free mapping for each of the of the two districts, Tsuen Wan and Kwun Tong for walkability analysis.
2. Creation of BIM-3DGIS for walkability visualization

3.2.1 Creation of 3D GIS Outdoor and Indoor Pedestrian Network & barrier free mapping for Tsuen Wan and Kwun Tong for walkability analysis.

There were three major tasks in this part, including:

- 1) Creation of Kowloon Bay to Kwun Tong 3D GIS Outdoor and Indoor Pedestrian Network map (path center line).
- 2) Creation of Tsuen Wan 3D GIS Outdoor and Indoor Pedestrian Network map (path center line).

The first task, creating the 3D GIS mapping pedestrian networks of Tsuen Wan and Kwun Tong, was completed in July 2019 as reported in the interim report of 31st August 2019. The 3D GIS pedestrian networks of Tsuen Wan and Kwun Tong was provided from the HKU team to the HKUST team in November 2019 for network analysis and walkability analysis. In the following, we briefly summarize and describe the pedestrian networks produced by the HKU Team led by Professor Chiaradia.

3.2.1.1 3D GIS Kwun Tong & Kowloon Bay Outdoor and Indoor Pedestrian Network map

The extents of the pedestrian network maps developed for Kwun Tong and Kowloon Bay can be seen in green in **Figure 2**. The network is made of connected links, which connect between two junctions or a junction and a dead end. Path center line is the principle of the link. The outdoor network is based on iB1000 map and modified by on-site checks.

For outdoor links, the attribution table is shown in **Table 2**. The ground or street level is categorized as Level_0. Link between the street with the above ground is categorized as Level_1. The category of linkages between the ground and the underground is marked as Level_L1. The pedestrian tunnel is marked as Level_L2. Metro underground is marked as Level_L3.

For the interior pedestrian network, the mapping follows the same principle, the path center line, link attributes are further categorized by floor levels. Figure 3 and Figure 4 show the Kwun Tong MTR Station area and the surrounding 3D GIS pedestrian network analysed with the sDNA (Cooper and Chiaradia, 2020) software in ArcScene.



Figure 2. Map of Kwun Tong and Kowloon Bay Pedestrian Network

Readily available items

SPPR_KTKB_gdb

- SPPR_KTKB_Type
- SPPR_KTKB_Bth
- SPPR_KTKB_Buildingvolume
- SPPR_KTKB_Floor

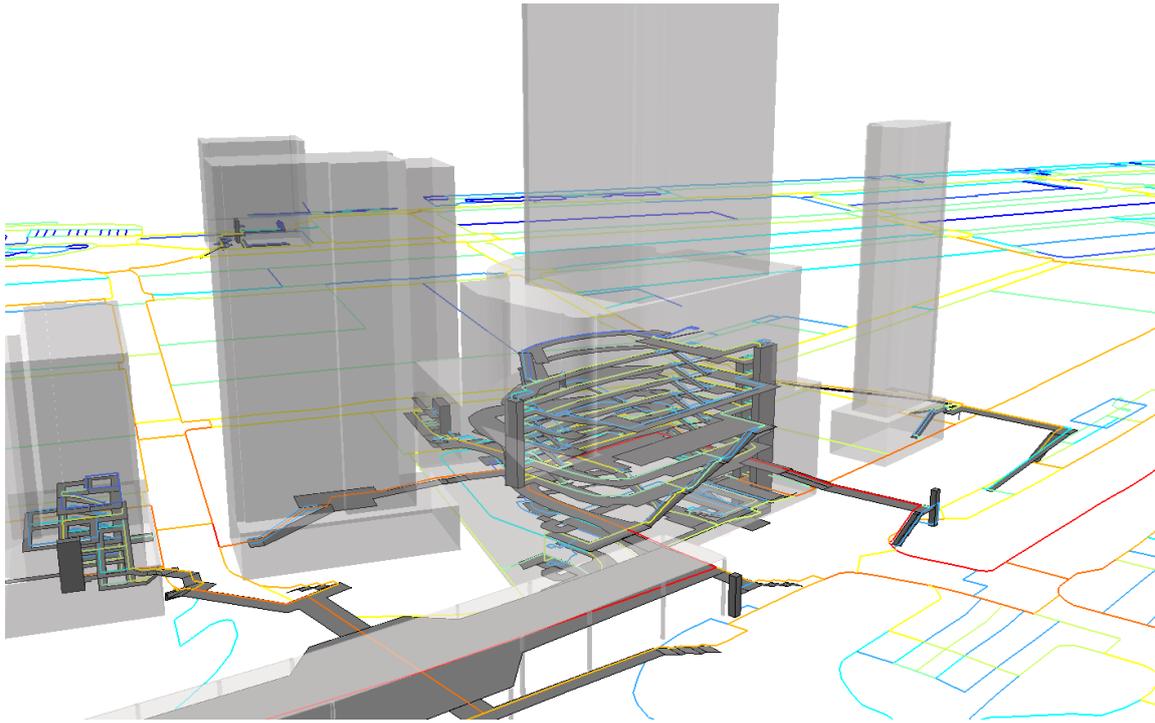


Figure 3. Kwun Tong MTR Station area, 3D GIS pedestrian network analysed with sDNA in ArcScene.

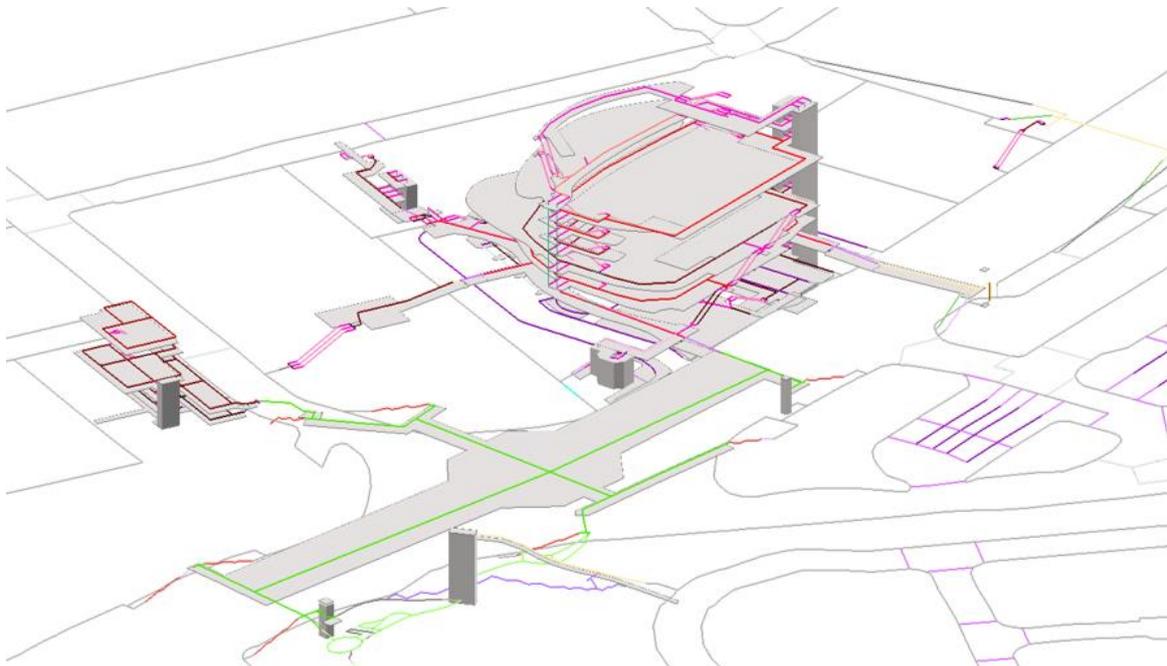


Figure 4. Kwun Tong MTR Station area, 3D GIS pedestrian network in ArcScene.

3.2.1.2 3D GIS Tsuen Wan Outdoor and Indoor Pedestrian Network map

The extent of Tsuen Wan O-I pedestrian network map can be seen in **Figure 5**. The network is made of connected links, linking between two junctions or a junction and a dead end. Path center line is the principle of the link. The outdoor network is based on iB1000 map and modified by on-site checks.

For outdoor links, the attribute table is shown in **Table 2**. The ground/street level is categorized as Level_0. Link between the street with the above ground is categorized as Level_1. The categories on the. The category of linkages between the ground and the underground is marked as Level_L1. The pedestrian tunnel is marked as Level_L2. Metro underground is marked as Level_L3.

For the interior pedestrian network, the mapping follows the same principle, the path center line, link attributes are further categorized by floor levels.

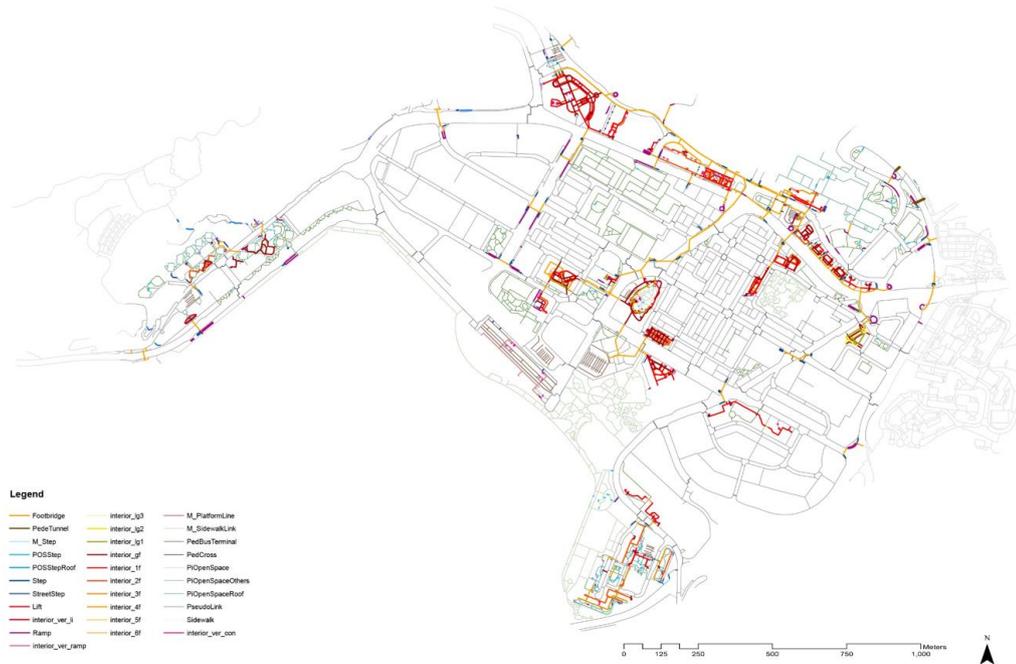


Figure 5. Map of Tsuen Wan Pedestrian Network

Readily available items

- SPPR_TW_gdb
- SPPR_TW_Type
- SPPR_TW_Bth
- SPPR_TW_Buildingvolume
- SPPR_TW_Floor

Table 2. Definition of Domain Value used for the Feature Type Attribute

Domain Value	Description
Level 0	
Sidewalk	Paths along the two sides of a road centreline
Ramp	A sloping surface joining two different levels of height
StreetStep	Steps on the hilly surface
M_SidewalkLink	Linking the exit of the metro station with the sidewalk

PedBusTerminal	Network in bus terminals
PedCross	A place designated for pedestrians to cross a road
PiOpenSpace	Paths on the pavements in open space
PiOpenSpaceOthers	Paths in open space except for those on the pavement
POSStep	Steps in open spaces
PseudoLink	The pseudo crossing is at places where the pedestrian could actually cross but not indicated with a zebra crossing in the road marking data, and there is a break in the fences of both sides of a road.
Level 1	
Step	To join two features with different levels of height
Elevator	A type of vertical transportation that moves people or goods between floors of a building, vessel, or other structure.
Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building
VirtualPIN	The indoor network of a publicly accessible building by linking the entrances of the building and centre of the building
Level 2	
Footbridge	A bridge designed to be used by pedestrians
PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof
POSStepRoof	Steps on building's roof
Level L1	
M_Escalator	Escalator connecting metro underground
M_Step	Step connecting the ground and metro underground
Level L2	
PedeTunnel	A road for pedestrian passing under another road
Level L3	
M_PlatformLine	The paths in the underground before entering into the metro system

Table 3. Metadata of the 3D pedestrian network Kowloon Bay – Kwun Tong

Pedestrian network types and height levels	Category description	Number of links
Level_0		
Sidewalk	Paths along the two sides of a road centerline	74957
Ramp	A sloping surface joining two different levels of height	1201
StreetStep	Steps on the hilly surface	1011
M_SidewalkLink	Linking the exit of the metro station with the sidewalk	94
PedBusTerminal	Network in bus terminals	1950
PedCross	A place designated for pedestrians to cross a road	3135
PiOpenSpace	Paths on the pavements in open space	55415
PiOpenSpaceOthers	Paths in open space except for those on the pavement	39964
POSStep	Steps in open spaces	2717
PseudoLink	The pseudo crossing is at places the pedestrian would actually use to cross but not indicated with a zebra in the road marking data, and there is a break in the fences of both sides of a road.	2626
BicycleTrack	Bicycle lanes	295
HikingTrail	Hiking trail paths (we only constructed the sections in Hong Kong island)	0
Level_1		
Step	To join two features with different levels of height	5241
Elevator	A type of vertical transportation that moves people or goods between floors of a building, vessel, or other structure.	0
Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building	114
VirtualPIN	The indoor network of a publicly accessible building by linking the entrances of the building and centre of the building.	0
Level_2		
Footbridge	A bridge designed to be used by pedestrians	2832
PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof	6089
POSStepRoof	Steps on building's roof	235
Level_L1		
M_Escalator	Escalator connecting metro underground	92

M_Step	Step connecting the ground and metro underground	154
Level_L2		
PedeTunnel	A road for pedestrian passing under another road	313
Level_L3		
M_PlatformLine	The paths in the underground before entering into the metro system	565

Table 4. Metadata of the 3D pedestrian network Tsuen Wan

Pedestrian network types and height levels	Category description	Number of links
Level_0		
Sidewalk	Paths along the two sides of a road centerline	21666
Ramp	A sloping surface joining two different levels of height	598
StreetStep	Steps on the hilly surface	334
M_SidewalkLink	Linking the exit of the metro station with the sidewalk	32
PedBusTerminal	Network in bus terminals	687
PedCross	A place designated for pedestrians to cross a road	881
PiOpenSpace	Paths on the pavements in open space	11837
PiOpenSpaceOthers	Paths in open space expect for those on the pavement	5634
POSStep	Steps in open spaces	367
PseudoLink	The pseudo crossing is at places the pedestrian would actually use to cross but not indicated with a zebra in the road marking data, and there is a break in the fences of both sides of a road.	843
BicycleTrack	Bicycle lanes	0
HikingTrail	Hiking trail paths (we only constructed the sections in Hong Kong island)	0
Level_1		
Step	To join two features with different levels of height	1357
Elevator	A type of vertical transportation that moves people or goods between floors of a building, vessel, or other structure.	0
Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building	18
VirtualPIN	The indoor network of a publicly accessible building by linking the entrances of the building and centre of the building.	0

Level_2		
Footbridge	A bridge designed to be used by pedestrians	1386
PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof	1609
POSStepRoof	Steps on building's roof	94
Level_L1		
M_Escalator	Escalator connecting metro underground	9
M_Step	Step connecting the ground and metro underground	28
Level_L2		
PedeTunnel	A road for pedestrian passing under another road	21
Level_L3		
M_PlatformLine	The paths in the underground before entering into the metro system	119

3.2.2 Creation of BIM-3DGIS for walkability visualization

3.2.2.1 Background Study and Literature Review

In the beginning, a literature review on 3D city modeling was conducted (Ministry of Housing and Urban-Rural Development 2010; Open Geospatial Consortium 2012). In particular, the definition of various levels of detail (LoD) was studied, as shown in **Figure 6** and **Figure 7**. For example, a LoD1 model is mainly composed of object blocks as generalized features, while a LoD4 model encodes the detailed interior features of each building. Moreover, typical categories and attributes of infrastructure for 3D city modeling were summarized, including but not limited to the name and dimension of buildings, roads, footbridges, city furniture.

	LOD0	LOD1	LOD2	LOD3	LOD4
Model scale description	regional, landscape	city, region	city, city districts, projects	city districts, architectural models (exterior), landmark	architectural models (interior), landmark
Class of accuracy	lowest	low	middle	high	very high
Absolute 3D point accuracy (position / height)	lower than LOD1	5/5m	2/2m	0.5/0.5m	0.2/0.2m
Generalisation	maximal generalisation	object blocks as generalised features; > 6*6m/3m	objects as generalised features; > 4*4m/2m	object as real features; > 2*2m/1m	constructive elements and openings are represented
Building installations	no	no	yes	representative exterior features	real object form
Roof structure/representation	yes	flat	differentiated roof structures	real object form	real object form
Roof overhanging parts	yes	no	yes, if known	yes	yes
CityFurniture	no	important objects	prototypes, generalized objects	real object form	real object form

Figure 6: Definition of LoD Requirement based on CityGML Encoding Standard (Open Geospatial Consortium 2012)

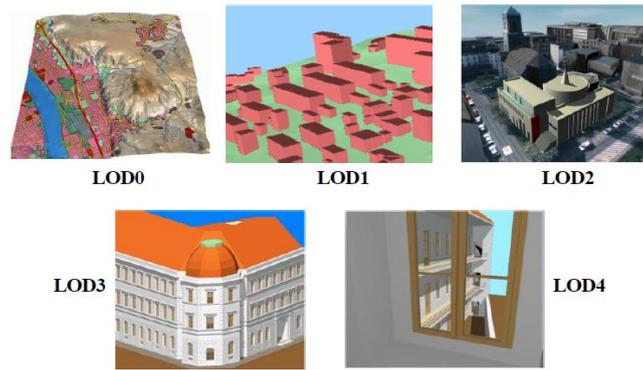


Figure 7: Graphical Illustration of 3D Models with Different LoD (Open Geospatial Consortium 2012)

Furthermore, several factors influencing the pedestrian route choices were extracted from previous studies (Transport for London 2010), including the actual distance, crowdedness and perceived comfort or safety of a pathway. Specifically, perceived comfort or safety may be related to any grade separation like stairs and elevators, number of crossings and associated traffic signals, as well as environment attractiveness such as lighting and air-conditioning. Since disabled people was considered one of our target groups, literature review was conducted on the investigation report of barrier-free facilities in Kwun Tong (Kwun Tong District Council 2014) and barrier-free design guideline (Buildings Department 2008). The categories and design requirements of barrier-free facilities were summarized, such as the dimension of doors and elevators, provision of auxiliary facilities like tactile guide path, railing or ramp.

To understand the specific need in Kwun Tong neighborhood, a meeting was held on 16 Jul 2018 with Mrs. Ann So, who at that time was the chair of Kwun Tong Transportation Committee. She provided detailed information of the local conditions in Kwun Tong, including its zonal characteristics, walking pattern of local citizens, existing walkability policies, future development of regional pedestrian network, target groups to be prioritized, etc. Based on her description, a network map was constructed by our team to visualize the conceptual walkability in Kwun Tong, as shown in **Figure 8**. The acquired knowledge about Kwun Tong greatly supported our on-field survey and creation of 3D model.

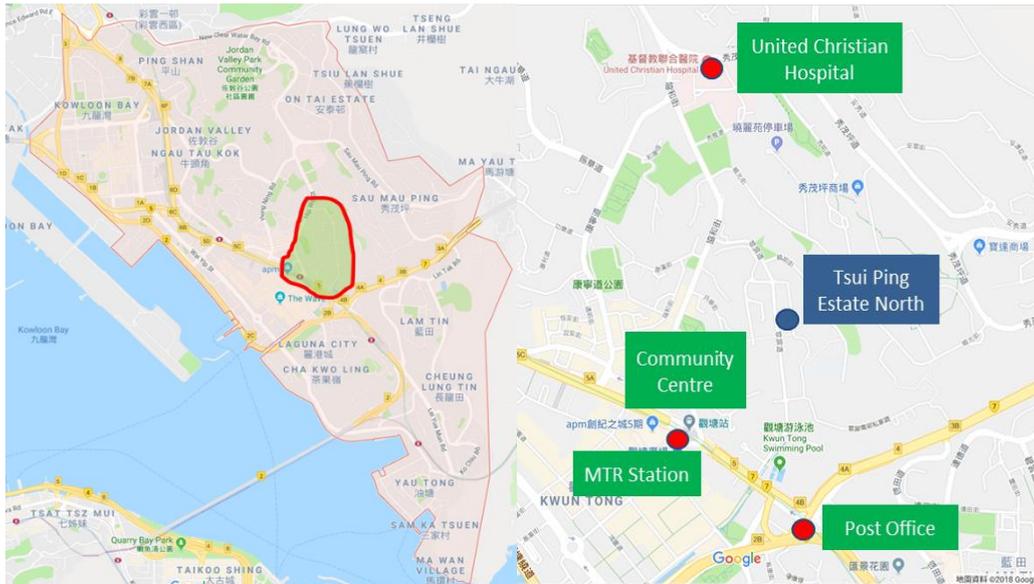


Figure 9: Geographical Boundary and Surrounding Facilities of Tsui Ping Estate North

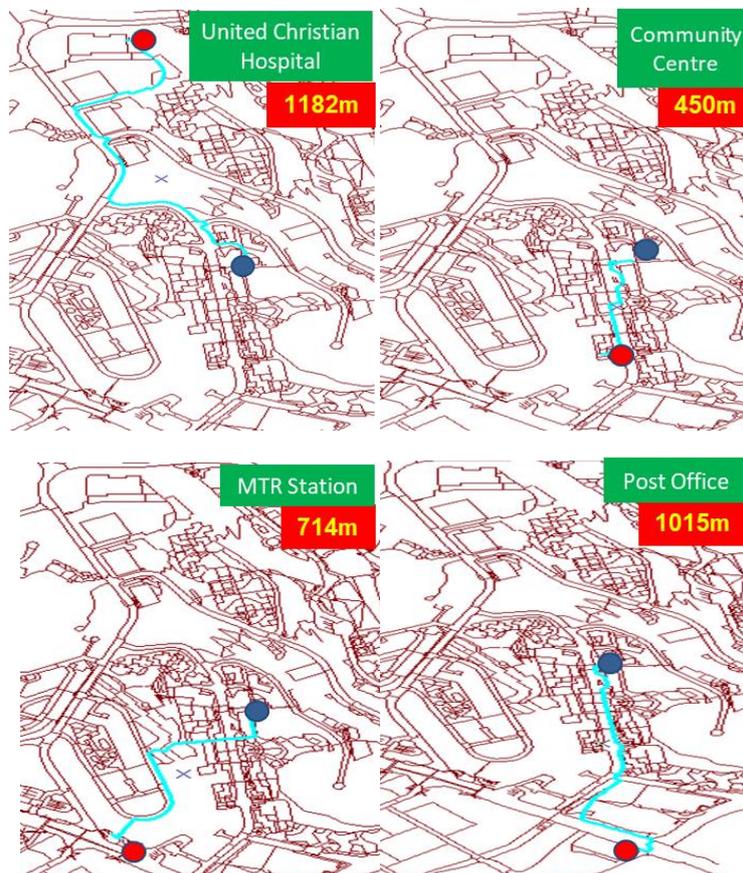


Figure 10: Walking Distances Between Tsui Ping Estate North (Blue Dots) and its Surrounding Community Facilities (Red Dots)

3.2.2.3 Construction of BIM Model

To capture the existing walkability of TP-North, two field surveys were conducted in late September 2018 and early November 2018 respectively. Our first visit aimed at a walkthrough

along the possible paths in TP-North to examine its regional connectivity. The locations of mobility facilities in TP-North were recorded, as summarized in **Figure 11**. Some mobility facilities include elevators, escalators, stairs and ramps. A major walkability problem in TP-North was found, i.e. there were many stairs but only few elevators. This significantly hindered the vertical movement of residents, which was problematic since the topography of TP-North was composed of multiple floor levels and steep slopes. Therefore, it was considered crucial to analyze the existing walkable network of TP-North. To this end, construction of a 3D BIM model was targeted to facilitate such spatial analysis.

