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Underground pedestrian network for urban commercial development in Tsim Sha Tsui of Hong Kong

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Abstract

Tsim Sha Tsui is one of the most important CBD areas in Hong Kong. From early 2000s, a new underground pedestrian network was being developed to extend the original Tsim Sha Tsui Metro Station to access a broader scope. This paper introduces statistical analyzes on land use, pedestrian flows, pedestrian trajectories as well as qualitative investigation on planning strategies, urban renewal and real estate development to answer the following research questions: How people use this underground space network as a second level of regional pedestrian system parallel to the surface street network? How this underground pedestrian system distributes people to improve accessibility of commercial land use? How newly-developed large-scale shopping malls directly connected to the underground space distribute pedestrians to the community more efficiently as well as benefit to their own profits?

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Keywords: Underground spaces, pedestrians, commercial land use, urban design, urban renewal.

1. Introduction

Tsim Sha Tsui (hereafter abbreviated as TST except indicating specific metro stations) locates on the south tip of Kowloon Peninsula of Hong Kong. It has become one of the most important CBD areas in this high-density city

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since the earliest development of Kowloon and Victory Harbor. From early 2000s, a new underground pedestrian network was being developed to extend the original Tsim Sha Tsui Metro Station which has served TST for 2 decades to access a broader scope. After 10 years of construction, TST underground space is composed by pedestrian subways under six main streets, connecting two large-scaled metro station halls and several shopping malls (Fig. 1). This network connected three TST commercial districts originally segregated by north-south direction traffic roads [1] and was able to access most majority of urban functionalities in TST [2].

Although TST underground space network serves both as a key urban function spot in this CBD area and a typical urban design example of high-density city, there are only few academic studies focusing on this case. Adam Frampton and colleagues made 3D map as simple analysis of the network in their illustrative book "City Without Ground" [3]. Grace Gu discussed its transportation function in its early development stage in her master thesis [4]. A more comprehensive analysis on this system and its relationship of TST land use can be found in another master thesis by Wu Jingwei [2]. However, Wu's study only use static land use and building volume data in an analytical scale of the whole TST region, which may not be able illustrate detailed or dynamic phenomena of this underground space network. The system's erformance on regional commercial development is still not yet understood specifically.

This paper focuses on how TST underground space network affect the regional commercial potentials by redistributing amount of people and their walking activities. The research approach is introducing statistical analyses on land use, pedestrian flows, pedestrian trajectories as well as qualitative investigation on planning strategies, urban renewal and real estate development to investigate three hypotheses on: (1) TST underground space created a more important regional pedestrian system parallel to the surface street network; (2) This underground pedestrian system improves accessibility of commercial land use of TST region; and (3) Newly-developed large-scale shopping malls also efficiently contribute to community commercial development besides benefit to their own profits from their direct connection to the underground pedestrian network.

