Tunnelling and Underground Space Technology 82 (2018) 1–8

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Hong Kong's urban planning experiment in enhancing pedestrian movement from underground space to the surface

John Zacharias[a,*], Jie He[b]

[a] Laboratory for Urban Process Modelling and Applications, Peking University, Fourth Red Building, Beijing 1000871, China
[b] School of Architecture, Tianjin University, China

ABSTRACT

Hong Kong has promoted intensive development at transport nodes since 1994, by offering density bonuses in exchange for certain public goods. In particular, private investment is leveraged to contribute infrastructure that is intended to facilitate pedestrian movement from underground to the surface, while also enhancing the travel experience and providing public open space amenities. Two recent cases are evaluated to measure the extent to which such privately provided public facilities improve on the traditional approach for bringing pedestrians to the street environment and also contribute to local revitalization. The two cases offer somewhat different results, illustrating the importance of the internal arrangements. The underground system at Tsim Sha Tsui as a whole enhances the capacity of the surface system and reinforces it, although the two specific projects contribute little to vertical pedestrian flow or to local street-level revitalization. The present evaluation method may be used to facilitate negotiations between the public authority and private developers in the context of high-density nodal development.

1. Introduction

In Hong Kong's latest form of intensive, multi-layered development, new multiple use projects link the underground concourses of the Mass Transit Rail (MTR) system to the surface, with density bonuses offered to the developers in exchange for certain public goods. The recent intensive use of underground space is in keeping with the broader goals of sustainability (Bobylev, 2016) and the conservation of precious land resources (Sterling and Nelson, 2013). The public goods in the Hong Kong case include high-quality connections between the underground concourses and the surface. Also included are public open space provisions and improvements to the street environment, especially those enhancing the pedestrian experience, for the larger pedestrian flows expected from such high-density development. The general purpose is to use these new developments to strengthen or revitalize the street environment, while allowing the developers to profit from their direct connection to the emerging underground system. Our question is whether this strategy is effective and ultimately, although we cannot prove it directly, whether it is worth the substantial floor space bonuses offered to the developers in exchange for these public amenities. Considering the continued development of this kind in Hong Kong and similar projects in Mainland cities and elsewhere in the world, it is important to know whether the scheme delivers public benefits commensurate with expectations, and whether it is a more optimal solution compared with the conventional planning alternatives. In view of the relatively limited knowledge on the outcomes of such strategies (Cui and Lin, 2016), this paper is intended to contribute to that knowledge base.

The two selected cases are the recently opened K11 Art Mall and the iSquare developments, both located in the Tsim Sha Tsui (TST) area of Kowloon. Our evaluation consists of examining the following: 1 – whether the project is more effective in delivering pedestrians from the underground concourse to the street than are conventional direct connections; 2 – whether the amenities included in the projects to compensate for the density bonus do indeed result in more intensive use than the conventional public space system; and 3 – whether the project contributes to local commercial revitalization by attracting larger numbers of pedestrians from the underground system, into the surrounding area on the surface.

Before outlining the methods used for this research study, we should consider what similar bonus schemes in the planning system are known to achieve. We also briefly describe the standing policy debate on how density bonuses concur with the concept of carrying capacity, which has traditionally underpinned the right of government to limit land use intensity.

Density bonuses in planning regulations have a long history and are widely practiced today. The research literature provides a mixed assessment of the utility of density bonuses, and eventual public benefits. New York City introduced a density bonus for the provision of public open space at ground level in 1961 (Weiss, 1992), which was later copied by cities such as Montréal. In the Montréal case, an additional bonus consisted of discounting all useable underground floor space in

* Corresponding author.
E-mail addresses: johnzacharias@pku.edu.cn (J. Zacharias), janushe@tju.edu.cn (J. He).

https://doi.org/10.1016/j.tust.2018.07.025
Received 8 December 2017; Received in revised form 1 May 2018; Accepted 9 July 2018
Available online 21 July 2018
0886-7798/

the CBD in the calculation of the total permissible density, until its cancellation in 1988. In this case, the substantial benefits reaped by commercial developers from this high value underground space made such a bonus unnecessary for underground development. Such bonus provisions have been severely criticized as sacrificing design quality for the sake of urban vitality in the case of Sydney (Punter, 2005), or as overbuilding to take advantage of the bonus in the case of New York City (Kayden, 2000). The design issue in particular was taken up by the Hong Kong Town Planning Board (TPB) in the case of the density provisions for the developments in TST. Three-dimensional design control in Hong Kong, arguably exacerbated by density bonuses, has been the object of criticism (Chan and Yung, 2004). Density bonuses have also been used for other public purposes worldwide. Chicago offers a density bonus to developers who implement a green roof in the CBD, presuming reduced run-off and lower ambient temperatures in the summer (Taylor, 2007) as compensation for the additional building bulk. California offers a bonus to provide a certain proportion of affordable housing but with modest benefit or their concentration in already disadvantaged areas (Ryan and Enderle, 2012).

The density bonus scheme in Hong Kong is supported by some recent policy suggestions in Mainland China. Density bonuses have been advocated to raise ridership on urban rail systems (Yang et al., 2016), in statutory plans that generally provide uniform density provisions across broad swathes of urban fabric. The recommended adjustment of transit-oriented development to the Chinese context is inspired by the relatively large pedestrian catchment area around the metro station, approaching 500 m (Sun et al., 2016). Because active transport can be encouraged in this range, some analysts suggest greatly enlarging the urban area where such density bonuses are allowed (Xu and Zhang, 2016).