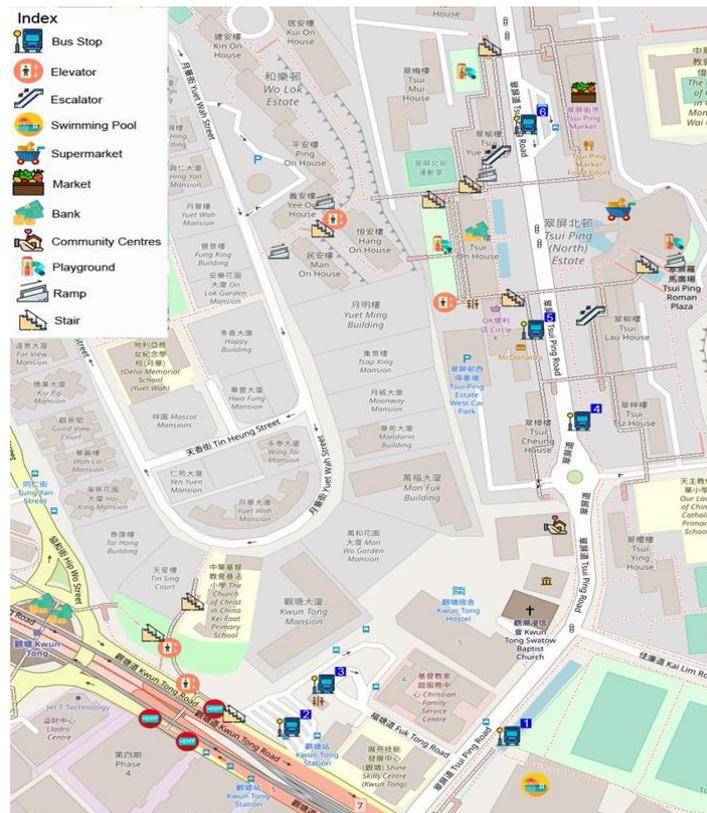


Figure 11: Locations of Mobility Facilities in Tsui Ping Estate North

Upon our BIM model construction, a BIM-based data model has been developed to summarize the walkability attributes to be encoded, as tabulated in **Table 5**. Each facility type owns a specific list of attributes. This data model served as our reference and governed how detailed our modeling should be.

Table 5: BIM-based Data Model for the Attributes of Each Facility Type

Walkway	Stair	Escalator	Elevator	Ramp	Footbridge	Crossing	Pseudo crossing
Width	Width	Width	Acceleration	Width	Width	Pedestrian green time	
Slope	Number of steps	Moving direction	Waiting time	Slope	Covered	Pedestrian red time	
Covered	Rise of each	Moving speed	Door open duration			Unsignalized with zebra	

	step					marks	
Air-conditioned	With railing	Opening hour					
Opening hour							
Near garbage room							
Lighting condition							

From early October 2018 onwards, a BIM model of the Tsui Ping Commercial Complex inside TP-North was being built for our network analysis. Some references for our model building included the facility location aforementioned, floor plans available inside TP-North, as well as architectural drawings from the HeBROS website under the Housing Department. In our BIM model, the topography of TP-North was reconstructed with three discrete levels in our model. **Figure 12** shows the defined levels, associated facilities and realistic appearance of the Tsui Ping Commercial Complex. Having built a preliminary model with approximate geometry and envelop layout, our second visit to TP-North in early November 2018 aimed to collect more detailed geometry measurement, such as widths of corridors and step counts of stairs. It is considered that a model with precise geometry is important for walkability analysis. For example, a narrow corridor could strictly block the movement of disabled persons with wheelchairs. A precise digital model would enable a realistic analysis of the pedestrian network. Therefore, our BIM model targeted at accurate geometric layout.

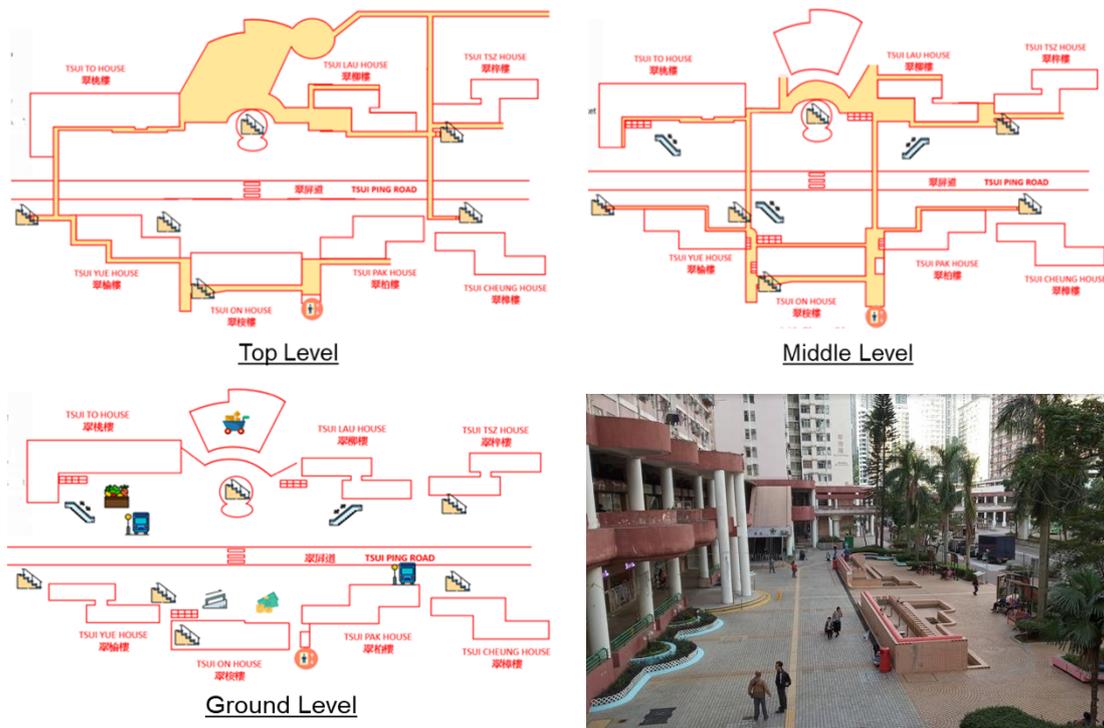


Figure 12: Floor Plans and Actual Appearance of the Three Levels in our BIM Model

Our BIM model was constructed with a software named Autodesk Revit, which has been one of the most common BIM modeling tools. The model could be exported to different file formats

such as 3D AutoCAD. **Figure 13** shows an overview of our BIM model of TP-North, which covered the walkway around TP Road, spanning from the TP Commercial Complex to Kwun Tong Community Centre.

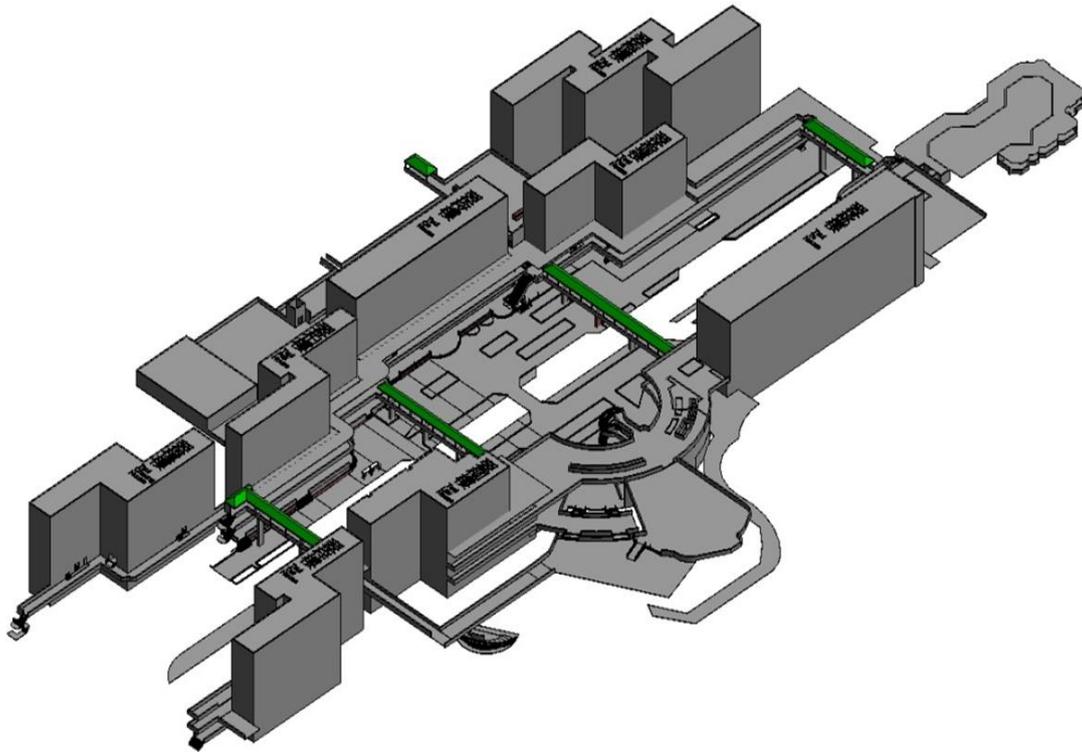


Figure 13: Overview of our BIM Model of Tsui Ping Estate North

Regarding its level of details, the residential buildings were represented by rectangular boxes because our concerned walkable network mainly covered the public space around these buildings, such as corridors inside the Tsui Ping Commercial Complex. In particular, the major walkways, mobility facilities and auxiliary furniture that potentially influence pedestrian movement are modeled as precise as feasible. For example, stair steps with or without railing and the width of elevator door were reconstructed in details, in order to accurately reflect the realistic comfort level of pedestrians when accessing them. Nevertheless, for the buildings, mainly the exterior envelopes of the building blocks were sketched at their corresponding locations. Walking areas inside residential apartments were not modeled.

3.2.2.4 BIM Modeling with Extended Study Area

Based on the methodology and experience of BIM modeling in our pilot area, the coverage of our BIM model has been extended to enable a wider-scale walkability analysis. **Figure 14** and **Figure 15** respectively show the topographic boundary and a screenshot of our latest BIM model constructed in Autodesk Revit. The model mainly covers the TP-North Commercial Complex, Kwun Tong MTR station, Kwun Tong seafront (South side) and Ngau Tau Kok MTR station (West side). Such an extended study area has enabled a more valuable walkability analysis among several points-of-interest (PoIs), including the residential TP Estate, commercial and leisure zones to the Kwun Tong south, as well as facilities within two neighboring MTR stations.



Figure 14: Coverage of the Latest BIM Model Constructed

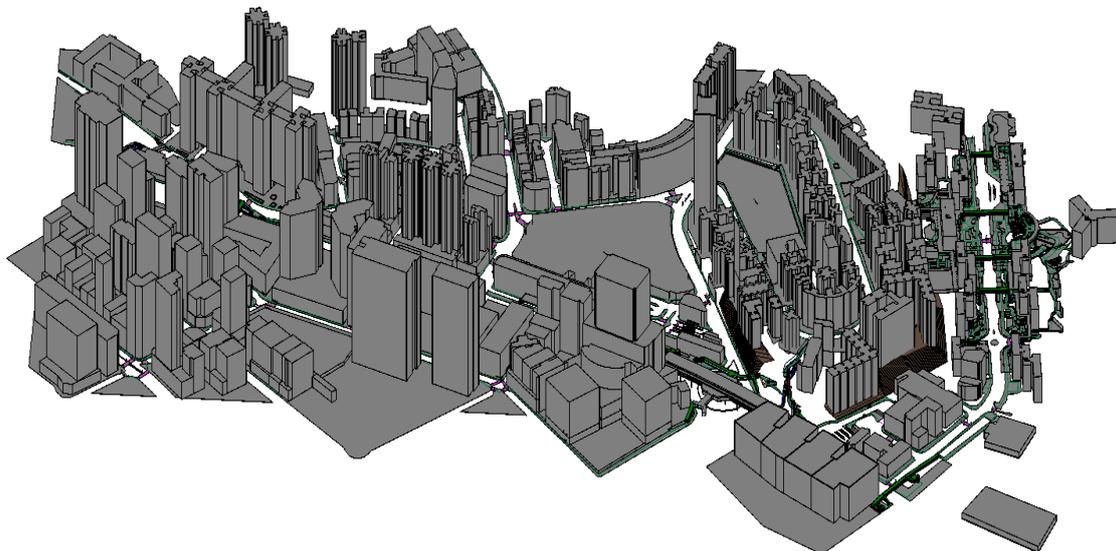


Figure 15: Overview of the Latest BIM Model in Autodesk Revit

Although walking areas inside residential apartments were not modeled, the indoor walkable paths inside plazas where people could go to/from MTR stations have been included. For example, the walkways and stairs inside APM plaza that link the MTR station and outdoor ground level have been modeled. The geometric and semantic correctness of our BIM model have been validated by the 1:1000 street maps from Lands Department, as well as our comprehensive field measurement with the walkability-related facilities located.

3.2.2.5 Construction of 3D Walkability Network

Based on the constructed BIM model, a 3D walkability network is generated to represent the geometric connectivity and walking attributes of the study area. Literature review has been conducted to investigate some existing methods of network representation. In particular, Medial Axis Transform (MAT) was adopted because its representation can intuitively describe the attributes of walking facilities (Teo and Cho 2016). Generally, each facility or area is first

represented by its center point, and then a full network is formed by linking up these points by straight lines. **Figure 16** illustrates some generic examples of network produced by MAT.

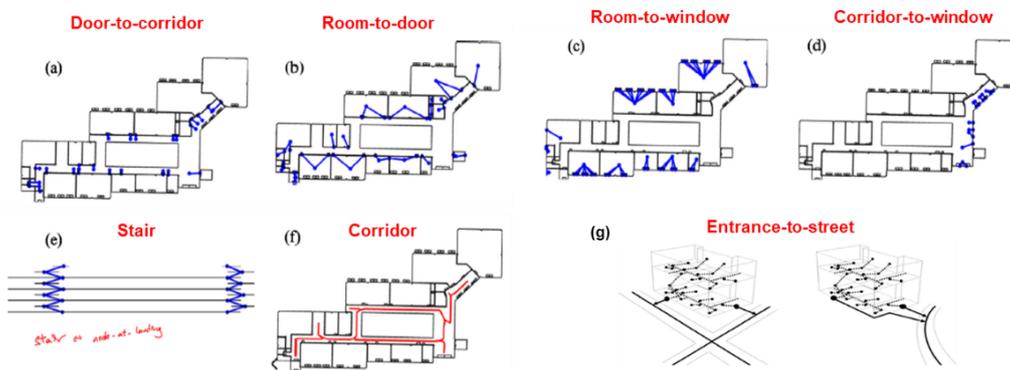


Figure 16: Generic Examples of Network Representation by Medial Axis Transform

For efficiently generating the network, a plugin is developed with Dynamo, the application programming interface (API) in Autodesk Revit. **Figure 17** illustrates the interface of our plugin used in the modeling environment, with the following procedures: Modelers first place the necessary nodes over the BIM model. Then, with the plugin, a pair of nodes and the appropriate facility type for linking the nodes are selected. Revit family templates are pre-defined for each type of network, which could be easily selected by modelers to construct. Such object-oriented management of BIM components greatly smoothen the network construction process. Eventually, the whole network and corresponding attributes is generated effectively.

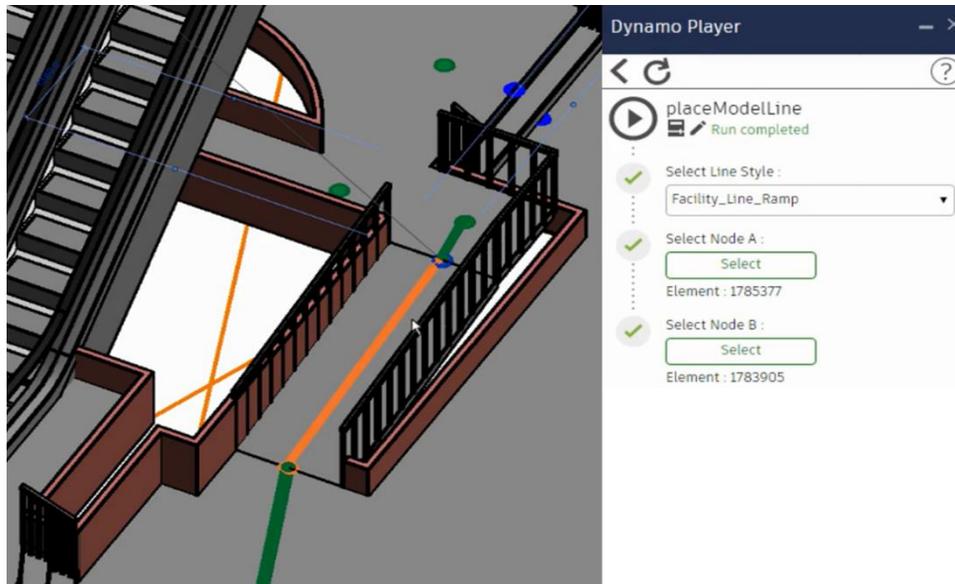
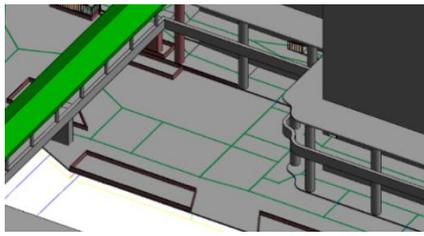


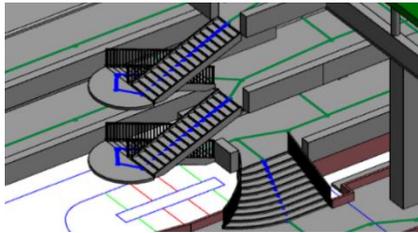
Figure 17: Interface of the Developed Dynamo Plugin for Network Generation

Based on the MAT method and our Dynamo plugin, a 3D walkability network has been constructed, with the same topographic coverage as our BIM model. **Figure 18 (a)-(f)** illustrate some examples of network produced for each facility type. A full network was constructed which captures the geometry and connectivity of the walking areas. A sample snapshot of our MAT network encoded in Autodesk Revit is illustrated in **Figure 19**, where each type of line segment stores a specific list of attributes. By integrating these attributes with the connectivity,

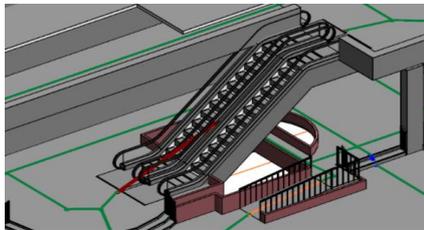
our completed network describes the walkability of a study area.



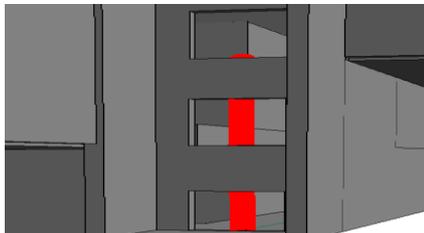
(a) Walkways (in green lines)



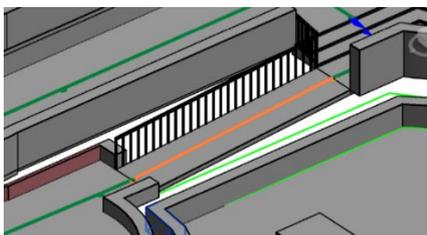
(b) Stairs (in blue lines)



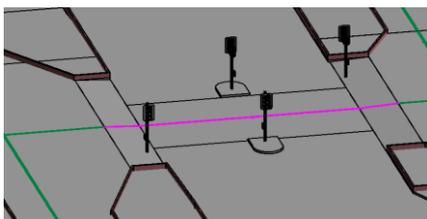
(c) Escalators (in brown lines)



(d) Elevators (in red lines)



(e) Ramps (in orange lines)



(f) Crossings (in purple lines)

Figure 18(a)-(f): Examples of Each Facility Category in our 3D Walkability Network

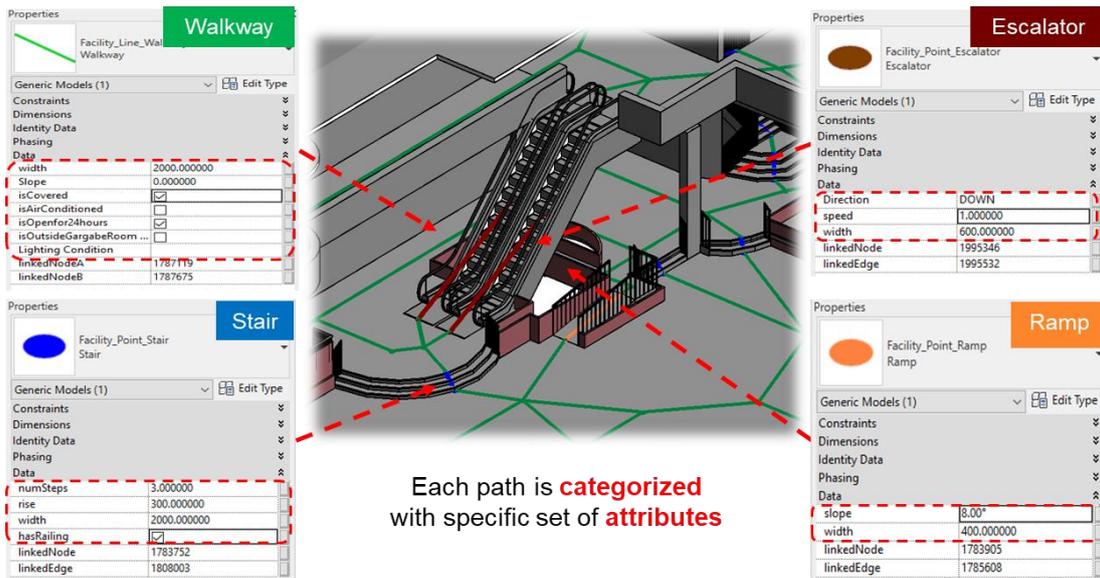
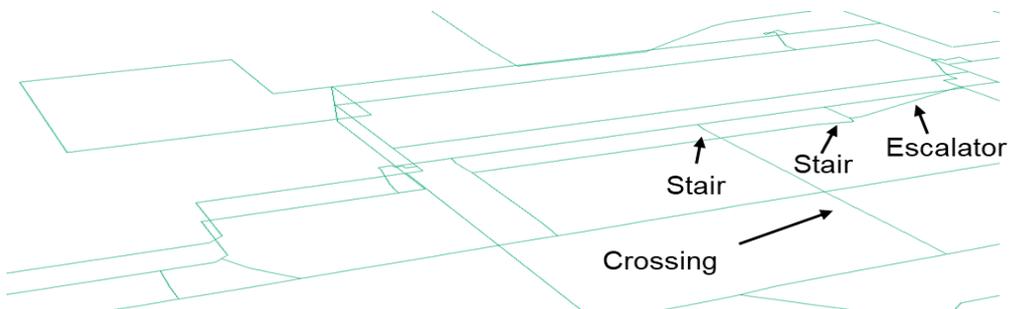
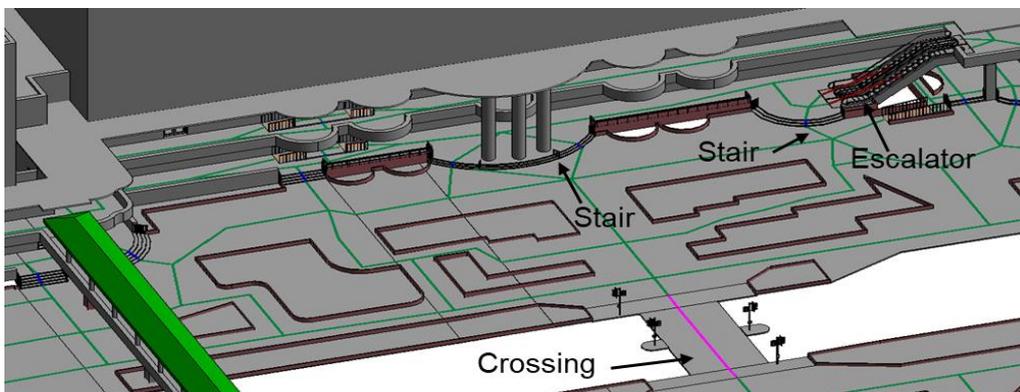


Figure 19: Sample Snapshot of the MAT Network

The HKU team of Task 2 has also constructed a 3D walkability network (Sug et al. 2018), based on 3D GIS methodology. Hence, their GIS network is compared with our BIM network. **Figure 20** illustrates a sample snapshot of the same area, built with the two methodologies respectively.