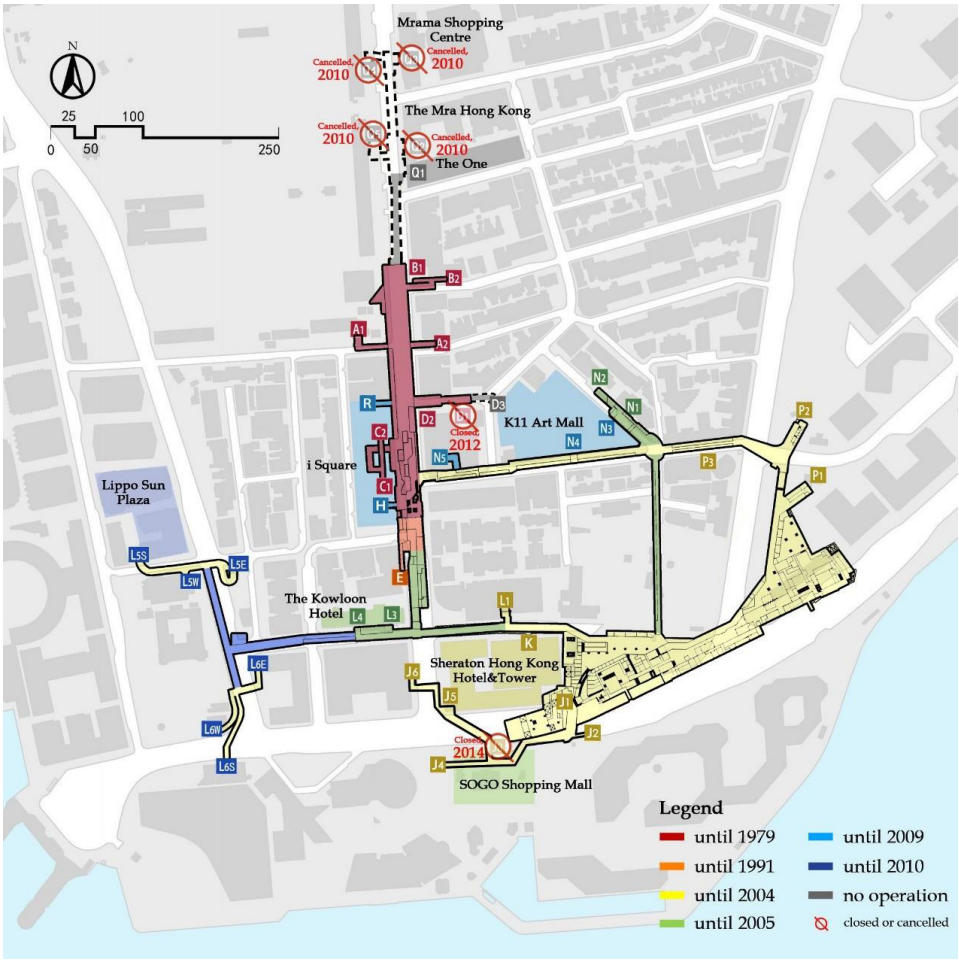

Fig. 1. TST underground space network plan and its development stages.

2. Research Methodology

This study uses pedestrian flow as index of business potential for commercial land use especially retail and catering, as more volume of people's flow will bring more walk-in shop visiting and purchasing opportunities. Individual pedestrian activities are also introduced to investigate how people use certain infrastructure to access different kinds of surface destination from underground spaces. Land use and observation data are spatially analyzed by the research team through GIS and Space Syntax software.

2.1. Data Acquisition

Data collected for this study including static built environment data and dynamic environmental behavior data. Hong Kong survey maps are employed as the base map and the underground spaces are redrawn by the research team according to CentaMap [5], information from TPB Statutory Planning Portal website information [6], and gazettes from various HKSAR Government departments. Other static and dynamic data acquisitions are elaborated in the following sections.

2.1.1. Land Use Categorization

According to the categorization by Carmody and Sterling [7], land use of TST are divided into 8 types (shopping mall, retail, catering, entertainment, service, office, hotel, and residence). In order to investigate the most related commercial activity with pedestrians, functionality types of the first and second floor of the building in TST study area are introduced and calculated instead of ordinary block land use or volume of a whole building block. Research team use Google Earth Street View as reference to record location and length of different shops along street elevations. Then an algorithm is invented to estimate floor areas of each categories according to the proportions of a building boundary. The algorithm is automatically operated in ArcGIS to calculate floor areas of each category in the whole TST region as well as individual building or designated district.

2.1.2. Pedestrian Flow Observation

Pedestrian flows of 33 underground space exits, 14 sections of subways and 70 sections of surface streets are collected in both weekday and weekend (or holiday) respectively in 4 rounds of field survey on April of 2014, January to February and September of 2015, and March of 2016. Surveyors recorded pedestrian flow of each observation point with a 2-minutes videos around 10:00, 13:00, 15:00, 18:00 and 21:00 on the survey date. Number of pedestrians and other attributes, such as walking directions and numbers of pedestrian genders, are recorded and input into a GIS database by desktop works.

2.1.3. Walking Trajectories

Research team tracked pedestrian trajectories starting from two typical newly developed shopping malls, the K11 Hong Kong Art Mall (hereafter referred as K11) and iSQUARE in early February of 2015 and early March, 2016. Surveyors randomly tracked pedestrians who went into the mall from underground exits N3 and N4 of K11, and H and R of iSQUARE, which are directly connected with the underground space. If a tracked pedestrian spends more than 5 minutes stay in either a building except these two malls or a certain shop within the malls are considered that he or she has reached their destination. Surveyors marked the trail on a map and record their destination types as well as the pedestrian's personal features such as gender, age group, numbers of accompanied people, and approximate domestic or tourism visiting. Totally about 500 paths in K11 and 640 paths in iSQUARE were recorded.

2.2. Data analyses

Research team investigates the pedestrian phenomena through various spatial analytical and visualization approaches, including Space Syntax, ArcGIS-based geostatistical computation, line density analysis, as well as simple correlation statistical analyses.

2.2.1 Pedestrian Flow Simulation

The ideal but unfeasible approach is to simulate the pedestrian flows in surface streets without underground space, then compare the simulation results with site observation. Integration of streets calculated by Depthmap becomes a parameter measuring all streets under the condition of no underground space to some extent. If the integration has a high correlation with pedestrian flows in the surface streets without vertical subways, it can be used to simulate the pedestrian flows in the surface streets with vertical subways under the same condition that there is underground space network but no vertical subways below.

