RGC Ref. No.:
UGC/IIDS13/E01/14
(please insert ref. above)

RESEARCH GRANTS COUNCIL

COMPETITIVE RESEARCH FUNDING SCHEMES FOR THE LOCAL SELF-FINANCING DEGREE SECTOR

INTER-INSTITUTIONAL DEVELOPMENT SCHEME (IIDS)

Completion Report

(for completed projects only)

Submission Deadlines:
1. *The unspent balance, if applicable, and auditor's report: within six months of the approved project completion date.*
2. *Completion report: within twelve months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Inter-institutional Architecture and Urban Design Programme-

"Adaptive Urbanism- Hong Kong New Town Development 1960-2046"

2. Investigator(s) and Academic Department/Units Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Paul CHU Hoi Shan, Head & Associate Professor	Department of Architecture, Chu Hai College of Higher Education
Co-investigator(s)	Brian McGrath, Dean & Professor	School of Constructed Environments, Parsons the New School (USA)
	HSUEH Cheng-Luen, Assistant Professor	Department of Architecture, National Chengkung University (Taiwan)
Others	Nil	Nil

3. Project Duration

	Original	Revised	Date of RGC Approval *(must be quoted)*
Project Start Date	15 Dec 2014	15 Dec 2014	Attached Ref. GRC2014.Paul_Chu(2) refers
Project Completion Date	14 Sept 2015	14 Mar 2016	
Duration *(in month)*	9 months	15 months	

Deadline for Submission of Completion Report	14 Sept 2016	14 Mar 2017	

Part B: The Final Report

5. Collaboration with other Self-financing Degree-awarding Institutions / Schools

Collaborating self-financing institution / school	% of participation	Distinctive element(s) that the institution / school is responsible for the project
Nil	Nil	Nil

6. Project Objectives

6.1 Project delivery

Timing	Original Milestones	Revised Milestones	Date of RGC Approval *(must be quoted)*
Oct 2014	Expression of interest	Oct 2014	Attached Ref. GRC2014.Paul_Chu (2) refers
Nov 2014	Confirmation of scholars and participants	Jun 2015	
Jan 2015	Confirmation of venue	Jul 2015	
Jan 2015	Collection of guest lectures information	Aug 2015	
Mar 2015	Programme implementation	Nov 2015	
Sept 2016	Programme consolidation	Mar 2017	

6.2 Speaker(s)

Title / Name (Surname in capital letters)	Post / Institution / School	Title / Topic of presentation / course	Previous research links with Hong Kong institutions / schools (Nature and Date (month/year))
Professor Brian McGRATH	Dean, School of Constructed Environments, Parsons the New School (USA)	'Adaptive Urbanism'	Symposium 'Emerging Public Space in the Pearl River Delta', Hong Kong Poly University, March 2017
Professor David Grahame SHANE	Professor, GSAPP, Columbia University (USA)	'Rapid Urbanization & Hong Kong Design'	Book 'MaLL City: Hong Kong's Dreamworlds of Consumption, the University of Hong Kong, November 2016
Professor Joshua Wayne ROBERTS	Assistant Professor, Department of Architecture,	'New Town Evolution'	Former Assistant Professor, City University of Hong Kong, Sept 2010-2013

	Chu Hai College of Higher Education		
Professor Peter BONGRAERTS & Professor Nick CEULEMANS	Associate Professors, Department of Architecture, Hasselt University (Belgium)	'Learning from Tuen Mun'	'City as a Resource (Shenzhen)' project, Chu Hai College of Higher Education, Oct 2014
Eugenia Vidal Casanovas	Architect and Landscape Architect, Former Director of the Istambul Urban Municipal Office	'Infrastructure Urbanism'	Workshop 'Riviera Gardens after Chu Hai', Chu Hai College of Higher Education, Mar 2013
Professor Sylvia NGUYEN	Assistant Professor, Department of Urban Planning and Design, the University of Hong Kong	'New Town T.O.D. Models'	T.O.D. studies, the University of Hong Kong
Professor HSUEH Cheng-Luen	Assistant Professor, Department of Architecture, National Cheng-kung University (Taiwan)	'Adaptive Reuse'	Workshop 'Riviera Gardens after Chu Hai', Chu Hai College of Higher Education, Mar 2013

6.3 Please provide copies of promotional materials, number of participants, survey/statistics on participants, e.g. country of origin, research background, etc., a copy of evaluation form/questionnaire and the consolidated feedback with response rate. Photos of the event(s) are preferred but optional.