(a) 3D GIS Network



(b) 3D BIM Network

Figure 20(a-b): Comparison between GIS and BIM Networks

3.2.2.6 Walkability Scoring

The completed network consists of many intermediate nodes which are connected by links. Given any pair of origin and destination points, different paths can be formed by walking through a series of connected links. Since each single link stores the walkability attributes for its corresponding type of facility, the walkability of a path can be quantified by summing over all the associated links. Subsequently, by comparing the walkability values of different paths, the ‘least-cost’ path between any 2 points can be computed. In our analysis, the walking cost of a path is quantified as time in minutes, as shown in **Equation (1)**. It sums up the cost of every link associated with the path. Considering a particular pedestrian on the i^{th} link, $\frac{d_i}{v_i}$ denotes the actual walking time, while t_i accounts for any additional time spent, e.g. waiting for elevators or crossings. The sum of these two values denotes the actual time spent on a link. Furthermore, β_i is the utility factor that describes any extra cost of walking along a link, e.g. no overhead cover in case of adverse weather. With the utility factor imposed on a link, the resulting cost represents the perceived time spent. The total cost of a path T is the sum over a number of L links that are associated with the path.

$$T = \sum_{i=1}^L (\beta_i * \frac{d_i}{v_i} + t_i) \quad (1)$$

T is the walking cost of a path of a particular pedestrian (in minutes), where for the i^{th} link:

- d_i is the length, i.e. walking distance
- v_i is the moving speed of a pedestrian
- t_i is the additional time spent other than walking
- β_i is the utility factor

In Equation (1), the two variables v_i and β_i describe the behaviors of different pedestrian groups. For example, along the same walkway, the physical and perceptual characteristics of normal people could be very different from wheelchair users. Therefore, to account for the group-specific characteristics, literature review was conducted to estimate appropriate values of these parameters. **Table 6** summarizes the estimated moving speeds along walkways and stairs, while **Table 7** summarizes that along ramps of different slopes. The discomfort factors for different pedestrian groups are summarized in **Table 8**.

Table 6: Estimated Moving Speeds of Different Pedestrian Groups (Buchmüller and Weidmann 2006; Karmarkar et al. 2011)

Pedestrian Group	Moving Speed (m/s)		
	Walkway	Stair (upwards)	Stair (downwards)
Normal people	1.19	0.68	0.78
Elderly without wheelchair	1.06	0.61	0.69
Wheelchair user	0.70	N/A	N/A

Table 7: Estimated Moving Speeds of Different Pedestrian Groups along Ramps (Buchmüller and Weidmann 2006; Karmarkar et al. 2011)

Pedestrian Group	Moving Speed (m/s)					
	$\geq 2.86^\circ$		$\geq 5.71^\circ$		$\geq 8.53^\circ$	
	Up	Down	Up	Down	Up	Down
Normal people	1.15	1.24	1.07	1.25	0.98	1.26
Elderly without wheelchair	1.02	1.11	0.95	1.12	0.87	1.12
Wheelchair user	0.67	0.73	0.63	0.74	0.58	0.74

Table 8: Estimated Discomfort Factors for Different Pedestrian Groups under Different Weather Conditions (Barker 2012; Chan et al. 2006)

Pedestrian Group	Discomfort Factor		
	Cloudy	Sunny	Rainy
Normal people	1.00	1.03	1.05
Elderly without wheelchair	1.00	1.15	1.35
Wheelchair user	1.00	1.15	1.35

As for moving speeds, the slower speeds along stairs lead to higher walking cost on the stair links which are to be avoided as much as possible in path searching. Specifically, the zero speed along stairs for wheelchair users constitutes an infinitely high cost, i.e. strictly non-walkable. As for the utility factors, only the discomfort along non-covered walkways due to adverse weather is considered currently, including cloudy, sunny and rainy conditions. With ‘cloudy’ being the baseline, the higher values for ‘sunny’ and ‘rainy’ impose extra discomfort on all the non-covered walkways. Compared with normal people, higher values of utility factor were imposed on elderlies and wheelchair users. This suggests that these pedestrian groups are perceptually more sensitive to adverse weather, such that the path searching for them might aim at covered walkways as much as possible.

3.2.2.7 Pedestrian Flow Simulation

To simulate the movement of different pedestrian groups, an existing simulation software called Pathfinder developed by the Thunderhead Engineering was utilized. Our BIM model was imported to Pathfinder as a 3D CAD file. The walkable floors, rooms, as well as possible origins and destinations were manually defined on top of the imported geometry. The pedestrian flow distribution among them was tabulated. For example, pedestrians alighting at the bus stop in TP-North Estate on the ground floor were uniformly distributed to different POIs, such as the market upstairs and different residential building blocks nearby.

Pathfinder supports agent-based definition of walking behaviors, including walking speed and

route choice constraint (Thunderheadeng.com, 2019). A set of behavior profiles were defined, each representing a type of pedestrians with specific walking behaviors and accessibility to different facilities. Specifically, the aforementioned moving speeds of different pedestrian groups were encoded accordingly, such that each pedestrian agent may exhibit different walking characteristics in the simulation environment. Furthermore, the constraints that determine the route selection logic of a particular pedestrian group were also encoded. For example, a disabled person with wheelchair does not prefer escalators and stairs, thus never chooses such paths. Hence, before the simulation, the candidate paths that are inaccessible to each pedestrian group were programmed.

Upon actual simulation, the path accessibility also depends on the geometric layout of certain facilities. An interesting example is shown in **Figure 21**, the passage next to the ramp and escalator was too narrow for wheelchairs to pass through, which naturally blocked the wheelchair movement, and the person needed a detour around there to continue the journey. For more examples, the door gap of an elevator may be too narrow for a wheelchair, or the slope of a ramp may be much steeper than the barrier-free design standard. Even though elevators and ramps favor the access of wheelchairs, the facility attributes eventually may disable the path accessibility. Through our pedestrian flow simulation in a digital environment, the walking path of a particular pedestrian agent is obtained for subsequent analysis.



Figure 21: Example of Inaccessible Facilities Observed from Pedestrian Simulation

3.3 Task 3 – Investigating walking behavior

Task 3 aimed to investigate the determinants of walking behavior and develop walking utility functions for analyzing key policy interventions to promote walkability.

3.3.1 Walking attributes

Based on a review of previous studies as well as an assessment of the situation in Hong Kong, we first defined a list of walking attributes that would influence walking behavior, as listed in **Table 9**. The walking attributes can be classified mainly into three categories, i.e. Physical, Safety, and Aesthetic. The physical category covers the type of physical infrastructure, dimensions, connectivity etc. While the safety category includes people perception of the safety environment, such as traffic safety and personal safety of the walking facility. The aesthetic category captures the environmental aspects of walking, such as greenery, water and artificial elements.

Table 9. Preliminary Walking Attributes (Influential in bold)

Attributes	Factors	Description
Physical	Type of infrastructure	Infrastructure type Examples: Footbridges / underground tunnels / zebra crossing / Signal / Stairs
	Dimensional	Physical dimensions Examples: Width, Length , depth, Slope , height, etc.
	Connectivity with other places or infrastructures	Connection with other places (e.g., business district and residential district) or infrastructures (e.g., industrial and commercial buildings) Examples: MTR station / office building / shopping mall
	Ease of access (accessibility)	Walking-supporting facilities Examples: Escalator / Elevator / walking sideway / Ramp / Dropped Kerb / Stair Lift
	Amenities	Facility or protection measure Examples: air-conditioned / Coverage / toilet / cycling facilities / seat / etc.
Safety/ security	Traffic safety	Modal conflict and accident rate Example: pedestrians mix with automobile and bicycle/ crossing with or without light/etc.
	Personal safety	Safety of pedestrian Examples: street lighting/ fences (metal, concrete)/etc.
Aesthetic	Water	Location near water Examples: sea / river / lake / etc.
	Greenery	Area of greenery Examples: evergreen trees / annuals / etc.
	Artificial elements	Man-made attractiveness Examples: store / park / street landscaping / etc.

We then narrowed the list of attributes and extract the influential attributes from the full list. The list of influential attributes is crucial for the survey design and development of the integrated BIM-3DGIS platform. The list was defined to strike the balance between the level of details to be captured as well as the computational burden in coding the integrated BIM-

3DGIS platform.

To better define the representative user groups in the study areas, before conducting the surveys, we conducted community interviews with district leaders, including the former Chairs of the Traffic and Transport Committees in the District Councils of Kwun Tung and Tsuen Wan, Ms. Ann So and Mr. Peter Lo, on 16 July 2018 and 20 July 2018, respectively. Two meetings were arranged to collect views and special needs of the aged and people with disability. The research team interviewed four physical disabled (wheel-chaired) people at Hong Kong Society for Rehabilitation on June 28, 2018. Special needs were identified including self-service and barrier-free facilities. Another interview was carried out with the elderlies (over age 80) at St. James' Project Care Neighborhood Elderly Centre on July 5, 2018. These meetings and interviews helped identify the important attributes that should be considered in the walking behavior analysis in Task 3, and pinpointed the attributes that the other user groups, such as the elderlies and people with disabilities, cared the most.

After the meetings and interviews, we highlighted some important attributes, highlighted in bold in **Table 9**, including Footbridges, Signals, Stairs, Length, Slopes, Escalator, Elevator, Ramp, Dropped Kerb, Stair Lift and Top Coverage.

3.3.1.1 Preliminary Perception Survey

To obtain the responses from the general public, or the daily users in the pedestrian network, we conducted a preliminary survey in Kwun Tong area on 21st Oct 2018. The survey aimed to collect pedestrians' perceptions on the attributes and information on their paths. The survey was divided into three groups in three areas, namely in Tsui Ping Estate (residential area), Shui Wo Street Market (shopping area) and Kwun Tong Pier (recreational area). The interviewees were asked to indicate the actual path on a paper map, select and rank the walking attributes that they were most concerned about. The results showed that most pedestrians were reluctant to reveal their origins, destinations and paths due to privacy concerns. For the pedestrians who were willing to respond to the survey, they had difficulty of identifying their paths in the map. They were able to state a few points of interest, attractions or landmarks in the area that they were familiar with. Another finding was that the attribute list was too long for interviewees to respond to. These experiences helped us refine the survey to improve its accuracy and efficiency.

We made several improvements before conducting on-street perception survey. We modified the attribute list by adding classifications, as shown in **Table 10**, so that interviewees can clearly identify the class of attribute first, before looking into the detail. An online survey platform, called "Qualritcs", was developed to facilitate the survey method. The platform enabled interviewees to point their paths in a tablet, where the level of detail in the map can be manually adjusted by zooming in or zooming out. The path data could be extracted to an excel format to save effort for data input. A briefing session was also held before the survey to ensure that all interviewees were familiar with the area. We also developed another way to collect pedestrian path using mobile application (app) with Global Positioning System (GPS) called "Goaway". The Goaway app was a free app that was widely available in the mobile app market, but it is not available now. It recorded the positions of the paths in longitude and latitude in near five seconds interval using GPS, providing path data with satisfactory accuracy. We then

extracted the walking trajectories as GPX file.

Table 10. Walking Attributes

<u>1. Distance/ Time</u>				
1.1 Shortest Distance (Rank: 1)	1.2 Pedestrian signal waiting time (2)	1.3 Lift waiting time		
<u>2. Pedestrian Facilities</u>				
2.1 Footbridge or Tunnel (6)	2.2 Escalator (7)	2.3 Elevator	2.4 Slope (3)	2.5 Number of Stairs
<u>3. Facilities</u>				
3.1 Bus stop/MTR station (4)	3.2 Shops / convenient store / fast food restaurant	3.3 Shopping Mall	3.4 Park / Greenery	3.5 Waterfront / Attractions
3.6 Bench	3.7 Washroom			
<u>4. Safety</u>				
4.1 Barrier	4.2 Pavement	4.3 Traffic signal / Safety island / Zebra crossing (8)	4.4 Lighting	4.5 Construction work nearby
<u>5. Sidewalk</u>				
5.1 Width (10)	5.2 Traffic	5.3 Pedestrian Traffic (5)	5.4 Noise level	5.5 Cover
5.6 Air-conditioned	5.7 Hygiene (9)			

3.3.1.2 On-street Perception Survey

On 22nd Jan 2019, we conducted a detailed on-street survey using the online survey form (can be found via: <http://bit.ly/hkust-survey>, in traditional Chinese). Interviewees were asked about their origins, destinations, and the paths taken via the map shown in the tablet. The survey also recorded their preferences on the walking attributes as well as the respondents' social demographic information. A total of 66 data points was collected.

3.3.1.3 Walking surveys distributed to Schools

Using the online survey developed, the survey was sent to secondary schools in the Kwun Tong area to invite their students' participation in the survey. One important note is that the survey not only covered students, but also their family members for filling in the survey. The survey forms were either distributed in paper form or the online form based on schools' preferences

(the online form can be found via: <http://bit.ly/hkust-survey>, in traditional Chinese). In total, 12 secondary schools in Kwun Tong were contacted and two schools were willing to distribute the survey to their students. Combining the on-street survey conducted in Jan 2019, we collected a total of 337 survey responses. In addition, the online survey asked respondents to provide their last walking trip in Kwun Tong by plotting its path using dots on a map. The dots were then mapped to the nearest link in our GIS network discussed in **Section 3.3.2.1**.

The online survey developed for Kwun Tong area was also sent to eight secondary schools and four primary schools in the Tsuen Wan area. Using the similar approach in Kwun Tong, the survey was intended to distribute in paper form or the online form based on schools' preferences (the online form can be found via: https://ust.az1.qualtrics.com/jfe/form/SV_3VjriyIHFwxaDs1, in traditional Chinese). However, we have received no responses from the schools possibly due to the outbreak of COVID-19 in the 2020 year.

3.3.1.4 Statistical analysis of the Walking Perception Surveys

As shown in **Table 10**, a total of 27 walking attributes, grouped in five categories, were considered in the on-street walking surveys conducted on 22nd Jan 2019 as well as in the survey distributed to the participating secondary schools. The survey asked respondents to rank the five most important and five most unimportant attributes that they consider in their walking trips. The first ranked attribute is assigned a score of 5, and a score of 4 for the 2nd attribute, and so on. From the survey, we found that the top ten most important attributes (shown on the left hand side of **Table 11**) are: (1) Shortest Distance, (2) Pedestrian signal waiting time, (3) Slope, (4) Bus stop/MTR station, (5) Pedestrian Traffic, (6) Footbridge or Tunnel, (7) Escalator, (8) Traffic signal / Safety island / Zebra crossing, (9) Hygiene and (10) Width. Among the important attributes, “shortest distance” is the most important attribute with a score much higher than those of other attributes. The other important attributes are mostly related to the physical attributes or infrastructure type, such as slope, bus stop, footbridge, escalator and width. The ten unimportant attributes (shown on the right hand side of **Table 11**) include: (1) Bench, (2) Lift waiting time, (3) Air-conditioned, (4) Pedestrian signal waiting time, (5) Waterfront / Attractions, (6) Washroom, (7) Park / Greenery, (8) Lighting, (9) Traffic and (10) Footbridge or Tunnel. Surprisingly, the attributes, Pedestrian signal waiting time and Footbridge or Tunnel appear on the top 10 of both important and unimportant lists. It can be concluded that there are diversified opinions in the Kwun Tong area regarding the above attributes.

Table 11. Survey results: Ranking of (a) important and (b) unimportant walking attributes

Attributes Based on most important attribute score	Score	Attributes Based on most unimportant attribute score	Score
1.1 Shortest Distance (1)	2394	3.6 Bench	498
1.2 Pedestrian signal waiting time (2)	261	1.3 Lift waiting time	443
2.4 Slope (3)	192	5.6 Air-conditioned	299
3.1 Bus stop/MTR station (4)	192	1.2 Pedestrian signal waiting	290

5.3 Pedestrian Traffic (5)	122
2.1 Footbridge or Tunnel (6)	116
2.2 Escalator (7)	116
4.3 Traffic signal / Safety island / Zebra crossing (8)	113
5.7 Hygiene (9)	93
5.1 Width (10)	89
1.3 Lift waiting time	88
5.5 Cover	84
3.2 Shops / convenient store / fast food restaurant	77
2.3 Lift	64
4.4 Lighting	56
4.1 Barrier	52
2.5 Number of Stairs	51
4.2 Pavement	50
5.2 Traffic	50
3.4 Park / Greenery	40
3.7 Washroom	40
3.3 Shopping Mall	34
5.4 Noise level	29
4.5 Construction work nearby	28
5.6 Air-conditioned	19
3.5 Waterfront / Attractions	10
3.6 Bench	10

time	
3.5 Waterfront / Attractions	260
3.7 Washroom	212
3.4 Park / Greenery	160
4.4 Lighting	140
5.2 Traffic	128
2.1 Footbridge or Tunnel	124
4.5 Construction work nearby	109
5.4 Noise level	109
5.1 Width	102
3.2 Shops / convenient store / fast food restaurant	99
2.4 Slope	97
3.1 Bus stop/MTR station	96
2.2 Escalator	91
2.5 Number of Stairs	90
4.1 Barrier	81
3.3 Shopping Mall	77
2.3 Lift	75
4.3 Traffic signal / Safety island / Zebra crossing	67
5.7 Hygiene	60
4.2 Pavement	53
5.5 Cover	46
5.3 Pedestrian Traffic	27
1.1 Shortest Distance	21

Remark: The attributes were scored in a scale from 1 to 5, where score 5 refers to the case when the respondent ranked as the most important attribute, and score 1 refers to the 5th important attribute. This scoring applies to the unimportant attributes on the right-hand-side table.

3.3.2 Walking behavior analysis

3.3.2.1 Kwun Tong GIS pedestrian network

A two-dimensional (2D) GIS pedestrian network of Kwun Tong was created by Task 2 originally before the 3D GIS pedestrian network. A screenshot of the network GIS file is shown in **Figure 22**. The network, centered at the Kwun Tong Downtown, was enclosed by the Sau Mau Ping Road from the north, Tseung Kwan O Road from the east, Hong Ning Road from the west and Kwun Tong Pier from the south. The possible pedestrian walking links in the defined area were captured and classified into 19 walking attributes, as shown in **Table 12**. The 19 walking attributes were classified into seven categories based on their characteristics.