2.2.2. Statistical Analyses

On one hand, the correlations between the pedestrian flows of the surface streets, underground space network and its exits respectively, can describe the distribution of pedestrian flows between these multi-level pedestrian systems.

On the other hand, the correlations between the pedestrian flows and commercial land use distribution, can infer if the construction of the underground space network enhance commercial potential.

3. Effects of Underground Network

According to the pedestrian distribution phenomena, effects of TST underground network may be shown in two aspects. Firstly, underground network carries more pedestrian flow and creates better accessibilities than the surface streets. The lower layer of pedestrian system serves as a substitution to the surface streets. Secondly, surface commercial facilities are benefit from the deliberately designed exit locations which redistribute increasing pedestrians generated by the underground network.

3.1. Substitution Effect of Underground Network to Surface Streets

The underground space network influences the whole pedestrian environment by the substitution effect of subways to surface streets. According to the site survey findings, these substitutions shown their differences between short-range and long-range pedestrian activities.

3.1.1. Short-distance Substitution

Short-distance substitution is a compulsive choice for pedestrians to cross restricted surface motor lanes by subways. For example, the subways among exits L5 and L6, which evolved from existing pedestrian facilities, still maintains their function as underpasses. Daily average pedestrian flow sum of six exits of L5 and L6 largely exceeds that of underground subway section to the stations (see Fig. 2), which means more people just use the subways to cross the traffic roads in a small range. Series of J exits were planned in the same pattern. But since there are both other surface approach crossing Salisbury Road and denser exits distribution around, its substitution phenomenon is not as obvious as L5 and L6.

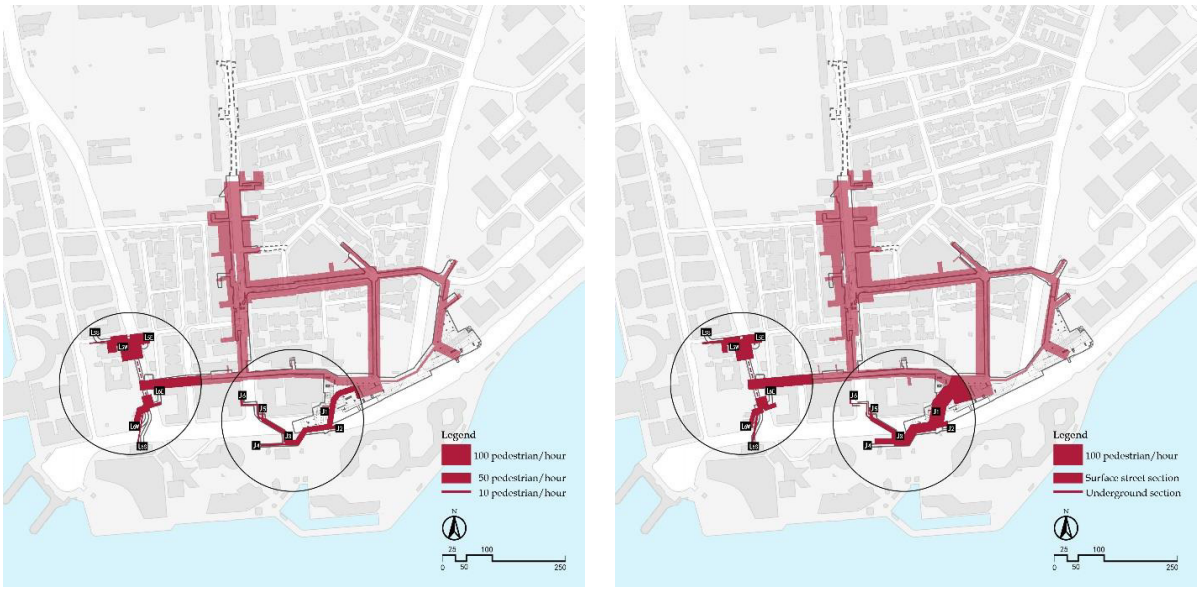

Fig. 2. Daily average flows during weekdays (left) and weekends (right): left circles indicate L5/L6 region; right circle includes J series exits.