Hong Kong has promoted nodal development at MTR stations since the early 1990s. The initial MTR system opened in 1979 with new lines and line extensions under development in 2018. While the early system provided direct pedestrian links from underground concourse to street level, often following negotiations with landholders, later development such as at Hysan Place and Pacific Place integrated the metro facilities with multi-level commercial complexes at relatively high density. In these cases, exits were provided directly into the commercial complexes themselves. Bonuses were awarded for such development starting in the 1990s and continue today. The emphasis on vertical development in new projects at transport nodes has been criticized for the weak planning control exercised over building form and visual impacts at the city scale (Chan and Yung, 2004). In response to these critiques as well as the resistance of developers to pursue residential development at transport nodes (Tang and Tang, 1999), the TPB enhanced its requirements on private development for features in the public realm. For example, floor area bonuses were offered for providing green building features since 2011 (Qian et al., 2016). The literature remains somewhat critical of these planning practices, due to dependency on a general evaluative approach, largely based on qualitative results; therefore, a quantitative approach to evaluation is required. The present paper is an attempt to evaluate the results in two major cases, based on the intentions of the density bonus scheme published in the Town Planning Board documents.

2. The Hong Kong Tsim Sha Tsui underground development

Hong Kong, with its limited land resource and difficult terrain, has long been active in exploiting the potential of its underground resource (Wallace and Ng, 2016). The city is notable for its extensive underground utility networks, road tunnels and, since the 1970s, the urban rail system. Driven by the limits to sea reclamation and the strong public desire to preserve Hong Kong's extensive country parks, development efforts have been focussed on underground development potential.

The Hong Kong MTR built up underground facilities largely in an effort to improve accessibility from the surface to its stations. These underground passages almost invariably lead directly to the street, rather than through buildings. An extensive underground network was developed at TST, at the southern end of Kowloon peninsula, in part to alleviate heavy pedestrian flows on the surface streets. The extent to which these underground facilities actually serve the purpose of alleviating surface flows is examined here. This underground system, like its predecessors, provided direct commuting routes from the stations to locations at roadside; however, more recently, Hong Kong has experimented with a new type of link between underground concourse and street, by inserting a multifunctional complex in between these levels. This plan has several objectives, including: 1 – to facilitate the movement of pedestrians by providing escalators, larger movement spaces, higher ceilings and a more elaborately designed and air-conditioned environment; 2 – to build the connection entirely with private financing, thus conserving public funds for the essential transit operations; 3 – to enable private operators to profit from the connection by inserting commercial facilities along the vertical route; 4 – to promote the revitalization of local streets by attracting passengers from the new commercial facility to the local street system. Provision of these facilities accompanied by a substantial density bonus to the developer, resulted in facilities stacked into tall towers atop the underground and surface level commercial facilities. In 2016 there were three such developments in Hong Kong: K11 Art Mall and iSquare in TST, and Hysan Place in Causeway Bay, with a fourth under construction along the waterfront in 2018.

The above-mentioned regulatory incentive approach is innovative in a number of ways and is being replicated in Hong Kong, as well as being examined for application elsewhere. As a model for urban development involving underground space, it offers ways to extract public goods quickly out of private real estate development. There are several possible areas of benefit that could be considered, but here we confine our investigation to the question of whether the provision of a privately provided, publicly accessible escalator between underground and surface is used more or less because of its incorporation in a shopping complex.

If this form of development promotes movement from underground space to the surface, it should also have positive externalities on the surrounding areas, by promoting a revitalization of commercial activities, in particular, on the surrounding streets. Although a qualitative assessment of the transfer areas of the public and privately provided systems is feasible, here we concentrate on a quantitative assessment using pedestrian flow as the indicator.

The bigger related question, which cannot be answered directly in this research, is whether the enormous density bonus provided to the developer for the provision of these transit-related services, is justified by the derived public benefits. Indeed, the amount of floor space permitted in the two developments of this case study greatly exceeds the maximum allowable density in TST. As revealed in the case of New York City (Kayden, 2000), the estimation of density bonus requirement from a business perspective, is difficult. In particular, such density bonus calculations do not appear in the TPB documents (TPB, 2015).

The underground space network of TST developed from 1979, followed by a major addition in 2004 and 2005 with opening of TST East station on the West Rail line, which was not connected with pedestrian service to TST station on the Tsuen Wan line. Both iSquare and K11 Art Mall opened on the same day in 2009, after detailed negotiations on the same issues with regard to metro access and open space provisions. Specifically, four publicly accessible open spaces were required in these two developments. The Hanoi Road frontage was adjusted several times to increase the walking space, upgrade the paving and include shade trees. Bulb-outs were included at all corners to facilitate pedestrian crossings and in general to accommodate the expected sharp increases in pedestrian flow (TPB, 2013) (Fig. 1).