Please refer to the attached Inter-institutional Architecture and Urban Design Programme.

6.4 Objectives as per original application

1. To expand the research capacity of the faculties through international collaborations;

2. To engage the faculties in this new developments and challenging research topics (sustainable future of New Town development) of the Architectural and Urban Design field;
3. To enable participants to conduct focused study and scholarly exchange under the guidance of visiting scholars and experts in an intensive programme manner;
4. To benefit the general public by inviting their participation in the open symposium and forum of the programme.

6.5 Revised objectives

Date of approval from the RGC: N.A.

Reasons for the change: N.A.

1.
2.
3. ....

6.6 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

Referring to the Objective 1, 2, 3 and 4 above-

a. How -
The project involved scholars and professors from Belgium, Spain, USA, Taiwan and Hong Kong who presented, discussed and carried out a collaborative research during the workshop. It expanded teaching staff of our department's research capacity from architecture scale to urban planning and design sophistication. Participating students from Hong Kong, China, Korea, Taiwan, Thailand and Belgium attended lectures and discussions, conducted site visits and workshops, presented study outcomes under the guidance the guest scholars and experts.

b. To what extent-
A large extent this project objective is considered to have been achieved. The information and research data were collected, examined, and shared amongst the participants (both guest tutors and students). The findings and suggestions were consolidated within the intensive 8-day programme, by which the symposium (lectures), forum (reports and presentations) were open for the public to attend.

c. Under-achievements and outline attempts to overcome problems-
The lectures took place at the auditorium of the college (Tsuen Wan) and they welcomed public to attend. Due to the relatively remote location and formal atmosphere, attendants other than the workshop participating students were found to be few. To combat this, the presentation and discussion sessions were adjusted to take place at Waterside Plaza, a shopping mall

where the architecture studios were located. Posters were posted to encourage public to attend, doors were kept open to invite others to join.

6.7 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	Addressed *(please tick)*	Percentage achieved *(please estimate)*
1. expanding the research capacity of the faculties via international collaborations	√	100%
2. engaging the faculties in Architecture and Urban Design field	√	100%
3. enabling participants to conduct focused study and scholarly exchange via international scholars	√	100%
4.benefiting public by inviting them in open forum, etc	√	70%

7. Research-related Outcome

7.1 Potential for further development of the research and the proposed course of action
(Maximum half a page)

It has a very high potential to conduct research in this area further. The project opens up different issues and aspects in new (now old) town transformation in Hong Kong. It stimulates relevant studies such as land utilization, employment distribution, urban ventilation, heat island effect, building blocks dispositioning, etc.

The proposed course of action is to, first, locate relevant professionals' expertise in the fields mentioned above; second, to identify research methodology for the study; third, to conduct the corresponding research in the specific areas in the site; fourth, to formulate a conclusion in a comprehensive manner.

7.2 Research collaboration achieved
(Please give details on the achievement and its relevant impact)

The project has collected the historical background and physical data of Tsuen Wan New Town from 1960s till 2015. After studied, discussed and consolidated by different scholars and workshop participants, a digital model which included topography, roads, parks, buildings, etc of different times of Tsuen Wan was built. Aged buildings, obsoleted warehouses, potential vacant sites were identified to investigate how the future population could be distributed to transit the town for a sustainable future. The research methodology can serve as a model for other 'old new towns' in Hong Kong.

7.3 Any new development and/or challenging research topic has / have been identified and inspired the possible new initiative(s) in future research work.

