Research Assessment Exercise 2020
Impact Case Study

University: City University of Hong Kong
Unit of Assessment (UoA): 17 - Architecture

Title of case study: Development of Pedestrian Movement Model for Analysing People Movement Pattern in Densely Populated Metro Stations and Complex Settings

(1) Summary of the impact

The research team led by Prof SM Lo has developed an agent-based model, **CityFlow**, for evaluating the crowd moving pattern. The model developed from scratch has been extensively applied for densely populated metro stations (6 million passenger trips per day). The work has directly benefited the HKMTR, one of the world's leading metro companies operating rail lines in Hong Kong, Mainland China, London, Sydney, Melbourne, Stockholm and as consultant for railway management globally, to assess crowd flow efficiency and safety in complex metro stations. This impact enabled HKMTR to establish crowd management policy, architectural layout re-planning and design for stations.

(2) Underpinning research

The MTR has assured the government and legislative council that they have been closely monitoring the utilisation and passenger flow of railway lines and stations (more than ½ the population in Hong Kong using metro everyday), with a view to adopting timely and effective measures to increase the carrying capacity of train services and to manage passenger flow at stations. The MTR has offered several contracts (contract sum more than HK$3 Million) to the research team at City University (led by Prof. S.M. Lo and his PhD students: J Ma, SB Liu, WL Wang, J Chen, ZT Li and others) to perform studies on crowd/ passenger flow in stations.

Research since the beginning of 21st century has built on the foundational work including extensive field data collection, video image capturing and microscopic computation modelling technique. A comprehensive and sophisticated agent-based model, **CityFlow**, has been developed to mimic the crowd flow density, individual movement characteristics and pedestrian flow pattern in complex settings.

The key underpinning research contributions may be summarised as follows:

- Comprehensive studies on crowd density and passenger flow pattern for more than 10 densely populated metro stations in Hong Kong, including Mongkok Station, Prince Edward Station, Central Station, Admiralty Station, Wanchai Station, Kwun Tong Station and etc. The studies have provided comprehensive information for MTR to establish crowd management policies, enhancement works at Kwun Tong Station, Kowloon Tong Station and determine the station capacity for future network planning;
- Supporting the re-design/ enhancement works of Mongkok Station by the world's renowned architect firm - OMA under the MTR Vision 2020 Project. The team has worked closely with OMA to adopt CityFlow to predict the passenger flow pattern in the proposed Mongkok Station settings;
- Supporting ARUP to evaluate the lift (elevator) evacuation pattern of passengers in the proposed Sai Ying Pun Station (over 80m below ground level) and the assessment report subsequently approved by the Hong Kong Buildings Authority;
- Development of crowd density guides for reference by MTR

Further extend the application of the research findings and the model, Prof. S.M. Lo has been (i) the Co-Principal Investigator of the Theme-based Research Scheme Project (awarded HK$40,850,000) entitled: Safety, Reliability, and Disruption Management of High Speed Rail and Metro Systems. The model has been used to establish the safety level/ risk for rail platforms and the disrupt management. (ii) the Co-Principal Investigator of the Collaborative Research Funding Project (awarded HK$4,700,00), entitled: Syndromic Surveillance and Modeling for Infectious Diseases. Based on CityFlow, computational model for analysing individual contact rate and exposure to disease in transportation hubs was developed.

(3) References to the research

[1] Liu SB, Lo SM, Ma J and Wang WL (2014), "An Agent-Based Microscopic Pedestrian Flow Simulation Model for Pedestrian Traffic Problems", IEEE Transactions on Intelligent Transportation Systems, 15(3): 992-1001.

[2] Wang WL, Lo SM, Liu SB and Kuang H (2014), "Microscopic modeling of pedestrian movement behavior: Interacting with visual attractors in the environment", Transportation Research Part C - Emerging Technologies, 44: 21-33.

[3] Wang WL, Lo SM, Liu SB (2017), “A cognitive pedestrian behavior model for exploratory navigation: Visibility graph based heuristics approach”, Simulation Modelling Practice and Theory, 77: 350-366

[4] Liu SB, Lo SM, Tsui KL and Wang WL (2015), "Modeling Movement Direction Choice and Collision Avoidance in Agent-Based Model for Pedestrian Flow", ASCE Journal of Transportation Engineering, 141(6): 04015001.

[5] Ma J, Lo SM, Song WG, Wang WL, Zhang J, Liao GX (2013), “Modeling pedestrian space in complex building for efficient pedestrian traffic simulation”, Automation in Construction, 30: 25-36.

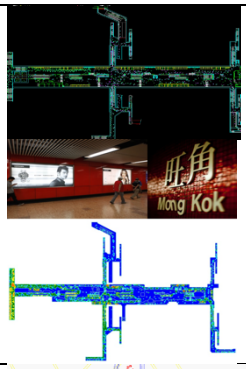
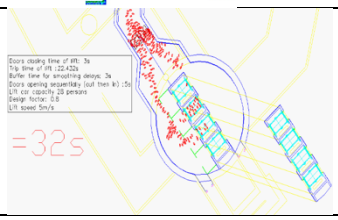
[6] Reports submitted to Hong Kong MTR under consultancy agreement A096-11 by City University of Hong Kong, 2014.