The subsequent TST development plan (TPB, 2013) incorporated the three developments where enhanced MTR access and wider streets

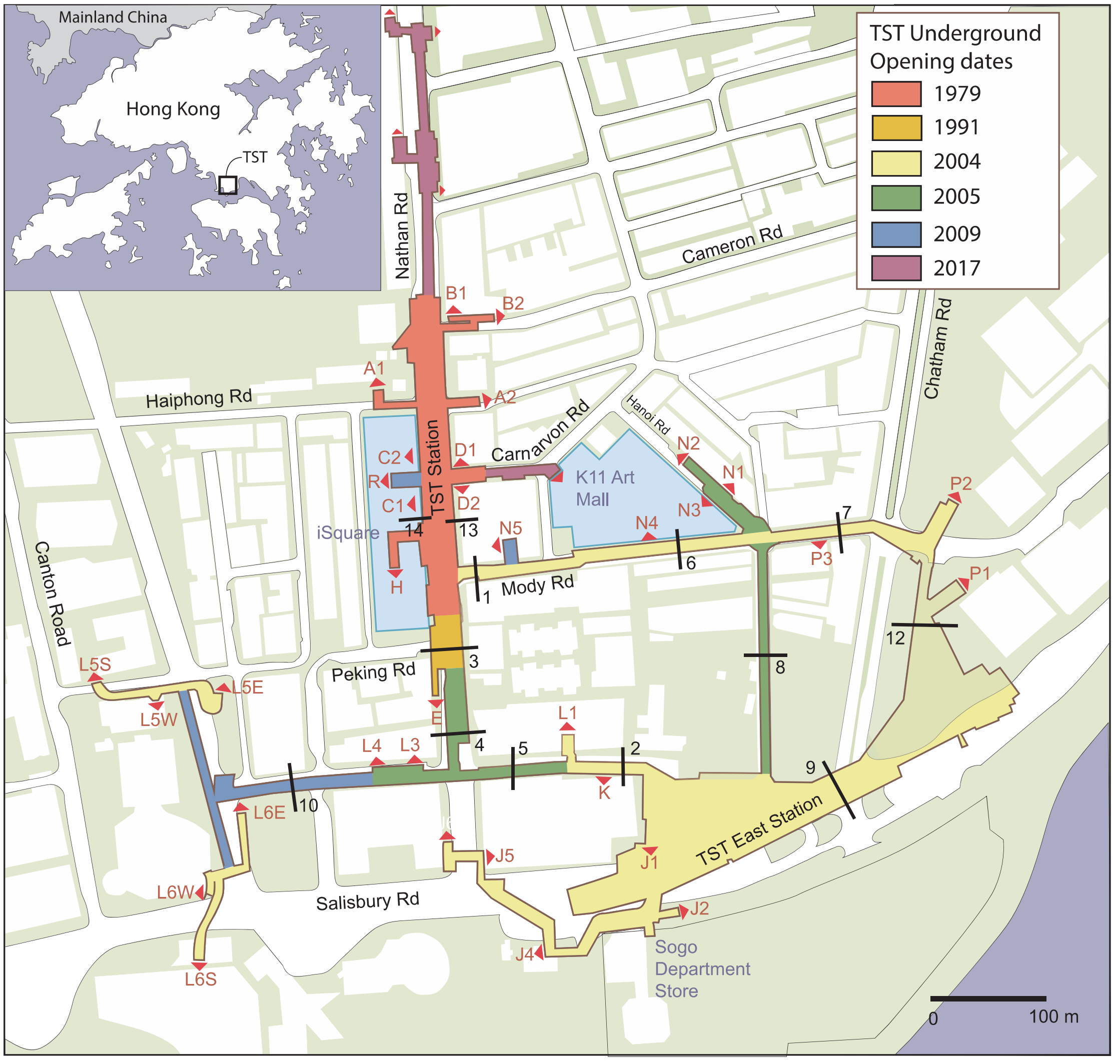

Fig. 1. The underground system at TST with the two cases, exits to the street and underground cordon count locations. Insert: TST in Hong Kong Special Administrative Region.

were required in exchange for permitting the building of commercial complexes with much higher density. The 250 m building height allowed in the case of K11 compares with a building height limit of 80–130 m for the rest of TST. The maximum plot ratio of 12.0 for TST was greatly exceeded by the building projects of K11 and iSquare. The Outline Zoning Plan states clearly that such developments, while offering significant advantages for the underground system, and for pedestrian circulation in particular, must be treated as exceptional. The reason for considering such developments as exceptional is the documented concerns about air circulation in TST as well as the need to preserve views of the mountain ridge line from Victoria Harbour (TPB, 2013). While iSquare is situated adjacent to Nathan Road, the most heavily travelled pedestrian corridor in TST, K11 is inserted in a complex layout of narrow streets, at some distance from any significant pedestrian flows and where the street-level commercial functions tend to be of a low order. While iSquare could have been expected to increase yet further the substantial pedestrian flow along Peking Road to the west, K11 was clearly expected to contribute to local area revitalization. The upgraded and widened streets, in addition to the open spaces, were intended to provide more public space that is generally lacking in TST.

3. Methods and materials

In order to compare pedestrian flows through the two complexes in question with pedestrian flows in the surrounding area, cordon counts were taken both in the underground and on the streets above. Cordon counts are the number of individuals crossing a designated line in both directions within a given time interval. Counts were taken at 33 underground exits to the street, 14 sections of underground concourses and 70 street segments. The bi-directional counts were conducted at 10 a.m., 3 p.m., 6 p.m. and 9 p.m. on four survey dates, to represent possible variations in trip purposes and destinations. In order to understand how passengers move from the MTR underground concourses into the buildings of iSquare and K11, use these complexes for activities on site and/or exit to ground level, unobtrusive tracking was also conducted. Individuals were randomly selected at underground exits N3 and N4 of K11 and underground exits H and R of iSquare. Selected individuals were tracked until they stayed inside a shop or a facility off the pedestrian concourse or street more than 5 min. The stop types were recorded in detail. In this way, there were 500 tracking records for K11 and 640 tracking records for iSquare. All the concourse, exit and street counts were entered in GIS, along with the tracking itineraries.