Figure 22. Two dimensional (2D) Kwun Tong GIS pedestrian network

Table 12. Walking attributes in the 2D GIS network

Group	Attributes	Description	Total number of links
1. Sidewalk			369846
	Sidewalk	Paths along the two sides of a road centerline	238631
	PedBusTerminal	Network in bus terminals	147
	PiOpenSpace	Paths on the pavements in open space	13119
	PiOpenSpaceOthers	Paths in open space expect for those on the pavement	105557
	PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof	11543
	Ramp	A sloping surface joining two different levels of height	849
2. Steps			35631
	M_Step	To join two features with different levels of height	3970
	POSStep	Steps in open spaces	19826
	POSStepRoof	Steps on building's roof	684
	Step	To join two features with different levels of height	4747
	StreetStep	Steps on the hilly surface	6404

3. Crossing	PedCross	A place designated for pedestrians to cross a road	49862
4. Footbridge			25425
	Footbridge	A bridge designed to be used by pedestrians	15696
	M_PlatformLine	The paths in the underground before entering into the metro system	3121
	M_SidewalkLink	Linking the exit of the metro station with the sidewalk	3851
	VirtualPIN	The indoor network of a publicly accessible building by linking the entrances of the building and centre of the building.	2757
5. PseudoLink	PseudoLink	The pseudo crossing is at places the pedestrian would actually use to cross but not indicated with a zebra in the road marking data, and there is a break in the fences of both sides of a road.	24406
6. Escalator	Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building	1016
7. Tunnel	PedeTunnel	A road for pedestrian passing under another road	255

A three-dimensional (3D) GIS pedestrian network of Kwun Tong was later developed by Task 2, as shown in the **section 3.2.1.1. Figure 23** shows the pedestrian network in Kwun Tong area, which covers a larger area than in the 2D GIS network. The network covers from north to Choi Hung, west to the Kwun Tong promenade and Kowloon Bay Area, south to Yau Tong, and east to On Tat Estate. The difference between 2D and 3D GIS network is that elevation information of the attribute is recorded. Based on the classification in 2D GIS network, 22 walking attributes in the 3D GIS network are grouped in 8 categories, listed in **Table 13**. Walking attributes in Kwun Tong 3D GIS network

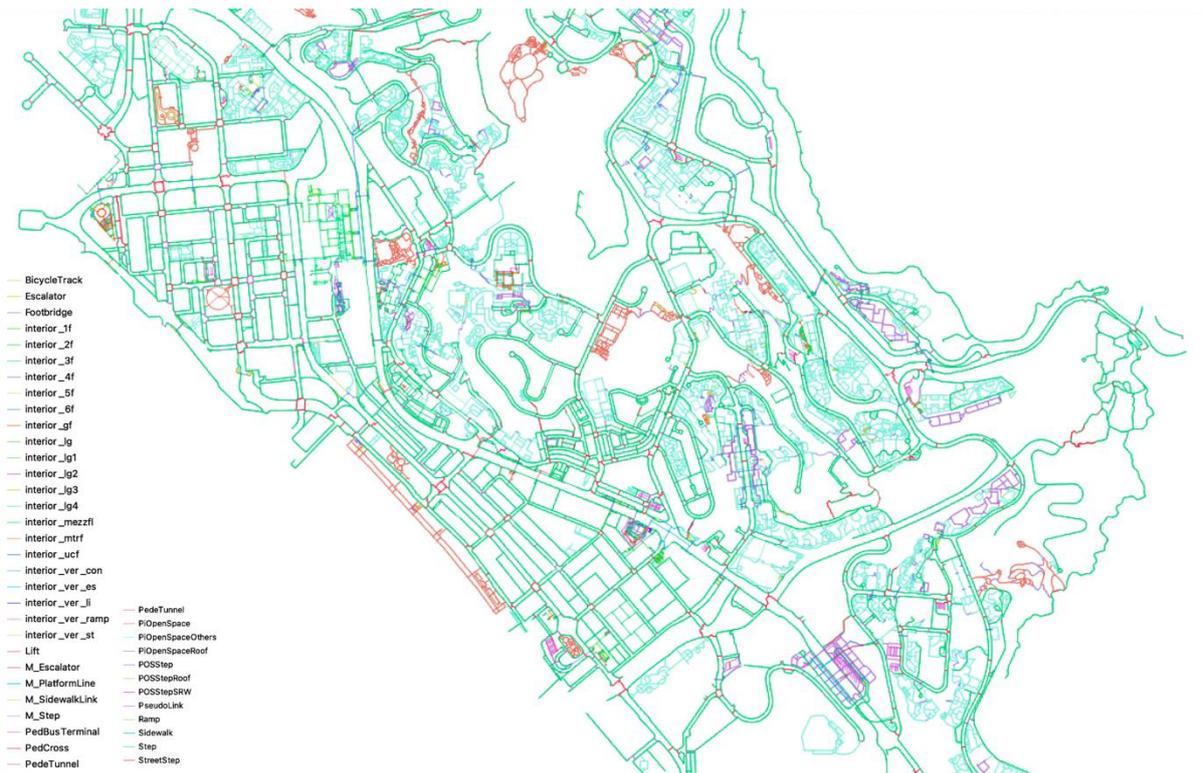


Figure 23. Three dimensional (3D) Kwun Tong GIS pedestrian network

Table 13. Walking attributes in Kwun Tong 3D GIS network

Grouping	Pedestrian network types and height levels	Category description	Number of links
1. Sidewalk			
Level_0	BicycleTrack	Bicycle lanes	295
	Sidewalk	Paths along the two sides of a road centerline	74957
	PedBusTerminal	Network in bus terminals	1950
	PiOpenSpace	Paths on the pavements in open space	55415
	PiOpenSpaceOthers	Paths in open space expect for those on the pavement	39964
	M_SidewalkLink	Linking the exit of the metro station with the sidewalk	94
	Ramp	A sloping surface joining two different levels of height	1201
Level_2	PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof	6089
2. Steps			
Level_0	StreetStep	Steps on the hilly surface	1011
	POSStep	Steps in open spaces	2717
Level_1	Step	To join two features with different levels of height	5241

Level_2	POSStepRoof	Steps on building's roof	235
Level_L1	M_Step	Step connecting the ground and metro underground	154
3. Crossing			
Level_0	PedCross	A place designated for pedestrians to cross a road	3135
4. Footbridge			
Level_1	VirtualPIN	The indoor network of a publicly accessible building by linking the entrances of the building and centre of the building.	0
Level_2	Footbridge	A bridge designed to be used by pedestrians	2832
Level_L3	M_PlatformLine	The paths in the underground before entering into the metro system	565
5. Pseudo Link			
Level_0	PseudoLink	The pseudo crossing is at places the pedestrian would actually use to cross but not indicated with a zebra in the road marking data, and there is a break in the fences of both sides of a road.	2626
6. Escalator			
Level_1	Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building	114
Level_L1	M_Escalator	Escalator connecting metro underground	92
7. Tunnel			
Level_L2	PedeTunnel	A road for pedestrian passing under another road	313
8. Elevator			
Level_1	Elevator	A type of vertical transportation that moves people or goods between floors of a building, vessel, or other structure.	0

3.3.2.2 Tsuen Wan GIS pedestrian network

Similar to Kwun Tong, a three-dimensional (3D) GIS pedestrian network of Tsuen Wan was developed by Task 2, as shown in **section 3.2.1.2. Figure 24** shows the pedestrian network in Tsuen Wan area, bounded from west to Belvedere Garden, south to Tsuen Wan Riviera Park,

east to Texaco Road, and north to Tsuen Kam Interchange. The main difference between the pedestrian network of Tsuen Wan and that of Kwun Tong is that there are multiple layers with different elevations in Tsuen Wan, such as ground floor and 1st floor linking to the complicated footbridge network. The walking attributes in the 3D GIS network are grouped in 10 categories, as listed in **Table 14**.

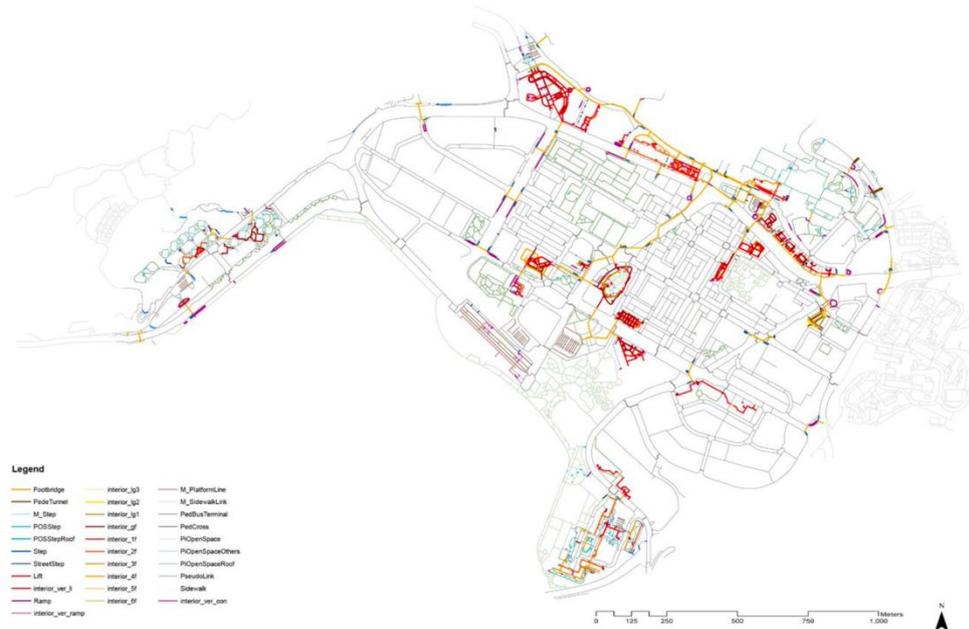


Figure 24. Three dimensional (3D) Kwun Tong GIS pedestrian network

Table 14. Walking attributes in Tsuen Wan 3D GIS network

Grouping	Pedestrian network types and height levels	Category description	Number of links
1. Sidewalk			
Level_0	Sidewalk	Paths along the two sides of a road centerline	21666
	PedBusTerminal	Network in bus terminals	687
	PiOpenSpace	Paths on the pavements in open space	11837
	PiOpenSpaceOthers	Paths in open space expect for those on the pavement	5634
Level_2	PiOpenSpaceRoof	Paths on pavements of the open spaces on building's roof	1609
2. Steps			
Level_0	StreetStep	Steps on the hilly surface	334
	POSStep	Steps in open spaces	367

Level_1	Step	To join two features with different levels of height	1357
Level_2	POSStepRoof	Steps on building's roof	94
Level_L1	M_Step	Step connecting the ground and metro underground	28
3. Crossing			
Level_0	PedCross	A place designated for pedestrians to cross a road	881
4. Footbridge			
Level_0	M_SidewalkLink	Linking the exit of the metro station with the sidewalk	32
Level_2	Footbridge	A bridge designed to be used by pedestrians	1386
Level_L3	M_PlatformLine	The paths in the underground before entering into the metro system	119
5. PseudoLink			
Level_0	PseudoLink	The pseudo crossing is at places the pedestrian would actually use to cross but not indicated with a zebra in the road marking data, and there is a break in the fences of both sides of a road.	843
6. Escalator			
Level_0	Escalator	A type of vertical transportation in the form of a moving staircase which carries people between floors of a building	18
Level_L1	M_Escalator	Escalator connecting metro underground	9
7. Tunnel			
Level_L2	PedeTunnel	A road for pedestrian passing under another road	21
8. Elevator			
Level_1	Elevator	A type of vertical transportation that moves people or goods between floors of a building, vessel, or other structure.	27
9. Interior Sidewalk			
Multiple Levels	interior_1f	The sidewalk in the indoor network in 1f	1525
	interior_2f	The sidewalk in the indoor network in 2f	1063
	interior_3f	The sidewalk in the indoor network in 3f	451

	interior_4f	The sidewalk in the indoor network in 4f	66
	interior_5f	The sidewalk in the indoor network in 5f	38
	interior_6f	The sidewalk in the indoor network in 6f	12
	interior_gf	The sidewalk in the indoor network in ground floor	1280
	interior_lg1	The sidewalk in the indoor network in lower ground 1f	181
	interior_lg2	The sidewalk in the indoor network in lower ground 2f	46
	interior_lg3	The sidewalk in the indoor network in lower ground 3f	43
	interior_ver_con	The sidewalk in the indoor network	1847
	interior_ver_st	The sidewalk in the indoor network	507
10. Ramp			
Level_0	Ramp	A sloping surface joining two different levels of height	530
	interior_ver_ramp	Ramp in the indoor network	55

3.3.2.3 Pedestrian path tracking survey in Kwun Tong

On 21st Jan 2019 in the early evening, we conducted a tracking survey to collect pedestrian walking paths using the mobile app called “Goaway” with the use of GPS. The interviewers, using their mobile devices with the app, randomly picked pedestrians and followed them in Kwun Tong. At one survey location, the interviewer randomly selected a pedestrian to follow, then terminated the tracking process when the pedestrian arrived at his/her destination (such as residential or commercial buildings), or outside a predefined boundary. The origin, destination, social demographics (e.g. gender, age) and personal characteristics (e.g., wearing headphone, carrying a trolley or heavy bag) were recorded. The interviewer then selected another pedestrian and tracked his/her path. A total of 148 pedestrian paths was collected using this app, and 50 additional paths from the survey distributed to the schools in Kwun Tong, adding total of 198 valid paths for further analysis. **Figure 25** shows the pedestrian trajectories in the 2D-GIS network in Kwun Tong. The actual path taken was mapped manually to the 2D GIS network based on the GPS data and the surveyor’s additional route information marked during path tracking, as shown as the blue line in **Figure 26 (a)**. **Figure 26 (b)** shows the shortest path given this OD pair, which, as can be seen, is different from the path used by that pedestrian.

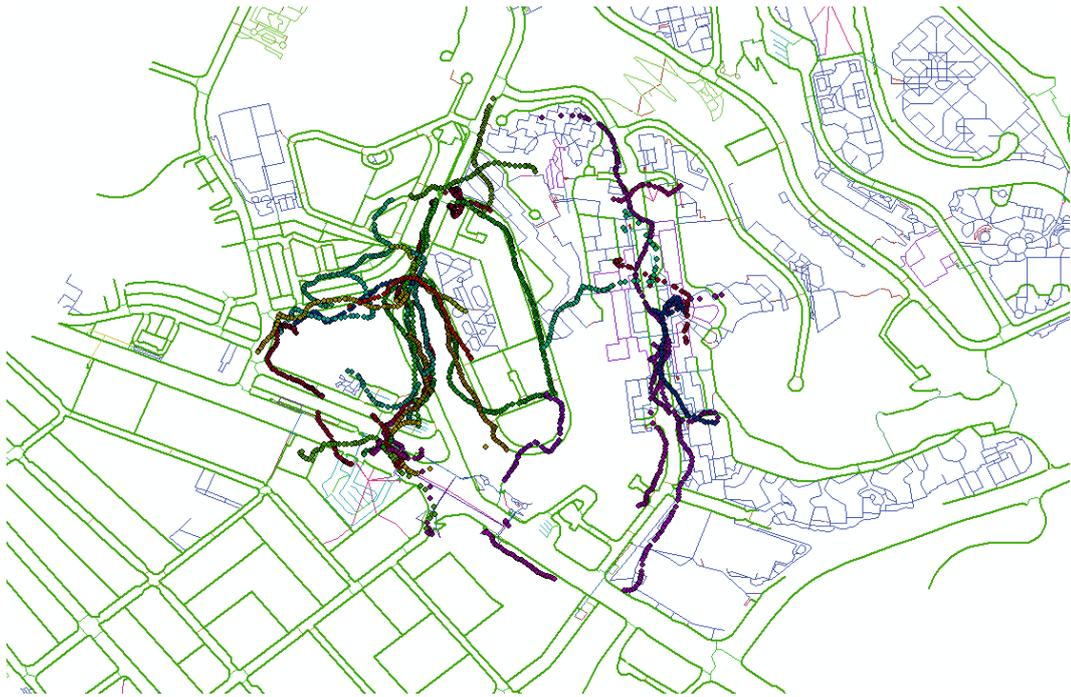


Figure 25. GPS data samples in the 2D Kwun Tong GIS network

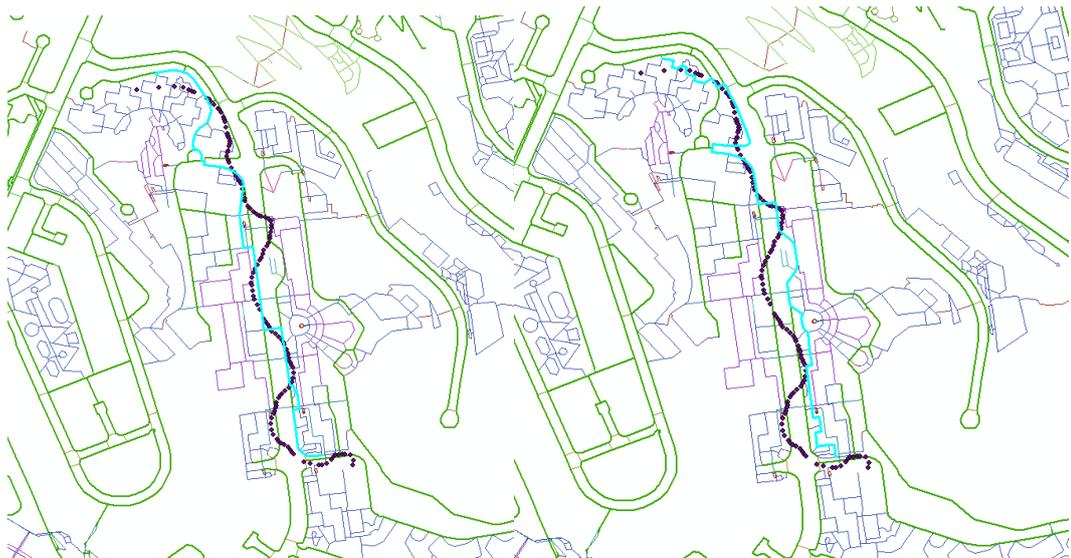


Figure 26.(a) A sample GPS data and its mapping to the 2D network, (b) the shortest path for this OD pair

3.3.2.4 Pedestrian path tracking survey in Tsuen Wan

Similar to the approach in Kwun Tong, we conducted a pedestrian path tracking survey in Tsuen Wan. The Tsuen Wan pedestrian network is completely different from that of Kwun Tong. It consists of several layers with different elevations, such as ground floor and 1st floor linking to the complicated footbridge network. The difficulty of deploying GPS tracking survey in Tsuen Wan was that GPS mobile application recorded only trajectories without elevation, indicating no information on which floor the pedestrian walks on. Because of the previous used mobile app “Goaway” is not available in the mobile application market now, we changed to

the mobile app “Relieve” which has the basic function of recording pedestrian trajectories using GPS, but also enables users to take photos on the surroundings and notes along the path. These data, trajectories, photos and notes will allow our surveyors to manually map the correct path with elevation in the 3D GIS map in the later stage. **Figure 27** shows 153 GPS trajectories (as continuous dots) collected during this period in the 3D Tsuen Wan GIS map and 147 trajectories are valid for our further analysis.

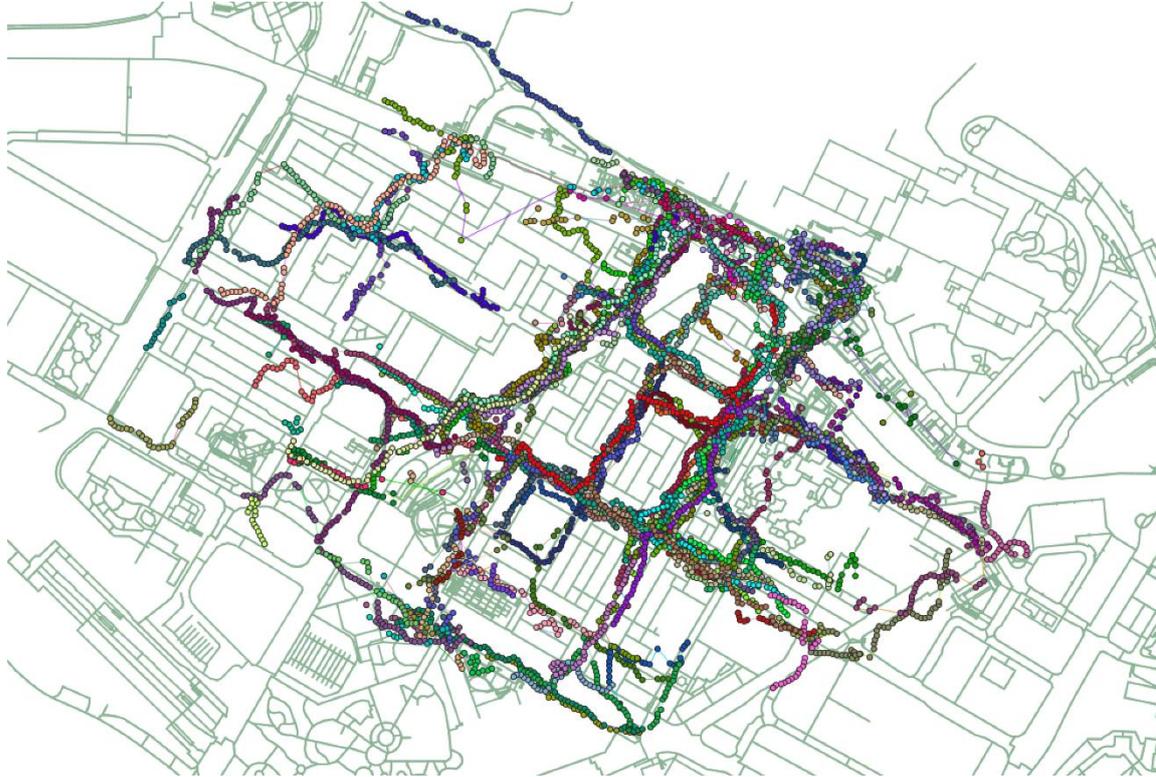


Figure 27. GPS data from the pedestrian path tracking survey in 3D GIS network (Top view)

3.3.2.5 Route Choice Model in Kwun Tong and Tsuen Wan

The collected trajectory data in Kwun Tong and Tsuen Wan areas represented the actual paths taken by pedestrians, hence constitutes their revealed preferences. With these trajectory data, we analyzed the route choice behavior by the discrete choice modeling approach. In particular, we adopted the bounded choice model (Watling et. al, 2018). With the surveyed trajectory data, a linear utility function for a walking path k is formulated as the following:

$$U_k(\beta_j) = - \sum_a \sum_j \beta_j x_{k,j}^a$$

Where U_k is the walking utility function of path k in an origin-destination (OD) pair
 $x_{k,j}^a$ is the length of the walking attributes j in link a that on the path k (in meters)
 β_j is the calibration parameter for walking attribute j .

The k path is the observed path from our tracking survey, and only this path is revealed. We needed to generate other paths with the same origin and destination, which pedestrians may consider, before making the actual walking trip, namely the path choice set. The choice set p , i.e., the path set possibly considered by pedestrians, was generated based on the k -shortest path

algorithm. In addition to the shortest path, the k-shortest path algorithm generated the 2nd best, 3rd best, up to the kth best paths. A total of 100 k-shortest paths for each OD pair were extracted and selected for our analysis, in both Kwun Tong and Tsuen Wan. To capture the path overlapping effect in the choice set, the path-size logit model (Ben-Akiva and Bierlaire, 1999) was adopted. The modified utility function was hence modified as follows:

$$U_k(\beta_j) = - \sum_a \sum_j \beta_j x_{k,j}^a + \beta \cdot \ln(S_k)$$

where S_k is the path size of path k , calculated as:

$$S_k = \sum_a \frac{l_a}{L_k} \frac{1}{\sum_j \delta_{aj} \frac{1}{L_j}}$$

Where l_a is the length of link a that on path k
 L_k is the total length of path k
 δ_{aj} is an indicator to represent if link a is on path j

Based on the logit model, the choice probability of choosing path k among all the possible paths p in the given origin-destination pair is given by the following formula:

$$\Pr(U_k) = \frac{\exp(\gamma \cdot U_k)}{\sum_{i \in p} \exp(\gamma \cdot U_i)}$$

The higher the utility of a path, or the lower the cost of a path, the higher choice probability that pedestrian would choose from. One disadvantage of the logit model is that there are paths with non-zero probability even if the utility or a path is very low, or extremely high cost. To cater for the issue, we adopted the bounded choice model (Watling et. al, 2018), which incorporate additional bound parameters to screen out paths that are too costly. The modified choice probability is given by:

$$\Pr(U_k) = \frac{(\exp(\gamma \cdot (U_k - \max(U) + \delta)) - 1)_+}{\sum_{i \in p} (\exp(\gamma \cdot (U_i - \max(U) + \delta)) - 1)_+}$$

where $(x)_+ = \max(x, 0)$. With the trajectory data and the utility function, the above walking attribute parameters β_j can be calibrated using the maximum likelihood estimation (MLE) method. The idea is to find the best walking attribute parameters β_j such that the likelihood function defined below is maximized to fit with all the trajectory data:

$$\max_{\beta_j} L(\beta_j) = \sum_n \sum_k y_{kn} \cdot \log(\Pr(U_k(\beta_j)))$$

Where L is the likelihood function
 n is the index of each trajectory data
 y_{kn} is the observed data for walking path k for data n , equals 1 if path k is observed to be used by a pedestrian, 0 otherwise.