3.1.2. Long-distance Substitution

Comparing to the above-mentioned short-distance substitution, long-distance pedestrian activities is more significant since it has created a systematic network layer in vertical dimension in TST. Integration parameter of streets is introduced to describe the possible pure surface pedestrian intensity without underground space. Low correlation between the integration values and the observed pedestrian flows can be found (R^2=0.06899) for all streets, while much higher correlation (R^2=058485) apperars if excluding those streets which have respectively vertically paralleled subways (Fig. 3). Simulative pedestrian flows of surface streets with or without subways illustrates the same pattern by comparing with site observations (Fig. 4). Real pedestrian flows on both surface and underground streets in Fig. 4 illustrate that the total amount of pedestrians distribution basically still follow the pattern determined by physical street network, while certain amount of people use subways instead of surface road respectively.

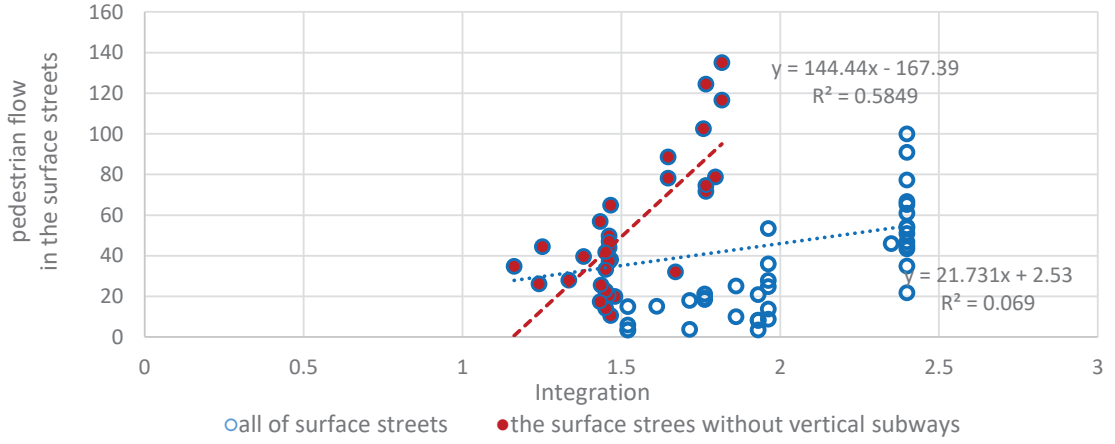

Fig. 3. Correlation of integration and daily average pedestrian flows of surface streets.

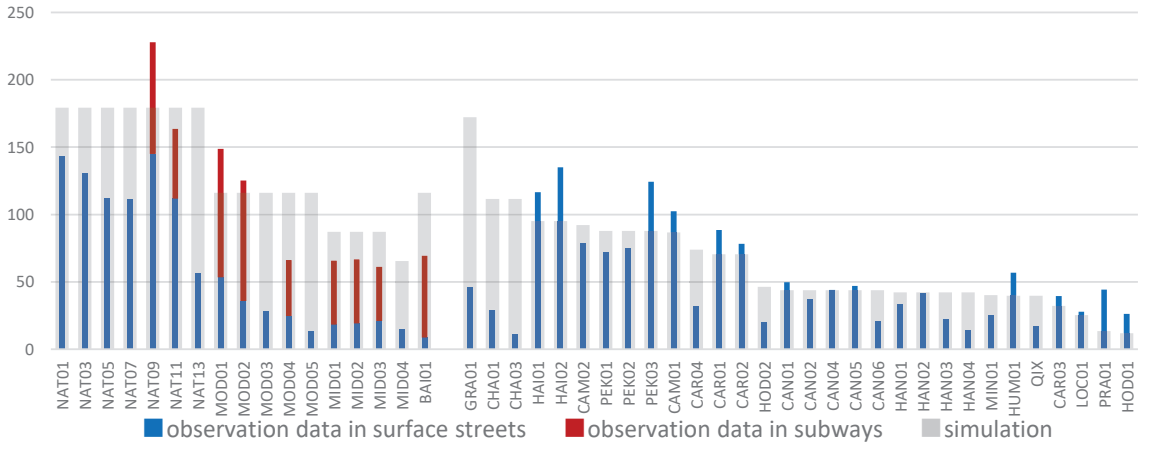

Fig. 4. Comparison between simulative street pedestrian flows and site observations.

3.2. Commercial Land Use and Underground Space Network

As in one of the main CBD areas in Hong Kong, TST underground space definitely accelerate commercial development, especially retails and catering, besides its functionality as infrastructure. Surface pedestrian flows regenerated by subway exits are investigated and their effects on different commercial land use are interpreted to explain contributions of the underground space.