Correlation analysis was conducted to evaluate the extent to which the underground flows map on to the street flows. If the correlation between the flows is high, the underground system is simply completing the surface flow, or providing a somewhat different experience for the pedestrian but with the same movement distribution. Similarly, the correlation between exit flows and street flows reveals the pedestrian contribution level of exit flows to street flows. Finally, there are several pre-existing direct exits from the underground pedestrian concourse to the street, on the same corridors as the new exits inside the two new complexes. Have the new exits, with their enhanced indoor environment and supporting commercial facilities, drawn passengers away from the conventional stair and escalator corridors to the street, assuming those entering the complexes are intending to exit to the street?

Cordon counts at all the underground entrances to the two malls were taken, in relation to the corridor flows. These in-flows of pedestrians can be modelled using three approaches: Firstly, we had 500 tracks at K11 and 640 tracks at iSquare, which revealed the proportion of pedestrians finally exiting to the street. These generated local trips are compared with those of adjacent direct exits to the street. The track model is compared with random assignment, where it is assumed every pathway at a choice point has an equal chance of being selected. That is, with random assignment, the pedestrians are evenly distributed among possible exit pathways at every decision point. A reasonable expectation is that planning inputs would produce outcomes that perform better than random generation. These relations between flows provide a measure of the contribution of the facility provided within the commercial complex to the pedestrian flows.

Additional counts were conducted in 2017 to collect bigger samples of the choice points in the underground system adjacent to the two malls under study. This enables a statement concerning the global contribution to surface movement by interposing a commercial facility with escalators.

Finally, the two cases of iSquare and K11 merit more detailed comparison. With just two cases, we should see how much locally based factors influence the outcomes. The factors themselves are of interest in this context as well since they may help to build a comprehensive evaluative model.

Planning documents were consulted at the Town Planning Board offices as well as through the TPB portal.

4. Urban development background of the TST area, K11 Art mall and iSquare mall

The TST station is on the busy Tsuen Wan line of the MTR, opened in 1979 with 8 exits all connecting to ground level at the street. A southerly extension to the station concourse, already contained within the Nathan Road right-of-way, and exit E (Fig. 1), were opened in 1991, to expand catchment area of the station to the south with its heavy pedestrian flow east-west along the Kowloon waterfront. By 2007, TST was the busiest MTR station in the urban rail system (Ming, 2007). In 1994, the Hong Kong Government Transport Department proposed to connect the MTR and the Kowloon-Canton Railway (KCR) at TST. Then, an underground route was inaugurated to connect the stations by the shortest path under Mody Road in 2004. In 2005, the final connection was made from the south end of the TST MTR Station to the Chatham Road underground concourse. Further extensions from the TST East Station were constructed to Sogo department store and the TST waterfront in 2005. iSquare was opened in 2005 with the associated direct exits from TST station, exits H and R.

These developments attest to the Hong Kong Government's continued interest in making a complete underground system in TST area, that is already the most extensive in the city. TST area is heavily built up while contained by water and green hillsides, where four underground rail lines running in parallel have little physical connection between them. A pedestrian connection system has built up on the two central lines, the Tsuen Wan Line and the West Rail Line, but there will be connections aboveground east and west.

As we will see, the underground system provides a walking network that maps almost entirely on street-level flows, thus increasing the walking system capacity. A second outcome of the development of the underground pedestrian system is to add significant commercial value to basements at selected locations adjacent to the underground concourses. A third outcome is the concentration of flows and commercial impact at key nodal points, in contrast to the early development history of TST area and its dense network of commercial streets.

The planning of the underground network in the 1990s made clear that there would be significant development opportunities associated with this network. The proposed development of hotel, serviced apartment and shopping centre at K11 was considered as early as 2001 for the assembled property on the block. Not all properties on the block were acquired for development when works were undertaken, such that the project had to be configured around existing structures.

Since 1994, the TPB has practiced a two-tier system of planning control, offering density bonuses to developers who assemble land parcels into a larger site. The principle was that only on larger sites could developments internalize public space amenities, as well as absorb eventual externalities such as car parking. However, such bonus provisions were rarely exploited for housing because of the long lead time in assembling property and due to the trade-off that developers make between lead time cost on one hand and eventual additional floor space and amenities on the other (Ryan and Enderle, 2012). In their 1999 study, Tang and Tang also found that developers began to propose more residential-commercial or purely commercial development where the density bonuses were higher, along with the potential returns on investment. This was the case with the K11 development, where serviced apartments, a hotel and a shopping centre were combined in the early planning proposal of 2001.

In exchange for the substantial bonuses for this development, the TPB required the following provisions in the projects:

(1) Public facility provisions to accommodate pedestrian circulation within the site and on the surrounding streets, in anticipation of increased pedestrian flows from the high-density development and from the busy TST station and an eventual pedestrian movement increase as a result of the TST East Station.
(2) Extensive tree planting on the surrounding streets, in compensation for trees removed by the construction works on the site.
(3) Public open space provisions in two locations on the site, one of which served as a direct connector between Bristol Avenue and Hanoi Road (Xu and Zhang, 2016).
(4) Visual impact studies showing urban landscape effects on the surrounding neighbourhood and on the skyline.