3.3.2.6 Calibration results and comparison

In the 2D GIS network of Kwun Tong, we considered seven attributes, including Sidewalk, Step, Pedestrian Crossing, Footbridge, Pseudo Link, Escalator and Tunnel. Due to limited trajectory data that go through escalators and tunnels, and limited number of attributes presented in the area, we ignore the attributes in this calibration. This limitation of the revealed preference approach is complemented by the stated preference survey to be discussed in **Sections 3.3.2.7** and **3.3.2.8**. In all, there are five attributes considered in Kwun Tong, namely, Sidewalk, Step, Pedestrian Crossing, Footbridge and Pseudo Link.

Similarly, there were ten attribute groups considered in the 3D GIS network of Tsuen Wan,

including Sidewalk, Step, Pedestrian Crossing, Footbridge, Pseudo Link, Escalator, Tunnel, Interior Sidewalk and Ramp. Tunnel and Lift are ignored, again, due to limited GPS data go through those attributes. Only Sidewalk, Step, Pedestrian Crossing, Footbridge, Pseudo Link, Escalator, Interior Sidewalk and Ramp were considered in this calibration.

The cost coefficients are summarized in **Table 15**. The attribute values are all normalized with respect to sidewalk, i.e. cost coefficient of sidewalk equals one. The higher the value represents the higher the cost of that attribute, or lower willingness for pedestrians to choose certain paths with those attributes. For the Kwun Tong area, it is observed that the corresponding cost of step, pedestrian crossing, footbridge, pseudo link and escalator were estimated to be 8.9285, 4.7731, 2.9649 and 7.5048, respectively. For the Tsuen Wan area, the corresponding cost of step, pedestrian crossing, footbridge, pseudo link, escalator, interior sidewalk and ramp were estimated to be 14.8277, 2.7330, -67.3030, 2.6752, 30.1073, 6.1876 and -188.0257, respectively.

Table 15 Utility model calibration results in Kwun Tong and Tsuen Wan

Attribute	Kwun Tong		Tsuen Wan	
	Value (per meter)	p-value	Value (per meter)	p-value
Sidewalk	1.0000	0.0000	1.0000	0.2816
Step	8.9285	0.0000	14.8277	0.0000
Crossing	4.7331	0.0000	2.7330	0.0570
Footbridge	2.9649	0.0000	-67.3030	1.0000
Pseudo Link	7.5048	0.0000	2.6752	0.0610
Escalator	-	-	30.1073	0.0000
Tunnel	-	-	-	-
Lift	-	-	-	-
Interior Sidewalk	-	-	6.1876	0.0002
Ramp	-	-	-188.0257	1.0000
Path size coefficient	117.9806	0.0000	761.7967	0.0000
Sample	198		147	
log likelihood(0)	-974.3605		-678.4227	
log likelihood	-712.1987		-404.8928	

Comparing the results from Kwun Tong and Tsuen Wan, we observed discrepancies in the values and pedestrian route choice behaviors. The value for crossing in Kwun Tong (4.7331) was smaller than that of pseudo link in Kwun Tong (7.5048), which generally is consistent with our intuition that people prefer safer crossings with markings to those without (pseudo link). However, in Tsuen Wan, we observed very similar values for crossing (2.7330) and pseudo link (2.6752), showing that the protection from typical crossing is compensated by the convenience provided by the pseudo link. Pedestrian in Tsuen Wan are much sensitive to steps than in Kwun Tong (14.8277 in Tsuen Wan but 8.9285 in Kwun Tong).

Though we found counter-intuitive results for the Escalator, Interior Sidewalk and Ramp attributes, escalators and ramps are facilities for pedestrians to overcome the elevation difference so that small cost values are expected. We also expect the value of interior sidewalk to be similar or lower than that of sidewalk, as cover or air-conditioning is provided in the

interior sidewalk. We also found the value for footbridge in Tsuen Wan to be negative, meaning pedestrian regarded footbridge as a benefit rather than a cost, though its value was not statistically significant.

3.3.2.7 Online stated-preference surveys (1)

In the tracking surveys, we collected in total 345 valid pedestrian GPS trajectories in Kwun Tung and Tsuen Wan. These collected trajectory samples were only able to cover a limited set of walking attributes. In other words, some other walking attributes were not revealed or represented in the trajectory data, therefore we could not generate the corresponding attribute coefficients for those attributes (i.e., the cost ratio or importance relative to sidewalk). Such attributes included escalator and tunnel in Kwun Tong and lift and tunnel in Tsuen Wan.

This limitation motivated the use of stated preference survey. Walking attributes that were not captured in the revealed-preference survey data were constructed in hypothetical scenarios and shown to interviewees to obtain their preferences. The stated preference survey aimed to cover the additional walking attributes that were found to be important in perception surveys. The attributes included: 9) Pedestrian Signal, 10) Elevator, 11) Slope, 12) Air-conditioned, 13) Width, 14) Pedestrian Traffic, and 15) Vehicle Traffic. In this survey, the walking attributes were set to be different discrete levels as shown in **Table 16**. Based on the above attribute definition, **Figure 28** shows all the walking attribute information in a single path.

Table 16. Walking attributes and designed levels

Attribute	Level							
Distance (Sidewalk)	100m				200m			
Shop	Yes				No			
Greenery	Yes				No			
Lighting	Yes				No			
Width of Walkway	3-4 people wide				>4 people wide			
Pedestrian Traffic	High				Low			
Air Con.	Yes				No			
Cover	Yes				No			
Crossing	FB* w/ escalator	FB* w/ lift 1 min	FB* w/ lift 0 min	FB* w/ ramp	FB* w/ stair	PS*	PS*	
						1 min	0 min	
Weather	Sunny			Rainy			Cloudy	

FB*: Footbridge

PS*: Pedestrian Signal



Figure 28 Design Figure in Stated Preference

In this project, the stated-preference survey was designed in a simple way wherein each comparison question only contained two choices, with each choice corresponding to a path with multiple walking attributes. To limit the number of comparison questions in a reasonable number, we implemented an orthogonal design so that each interviewee was presented with 20 pairs of choices so as not to overburden the interviewees. **Figure 29** shows one of the comparison questions in the survey with two path choices. Path A is a path with 100 meters walking in a narrow sidewalk, shops, greenery, in a rainy weather. Pedestrians have to cross a road using a footbridge and stairs. On the other hand, path B is a path with 200 meters walking in a wider sidewalk, without shops, greenery, in a cloudy weather. Pedestrians have to cross a road using a signalized facility with 1 min waiting time.



Figure 29 Stated Preference Survey example

The stated-preference survey was distributed via the google form (<https://forms.gle/euAtRjKqbpHqXo3Q06>) online. We collected 104 responses. We recognized

that we were unable to ascertain that the online survey was distributed to all user groups, such as the elderly and people with disabilities. For those groups, it is better to conduct the survey in person as they may be unfamiliar with online surveys, but we were not able to conduct in such a way due to COVID-19 in this period. This is a limitation on the results obtained.

Similar to the utility models calibration using GPS trajectory data, the β_j cost coefficients can be calibrated based on the stated-preference survey data. The cost coefficient in this case, however, are related to the discrete attribute levels. **Table 17** shows the relative cost coefficient, and the corresponding choice probability.

Positive value of the relative cost coefficient indicates that pedestrian prefer the choice over other choices. The positive cost coefficient (+0.41435) in the choice of “100m” of walking in the “distance” attribute shows that pedestrian would prefer the choice of “100m” over the other choice “200m”. The choice probability can also be computed. The choice probability shown in the third column also reflects that people prefer a shorter than a longer one as the choice probability of ‘100m’ is greater than that of “200m”. It is consistent with our intuition that pedestrians prefer a shorter path over a longer path. It applies to the “Shops”, “Greenery”, “Air Conditioning”, “Cover”, “Crossing” and “Weather” attributes. Pedestrians prefer a path with shops, greenery, air condition, cover, and take footbridges with escalator to cross a road in a cloudy weather situation. However, it is counter-intuitive in the “Lighting” and “Width” attributes as pedestrian would prefer a path without lighting and with high pedestrian traffic level.

Table 17. Stated Preference calibration results

Distance	Relative cost coefficient	Choice Probability
100m	0.41435	0.6961
200m	-0.41435	0.3039
Shop		
Yes	0.00840	0.5042
No	-0.00840	0.4958
Greenery		
Yes	0.10845	0.6047
No	-0.10845	0.3953
Lighting		
Yes	-0.04005	0.4800
No	0.04005	0.5200
Width		
3-4 People Wide	0.02884	0.5144
>4 People Wide	-0.02884	0.4856
Pedestrian Traffic Level		
High	0.17316	0.5857
Low	-0.17316	0.4143
Air Conditioning		
Yes	0.21245	0.6047
No	-0.21245	0.3953
Cover		
Yes	0.01550	0.5078

No	-0.01550	0.4922
Crossing		
Footbridge with escalator	1.3413	0.4224
Footbridge with lift and 0 minute waiting	-0.6847	0.0557
Footbridge with lift and 1 minute waiting	-0.5026	0.0668
Footbridge with ramp	-0.2547	0.0856
Footbridge with stair	-0.4224	0.0724
Pedestrian signal crossing with 0 minute waiting	0.5250	0.1867
Pedestrian signal crossing with 1 minute waiting	-0.0018	0.1103
Weather		
Cloudy	0.33574	0.4527
Rainy	-0.15220	0.2779
Sunny	-0.18356	0.2693

3.3.2.8 Online stated-preference survey (2)

From the last online stated-preference survey (1), we received suggestions to improve the quality and accuracy of the survey. People found it hard to distinguish the difference between the two choices as represented by the two images about the two different paths. In addition, only English language was provided in the online stated-preference survey (1). This limited the responses from the user groups who were not good at English. The online stated-preference survey was subsequently revised. The difference between the two images in each question was clearly indicated, and traditional Chinese version was provided, as shown in **Figure 30**. In total, we received 149 responses. The data were still being processed and will be combined with the data collected in the online stated-preference survey (1) in our subsequent studies.



Figure 30. Sample question in the online stated-preference survey (2)

3.3.2.9 Origin-Destination Survey

The route choice model only provided the route choice behavior given an origin-destination pair. To fully consider the existing performance of the pedestrian network, the number of trips between origins and destinations were of interest, and the number of trips can be captured by an Origin-Destination Survey. We conducted the origin-destination survey on 21-Jan-2021 from 5:00 pm to 8:00 pm in Kwun Tong.

The origin-destination survey consisted of two parts. The first part was to count the direction pedestrian link flow across major screen-lines. There were two sets of screen lines, representing east-west directions, shown in **Figure 31** (a) in blue, and north-south directions, shown in **Figure 31** (b) in red. The link count data provided the pedestrian volume level, which will be used for scaling the volume of OD pair.



Figure 31. Origin-Destination Survey – Link flow counts on (a) Blue screen line, (b) Red Screen line

The second part of the origin-destination survey was to ask pedestrians about their origins and destinations directly. We classified downtown Kwun Tong into different regions defined in **Figure 32**, pedestrians were then asked to quickly answer their origin and destination within a few minutes. The age, gender of the pedestrian, and their trip purpose were also recorded. The data were still being processed and will be used in our subsequent studies.

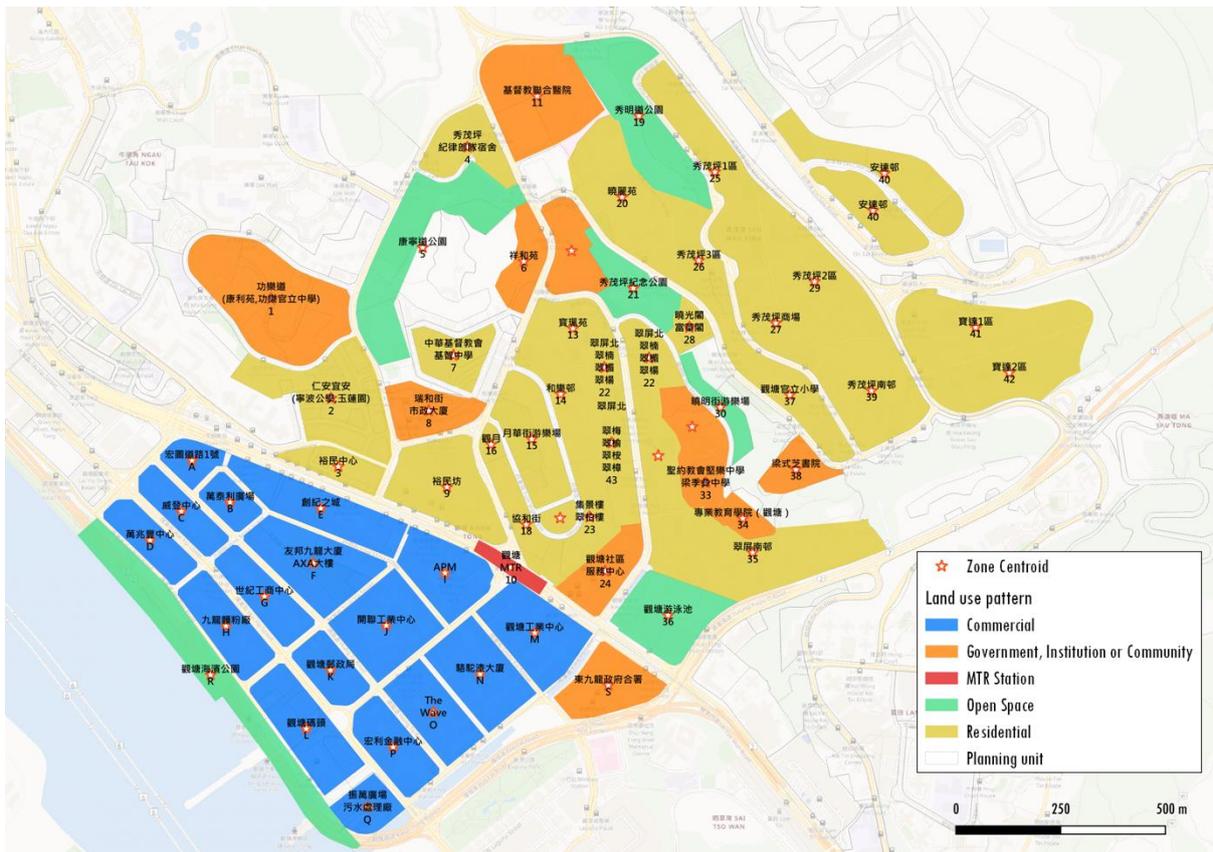


Figure 32. Kwun Tong - Study regions based on land use pattern and zone centroids

3.4 Task 4 – Accessing Policy Options

Task 4 was about assessing policy options for Tsuen Wan and Kwun Tong to enhance and promote walkability via policy modelling, stakeholder analysis, and multi-criteria decision analysis.

3.4.1 Developing a policy inventory for walkability in Hong Kong

We have been continuously building up and consolidating a policy inventory regarding walkability enhancement in Hong Kong and beyond. In particular, we looked into various types of policy documents issued by different departments, such as ordinances and regulations, planning and design manuals, standards and guidelines, codes of practices and technical circulars. We also identified responsible agencies and departments for different measures in our policy inventory.

During the policy inventory building process, especially in the case of Hong Kong, we identified dozens of measures and actions that aim at enhancing walkability and fostering a pedestrian friendly environment in the city. We discovered that existing major policy measures to enhance walkability include: (a) Regulatory measures which aim at improving pedestrian safety, such as setting up and reviewing speed limits regularly, forbidding parking and cycling on pedestrian pavements; (b) investments in infrastructure which aim at improving connectivity and accessibility in public places for all groups of people, such as providing hillside escalators, ramps and lifts at footbridges and subways, etc. (c) provision and maintenance of facilities or arrangements which aims at improving the comfort level for pedestrians, such as establishing

traffic calming zones, providing covers and seats at bus stops. (d) along with the functional and practical considerations, special emphasis on the visual attractiveness and aesthetic (or “design”) aspects of facilities being provided, such as decorating pavement railings with planter boxes, encouraging street art at footbridges and subways, etc.

Table 18 provides an easy way to identify the department(s) responsible or to contact for specific measures of walkability where more attention may be needed. Moreover, the decision criteria for specific measures can also be useful later at the stage of formulating policy options, since the decision criteria can point out potential obstacles or limitations and thus assist in identifying which options may be more feasible than others.

Table 18. Policy inventory related to walkability enhancement in Hong Kong

Organization-based measures		
Walkability dimension	Specific measures	Responsible authorities/departments (areas of responsibility)
Safety	Providing footbridges or subways	PD and CEDD (involved in planning and design); TD (provide advice from transport perspective); HyD and CEDD (project implementation); HyD (post-construction management)
Safety	Managing street obstruction	TD , HyD and CoP (to be consulted for repair works on road for footbridges; responsible for putting warning signs for road works); FEHD (responsible for regulating on shop front extensions, giving notice to shop owners, and removing obstruction in the case of non-compliance)
Safety	Conducting improvement works on roads and walkways to enhance pedestrian safety	HyD (responsible for the design and erection of guardrails; responsible for maintenance and conducting regular inspections of roads and pedestrian footpaths); and TD (its regional offices are responsible for conducting regular reviews in their respective localities to consider whether railings should be maintained, removed, replaced or added, as well as to determine type of railings on public roads)
Safety	Adding lighting facilities	HyD (manages lighting after installation); Lighting Division (under the HyD; receives and approves lighting designs; conducts final inspection); Bridges and Structures Division (under the HyD; needs to be consulted on the light design); BA (responsible for the design of temporary covered walkways around construction sites)
Safety	Adding crossing	CfT

	facilities	
Safety	Pedestrianizing streets or creating precincts	TD, PD and Town Planning Board (responsible for approving the rezoning of specific road sections as pedestrian precincts)
Safety	Providing proper signage and signal;	CFT; LCSD; EMSD (responsible for the maintenance of electrical and mechanical facilities on the roads, including all traffic lights, beacons at zebra crossings, push buttons for signal lights at pedestrian crossings, e-ATS, and traffic surveillance closed circuit television camera systems (CCTV)).
Safety	Adding smart devices or audible traffic signals for signalized consolidating street furniture	TD
Safety	Managing trees (e.g. pruning to maintain visibility, cutting dead branches to prevent accidents, etc.)	LCSD (responsible for trees along non-expressway public roads); HyD (responsible for trees within the boundary of expressways; clearance of vegetation that poses imminent danger to the pedestrian and road users); AFCD (responsible for country parks); HAD (responsible for trees along footpaths in village environments and access roads)
Connectivity	Providing lifts, escalators, ramps at footbridges or subways	EMSD (responsible for the daily operation and maintenance of lifts and elevators at public walkways including footbridges); EMSD and HyD (receives complaints regarding lifts and escalators at footbridges)
Connectivity	the Universal Accessibility Programme	District Councils (nominating existing walkaways for the UA programme); HyD
Connectivity	Implementing hillside escalator links and elevator projects (HEL)	TD; HyD (responsible for arranging gazettal of HEL proposals and handling objectives, if any; where necessary, carrying out land acquisition, carrying out public engagement with various stakeholders)
Connectivity	Providing crossings at desired line	CFT
Connectivity	Providing access walkways to waterfront	PD; DEVB; Harbour Office (under the DEVB; responsible for implementing various harbour front enhancement initiatives); Harbour Commission (advisory body)

Connectivity	Enhancing the accessibility of various means of public transport	MTRCL; CFT
Comfort	Providing seating, resting points and other amenities	
Comfort	Providing covered walkways	HyD; TD (Traffic Engineering Divisions)
Comfort	Improving pedestrian way-finding system	TD
Design	Providing street trees and soft landscape	LCSD (vegetation maintenance along public roads; planting on the roof or inside of footbridges, covered walkways, landscaped deck or noise enclosure cum open space); HyD (In emergency situations, responsible for the removal of fallen trees or overgrown bushes or grass that pose an imminent danger to the pedestrian and/or road users); HAD (vegetation along footpaths in village environs); Works Branch under DEVB
Design	Providing public art, streetscape enhancement	HyD; District Offices under HAD; HKTB
Authority-based measure		
Walkability dimension	Specific measures	Responsible authorities/departments (areas of responsibility)
Safety	Motor vehicle speed limit	TD, HyD and CoP
Safety	Prohibiting parking on pavements	CoP (responsible for receiving complaints (e.g. through HKPF's e-Report Centre and taking action against illegal parking and vehicle obstruction on pavements))
Safety	Prohibiting cycling (and cycle parking) on pavements	CoP
Comfort	Relaxing requirements for adding covers to public walkways as stipulated in TPDM	HyD; TD (Traffic Engineering Divisions)
Information-based measure		
Walkability dimension	Specific measures	Responsible authorities/departments (areas of responsibility)

Safety	Educational campaigns or advertisements	TD; CoP
Comfort	Improving pedestrian way-finding system	TD
Comfort	HKeMobility Application	TD
Treasure-based measure		
Walkability dimension	Specific measures	Responsible authorities/departments (areas of responsibility)
Connectivity	Waiving land premium for footbridges or subways financed by private sector	DEVB; LDAC

Legend:

HKPSG	Hong Kong Planning Standard Guidelines
HPPG	Harbour Planning Principles and Guidelines
EMSD	Electrical and Mechanical Services Department
HyD	Highways Department
TPDM	Transport Planning and Design Manual
BA/BD	Building Authority/Building Department
CEDD	Civil Engineering and Development Department
CfT	Commissioner for Transport
CoP	Commissioner of Police
FEHD	Food, Environment and Hygiene Department
DL	Director of Lands
PLDM	Public Lighting Design Manual
TD	Transport Department
DoH	Director of Highways
PD	Planning Department
HKPF	Hong Kong Police Force
AFCD	Agriculture, Fisheries and Conservation Department
HAD	Home Affairs Department
DEVB	Development Bureau
TCW	Technical Circular (Works)
DC	District Council
HKTB	Hong Kong Tourism Board

3.4.2 Developing a policy instrument framework for walkability enhancement

We have also adopted a policy instrument perspective to facilitate policy option recommendations and policy analysis.

Policy instruments are actual means or devices governments have at their disposal for implementing policies, and among which they must select and take into account in formulating policy (Howlett & Ramesh, 2003). Utilizing a policy instrument framework, which consists of organization-, authority-, information-, and treasure-based policy tools (or measures), can enable us to identify the types of instruments that are emphasized and those that might be lacking in Hong Kong. This process can assist in generating policy options to enhance walkability in Hong Kong and beyond. An enhanced policy inventory utilizing the policy instrument framework can be found in **Table 18**. An overview of key policy instrument for walkability enhancement can be found in **Table 19**.