Currently the research topic 'Role of building blocks design in relation to urban ventilation to achieve a livable new town environment' is carried out by the department, as an extension of the workshop endeavor. It identifies the intrinsic relationship between current building regulations (hence the building forms) and the resultant city form nowadays, reveals the building, zoning, and planning laws, and carries out digital and physical experiments and tests.

8. The Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

The nature of the project is a down-to-earth and practical research that investigates future design of new towns in Hong Kong, where the definition of 'self-sufficiency' are reviewed as a result of improvement in transportation, demographic and employment changes since its establishment in 1960s. It is important to other 'old new towns' in Hong Kong, which were designed with factories and warehouses as one of the major source of job opportunities, now under the process of transformation. The value of the research project lies on the consolidation of international architectural and urban design expertise's wisdoms on the issues of the subject, plus the use of digital model to understand, test, and project the future of new towns in Hong Kong.

Part C: Research Output

9. Recognized conference(s) paper(s) related to this project was/were delivered

(Please attach a copy of each conference abstract)

Month/Year/ Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this report *(Yes or No)*	Acknowledged the support of RGC *(Yes or No)*
5-7 Jun 2017	Effect of Residential Tower Geometries on Urban Wind Environment*	World Sustainable Built Environment Conference 2017 (Hong Kong)	No	Yes	No

*as a continuous process after the programme; jointly published in the name of Thilakaratne, R., Chu, P. & Xiao, Y; Abstract attached

10. *Research Personnel trained*

Name	Capacity
NA	NA

11. Other impact

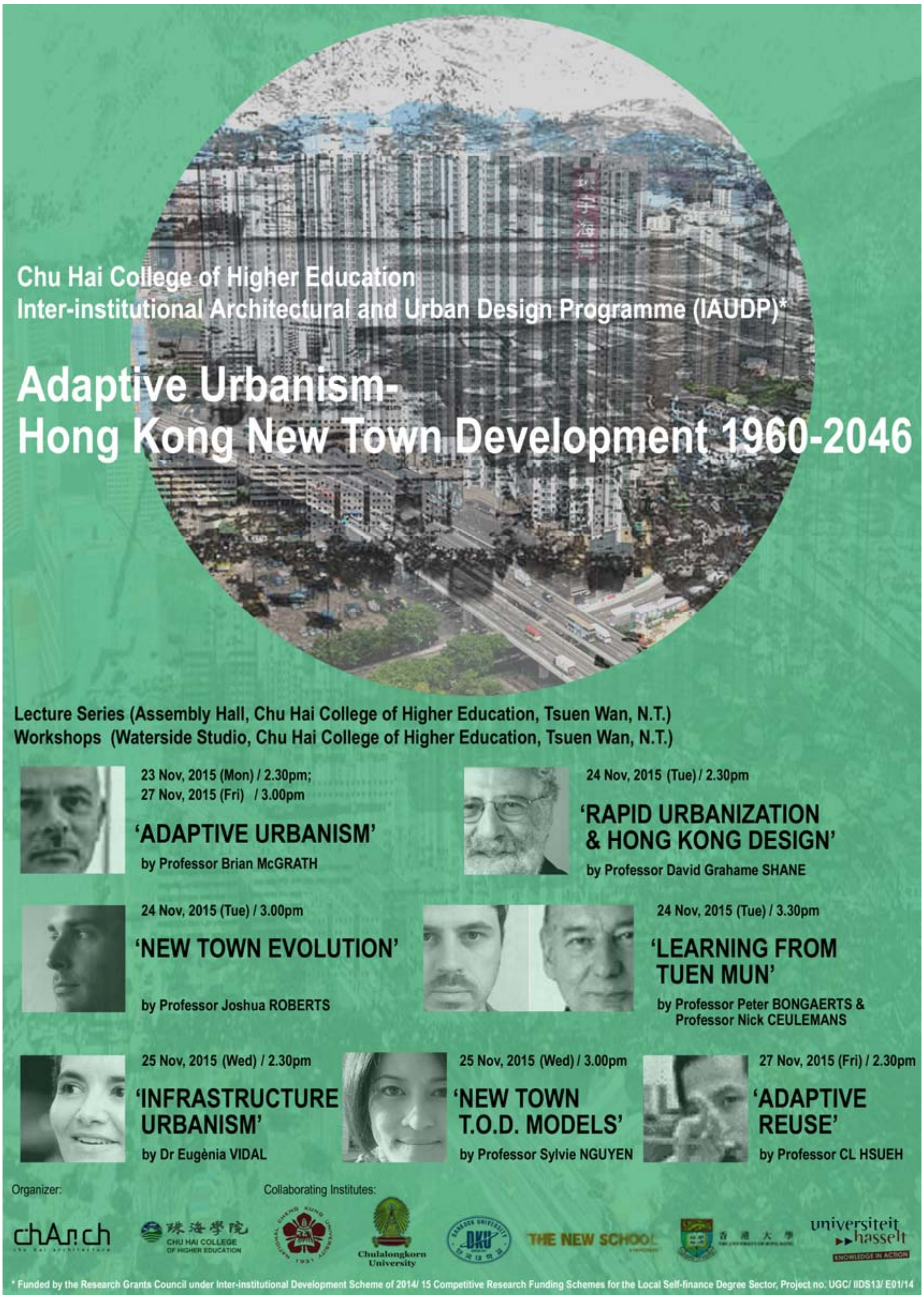
(e.g. prizes, collaboration with other research institutions, technology transfer, etc.)