5. Results

The pedestrian flows for the underground system are presented in Table 1, and keyed to Fig. 1.

Pedestrian flows on the streets are closely related to the flows exiting from the underground system. As indicated by our counts, the exit pedestrian flows are 43% of the corresponding street-level flows. Linear regression shows that 77% of the flow on weekdays can be explained by a corresponding exit flow, 62% on weekends (Fig. 2). The lower figure on the weekend can be explained by the more complex pedestrian circulation of days when there is more shopping activity. The street pedestrian flow hierarchy may have existed before the introduction of the underground system – we have no data to verify whether this was the case – but the present underground plan is strongly reinforcing the flows on the surface.

However, the underground and surface systems are not uniquely mapped one on top of the other. The direct underground links across Nathan Road at exits A1/A2 and at TST station (Fig. 1) constitute major pedestrian flows that exceed those on the surface at those locations. Moreover, the significant pedestrian volume at exit N4 into K11 demonstrates the attraction of the underground link to access that facility,

Table 1
Pedestrian volume counts in the underground system at Tsim Sha Tsui.

	Volume (pedestrians/hour*)									
	Weekday (2015-01-29)					Holiday (2014-04-21)				
	10–11 am	1–2 pm	2–4 pm	6–7 pm	9–10 pm	10–11 am	1–2 pm	2–4 pm	6–7 pm	9–10 pm
Exit										
A1	3240	4740	4110	7550	2580	3540	4350	5250	5520	2280
A2	750	1080	1170	1410	1500	3390	5850	6930	8010	5370
B1	1440	1500	1260	3360	1560	810	1590	2100	2790	1290
B2	1650	2520	3540	4830	2820	1770	3240	2040	3540	2100
C1	630	600	600	630	150	720	510	1320	870	570
C2	90	270	390	450	480	150	120	420	210	300
D2	1830	1320	1920	2940	1410	1440	1470	1440	2340	1080
E	1200	1050	1140	2100	1080	840	990	930	1170	840
H	1200	1380	2430	1710	1350	300	2220	1710	2130	1560
J1	150	300	150	480	240	270	90	510	660	270
J2	960	1350	720	1080	510	2310	1170	2160	1440	630
J3	–	–	–	–	–	120	780	2130	1320	570
J4	450	300	720	840	420	120	1500	2820	1770	1830
J5	360	630	660	600	600	610	1620	1140	660	360
J6	870	930	120	600	300	60	300	360	570	360
K	870	720	600	1080	390	780	510	1260	840	1680
L1	330	450	240	300	90	150	150	180	150	0
L3	750	210	360	360	330	330	780	270	180	360
L4	180	390	600	60	300	330	270	180	300	60
L5E	1530	4140	3900	4230	2820	1260	2400	3540	4590	2130
L5S	1260	3000	2550	3180	1740	1110	2010	2340	2310	1020
L5W	2040	3120	2790	4200	1290	1440	3360	2760	3870	2370
L6S	210	810	240	330	180	150	750	1200	750	390
L6W	960	1350	1350	3840	1020	1320	1800	2760	2940	2400
L6E	330	750	1230	1290	690	630	1230	1710	1950	1440
N1	570	360	480	1260	900	540	630	720	990	780
N2	810	450	360	420	60	330	450	180	810	90
N3	60	480	270	420	300	780	810	930	1290	1080
N4	510	1230	1170	2790	900	1080	630	1500	1350	1500
N5	660	600	960	360	150	630	390	1170	420	180
P1	420	930	1110	2340	1410	990	1110	1530	1830	300
P2	840	1500	840	3510	900	1080	1110	960	1260	450
P3	270	360	450	990	300	510	870	360	600	600
R	720	990	630	1980	1260	990	1440	1620	990	1170
Underground corridor										
1	3720	4230	4690	13,080	2700	4410	3750	3600	5700	2970
2	2370	2100	1500	4800	1470	3330	2070	2220	2820	3300
3	2550	3270	3930	10,950	4140	2880	5310	5130	6120	5970
4	2490	2280	2160	5670	2940	2250	2820	4530	3540	1920
5	2070	1590	2370	4470	1530	2100	2550	3120	3930	1770
6	4530	4470	5040	8610	4170	3570	5100	4770	5160	3210
7	1860	2070	1980	5130	1410	1020	1590	1140	1710	990
8	2610	2340	2430	7590	3180	4080	5520	4650	4800	2190
9	270	870	750	840	330	360	990	780	630	330
10	2610	2340	2340	4410	2520	1740	2940	1420	2960	3510
12	1050	1800	2310	4650	1860	1860	1470	2460	3060	1530
13	1500	3540	3270	4590	1740	3810	9720	8970	9660	6210
14	5220	4080	3060	6900	840	2400	4230	3330	4500	870

* Rounded to 10.

over the surface alternative on Mody Road.

Based on these results, .22 (SD = .12) of the pedestrian volume on the link between TST and TST East is solely the result of N3 and N4 exits to K11. However, the flow into iSquare at TST is .49 (SD = .08) of the flow on the corridor at TST Station. Nearly all of this flow into iSquare is to the two escalators (.98, SD = .02; .86, SD = .04), rather than in circulation at the station concourse level of iSquare. The facilities including these escalators in iSquare do not deliver passengers directly to the street in an apparent attempt to encourage circulation within the shopping centre, but these strong pedestrian flows are directed to the street, in sharp contrast with the underground facilities of K11.