3.2.1. Contribution to Pedestrian Flows in Surface Streets

All underground space exits except those straightly linked with shopping malls internally are introduced to examine the correlation between pedestrian flows on surface streets and pedestrians out of the exits. The relatively higher R2 (0.54489) illustrates the function of these exits in generating surface pedestrian flows. More detailed contributions of each exits, which is defined as the proportion of pedestrians out of the exits in the numbers of peoples on the street, are illustrated in Fig.5.

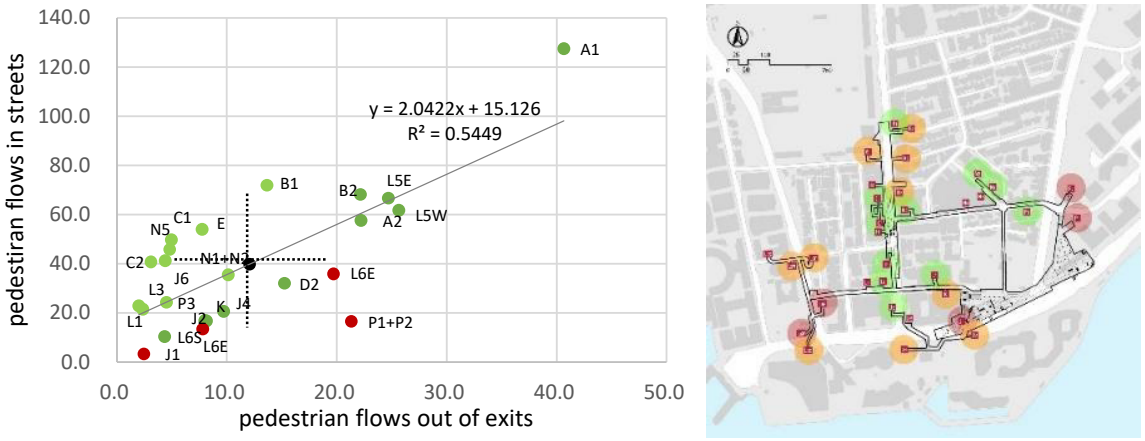

Fig.5. Correlation of daily average pedestrian flows in streets and out of exits.

3.2.2. Relationship Between Surface Pedestrian Flows and Commerical Land Use

Since it is found that the correlations of eight types of land use with pedestrian flows on the streets are all low, land use are then investigated according to three different areas subdivided according to urban fabrics and commercial formats (see Fig.6). Data within these areas are far more correlated than the whole TST, which verifies the complexity of commercial distributions in TST. In Area 1 mainly composed by large shopping malls, the correlations of shopping mall and integrated commercial attraction are very high because the single-functional mode limits pedestrians' destination. Area 3 where keeps traditional small-scaled street network over 100 years has low correlations of every type of land use with the pedestrian flows. However, correlation of the weighted commercial value raises in calculation, which infers the commercial diversify is a kind of mutually beneficial symbiosis to improve the integrated attractiveness. The correlations within Area 2 are in between just as its spatial and commercial characters which composed both small blocks with large development projects. Shopping mall dominates the land use attractiveness in both Area 1 and 2, but plays a different role in Area 3 (Table 1).

Table 1. Correlations of daily average pedestrian flows in surface streets and commercial land uses.

	Shopp-ing Mall	Enter-tainment	Retail	Office	Catering	Service	Hotel	Resi-dence
All	-0.1866	-0.7087	-0.0123	-0.1606	0.0381	0.0008	-0.0898	-0.4467

Area 1	0.6278	--	--	--	-0.8133	--	--	--
Area 1 (50m to exits)	0.5896	--	--	--	0.2355	--	-0.6621	--
Area 2	-0.3333	--	0.0637	--	0.0519	0.5282	--	--
Area 2 (50m to exits)	0.8747	--	0.1399	--	0.391	0.117	--	--
Area 3	-0.6268	-0.7087	-0.0429	-0.4253	-0.0004	0.1246	--	-0.3862
Area 3 (50m to exits)	0.0907	0.0635	-0.3015	--	0.0376	0.0399	--	-0.4889