Prize:
Green Building Award 2016- Finalist (Research and Planning Category)
Improving pedestrian wind environments: analysis of the effect of building typologies on urban air ventilation from 1960 to 2015

Inter-institutional Architecture and Urban Design Programme

Adaptive Urbanism- Hong Kong New Town Development 1960-2046

** Funded by the Research Grants Council under Inter-institutional Development Scheme of 2014/ 15 Competitive Research Funding Schemes for the Local Self-finance Degree Sector, Project no. UGC/ IIDS13/E01/14*



Programme scholars and experts:

- Professor Brian McGRATH, Dean, School of Constructed Environments, Parsons the New School for Design (USA)
- Professor David Grahame SHANE, Columbia University (USA)
- Professor Eugènia Vidal CASANOVAS, Universitat Politècnica de Catalunya (Spain)
- Professor Peter BONGAERTS, Univeriteit Hasselt (Belgium)
- Professor Nick CEULEMANS, Univeriteit Hasselt (Belgium)
- Professor HSUEH Cheng-Luen, National Cheng-Kung University (Taiwan)
- Professor Joshua ROBERTS, Chu Hai College of Higher Education (Hong Kong)
- Professor Sylvia NGUYEN, the University of Hong Kong (Hong Kong)

Participating Students:

- Univeriteit Hasselt (Belgium)
- National Cheng-Kung University (Taiwan)
- Chulalongkorn University (Thailand)
- Dankook University (Korea)
- Chu Hai College of Higher Education (Hong Kong)