Table 19. Overview of key policy instruments for walkability enhancement

Instrument type	Three major dimensions of walkability enhancement		
	Safety/Security	Access/Connectivity	Comfort/Pleasantness
Authority-based/regulatory instrument	<ol style="list-style-type: none"> 1. Vehicle standards 2. Vehicle speed/parking limits 3. Vehicle access restrictions 4. Urban planning and infrastructure design 5. Proper street management 	<ol style="list-style-type: none"> 1. (Re) Designing planning and infrastructure design guidelines and regulations 2. Other relevant operational codes 3. Proper street management 	<ol style="list-style-type: none"> 1. (Re) Designing planning and infrastructure design guidelines and regulations 2. Other relevant operational codes 3. Proper street management
Treasure-based/economic instruments	<ol style="list-style-type: none"> 1. (Road) Pricing 2. Budget supports 3. Taxes 4. Subsidies 	<ol style="list-style-type: none"> 1. Budget supports 2. Subsidies 3. Premium waives 	<ol style="list-style-type: none"> 1. Budget supports 2. Subsidies 3. Premium waives
Organization-based instruments	<ol style="list-style-type: none"> 1. Direct public infrastructure provision (e.g., walkway systems) 2. Government (re)organization 3. Proper street management 	<ol style="list-style-type: none"> 1. Direct public infrastructure provision (e.g., footbridges, subways, lifts, escalators) 2. Government (re)organization 3. Proper street management 	<ol style="list-style-type: none"> 1. Direct public infrastructure provision (e.g., covered walkways, benches, drinking fountain) 2. Government (re)organization 3. Proper street management
Information-based	<ol style="list-style-type: none"> 1. Awareness campaigns 2. Advertisements 	<ol style="list-style-type: none"> 1. Information provision 2. Data and statistics 	<ol style="list-style-type: none"> 1. Information provision 2. Data and statistics 3. Knowledge creation

instruments	3. Education 4. Leadership & signaling	3. Knowledge creation (e.g., R&D into new technologies)	(R&D)
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Source: Author’s construct, developed based on the policy instrument framework by Howlett and Ramesh (2003).

3.4.3 Policy instrument comparison across Hong Kong, Singapore, and Shanghai

We also collected relevant data from other cities outside Hong Kong selected in this study. A comparison table (**Table 20**) regarding walkability enhancement measures in three Asian cities, namely, Hong Kong, and other two similar cities including Shanghai, and Singapore is provided. In line with the enhanced policy inventory in **Table 18**, this comparison Table also utilizes the policy instrument framework, which enabled us to identify the differences and similarities of walkability enhancement among the selected cities and was useful for policy option recommendations.

Table 20. Walkability measures comparison across Hong Kong, Shanghai, and Singapore

Walkability dimension—*Safety*

	Hong Kong	Shanghai	Singapore
Organi- zation- based	<ul style="list-style-type: none"> • Providing footbridges or subways • Managing street obstruction • Conducting improvement works on roads and walkways to enhance pedestrian safety • Adding lighting facilities • Adding crossing facilities (e.g. smart devices or audible traffic signals for signalized pedestrian crossings) • Providing proper signage and signal; consolidating street furniture such as traffic signs and directions • Pedestrianizing streets or creating precincts 	<ul style="list-style-type: none"> • When pedestrians inevitably cross the bus lane, they need to be clearly marked, and the crosswalk is arranged at the end of the bus lane. • Vehicle-pedestrian separation: the motorway and non-motorway shall be set separately, and the facility belt shall be arranged between the sidewalk and non-motorway for physical isolation • Providing small roundabout or raised intersection, moderately curved road alignment • Real time traffic monitoring around the community 	<ul style="list-style-type: none"> • Providing various crossing facilities (e.g. pedestrian crossing lines, raised zebra crossings, kerb ramps, zebra crossing demarcated with markings, flashing beacons and signs, Green Man+, which gives persons with disabilities extra time to cross the road etc.) • Providing Pedestrian Overhead Bridge (POB) is built across at least Dual-Two road for safer crossing of pedestrians. • Providing safety bollards with bright strips of yellow retro-reflective sheeting and black arrows make bus stops more

			<p>visible.</p> <ul style="list-style-type: none"> • Pedestrianizing streets or creating precincts
Authority-based	<ul style="list-style-type: none"> • Motor vehicle speed limit • Prohibiting parking on pavements • Prohibiting cycling (and cycle parking) on pavements 	<ul style="list-style-type: none"> • Speed and parking limits • The chamfer radius of the red line of the intersection should be 10-20 meters for the intersection of the main road and other roads, 10-15 meters for the intersection of the secondary main road, etc. 	<ul style="list-style-type: none"> • Speed limits (generally 50km/h) (complemented by speed regulating strips and “Your Speed Sign”) • Prohibiting parking on pavements • Providing traffic calming devices (e.g. road hump)
Information-based	<ul style="list-style-type: none"> • Advertisement and educational campaigns 	<ul style="list-style-type: none"> • Advertisements 	<ul style="list-style-type: none"> • Advertisement and educational campaigns
Treasure-based	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A

Walkability dimension—*Connectivity*

	Hong Kong	Shanghai	Singapore
Organization-based	<ul style="list-style-type: none"> • Providing lifts, escalators, ramps at footbridges or subways (e.g. the Universal Accessibility Programme) • Implementing hillside escalator links and elevator projects (HEL) • Providing crossings at pedestrian desired line • Providing access walkways to waterfront • Enhancing the accessibility of various means of public transport 	<ul style="list-style-type: none"> • Building a greenway of about 2000 kilometers. • Rail stations are encouraged to increase the number of entrances and exits and integrate with surrounding roads, buildings, public spaces, etc. • Open the internal channels of existing public facilities (such as commercial buildings, cultural and sports facilities, park rivers, public transport stations, etc.) and multiple pedestrian channels between plots 	<ul style="list-style-type: none"> • Providing Pedestrian Overhead Bridge (POB), which is typically built across at least Dual-Two road for safer crossing of pedestrians • Providing cycling bridges (cycling bridges provide seamless commuting for all users - cyclists, pedestrians, joggers, personal mobility device users and persons with disabilities) • Providing lifts, escalators, ramps at POBs

		<p>to improve the accessibility of walking.</p> <ul style="list-style-type: none"> • A continuous open public space will be built 20 meters along both sides of the main river to improve the waterfront ecological environment. 	<ul style="list-style-type: none"> • Increasing the width of new footpaths from 1.5m to 1.8m, which is the adequate width for two typical wheelchairs to pass each other. Where there are observed or projected high pedestrian volume, footpath widths of more than 1.8m would be considered
Authority-based	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A
Information-based	<ul style="list-style-type: none"> • Improving pedestrian way-finding system • Improving the HKeMobility app 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • Improving pedestrian way-finding system (e.g. the Effective Wayfinding System)
Treasure-based	<ul style="list-style-type: none"> • Waiving land premium for footbridges or subways financed by private sector 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A

Walkability dimension—*Comfort*

	Hong Kong	Shanghai	Singapore
Organization-based	<ul style="list-style-type: none"> • Providing seating, resting points and other amenities • Providing covered walkways 	<ul style="list-style-type: none"> • Arranging pedestrian friendly station facilities at bus stops, such as waiting booths to avoid sun and rain, seats or leaning facilities, etc. • The public space of large-scale sports facilities and outdoor public space such as playground and stadium of colleges and universities should be open to the outside world. 	<ul style="list-style-type: none"> • Providing POB shelters: the bridge including the staircases are provided with shelter to protect pedestrians from light rain and direct sunlight. • Weather screens are provided behind benches where accessibility and circulation are not compromised. • Bus shelters are sized and built based on its commuter's

			usage/boarding counts.
Author ity- based	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A
Inform ation- based	<ul style="list-style-type: none"> • Improving pedestrian way-finding system • Improving the HKeMobility app 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • Improving pedestrian way-finding system (e.g. the Effective Wayfinding System)
Treasu re- based	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A

3.4.4 Interviewing government officials and district councilors

Semi-structured interviews were conducted with government officials from the Transport Department (Taskforce on Walkability), Energizing Kowloon East Office (EKEO), as well as District Councilors in Kwun Tong and Tsuen Wan. The insights that were collected from interviews provided enriched data for analysis, and together with the policy documents already collected and processed assisted in the formulation of policy options which was a main objective of Task 4. Regarding the interviews, below were some of the topics/questions that had been discussed:

➤ **General questions**

- To what extent do you think have the objectives with regard to promoting walkability which was announced in the 2017 Policy Address been achieved?
- What challenges, barriers or difficulties have you encountered in implementing walkability programs or measures?
- Please identify at least two (2) stellar programs or measures or schemes related to walkability. Why do you think these are outstanding?
- In your view, what improvements have there been in terms of Hong Kong people's walking habits?
- What do think will your work focus on with regard to promoting walkability in the coming years?

➤ **Information-based**

- The HKeMobility application has recently been enhanced, adding walking route search for some places. Please share the experiences so far regarding this application.

➤ **Treasure-based**

- Please share the experiences and thoughts with regard to footbridges as far as promoting walkability in Hong Kong?
- Pedestrian Environment Improvement Scheme (Transport Department): Why to date there

are only 70 completed schemes? What challenges have been encountered in implementing the Scheme?

- Do you think budget allocated to enhancing walkability (e.g., building lifts, escalator, and other barrier-free access; footbridges, elevated walkways, pedestrian tunnels) is adequate?
 - What areas in walkability do you think the government should be giving more attention, particularly in terms of financial resources? Why?
 - Whether incentives to private developers are sufficient to retrofit existing walkways in private properties with barrier free access facilities, e.g., lifts?
- **Organization-based**
- What is the staff size of the Walkability Taskforce under the Deputy Commissioner for Transport?
 - Kindly share with us the experiences of the Taskforce so far in promoting walkability. In your view, what are the areas for improvement regarding the work of the Walkability Taskforce to achieve its objectives?
- **Authority-based**
- In terms of street management, what do you think will be a more sufficient way to manage “shop front extensions” (SFEs)?
 - In light of experiences regarding the enforcement of specific regulations, what in your view are the areas that need adjustments, improvement or reinforcement?

3.4.5 Policy analysis: systematic analysis of policy options

After identifying and formulating the above-mentioned policy options for walkability enhancement, we aimed to assess and analyze those policy options employing the method of Multi-Criteria Analysis. A Criteria-Alternatives Matrix for walkability enhancement was developed in Table 18 and the following are the tentative criteria for analysis and their corresponding descriptions:

- **Effectiveness:** Effectiveness is the likelihood of achieving policy goals and objectives or demonstrated achievement of them.
- **Efficiency:** Efficiency means the achievement of program goals or benefits in relationship to the costs. Least cost for a given benefit or the largest benefit for a given cost.
- **Equity:** Equity means fairness and justice in the distribution of the policy’s costs, benefits, and risks across population subgroups.
- **Political feasibility** means the extent to which elected officials accept and support a policy proposal and the likelihood that the proposal of being enacted or implemented.

4 Research results and findings

The research results and findings are addressed by each task.

4.1 Task 1 – Developing vision statements and scope of policy interventions

Through the interviews and surveys stated in Section 3.1, many challenges have been identified for improving walkability.

It is a consensus from all stakeholders that four aspects should be considered for improving walkability and developing Hong Kong into a walkable city of world-class quality. They are: (1) “Make it connected” by enhancing pedestrian networks and connectivity; (2) “Make it safe” by providing a safe and quality pedestrian environment; (3) “Make it enjoyable” by making walking a pleasant experience; and (4) “Make it smart” by providing user-friendly information on walking routes and facilities using smart technology. The conventional vehicle-centric transportation planning process cannot fully address the needs and aspiration of walkability improvement.

4.1.1 Opinions of stakeholders

4.1.1.1 *People with disabilities*

Interviews with people with disability clearly indicated their preferences for footbridges and elevators/escalators for going on and off footbridges. Respondents from both Tsuen Wan (TW) and Kwun Tong (KT) ranked barrier-free facilities as the most important walkability attribute. Safety was also highly ranked. All these attributes had an average ranking of over 4.5/5. Accessibility and comfort were considered relatively less important, while the environment was ranked as the least important attribute. Respondents reported a mediocre average score of 3.6/5 and 2.7/5 for overall walkability friendliness for TW and KT, respectively, with TW rated higher, perhaps due to the extensive network of footbridges in TW.

All respondents stated that the current designs were sufficient to meet their needs, and improvements will mainly lie in increasing the extent, availability and implementation of barrier-free facilities.

Some respondents considered the existing facilities as scarce or difficult to access. Another common complaint was that there was generally a lack of signs and guides to barrier-free facilities for those in need. People not familiar with the region would not be able to access and use these facilities, despite the original design purpose.

4.1.1.2 *The elderly*

The interviewees ranked “connectivity” and “safety” as the most important considerations. Among many factors, “public parks”, “walking time” and “walking aids” were identified as top three factors affecting walkability for the elderly.

Respondents also pointed out the existence of non-walking-friendly joints and intersections that inhibited pedestrian friendly movements, especially for the elderly and the disabled, leading to connectivity issues.

4.1.1.3 *Residents, commuters and way-finders*

Two street surveys were conducted to collect the opinions of commuters and way-finders. One survey was at Kwun Tong MTR station and Kwun Tong Promenade on April 13, 2019, and another at the Tsuen Wan Riviera Park, Tsuen Wan Park, Yeung Uk Road, as well as Tai Ho Road on April 26, 2019. An online questionnaire was also designed and collected data from February to May 2020. Through these surveys, we collected 140 valid responses.

The surveys and questionnaire focused on the importance of five attributes of walkability (safety, accessibility, comfortability, environment, facilities), and satisfaction levels of each

attribute in Kwun Tong and Tsuen Wan. We identified “Accessibility” and “the Environment” as the attributes of high importance but at the same time with low satisfaction ratings.

Way-finders reported that road signs were not clear enough, and road signs alone were not sufficient for navigation in the region. Most of them must rely on mobile apps, such as google maps, for navigation. We also surveyed the adoption of new technologies to improve walkability. For both districts, the top-rated measures included development of intelligent traffic light, pedestrian signal lights with countdown clock; smart device for extending green light for the elderly and disabled, followed by availability of street sign and district map board for better navigation.

These survey results pointed out specific improvements as identified by users in these two districts and should be instrumental in formulating specific improvements plans in the future.

4.1.1.4 Traffic and Transport Committees of the District Councils

In our interviews with the Chairs of Traffic and Transport Committees of the District Councils in Kwun Tong and Tsuen Wan, their responses were insightful and adeptly summarized our findings. Their views should be duly considered on formulating future walkability improvement policies.

- The conventional transport planning process has been mostly vehicle-centric, not including pedestrian traffic as an essential element. In the future planning process, pedestrian or non-motorized transport should be included.
- In prioritizing the installation of footbridges, pedestrian flows or usage of the facilities should be carefully examined. Sometimes, the existing pedestrian flow may not be indicative of a facility's future usage. For example, an uphill street that is not heavily used today does not mean that it will not be with the addition of a suitably connected elevator.
- In developed older neighborhoods, finding suitable places to place footbridges with elevators or pedestrian tunnels may be challenging in view of pre-existing underground facilities and existing pedestrian and road width.
- Moreover, there are often conflicting interests among stakeholders and changing needs in pedestrian infrastructure improvement schemes. The main issues brought up include:
 - (1) *Unclear roles and responsibilities of operation and maintenance of pedestrian facilities.* Newly developed areas are easier to plan and construct footbridges, especially if they are connecting to commercial buildings, such as shopping centers. Nevertheless, in certain cases, the operation and maintenance of such facilities would become an issue if the roles and responsibilities of the different parties involved, as well as the cost allocation among them are not defined clearly ahead of time, such as between the commercial building management and residential building management.
 - (2) *Difficulty in achieving consensus among property owners.* In established urban areas, seeking agreements with surrounding property owners in planning a pedestrian facility (e.g., footbridge) could be challenging, as these owners would contend for the right of access to the footbridges, or raise objections based on damage to their views being blocked, etc. Another example quoted was objections raised by residents on decluttering of non-essential railings or traffic signs to make space for pedestrian walkways or to make the space more enjoyable. How to balance the benefits to the community while gaining agreements from affected residents is not easy. Sometimes

the process can take multiple years without coming to a resolution. It remains a question of how to set up a formal process so that such contentions can be resolved in a timelier manner.

- (3) *Land use changes render the need of certain pedestrian facilities obsolete.* In areas to be redeveloped with land use changes, such as from industrial to commercial and residential, the pattern of pedestrian flows will be changed. If the approval of pedestrian facilities takes a long time, the planned and existing facilities may not meet the needs of the upcoming changes. The example cited was the area around Texaco Road in Tsuen Wan. It is imperative to plan pedestrian facilities closely related to the future land use pattern and properly forecast the pedestrian flow pattern.
- (4) *Lack of cooperation among government departments for street management.* Street management involves a range of government departments for its operation, maintenance, and improvement. District Councilors often found it unclear which department(s) they ought to communicate and work with to address improvement issues.

4.2 Task 2 – Developing integrated BIM-3D GIS platform

4.2.1 Creation of 3D GIS Outdoor and Indoor Pedestrian Network & barrier free mapping for each of the of the two districts, Tsuen Wan and Kwun Tong for walkability analysis.

We have completed the tasks as described in section 3.2.1, and produced two 3D pedestrian networks, one for Tsuen Wan and one for Kwun Tong. These two networks are critical for conducting the analyses in Task 3.

In addition, we have produced a series of dissemination and application activities by means of six publications (2 published and 4 under review) and four conference presentations, as detailed below in Section 6.

4.2.2 Creation of BIM-3D GIS for walkability visualization

In addition to developing the pedestrian network through the 3D GIS and BIM approaches as described in Section 3.2, we also conducted some analyses to illustrate their use and potential applications. Specifically, we developed walkability analyses and visualizations to illustrate path choices for different user groups, as discussed below.

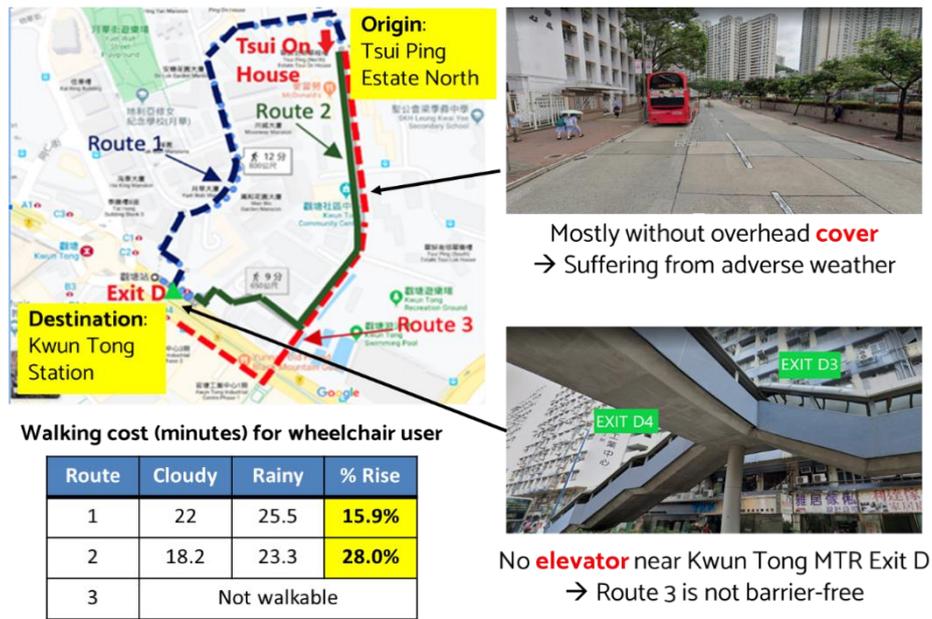
For walkability analysis, the network was first divided into three regions, as shown in **Figure 33**. Each region covers different kinds of Points of Interests (POIs) and facilities. Hence, each region was analyzed individually to identify existing problems that hinder walkability. The procedures of analysis for each region were as follows: A pair of origin (O) and destination (D) were first selected among the POIs. Then, pedestrian flow simulation was performed in Pathfinder, after which multiple possible routes between the OD pair were identified. For each route, using the 3D network and **Equation (1)** developed, two kinds of walking times were estimated: 1) actual walking time under $\beta_i = 1$ for any link i (cloudy condition), 2) perceived

walking time with the discomfort factor β_i considered (rainy condition). By comparing the walking times, some problems of the existing facility design were inferred. Subsequently, several what-if facility designs were implemented in the simulation engine, and the computation of walking times was repeated. Hence, their potential improvements in pedestrian walking were estimated with respect to our utility function. For better illustration, the analysis illustrated this with a wheelchair user group.

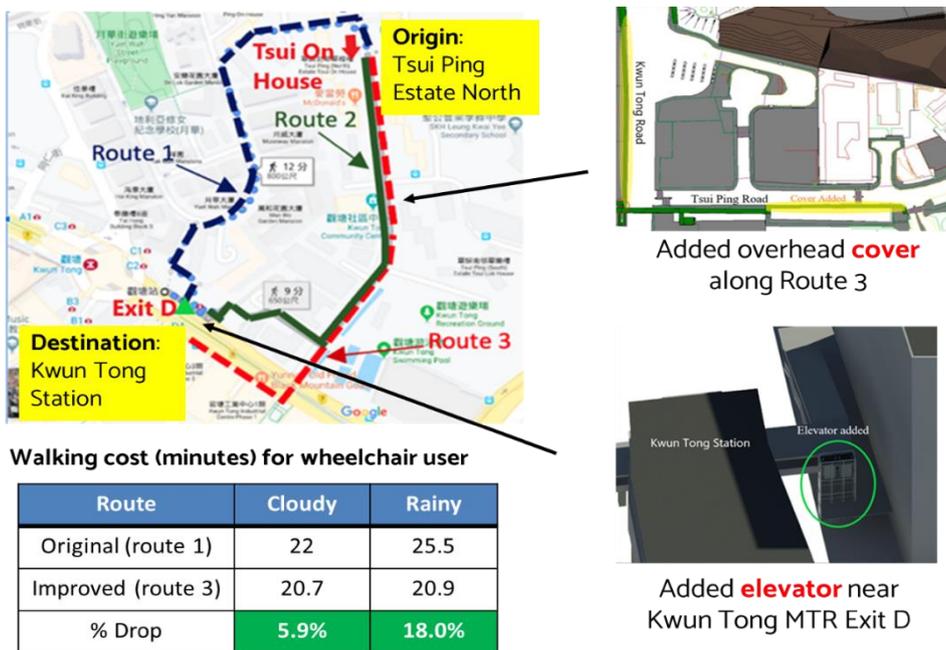


Figure 33: Divided Regions for Walkability Analysis

Region A captured several routes between the residential zone in TP-North and Kwun Tong MTR station. As shown in **Figure 34 (a)**, one of the routes was mostly without overhead cover, which suffered from adverse weather. Moreover, no elevator was provided for going up to the MTR station via the existing footbridge, i.e., not barrier-free. Hence, an attempted improvement was to add a cover and an elevator at the corresponding locations, as in **Figure 34 (b)**. After our simulation, the perceived walking cost of a wheelchair user was reduced by 18% under rainy condition.