Not all exits perform equally, although they were clearly designed to give equal opportunity to the surrounding street fabric from flows in the underground. There are 3 exits to the street from iSquare and 7 exits from K11. The strongest flows at iSquare are 24 times the flows at the weakest exit, while at K11, the strongest flows are 8 times those at the weakest. At K11, the correlation between exit volumes and street pedestrian volumes is .33, but at iSquare it is .97. The reasons for this difference are quite clear. In the case of iSquare, the building is at the corner of two major flows, along Nathan Road and along Peking Road, while at K11, the layout is more complex, with the various intersecting streets with relatively small flows of pedestrian traffic. The result also demonstrates the extent to which iSquare is integrated into the local pedestrian movement system.

The direct connection between TST and TST East station under Mody Road has become the busiest underground corridor in the emerging TST underground system. The main reason is the direct connection provided between the stations and the shortest walking distance, aided by a travellator, or moving sidewalk, between respective ticket gates. Of those individuals travelling in both directions

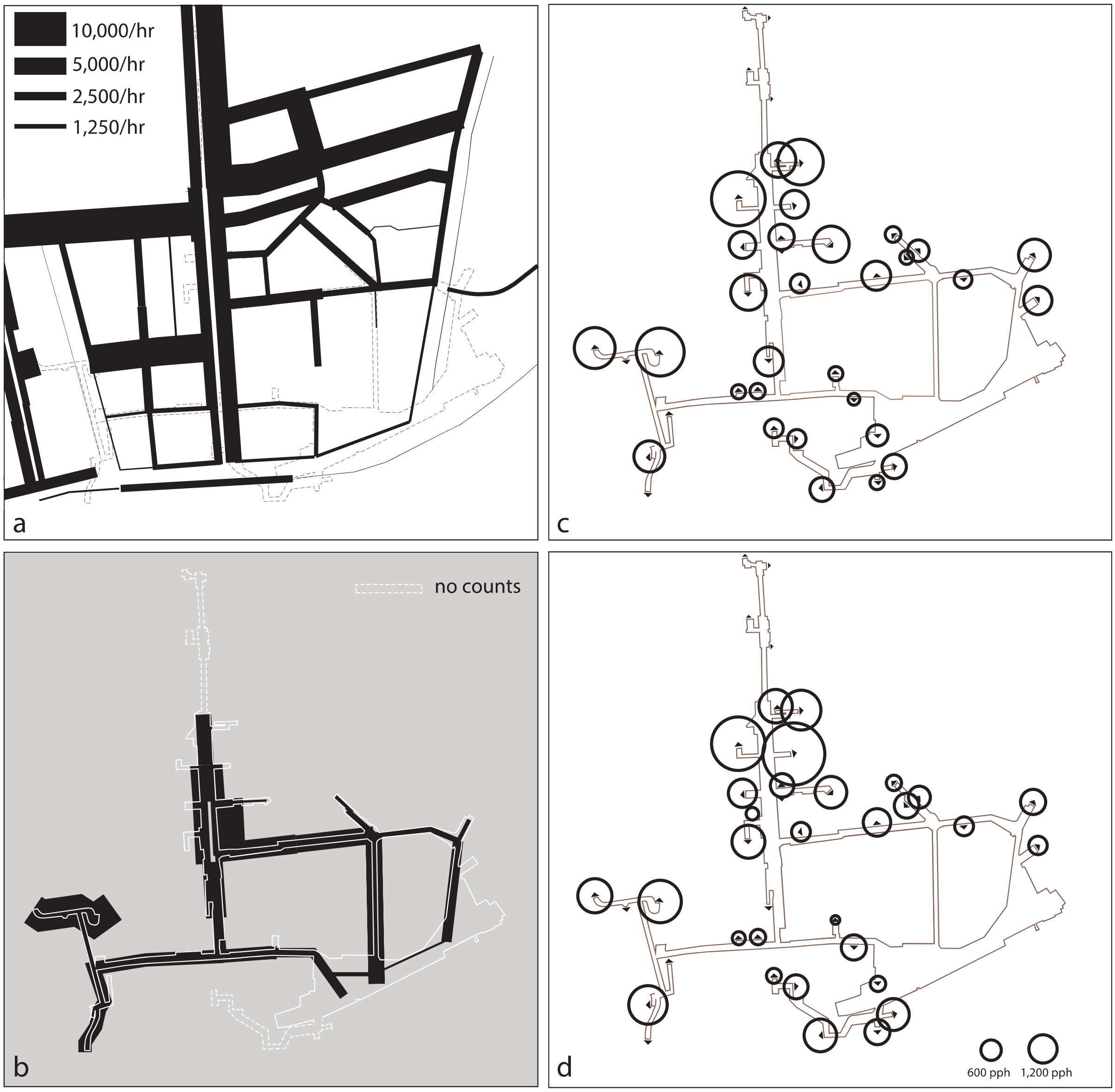

Fig. 2. Street-level pedestrian flows weekday (a); underground flows weekday (b); exit flows weekday (c) and holiday weekend (d).