(4) Details of the impact

The MTR is the top market share of transport operator in Hong Kong and operates internationally. There are approximately 6 million passenger trips per day (ptpd) for MTR which amounts to about 50% of the population using the metro service in Hong Kong. It is undoubtedly crowdedness at station concourse, platforms as well as in coaches is a serious issue that affects the efficiency of train operation and passengers’ safeness. In case of emergency, it is also important to allow people to escape from the train and the station quickly and safely. Similar crowdedness situation also happens in many Mainland China cities [Beijing (12 Million ptpd), Shanghai (10 Million ptpd), Guangzhou (10 Million ptpd), Shenzhen (5 Million ptpd), etc.], Taiwan, Japan, Korea and many Asia countries.

Prof. SM Lo was member of the working group for the preparation of the codes on means of escape/ fire resisting construction and fire safety committee of the Hong Kong Government. Owing to his in-depth knowledge of fire escape codes and people movement in complex settings, he has been leading research team to develop computation models for studying people escape and movement. With a group of PhD students, an agent-based pedestrian flow model: CityFlow, has been developed from scratch. The theoretical background of the model has been explained in many articles published in leading transportation and construction journals. The model, taking into account the movement behaviour of people, is capable of modelling the individual pedestrian movement in complex layout. The model has been validated and underpinned by extensive field data that have been collected by the research team with the assistance of MTR.

The research team over the years has been commissioned to study crowd movement and evacuation process in buildings, in particular for metro stations and the associated parts. The key practical impacts include:

(1) Commissioned by the MTR to study the most densely populated stations in Hong Kong. The stations include Mongkok Station, Kowloon Tong Station, Prince Edward Station, Yaumati Station, Kwun Tong Station, Central Station, Admiralty Station, Wanchai Station, Causeway Bay Station and others. The reports adopted by MTR to assess the crowdedness of these stations and analyse the efficiency of crowd flow. With the support of the evaluation, enhancement works have been conducted at Kwun Tong Station and Kowloon Tong Station. Moreover, findings serve as reference for crowd density guidelines adopted by MTR.	
(2) Nominated by MTR to work in associate with the world-renowned architecture firm, OMA for designing the layout of Mongkok Station renewal project.	
(3) Nominated by MTR to work in associate with ARUP for simulating the lift (elevator) evacuation process. The report was presented to Hong Kong Building Authority and approval was subsequently awarded.	
(4) The research forms the main part to support a major Theme-based Research Group entitled: Safety, Reliability, and Disruption Management of High-Speed Rail and Metro Systems (HK$42,000,000; funded by Hong Kong Research Grant Council commencing on 1 Jan 2016)	
(5) Prof. SM Lo was invited to give key-note speech concerning crowdedness modelling in many major national conferences and international conferences such as: - 486th Xiangshan Science Conference, Beijing by the Ministry of Science and Technology of China, April 2014 (http://www.xssc.ac.cn/); - 2nd Public Safety Technology Forum, Hefei by Chinese Academy of Engineering, December 2018; - Intelligent Transportation Studies Conference, Taipei, November 2016; - 3rd Annual International Conference on Architecture and Civil Engineering, Singapore, April 2015; - 1st International Forum on Disaster Studies, Daejeon, Korea, May 2016; - 5th Symposium on Transportation Science and Computation, Guiyang, May 2018	

- Presentation to management and engineers of Seoul Metro, April, 2019	

Beneficiaries

While accurate financial assessment of impact is difficult, we have evidence [A] and [B] given by MTR that the model offers substantial benefits to many projects involve in studying crowdedness and evacuation process. Clearly, the model can assist designers to establish an efficient layout of metro stations and buildings of complex settings. This can help to save space and indirectly save huge sum of money for station construction.

(5) Sources to corroborate the impact

[A] Letter of corroboration from Mr. P. Leung, the Building and Architectural Engineering Manager of Hong Kong MTR, who was the project in-charge for the crowdedness study in MTR Stations. In the letter, he described:
"CityFlow can satisfactorily model and predict the crowd movement and crowd density. The information generated by the model can assist metro company to plan and design the setting of stations and provide insights for facility management to assist operating team to manage and control crowd movement. It offers obvious benefit by allowing architects and engineers to establish an efficient layout in platforms and concourses for passengers and pedestrian movement and evacuation process. Our experience shows that CityFlow can offer better solutions than other similar computer simulation models used by us."

[B] Letter of corroboration from Dr. W. Lam, Senior Manager, Inno Asset Management and Governance of Hong Kong MTR. In the letter, he mentioned:
"CityFlow, an agent-based pedestrian simulation model, has been adopted for modelling the passenger/ crowd movement pattern in planning the layout of Kowloon Tong Station, an interchange metro station of Hong Kong. I also note that it has been used to simulate the evacuation pattern for the design of Sai Ying Pun Station, one of the deepest stations, of the new Hong Kong line."

[C] Grand Prize Award 2014: Outstanding Thesis Award by the Hong Kong Institute of Surveyors for SB Liu under the supervision of Prof. SM Lo (thesis entitled: Agent-based Modelling of Crowd Dynamics in Rail Transit Systems)

[D] Grand Prize Award 2015: Outstanding Thesis Award by the Hong Kong Institute of Surveyors for WL Wang under the supervision of Prof. SM Lo (thesis entitled: Modeling of Pedestrian Behavioral Dynamics in Complex Urban Setting and Built Environment)

[E] Prof. N. Tomii of Nohin University, Japan (former President of International Association of Railway Operation Research) has recognized the simulation works and to collaborate with Prof. SM Lo by inviting his PhD student ZT Li to visit/ exchange to his university to carry out research works on passenger flow in Japan rail stations.

[F] One of the group's publications has been mentioned by the Agent Modelling Laboratory, Laboratory for Artificial Science, Russian Academy of Science on its website (www.abm.center/digest/index.php?ID=317).