(a) Existing Walkability Problems in Region A



(b) Attempted Improvement of Facility Designs in Region A

Figure 34(a-b): Walkability Analysis in Region A

Region B covered several commercial buildings and the catering area next to Ngau Tau Kok MTR station. As shown in **Figure 35**, a wheelchair user needed an unreasonably long detour (red path) to cross the Kwun Tong Road, from the MTR station to Yee On Street area. The problem was, despite the several footbridges / subways across the major road, there was no elevator / ramp for barrier-free access to those nearby facilities, such that wheelchair users suffered from a 500m detour without overhead cover. Hence, an attempted improvement was to add elevators next to the nearest subway to facilitate vertical movement, as in **Figure 35**. By replacing the long detour with a direct subway crossing (green path), the perceived walking

cost under rainy condition was greatly reduced by 70%.

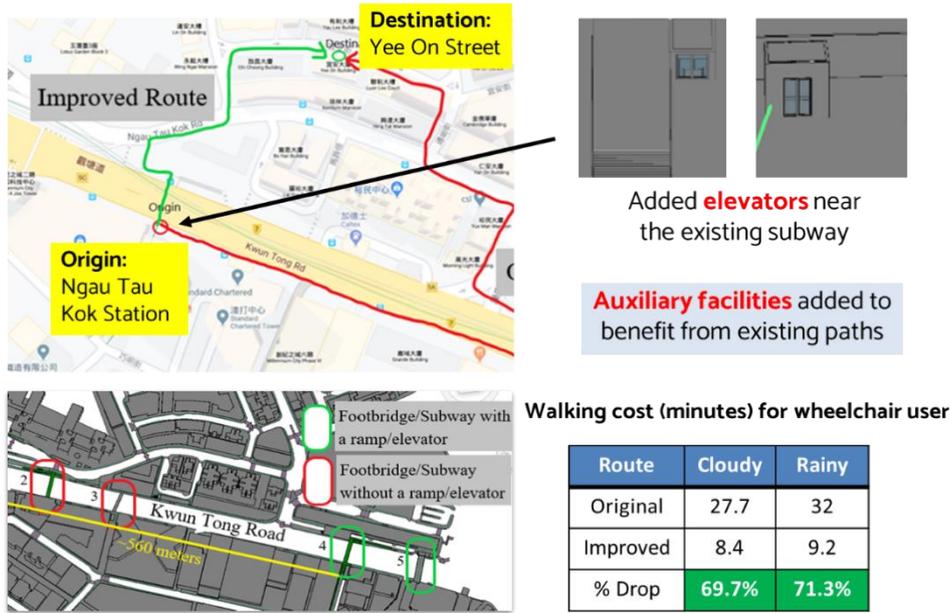


Figure 35: Walkability Analysis in Region B

Region C included the commercial area and seafront side to the south of Kwun Tong. As shown in **Figure 36**, the shorter route 1 with a footbridge was not barrier-free due to a missing elevator for wheelchair users, who suffered from a long and non-covered detour to arrive at the same destination. Hence, an attempted improvement was to make route 1 barrier-free by adding elevators next to the existing footbridge, as in **Figure 36**. After simulating the new design, the perceived walking cost under rainy condition was reduced by 14%.



Figure 36: Walkability Analysis in Region C

To summarize our observed walkability problems, several supporting facilities such as footbridges / subways were available but not accessible. These existing facilities were not barrier-free, due to the missing auxiliary facilities such as elevator / ramp. Pedestrians hence

suffered from a long detour with an overhead cover, leading to extra discomfort in adverse weather. By supplementing the auxiliary facilities, the pedestrian network potentially becomes more well-connected, where barrier-free access could enable more comfortable walking.

4.3 Task 3 – Investigating walking behavior

4.3.1 Accessibility analysis using Kwun Tong as a case study

Based on the cost coefficients calibrated in Kwun Tong, we studied the accessibility of several major destinations or the points of interest (POIs). The POIs included MTR station (Transport hub), APM (Shopping mall), Kwun Tong Promenade (Recreational area), United Christian Hospital (Public health facility), Yue Man Square (Transport transfer station) and Shui Wo Street Market (Shopping market). The accessibility analysis follows the same definition of regions in **Figure 32**.

We first analyzed the accessibility of Kwun Tong MTR station. For all other regions, except Kwun Tong MTR station, the minimum cost paths from the regions to the Kwun Tong MTR stations were generated. One important note is that the minimum cost path is different from the shortest path. The former accounts for the pedestrian route choice behavior by the cost coefficient for the walking attributes, which were studied and calibrated in **section 3.3.2.5** and **3.3.2.6** respectively, where the latter only considers the physical distance. The walking attributes were weighted by the corresponding cost coefficients, and the path cost summed up all the costs from the walking attributes in a path. Based on the minimum cost paths from other regions to Kwun Tong MTR station, the path cost for all other points in the map were interpolated, as shown in **Figure 37** as a contour map. The points with a similar path cost from the origin to Kwun Tong MTR station are highlighted in the same color.

The contour map helps identify the cover area of the POI, potential blind spot and improvement direction. For example, there is a sharp change in the contours near point M (觀塘工業中心, Kwun Tong Industrial Centre), as the path cost for the point to the origin drastic increases from 500-1000 to 1000-1500. It is because the present of long barriers around the Kwun Tong Industrial Centre, preventing pedestrian to pass through directly to point N. Pedestrian is required to take a longer detour hence pull up the path cost drastically. Another observation is that point 20 (曉麗苑, Hiu Lai Court) has a higher path cost to the MTR stations compared with the surrounding area which has similar distance to the MTR station. The high path cost may contribute to the fact that the area is surrounded by stairs, which pedestrians in Kwun Tong are not preferred (cost coefficient equals 8.92 in **Table 15**).

Similar path cost contour maps were generated from different POIs, such as APM (Shopping mall), Kwun Tong Promenade (Recreational area), United Christian Hospital (Public health facility), Yue Man Square (Transport transfer station) and Shui Wo Street Market (Shopping market), as shown in **Figure 38 - Figure 40**.

It is important to highlight the difference of our accessibility analysis with the existing walking

evaluation system such as Walk Score. Our approach is to model pedestrian route choice behavior, by calibrating the cost coefficient in a utility model against the revealed trajectory data in the area. The accessibility analysis developed in this study is based on an objective measure on pedestrian by revealed trajectories.

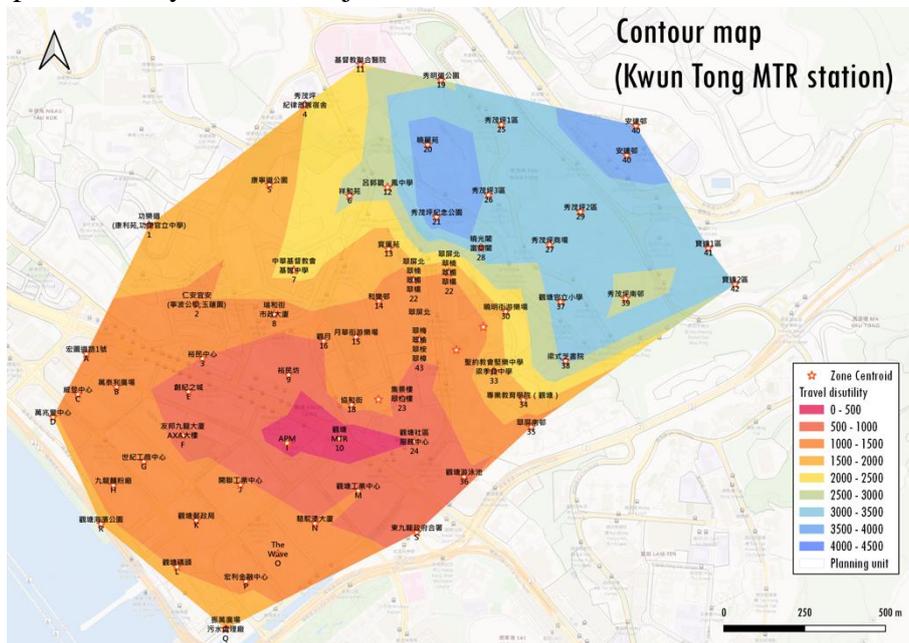


Figure 37. Path cost contour map for Kwun Tong MTR station

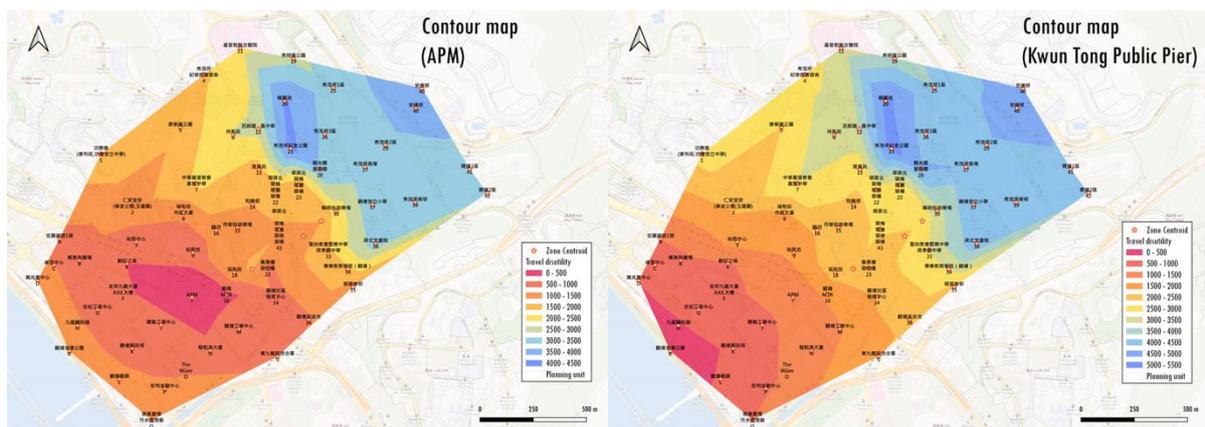


Figure 38. Path cost contour map for (a) APM; (b) Kwun Tong Public Pier

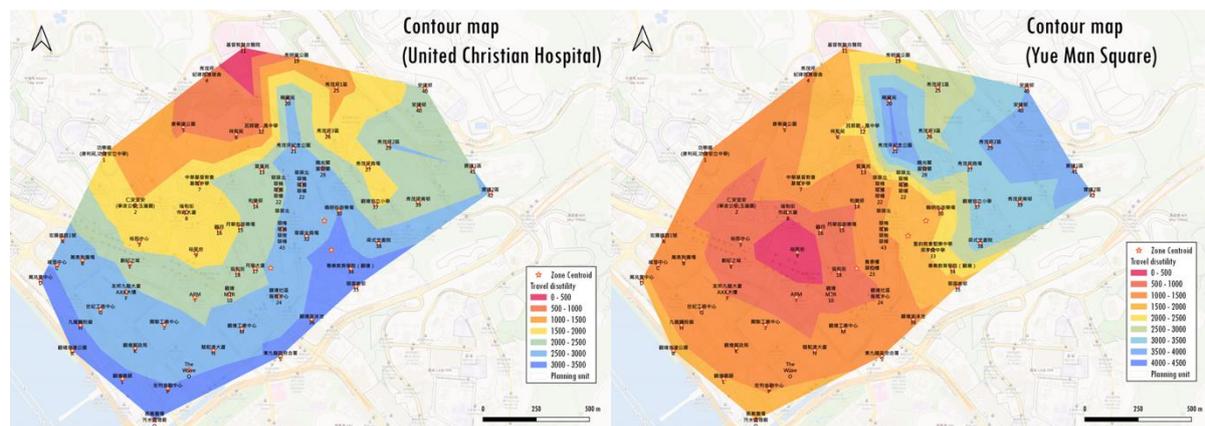


Figure 39. Path cost contour map for (a) United Christian Hospital; (b) Yue Man Square

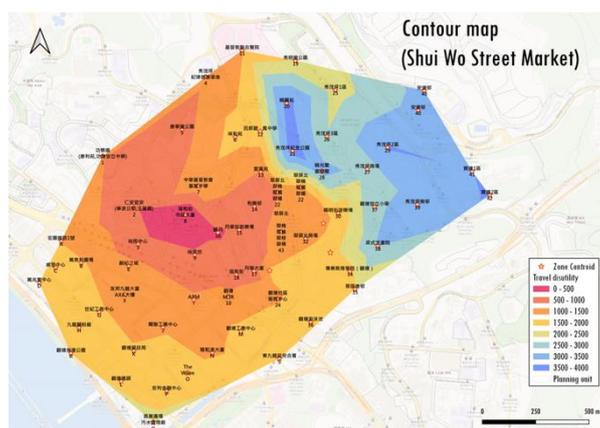


Figure 40. Path cost contour map for Shui Wo Street Market

4.4 Task 4 – Accessing Policy Options

Based on an understanding of the issues identified in Task 1, policy instruments focusing on supply and demand sides, as well as good practices from foreign experiences, we identified a set of key policy instruments for walkability enhancement (Table 19). Policy instruments are actual means or devices governments have at their disposal for implementing policies, and among which they must select and take into account in formulating policy (Howlett & Ramesh, 2003). Utilizing a policy instrument framework, which consists of organization-, authority-, information-, and treasure-based policy tools (or measures), can enable us to identify the types of instruments that are emphasized and those that might be lacking, as well as to identify possible policy options and recommendations for Hong Kong.

Based on the key policy instrument framework for walkability enhancement, combined with the opinions from interviews with relevant government officials and District Councilors, we further identified a set of policy options of the four categories which can potentially enhance the walkability in Hong Kong, especially in Kwun Tong and Tsuen Wan.

The following are introductions and descriptions of the policy options:

Authority and Regulatory-based options

4.4.1 Introducing specific zoning codes to enhance walkability

The process of transport planning is complex and multifaceted and requires the utilization and a good integration of the Comprehensive Transport Studies (CTS) models, feasibility studies, and land use planning at strategic and district levels. Zoning rules and regulations which regulate the use of land, play an important part here. Zoning could be a useful tool to create more walkable communities and public space. In Hong Kong, Outline Zoning Plan (OZP) is a kind of statutory plan which is prepared and managed by the Town Planning Board (TPB) established under the Town Planning Ordinance (Cap. 131). According to the Planning Department (PD), OZP is plan that sets out “the land-use zoning and major roads systems of individual planning scheme areas”. Each zoning plan shows for a particular zone “the uses

always permitted and uses that would require permission from the TPB upon application. The following are some sample zoning code elements in some American cities.

- Land use:
 - Commercial: a relevant zoning code can require commercial uses that support pedestrian activities. For example, San Francisco has zoning codes that supports pedestrian-oriented commercial uses and lays out in detail the acceptable uses for street level frontage on given streets.
 - Mixed-use: Neighborhoods and communities with a mixed land use can be interesting and attractive to pedestrians. Relevant zoning codes can require a mix of land use in certain neighborhoods and public spaces. For instance, the code from St. Lucie County, Florida, requires that each neighborhood contain a minimum number of retail and civic building lots.
- Streets:
 - Street furniture: proper and well-functioned street furniture plays an important role in a comfortable walking environment. A code from San Antonio, Texas, for example, requires a variety of different seating options, drinking fountains and trash cans in public spaces. The code also notes that street furniture should take into account the distinctive nature of the district in which the furniture is located.
 - Street walls: A zoning code from Seattle, Washington requires that each building facade should be built to the street property line along a minimum of 70 percent of the faced length.
 - Street trees: Street trees can be instrumental to adding to pedestrian comfort and enhancing the walking experience (especially in hot and humid climates). Shade trees can also give the sidewalk a sense of security and enclosure. Both Arlington and Peoria in the US require that street trees be spaced at an average spacing for not more than 30 feet apart.
 - Public art: If properly spaced, public art pieces can foster a vibrant and energetic public space. Relevant codes can encourage developers to provide public art by providing some incentives. For example, a code from Minneapolis, Minnesota requires that the art pieces should be located where it is sufficiently visible to the public, and the art pieces should be maintained in good order.

Organization-based options

4.4.2 Managing street obstacles and obstructions

Street obstacles and obstructions pose significant threats and dangers to ordinary pedestrians. For many years, the Hong Kong government has worked on combating “shop front extensions” (SFEs) to ensure the safety and permeability of public streets. In Hong Kong, illegal shop front extension is a complex street management problem that falls within the purview of many government departments. However, the problem of SFEs has persisted and the government’s counter measures have not always been effective and satisfactory. It has been reported that (1) some shop operators have adopted new tactics to avoid being fined, and that (2) law enforcement officers’ actions have not been consistent and effective, and that (3) the light penalty of FPNs have failed to deter some of the shop operators. To combat shop front

extensions and their associated problems related to walkability enhancement, law enforcement and relevant actions should be stepped up and improved. Possible recommendations include a) reviewing the fixed penalty system; b) enhancing inter-departmental enforcement; c) improving community involvement and public participation.

4.4.3 Developing signature programs

In order to foster an environment which is more livable and pedestrian-friendly, Hong Kong also needs to reconsider the significance of “public shared space”. The following case from New York is worth considering.

Since 2007, the Department of Transportation (DOT) of the New York City has partnered with community organizations (e.g., various NGOs) to create neighborhood plazas (including one-day plazas, interim plazas, and permanent plazas) to transform streets into vibrant, and high-quality public spaces under the NYC Plaza Program. Eligible community organizations can apply to the Plaza Program if they can demonstrate local support of the proposed plaza and the capacity to maintain it. DOT will fund the design and the construction of the successful applications. Most of the successful plazas are visually appealing and equipped with comfortable and flexible seating and tables. Most importantly, they are pedestrian destinations which are suitable for open-air activities. Over the years, the plazas have been proven to increase pedestrian volumes, enhance pedestrian safety, and improve local economic vitality.

Similar programs or projects can also be considered in Hong Kong’s local neighborhood and communities. For example, the Energizing Kowloon East Office (EKEO) in Kwun Tong has made some similar efforts. In 2013, the EKEO turned the Tsun Yip Street Playground into an organic farmer’s market on certain workdays, which attracted many office workers and nearby residents. Such efforts can be extended to other playground or public spaces with lower pedestrian flows in the district.



Figure 41. Brooklyn’s Pearl Street before and after redevelopment. Photo by Ryan Russo/NYC DOT

4.4.3.1 Developing safer streets programs (especially for the elderly)

As of the end of 2020, around 20% of the Hong Kong population are seniors over 65. However, according to the statistics provided by the Transport Department (TD), in the last few years, over 55% of pedestrian fatalities in Hong Kong were seniors over 65 (the figure even reached 75% in 2017). More importantly, the senior population in Hong Kong is increasing at a rapid speed. It is expected that the number of senior citizens will increase from 18.4% of the total population in 2019 to 33.3% in 2039. Therefore, it is of great significance that measures to be taken to enhance pedestrian safety for seniors.

The case of Singapore's Silver Zone may be a good example. According to Singapore's Land Transport Authority (LTA), a total of 50 Silver Zones will be completed by 2023. Silver Zones are areas with enhanced road safety measures which make it safer and more convenient for senior pedestrians to cross the roads. These features include distinctive signs, road features and markings which help to lower vehicle speeds and guide pedestrians to designated crossing points. Silver Zones are found in selected housing estates with a higher population of seniors and relatively higher accident rates involving seniors, as well as areas near amenities which seniors frequent. The speed limit in Silver Zones, where it is feasible to lower the speed limit, is generally 40 km/h. Silver Zones are being built in selected residential areas to enhance road safety for the elderly.

A similar approach to enhance pedestrian safety, especially for senior citizens, can also be found in New York's Safer Streets for Senior Initiative. This is a pedestrian safety initiative for older New Yorkers. Since launching the program in 2008, DOT has addressed senior pedestrian safety issues in 41 Senior Pedestrian Focus Areas (SPFAs) in the five boroughs. Since the program began, annual senior pedestrian fatalities have decreased 17% citywide, from an average of 65 fatalities per year between 1999 and 2008 to an average of 54 fatalities between 2009 and 2018. The Safe Streets for Seniors program studies crash data conducts outreach and develops and implements mitigation measures to improve the safety of seniors and other pedestrians, as well as all road users in New York City. DOT evaluates pedestrian conditions in these neighborhoods from a senior's perspective and implements safety improvements, such as extending pedestrian crossing times at crosswalks to accommodate slower walking speeds, constructing pedestrian safety islands, widening curbs and medians, narrowing roadways, and installing new stop controls and signals). Other typical safety improvements include: Countdown signals, signal timing, pedestrian safety islands, road diet, sidewalk extensions, raised crossings/intersections, bus stop improvements.

Information-based options

4.4.4 Improving and promoting the HKeMobility application

The HKeMobility application is an all-in-one mobile application which integrates three mobile applications previously developed by the Transport Department ("HKeTransport", "HKeRouting" and "eTraffic News"). According to TD, this all-in-one mobile application features an integrated route search for public transport, walking and driving (including MTR, Light Rail Transit, franchised bus, residents' service, green minibus, ferry, tram and peak tram, cross boundary coach to Huanggang/Lok Ma Chau, bus to Ma Wan and Discovery Bay).

However, according to the reviews and comments from two of the major application platforms (i.e., Google Play and Apple App Store), the HKeMobility application has multiple issues that can be further improved (e.g., currently slow or unstable, the user interface is not user-friendly, sometimes information not accurate). Moreover, the Transport Department can spend more effort on marketing and promoting the HKeMobility application to the public.

Policy analysis: systematic analysis of policy options

After identifying and formulating the above-mentioned policy options for walkability enhancement, we assess and analyze those policy options employing the method of Multi-Criteria Analysis. A Criteria-Alternatives Matrix for walkability enhancement is developed in **Table 21**.

Table 21. Criteria-Alternatives Matrix (CAM)

Criteria	Effectiveness	Efficiency	Equity	Political feasibility	Total
Scoring definitions	<p>Low: No/small likelihood of achieving objectives</p> <p>Medium: moderate likelihood of achieving objectives</p> <p>High: High likelihood of achieving objectives</p>	<p>Low: costs are high relative to benefits</p> <p>Medium: costs are moderate to benefits</p> <p>High: costs are low relative to benefits</p>	<p>Less favourable: low likelihood of achieving fairness in distribution of costs, benefits, and risks across population subgroups</p> <p>Favourable: moderate likelihood</p> <p>More favourable: High likelihood</p>	<p>Low: No/small likelihood of being enacted</p> <p>Medium: Moderate likelihood of being enacted</p> <p>High: High likelihood of being enacted</p>	
Authority/Regulatory-based options					
#1 Expanding CTS to include walking as a transport mode	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Less favorable <input type="checkbox"/> Favorable <input type="checkbox"/> More favorable	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	
#2 Zoning codes developme	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Less favorable <input type="checkbox"/> Favorable <input type="checkbox"/> More favorable	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	

nt					
Organization-based based options					
#3 Improving street management	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Less favorable <input type="checkbox"/> Favorable <input type="checkbox"/> More favorable	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	

Criteria	Effectiveness	Cost-Efficiency	Equity	Political feasibility	Total
Scoring definitions	<p>Low: No/small likelihood of achieving objectives</p> <p>Medium: moderate likelihood of achieving objectives</p> <p>High: High likelihood of achieving objectives</p>	<p>Low: costs are high relative to benefits</p> <p>Medium: costs are moderate to benefits</p> <p>High: costs are low relative to benefits</p>	<p>Less favourable: low likelihood of achieving fairness in distribution of costs, benefits, and risks across population subgroups</p> <p>Favourable: moderate likelihood</p> <p>More favourable: High likelihood</p>	<p>Low: No/small likelihood of being enacted</p> <p>Medium: Moderate likelihood of being enacted</p> <p>High: High likelihood of being enacted</p>	
Organization-based based options					
#4. Developing signature programs	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Less favorable <input type="checkbox"/> Favorable <input type="checkbox"/> More favorable	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	
#5 Developing Safer Street Programs	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	<input type="checkbox"/> Less favorable <input type="checkbox"/> Favorable <input type="checkbox"/> More favorable	<input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High	
<input type="checkbox"/> Information-based options					

#6 Promoting the HKeMobility application	<input type="checkbox"/> Low	<input type="checkbox"/> Low	<input type="checkbox"/> Less favorable	<input type="checkbox"/> Low	
	<input type="checkbox"/> Medium	<input type="checkbox"/> Medium	<input type="checkbox"/> Favorable	<input type="checkbox"/> Medium	
	<input type="checkbox"/> High	<input type="checkbox"/> High	<input type="checkbox"/> More favorable	<input type="checkbox"/> High	

5 Policy implications and recommendations

5.1 Appraising pedestrian infrastructure improvement

For any pedestrian facility improvement proposals, it is important to appraise them based on scientific, objective grounds. Such appraisals will provide evidence to justify or reject proposals, which will be much more rational than deciding purely based on subjective, sometimes personal preferences. To this end, the network analyzing tools developed in Tasks 2 and 3, including the what-if scenarios and walkability analysis in **section 4.2.2** and accessibility analysis in **section 4.3.1** are instrumental to depict the benefits and costs of walking infrastructure improvements. Before implementing the actual facility, appraisals such as the additions of crossing, footbridges and elevators can be evaluated based on the 3D-GIS and BIM platform and route choice model, respectively.