in the Mody Road underground concourse, 9.7% enter K11 at the N3, N4 and N5 exits. Of all pedestrians moving into K11, 75.2% either use K11 as a destination or return to the Mody Road concourse after shopping (67.4%) or engaging in some entertainment, strolling or using the public open space (20.8%). The remaining 24.8% of the total pedestrian flow exit to the surrounding environment after passing through K11, engaging or not in some activity in the shopping mall. The total flow to the street from the N3, N4 and N5 entrances to K11 is 22.6 persons/minute (ppm) in our counting frame, compared with the flow at D2 street exit at 31, and 37 ppm at N1, N2 exits to the street on Hanoi Road. In iSquare, in the comparable time frame there are 45.2 ppm to the street from the flows into iSquare, compared with 124 ppm on Peking Road to which the iSquare flow contributes. Overall, iSquare contributes 53.2% of the street flows on the three bounding streets weekday, compared with 46.2% at weekend. At K11, the exits contribute 36.7% of the street flow weekdays, compared with 32.6% at weekends.

Next we compare the output of the malls from underground concourse entry to delivery to the streets.

(1) *Exit rate comparison*: At K11, there are 6 exits to the street, which were clearly intended to maximize the contact with the local environment. At the rate of 22.6 ppm, the exit rate on concourse-level inflow is 6.3%. In the random assignment model, each direction at the decision point carries equal attraction. In this model, pedestrians entering K11 at N4 would be likely to exit at the street at a rate of 7.4%. K11 underperforms the random assignment model, meaning that the mall is relatively successful in retaining visitors; however, seen from the public interest perspective, the K11 circulation system contributes little to local street vitality.

(2) *Escalator arrangement*: At iSquare, the escalators starting at the metro concourse level lead to different floors from R and H entrances, although neither is directly connected to the street. Nevertheless, H escalator is used at more than double the rate of R to exit to the street. The huge differential is due to the placement of the exit gates from the paid zone of the station, in closer proximity to escalator H. The escalators at K11 are three floors of switchback escalators, delivering to each floor in turn. Clearly, the escalator arrangement has some effect on the retention of visitors, although other organizational and programmatic elements may play a part in

visitor retention.

The contribution of exit flows from the two malls to the street pedestrian flows can be used to measure the contribution of the two facilities to local area revitalization. In our case, we analyze the pedestrian tracks from the exits, with each trip ending when the person entered a shop or convenience in the public environment. From iSquare, the mean track distance from the building exit to the observed destination was 230.1 m (n = 355; SD = 122.8). At K11, it was 317.4 m (n = 175; SD = 167.8). While the 95% confidence bands for the two mean values overlap to some extent, as a result of the large variation in the length of individual trips, it is clear that the distribution in the local streets is greater at K11, although in both cases, the majority of exits were connected to destinations on the immediately adjoining streets and blocks. In fact, the distances traversed in the local environment are relatively modest compared with the trips made in the Montréal case with its extensive underground system (Zacharias, 2015).

Finally, both developments include an enhanced public environment and useable open space. The iSquare approach is a single open plaza that is programmable and can at the same time accommodate large pedestrian flows. Public open space provisions at K11 consist of a resting place and performance venue mostly for musical events. At K11, the central open space acts as a shortcut across the block, which together with the ground-level corridors of K11 Art Mall, have augmented the street grid considerably at this location.

6. Conclusion and discussion

This research set out to evaluate and compare the contribution of privately provided means of transport from the metro underground concourse to the surface. We used the pedestrian flows as an indicator of success in implementing the underground pedestrian facilities. A major conclusion is that the underground system as presently constituted, reinforces and provides an alternative to the surface route. The exit volumes from the underground space are also highly correlated with surface flows, demonstrating to what extent the street and MTR flows are interconnected in TST.

The transport contribution of the internal escalator systems compared to that provided by direct connections to the street, is minor. A larger proportion of TST passengers exits to the street in iSquare than at K11. If the main planning objective is to retain street vitality, then access through shopping malls associated with the station is believed to make more contribution than would direct connections. However, at K11 the great majority of those entering the mall are making it their destination with an eventual return to the metro. It serves to a considerable extent as a relay and relaxation point along a pedestrian transport route. The case of iSquare is somewhat different, in that more of those entering are also exiting to the streets with fewer visitors spending time there and with shorter overall visits than in the case of K11. In other words, the specific location with regard to the metro station, as well as the internal configuration of the travel system will have significant effects on the extent to which the underground walking facility supplements the public system. However, in neither case, when pedestrian choice is used as the criterion, would a bonus be merited for the provision of that particular transport facility.

TST is gradually transforming from a distributed street-oriented commercial zone to a nodal form of development area. Direct connections between the MTR stations, the underground concourses and the shopping malls reinforce the nodal system. Such development is in keeping with the intensification of land use in Hong Kong and its overall development trajectory. In particular, it would be expected that at the very high urban densities of Hong Kong and its high GDP per capita, that increasing attention would be focussed on underground development (He et al., 2012). Such intensive investment in underground space resources can take a variety of forms, of which the Hong Kong TST is but one type. While the private sector can subsidize the construction of the underground space and the pedestrian exit system, it may come at the price of street vitality. However, more needs to be done to understand the relationship between these underground nodal developments associated with mass transit and eventually with street vitality.