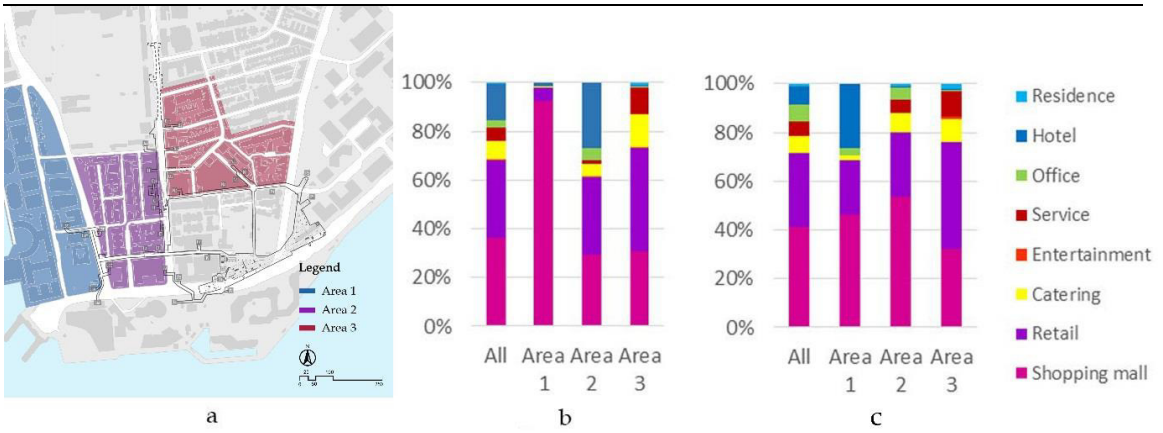

Fig.6. (a) three sub-divided areas; (b) proportions of land use; and (c) proportions within 50m scopes around the exits.

4. Regional Contribution of Large-scale Shopping Malls

Inaugurated on the same day at the end of 2009, K11 and iSQUARE are two significant urban renew projects in TST which reformed the underground space system as a new format of exit [1]. Each mall has two direct openings to subways on the underground level. Contributions of these exits on pedestrian distribution are interpreted base on surface/underground flows and tracking data from perspectives of both self-beneficial and community accelerations.

4.1. Underground Entrances as Pedestrians Generator

Similar pedestrian distribution patterns and strong correlations can be found between surface street pedestrian flows and the flows through 11 K11 surface pubic entrances and those 3 of iSQUARE associated with these streets. These data illustrate the successful commercial attraction of these giant malls on one hand, and on the other hand, also demonstrate the significance of these two malls serve as regional pedestrians generators. Contribution of underground entrances to both shopping malls itself as well as the community is also clearly indicated by the proportion of those two underground entrances flow to the amount of pedestrians of all street-level entrances of each mall respectively, which are 36% on weekday and 25% on weekend in K11, and in a similar but more stable level as 35% (weekday) and 33% (weekend) in iSQUARE.

Pedestrian trails show positive support to the significant performance of these entrances linking to the underground space. Most of the people entering these underground entrances only stay in the malls and are attracted by the shopping environment. However, function as commuting to surface streets is also obvious in specific exit locations such as H connect with Tsim Sha Tsui Station lobby to iSQUARE and N3 of K11. Even working or leisure preferences during weekdays and weekend can also be interpreted by flows of these exits. It proves that underground linkage of these shopping malls make great contribution in generating pedestrians passing through the building and providing more business opportunities for surrounding commercial land use.

4.2. District Accessibility Created by the Underground Connection

More than 1000 recorded pedestrian trials which illustrate the travel extents demonstrates the serving efficiency by these shopping malls. Since all paths are originated from those 4 underground entrances, pedestrian trails distributed in TST can be considered as accessibility of these vertical underground space connections. Fig. 7 and 8 illustrated different accessibility patterns in two cases.