As an illustration, we analyzed the pedestrian infrastructure improvement currently under construction in the Kwun Tong area (Legislative Council, 2016). Based on the accessibility analytical tools developed in **section 4.3.1**, the effects of walking infrastructure improvement in accessibility can be analyzed. Two walking facilities connect the hillside to downtown as shown in **Figure 42**. The first one, shown on the left-hand-side of **Figure 42**, is a connection with escalators from point 20 (曉麗苑, Hiu Lai Court) to point 21 (Sau Mau Ping Memorial Park 秀茂坪紀念公園). Another connection is near point 28 (曉光閣 Hiu Kwong Court) where a footbridge with elevators is built to connect Hiu Kwong Street to Tsui Ping Estate, show on the right-hand-side of **Figure 42**. The improvement schemes are realized in the 3DGIS pedestrian network in **Figure 43**.

pairs in the network, which can be achieved by analyzing the accessibility measures linking all POIs. In all, the overall benefit of such appraisals, or other changes in the pedestrian network, can be evaluated based on the developed analytical tools.

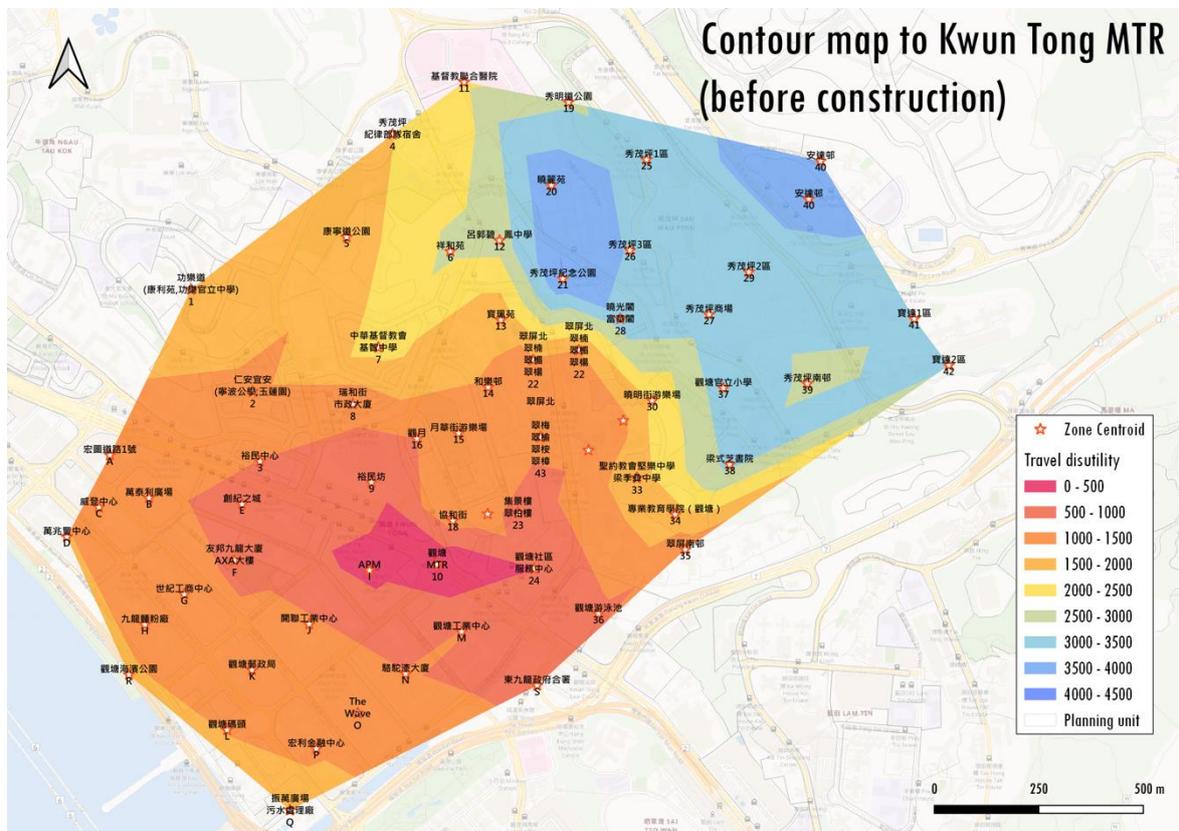


Figure 44. Path cost contour map for Kwun Tong MTR station before improvement

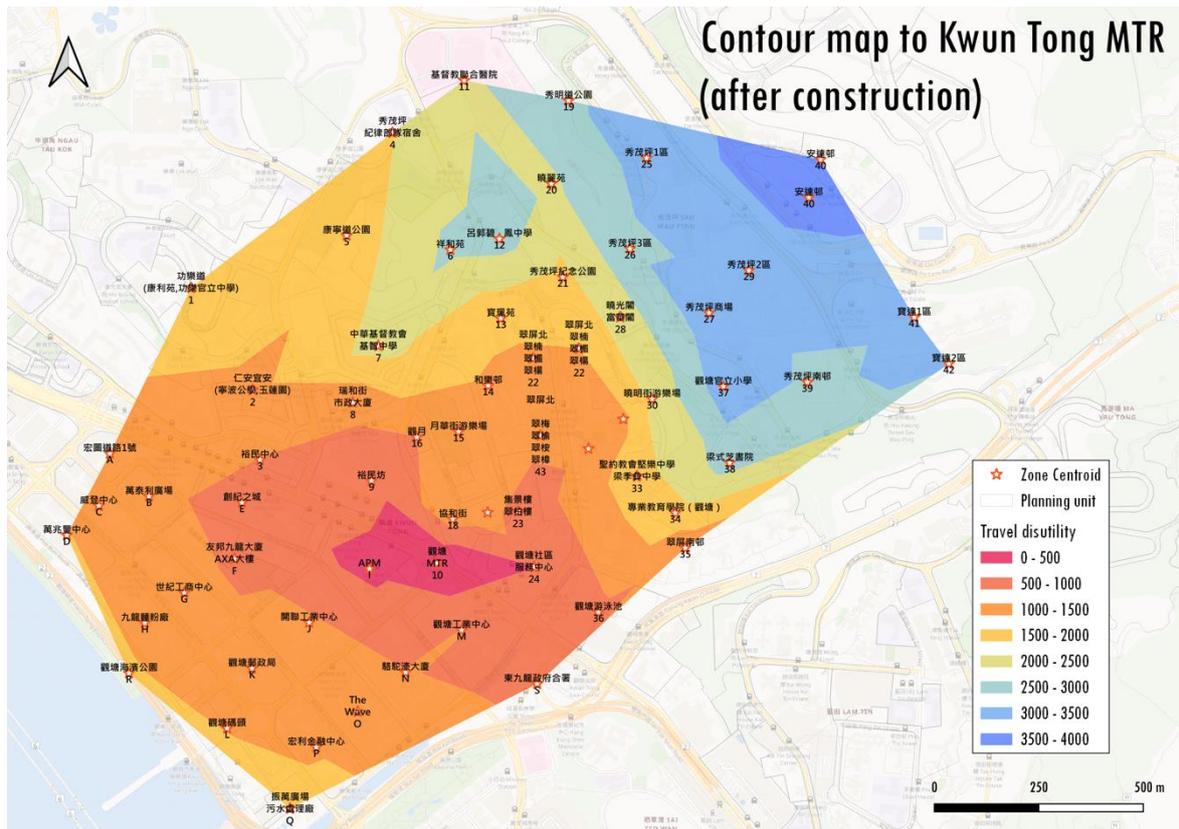


Figure 45. Path cost contour map for Kwun Tong MTR station after improvement

Table 22. Change in path cost before and after the improvement schemes

Zone	Zone label	Minimum path cost before Improvement	Minimum path cost after Improvement	Changes	%
Hiu Lai Court 曉麗苑	20	3952	2419	-1533	-39%
Sau Mau Ping Memorial Park 秀茂坪紀念公園	21	4022	1862	-2160	-54%
Sau Mau Ping (3) 秀茂坪3區	26	3448	2892	-556	-16%
Hiu Kwong Court 曉光閣	28	3324	2234	-1090	-33%
Leung Shek Chee College 梁式芝書院	38	3145	2712	-433	-14%

5.2 Coordinating street management

According to the interviews with District Councilors and government departments, it is apparent that street management is a complicated yet important issue for enhancing walkability. In practice, it was mentioned that more than ten government agencies or departments are involved in various aspects of street management, such as pavement maintenance by Highway Department, whereas if underground utilities are involved, the responsible departments may include Drainage Services Department, Office of the Communication Authority, Transport

Department, Electrical and Mechanical Services Department, design of pedestrian pathways and traffic facilities by Transport Department, managing obstruction and illegal occupation issues by Food and Environmental Hygiene Department, tree management by Lands Department, Leisure and Cultural Services Department, and Highway Department, waste management by Food and Environmental Hygiene Department and Environmental Protection Department, etc. According to the District Councilors, the Home Affairs Department is often the department they turned for coordination, and if needed, District Council will be redirected to other departments for further actions. This is, obviously, very difficult to navigate, and far from ideal.

We therefore see the need of establishing a single coordination unit or point of contact who is responsible for street management in a holistic manner. With well-defined roles, such coordination unit can work with different departments and agencies to develop proper processes and procedures for the design, construction and maintenance of walkability facilities, and for streamlining the communications between various government departments and Transport and Traffic Committees of District Councils.

5.3 Developing district signature programs

Signature programs draw attention, increase the profile of walkability, and allow people to experience first-hand the urban environment that is conducive to enjoyable walking. Such experiences would rally stronger public support for walkability enhancements even for areas outside the signature programs. We, therefore, recommend to develop walkability signature programs in each district if possible. Such signature walkability programs shall incorporate cultural, aesthetic, and leisure dimensions, while considering the specific demographics of the District.

A good example is that in 2013, the Energizing Kowloon East Office (EKEO) turned the Tsun Yip Street Playground into an organic farmer market on certain workdays, which attracted office workers and nearby residents. Other examples include Kwun Tong Promenade Waterfront Park and the Promenade in Tusen Wan West. Such efforts can be extended to other public spaces in the district.

5.4 Including walkability as part of the formal transport planning process

The Comprehensive Transport Study (CTS) is a series of transport planning studies conducted by the Hong Kong Government to develop a forward-looking, holistic and balanced transport plan for Hong Kong. Previous studies were commissioned in 1999 (CTS-3), 1986 (CTS-2) and 1973 (CTS-1), respectively. In these CTS versions, as a type of non-motorized trip, walking was not recognized in the planning process. The general premise was to accord a higher priority to motorized over non-motorized trip, even though a complete trip generally involves walking at both trip ends, such as the first and last mile connections. Such a policy that focuses solely on motorized trips leaves little room for placing walkability as a core part of transport planning. We, hence, recommend that walking be recognized fully as part of the transport planning process, such that a planning framework can be developed to address the end-to-end transport in a holistic manner.

An important feature of incorporating walkability into the transport planning process is to pay attention to the fact that different user groups have different needs, and hence will require different kinds of facilities. The elderly will need different pedestrian facilities from people with disabilities, or people who are new to the area or way-finders. It is vital to put universal access as an important planning criterion.

As the CTS planning process relies on data collected from the Travel Characteristics Survey (TCS) for model calibration, it is equally important to update the upcoming TCS exercise so that proper walking behavior, attributes, and characteristics will be captured.

5.5 Modifying regulations and guidelines for enhancing walkability

Relying on District Councils to report and propose walkability improvements in an ad hoc manner is fine, but it is far more efficient if a systematic and consistent way is developed to ensure that all new streets, and old ones to be modified gradually, will fulfill certain updated design standards or guidelines. This can be achieved through policy instruments, such as zoning rules and regulations as stipulated in the Outline Zoning Plan (OZP) or through the Hong Kong Planning Standards and Guidelines. Any change in the standards and guidelines will have implications on new as well as old pedestrian facilities, which will need a detailed study on its feasibility, practicality, and cost and benefit balance.

5.6 Providing information to facilitate and encourage walking

Providing end-to-end walking directions and information is very useful to people who are not familiar with the area. Even for people who are frequent travelers in the area, their perceptions may not be accurate, or their usual directions may not be the best for their needs. Hence, it will be very useful to provide walking directions and real-time guidance, similar to what vehicle navigation apps do. One issue with current commercial software is that they do not have accurate pedestrian networks encoded, leaving the recommended paths by these apps not perceived to be useful and accurate by users. Initially through our project, we developed detailed pedestrian networks for Tsuen Wan and Kwun Tong that can be used for this purpose. Recently, the Lands Department has released the pedestrian networks for the entire Hong Kong, which we expect will soon be adopted for developing much more accurate pedestrian navigation apps.

In fact, the Transport Department has already developed an app called HKeMobility, that integrates three mobile applications (“HKeTransport”, “HKeRouting” and “eTraffic News”). The app as of now is not widely known or used, and certainly it will benefit from further marketing and promotion effort and improvements to make it more user-friendly.

5.7 Specific recommendations for Kwun Tong and Tsuen Wan

While the above policy implications and recommendations will apply to both Kwun Tong and Tsuen Wan, the following are observations and recommendations for each of them individually.

5.7.1 Kwun Tong

Kwun Tong has been undergoing substantial changes in the land use pattern in recent years, from previous industrial areas into commercial and sometimes mixed commercial and residential uses, and with the opening of the attractive waterfront promenade. These changes

will create new patterns of pedestrian flows, and the demand for more accessible walking facilities toward the waterfront. All these call for the need of new pedestrian traffic forecasting and planning of appropriate pedestrian facilities.

One other concern expressed was the congestion, both vehicular and pedestrian traffic, around the roundabout between Hoi Yuen Road and Kwun Tong Road. It is essential to conduct a proper traffic assessment study and develop suitable mitigation solutions to address both types of traffic, which will be instrumental to opening up the area southwest of Kwun Tong Road and the waterfront for further development.

5.7.2 Tsuen Wan

Tsuen Wan is well known for its footbridge network in its central area. Despite all the difficulties in the planning and construction of footbridges, Tsuen Wan is a success story, as far as footbridges are concerned. Yet for areas away from the central area, such as Tsuen King Garden, uphill walking facilities are generally lacking. There is a need of walking facilities such as elevator and escalator for residents on the hillside to overcome the elevation, especially during the evening peak when it is challenging for residents to walk uphill, leading to heavy demand for the last mile uphill transit. In assessing the need of footbridges or elevators, the existing pedestrian flow may not be indicative of a facility's future usage, as an uphill facility that is not heavily used today does not mean that it will not be with the addition of a suitably connected elevator.

One concern expressed was about the redevelopment near Texaco Road. The redevelopment there creates new pedestrian flow pattern, and hence calls for the need of new pedestrian flow planning and the design of appropriate pedestrian facilities. In general, any redevelopment or rezoning of uses will substantially modify the pedestrian flows. Unless the transport planning process integrates pedestrian flow in its analysis, it will be hard to upkeep the changing needs and plan for walkability improvement accordingly.

5.8 Future thoughts

Before, walking quality assessments have been mostly conducted based on subjective measures through surveys, such as Walk Scores. With the analytical tools developed in this project, it is possible for the first time to develop objective quantifiable accessibility measures for walking based on the utility functions developed in Task 3 and the 3D pedestrian networks developed in Task 2, either from the perspective of POIs or from that of specific residential areas, or for the whole district by combining measures from these two perspectives. These accessibility measures are sensitive to even minor pedestrian facility improvements, as demonstrated in the results section. We recommend that such analysis can be adopted or applied to all districts, determining their walking accessibility measures for benchmarking and future references. These measures can also be used to justify or prioritize pedestrian facility improvement proposals in an objective manner, or to identify areas with special needs or poor accessibility.

The government has embarked on developing the Common Spatial Data Infrastructure (CSDI), and started the new Spatial Data Office. This will be extremely important for upkeeping the pedestrian networks and promoting their use, especially in the development of new pedestrian navigation apps catering to the needs of different user groups, such as for the elderly, for people

with different kinds of disabilities, for different weather conditions, such as different navigational paths for rainy and hot weathers.

6 Details of the public dissemination held

A 3-hour walkability workshop was held on 20-Sep-2019 at the Hong Kong University of Science and Technology. The workshop aimed to share our research progress to relevant stakeholders, including the Walkability Task Force of Transport Department, Lands Department, Planning Department, consultants including Mott MacDonald, Ove Arup and Partners, Urbis Limited and PlanArch Consultants Limited. COVID-19 has put a halt on organizing more workshops. But we plan to organize another workshop on 08-Apr-2021 to disseminate the major results, findings and policy implications to relevant stakeholders such as consultancy, government departments and agencies, and local district councils.

During the project periods, six publications and four presentation are generated, as listed below.

Book chapter: measuring accessibility using the 3D pedestrian network - Central

- Chiaradia, A., Zhang, L. 2021, Between the in-between: Research findings on data driven strategic urban design *in* Lu, X., Trumpf, S., Valin, I., 2021, Interstitial Hong Kong: Exploring the Miniature Open Spaces of High Density Urbanism, Berlin, Jovis Verlag
<https://www.jovis.de/en/books/product/interstitial-hong-kong.html>.

Paper published:

- Zhang, L., Chiaradia, A.*, Cui, M., Zeng, W., 2020, The Elders' Preferences for Open Spaces in Multi-level, Hyper Dense Sub-tropical City. *Urban Planning International* (in Chinese), 35(1) p. 36-46. Central - Shatin

Conference paper: use the 3D pedestrian network at HK wide scale.

- You, Z., Zhang, L., Chiaradia, A.* SURE-ANN, an adaptation of reference class forecasting for the assessment of large-scale urban planning vision. 14th IACP Annual Conference Shenzhen Dec. 5-13, 2020.
https://www.academia.edu/45601968/SURE_ANN_An_Adaptation_of_Reference_Class_Forecasting_for_the_Assessment_of_Large_scale_Urban_Planning_Vision
- You, Z., Zhang, L., Chiaradia, A.* Estimating Wider Economic Impacts of Transport Infrastructure Investment -ex-post analysis of accessibility change in Hong Kong, the TOD city which transport infrastructure should HK most invest in? Urban Rail? Road? Walking. 14th IACP Annual Conference Shenzhen Dec. 5-13, 2020
https://www.academia.edu/45601985/Estimating_Wider_Economic_Impacts_of_Transport_Infrastructure_Investment_Ex_post_Analysis_of_Accessibility_Change_in_Hong_Kong_the_TOD_city_Which_transport_infrastructure_should_HK_most_invest_in_Urban_Rail_Road_Walking
- Chiaradia, A, Zhang, L., S. Kahkhar. Challenges in good urban life: high density city and volumetric urban design liveability and well being. 14th IACP Annual Conference Shenzhen Dec. 5-13, 2020.
https://www.academia.edu/44869297/Challenges_in_good_urban_life_high_density_city_and_volumetric_urban_design_liveability_and_well_being

- Zhang, L., Between the in-between. "One River, Four Cities" Architectural Schools Young Scholar Forum. 2020-12-5. Wuhan, Huazhong University of Science and Technology.

Under review:

- You, Z., Zhang, L., Chiaradia, A.* SEM-ANN, an adaptation of reference class forecasting for the assessment of large-scale urban planning vision. The paper uses the 3D pedestrian network at HK wide scale released by LandsD in December 2020 . https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3761691
- Zhang, L., Chiaradia, A*, S Khakhar. M Cui. Volumetric urban design – 3D public space and accessibility evaluation. *New Architecture*. (under review).
- Zhang, L., Chiaradia, A.*, M Cui. Evaluating the Human-centered Accessibility of Open Space in High-density City - a Case Study of Hong Kong. *Landscape Architecture*. (under review).
- Zhang, L., Chiaradia, A.*, Urban volumetrics: spatial complexity and wayfinding, extending space syntax to three-dimensional space. *Environment and Planning B: Urban Analytics and City Science*. <https://arxiv.org/abs/2012.14419>

7 Conclusion

The 2017 Policy Address stated that “We will ... foster a pedestrian-friendly environment and promote ‘Walk in HK’”. It suffices to say that enhancing walkability is a top policy priority in Hong Kong, and a core element for smart city development. In response to this call, this project sets out to conduct a systematic analysis on walkability for Hong Kong. We divided the project into four tasks. Task 1 aimed to develop vision statements on walkability and scope of policy interventions for Kwun Tong and Tsuen Wan. Task 2 aimed to develop an integrated BIM-3D GIS platform for network walkability analysis and 3D visualization for policy applications. Task 3 aimed to investigate the determinants of walking behavior and develop walking utility functions for analyzing key policy interventions to promote walkability. Tasks 2 and 3 were to develop network and choice modeling analytical tools to assess walkability. Finally, Task 4 aimed to assess policy options in general, and for Kwun Tong and Tsuen Wan specifically, to enhance and promote walkability.

We have successfully completed all four tasks, identified needs of different user groups and issues and barriers for walkability improvement, developed network and choice modeling tools and policy options for the analysis, and came up with eight broad policy implications and recommendations, as listed below:

1. Appraising pedestrian infrastructure improvement
2. Coordinating street management
3. Developing District signature programs
4. Including walkability as part of the formal transport planning process
5. Modifying Regulations / Guidelines for enhancing walkability
6. Providing information to facilitate and encourage walking
7. Specific recommendations for Kwun Tong and Tsuen Wan
8. Future thoughts

We hope that these recommendations together with the accompanying analytical tools and policy instruments will be able to bring about enhancing walkability for Hong Kong.

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