The travel experience in these enhanced environments inserted between the underground and the surface should be investigated–in particular, to what extent do the enlarged space and more elaborate interior design contribute to the comfort and pleasure of travel? While comfort and pleasure may be important, it should also be noted that the particular designs in this case offer quite different time budgets. It takes much longer to travel to the surface at K11 because of a circuitous circulation plan, while iSquare provides a more direct route. To what extent saved travel time interacts with comfort and pleasure is worth exploring for the purposes of future underground-to-surface pedestrian transport infrastructure.

The question raised in this research is the following: Are the experiential benefits for pedestrian movement provided through the planning regulations a fair exchange for the awarded density bonuses? In the K11 case, the interposition of the shopping mall vertical movement system has negligible benefit for intra-level pedestrian movement related to the MTR. Instead, the mall provides a respite in the long pedestrian corridor linking the two MTR stations, providing an interesting place that remains relatively closed in on itself in spite of all the urban design interventions. iSquare's vertical movement system largely serves the public purpose of moving people from underground space to street, although not directly. That commercial approach to the question of moving people through private space, inclusive of public purposes, led to two quite different outcomes in these two cases. A priori evaluation of the public benefit would help the city achieve its goals for the development of the whole TST area. More modelling of future pedestrian flow is needed to provide a quantitative foundation for evaluating proposals, and specifically before committing to negotiations on the exchange of public and private goods.

Declaration of conflict of interest

None.

Acknowledgement

This research is supported by National Natural Science Foundation of China (project No. 51478300), Programme of Introducing Talents of Discipline to Universities of Ministry of Education of China (project No. B13011), and International Science and Technology Cooperation Program of China (project No. 2014DFE70210). The authors would like to express gratitude to all previous members from Tianjin University for help in data collection.

References

Bobylev, N., 2016. Underground space as an urban indicator: measuring use of subsurface. Tunn. Undergr. Space Technol. 55, 40–51.
Chan, E.H.W., Yung, E.H.K., 2004. Is the development control legal framework conducive to a sustainable dense urban development in Hong Kong? Habitat Int. 28, 409–426.
Cui, J., Lin, D., 2016. Utilisation of underground pedestrian systems for urban sustainability. Tunn. Undergr. Space Technol. 55, 194–204.
He, L., Song, Y., Dai, S., Durbak, K., 2012. Quantitative research on the capacity of urban underground space – The case of Shanghai, China. Tunn. Undergr. Space Technol. 32, 168–179.
Kayden, J.S., 2000. Privately Owned Public Space: The New York City Experience. John Wiley & Sons, New York.
Ming, P., 2007. Causeway Bay is extremely busy, so an underground pedestrian street is needed (28 June, 2007). Retrieved from http://life.mingpao.com/cfm/dailynews3b.cfm?File=20070628/nalgg/gga3.txt (accessed 04.08.15) (in Chinese).
Punter, J., 2005. Urban design in central Sydney 1945–2002: Laissez-Faire and discretionary traditions in the accidental city. Progr. Plann. 63, 11–160.
Qian, Q.K., Fan, Ke, Chan, E.H.W., 2016. Regulatory incentives for green buildings: gross floor area concessions. Build. Res. Inform. 44 (5–6), 675–693. https://doi.org/10.1080/09613218.2016.1181874.

Ryan, S., Enderle, B.E., 2012. Examining spatial patterns in affordable housing: the case of California density bonus implementation. J. Hous. Built Environ. 27 (4), 413–425.
Sterling, R., Nelson, P., 2013. City resiliency and underground space use. In: Zhou, Yingxin, Cai, Jungang, Sterling, Raymond (Eds.), Advances in Underground Space Development. Research Publishing, Singapore, pp. 56–114.
Sun, G., Zacharias, J., Ma, B., Oreskovic, N., 2016. Walking from metro: the effect of local built environment in Beijing. Cities 56, 91–98.
Tang, B., Tang, R.M.H., 1999. Development control, planning incentive and urban redevelopment: evaluation of a two-tier plot ratio system in Hong Kong. Land Use Policy 16, 33–45.
Taylor, D.A., 2007. Growing green roofs, city by city. Environ. Health Perspect. 115 (6), A306–A311.
TPB, 2013. Town Planning Board. Kowloon Planning Area No. 1: Approved Tsim Sha Tsui Outline Zoning Plan S/K1/28. Hong Kong TPB. Downloaded 2016-11-10 at http://www2.ozp.tpb.gov.hk/plan/ozp_plan_notes/en/S_K1_28_e.pdf.
TPB, 2015. Town Planning Board (HKSAR Government). Statutory Planning Portal 2. Retrieved from http://www1.ozp.tpb.gov.hk/.
Wallace, M.I., Ng, K.C., 2016. Development and application of underground space use in Hong Kong. Tunn. Undergr. Space Technol. 55, 257–279.
Weiss, M.A., 1992. Skyscraper zoning – New-York pioneering role. J. Am. Plann. Assoc. 58 (2), 201–212.
Xu, T., Zhang, M., 2016. Tailoring empirical research on transit access premiums for planning applications. Transport Policy 51 (SI), 49–60.
Yang, J., Quan, J., An, B., et al., 2016. Urban rail investment and transit-oriented development n Beijing: Can it reach a higher potential? Transport. Res. Part A-Policy Pract. 89, 140–150.
Zacharias, J., 2015. Underground pedestrian trips–trip generation, spatial distribution and activities in the Montréal underground. Tunn. Undergr. Space Technol. 46, 46–51.