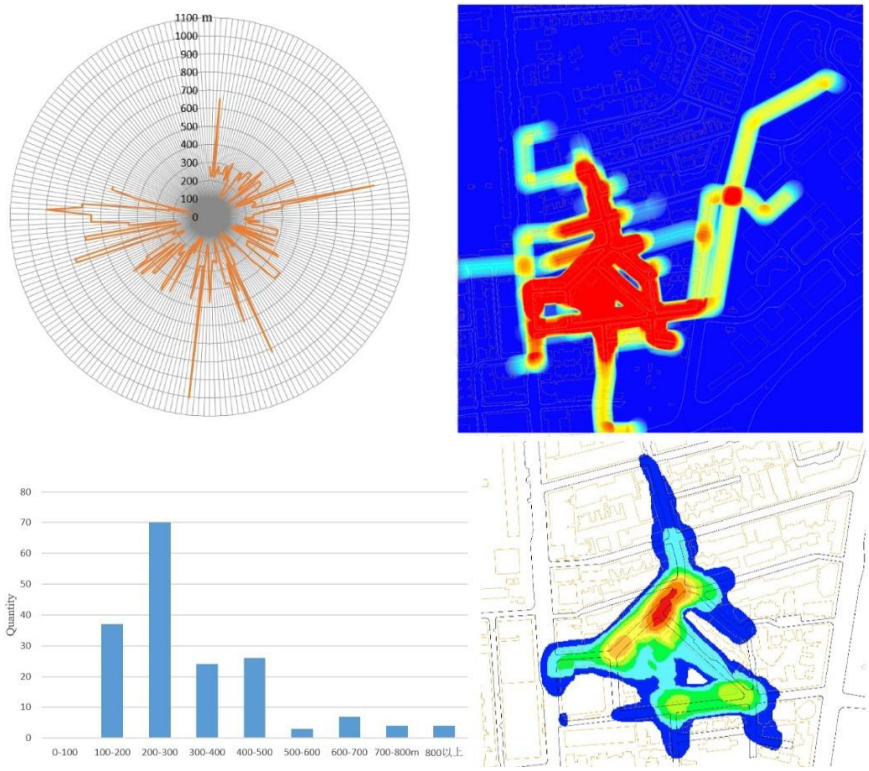

Fig. 7. Density of pedestrian trails and classified trail distances of K11.

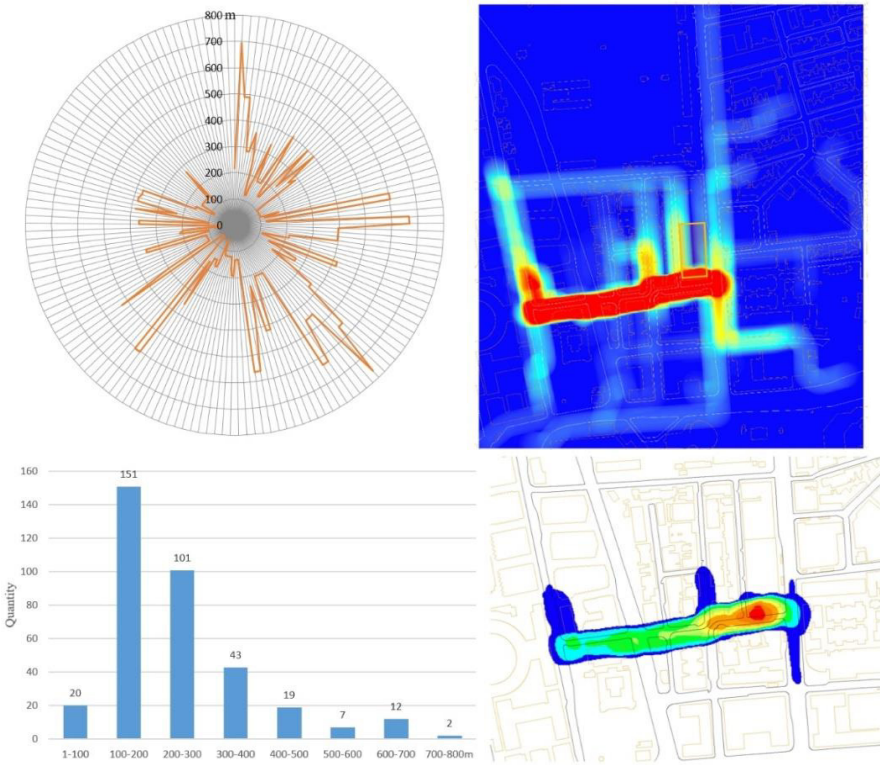

Fig. 8. Density of pedestrian trails and classified trail distances of iSQUARE.

5. Discussion

Above sections show data phenomena reflecting the three raised hypotheses raised. Analytical discussions can be made from the following aspects:

5.1. Parallel Pedestrian System

Besides the short-distance pedestrian substation which can be interpreted directly, different long-distance substitution formats can be found in pedestrian flows on Nathan Road comparing to Middle Road, Mody Road and Blenheim Road according to Fig. 4. Nathan Road with shopping malls and retails predominantly on both sides is the spine of the whole TST area and able to maintain large amount of pedestrians on surface. Only a small portion transfers to subways partly because Tsim Sha Tsui Metro Station occupied most of the underground Nathan Road subway and pedestrian density in public areas in the station are already very high. On the contrary, Middle Road is more like a back street of a couple of shopping malls, hotels and office towers, while Blenheim Avenue is narrow and impassable with few restaurants. And Mody Road is dominated by residences, which making pedestrians activities clear and definite. In the later three cases, subways bring much more pedestrians by the underground space itself and may not accelerate surface flows. Data analysis of pedestrian flows in underground space and surface streets in Fig. 3 and 4 can verify that there is a kind of proportional law for “distribution” or “increase” in long-distance pedestrian substitution. It may result from the characters of the streets on the surface, including the level of commercial development, and so on.

5.2. Efficiency of Exits

Session 3.2 illustrates evidences of the efficiency of exits in redistributing pedestrians. Exits can be regrouped by principles of proximity and service scopes as Fig. 9, which gain stronger correlation comparing to Fig.5. A, B and C exit groups have either large pedestrian flows or remarkable contribution to commercial potentials. Exits' contribution in Table 1 is also evidence of the high efficiency to the large-scale shopping facilities around these groups of exits.

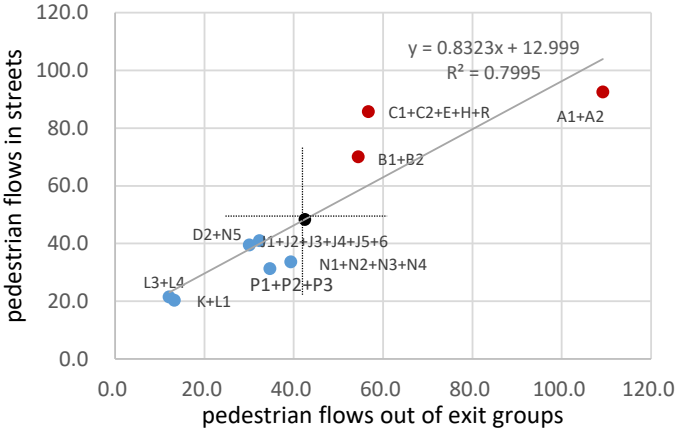

Fig. 9. Correlation of daily average pedestrian flows in streets and out of exit groups.

5.3. Connectivity Performance of the New Shopping Malls

As new vertical connection format defined by the research team [1], largest service scopes of K11 and iSQUARE can both reach 800 to 1000 m and majority service within half of its longest distances respectively. However, K11 extends its accessibility relatively evenly in surrounding community while on the contrary iSQUARE creates more intensive effects. Considering urban fabrics and land use of the sub-scopes of Area 2 and 3, it is obvious that these two cases both strength their distinguished commercial potentials within its community context. Although it is not clear that whether these shopping malls expedite or mitigate the pedestrian pattern associated with the urban fabric because of lack of longitude data, connectivity of these shopping malls in urban level can definitely be concluded.

6. Conclusion

Analyses based on site survey data proves the original three hypotheses. Pedestrian activities and preferences on either surface streets or subways depends more on integrated 3-dimentional urban pedestrian network under built environment context, such as automobiles and public transportation, urban morphology, land use, and so on. Planning of subways and exit locations is able to cooperate with maximizing TST commercial development. Case studies on K11 and iSQUARE ascertain their capability to redistribute pedestrians to either surface community or indoor shopping environment. Considering the subjective planning strategies by the Government shows the intension on connecting more commercial facilities directly to the transit stations [6], statistics on relationship of underground and surface retailing and catering land use with pedestrian flows of each exits will be helpful in deeper understanding on function of TST underground space. Mechanism driven from the data can also be introduced to other underground space design/planning and urban design or urban renewal projects.

Acknowledgement

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References

[1] J. He, Y. Huang, R. Du, J. Geng, Q. Zhang, and J. Yao, Underground Space Network for Commercial Development in Tsim Sha Tsui, Hong Kong". In Proceedings of 20th Inter-University Seminar on Asian Megacities (IUSAM 2015), University of the Philippines Diliman (ed.), digital version, Quezon City, 2015.

[2] J. Wu, Evaluation and Review of Comprehensive Development in Region of Hong Kong Tsim Sha Tsui Subway Station. Master Thesis, School of Architecture, South China University of Technology, Guangzhou, 2013.

[3] A. Frampton, J. D. Solomon, and C. Wong, Cities Without Ground: A Hong Kong Guide, ORO Editions, Novato, CA, 2012.

[4] J.G. Gu, Study on transport-related underground development: with review and suggestions for Tsim Sha Tsui. Master Thesis, Faculty of Architecture, The University of Hong Kong, Hong Kong, 2007.

[5] Centamap.com & Survey and Mapping Office, Lands Department, HKSAR Government, Centamap, 2015. Information on http://hk.centamap.com/, retrieved on 1 July, 2015.

[6] Town Planning Board (HKSAR Government) (2015). Statutory Planning Portal 2. Information on http://www1.ozp.tpb.gov.hk/, retrieved on 6 June, 2016.

[7] J.C. Carmody, and R.L. Sterling, Design strategies to alleviate negative psychological and physiological effects in underground space, Tunneling & Underground Space Technology. 2(1) (1987) 59-67.