Total number of participating students: 90

1	No.	Country of origin	School	Study Background	CHC Student Number	Surname	OtherNames	中文姓名	Year	Team	Group
35	34	Hong Kong	CHC	Architectural	201334010H	LAU	HOI LING	劉凱羚	B3	3	2000's
36	35	Hong Kong	CHC	Architectural	201334602E	TSANG	TAK SHAN ALISON	曾德珊	B3	3	
37	36	Hong Kong	CHC	Architectural	201434002H	HO	HONG YUEN	何康源	B3	3	
38	37	Hong Kong	CHC	Architectural	201434607E	LEUNG	ON MEI	梁安美	B3	3	
39	38	Taiwan	NCKU	Architectural	Nil	LI	TING-YI	李庭誼	B2	3	
40	39	Belgium	UH	Architectural	Nil	Goos	Chantal	Nil	M1	3	
41	40	Belgium	UH	Architectural	Nil	Sebastiani	Giulia	Nil	M1	3	
42	41	Hong Kong	CHC	Architectural	153401005	CHEN	MAN LONG	陳文朗	B2	4	
43	42	Hong Kong	CHC	Architectural	201234001H	FUNG	KAI HANG FELIX	馮啟鏗	B4	4	
44	43	Hong Kong	CHC	Architectural	201234013H	KWAN	HIU WA	關曉華	B4	4	
45	44	Hong Kong	CHC	Architectural	201234204H	LI	PUI YAN	李佩欣	B4	4	
46	45	Hong Kong	CHC	Architectural	201234216H	YEUNG	YU LUNG	楊裕龍	B4	4	
47	46	China	CHC	Architectural	201237202H	WAN	YOU	萬友	B4	4	2015's
48	47	Hong Kong	CHC	Architectural	201334008H	AU	ELAINE HANG LING	區鏗齡	B4	4	
49	48	Hong Kong	CHC	Architectural	201334603E	KWOK	KA CHON OTTO	郭家進	B3	4	
50	49	Hong Kong	CHC	Architectural	201434003H	LIU	TSZ CHING	廖芷晴	B3	4	
51	50	Hong Kong	CHC	Architectural	201434602E	LIN	WENBIAO	林文彪	B3	4	
52	51	Taiwan	NCKU	Architectural	Nil	YEN	CHIA-CHING	顏嘉慶	B4	4	
53	52	Belgium	UH	Architectural	Nil	Fryns	Vale'rie	Nil	M1	4	
54	53	Korea	DKU	Architectural	153401802	YOUN	DA HYE	YOUN	B4	5	
55	54	Hong Kong	CHC	Architectural	201234002H	LAW	SIU SHAN	羅兆珊	B4	5	
56	55	Hong Kong	CHC	Architectural	201234010H	HO	SZE KIT	何思杰	B4	5	
57	56	Hong Kong	CHC	Architectural	201234205H	TSANG	SIU LING	曾小玲	B4	5	
58	57	Hong Kong	CHC	Architectural	201234212H	LAU	DOI YEE	劉玳而	B4	5	
59	58	Hong Kong	CHC	Architectural	201334005H	LO	SHUK YAN	盧淑欣	B4	5	1980's
60	59	Hong Kong	CHC	Architectural	201334605E	WONG	KWUN WING	黃冠榮	B3	5	
61	60	Hong Kong	CHC	Architectural	201434005H	CHEN	TING KWAN	陳亭均	B3	5	
62	61	China	CHC	Architectural	201434203H	WU	BINJUN	吳斌君	B2	5	
63	62	Hong Kong	CHC	Architectural	201434601E	CHAN	KWAN WAI	陳君偉	B3	5	
64	63	Taiwan	NCKU	Architectural	Nil	YE	CHING-YI	葉靜怡	B4	5	
65	64	Belgium	UH	Architectural	Nil	Winters	Anne-Leen	Nil	M1	5	
66	65	Thailand	CL	Architectural	153401803	VATAPUKKANA	LEAMPANARAI	VATA	B4	6	
67	66	Hong Kong	CHC	Architectural	201234003H	TANG	SHEUNG HANG LESSON	鄧上行	B4	6	
68	67	Hong Kong	CHC	Architectural	201234008H	CHAN	PUI NI PENNY	陳珮妮	B4	6	
69	68	Hong Kong	CHC	Architectural	201234206H	LEUNG	LAI MAN	梁麗敏	B4	6	
70	69	Hong Kong	CHC	Architectural	201234211H	LAU	CHUNG HA	劉仲夏	B4	6	
71	70	Hong Kong	CHC	Architectural	201334004H	CHAN	HIU YI TIFFANY	陳曉頤	B4	6	
72	71	Hong Kong	CHC	Architectural	201337007H	NG	CHING FUNG	伍澄鋒	B3	6	1970's
73	72	Hong Kong	CHC	Architectural	201434007H	TANG	TSZ HEI	鄧子熙	B3	6	
74	73	China	CHC	Architectural	201434202H	LIU	YIYANG	劉億洋	B2	6	
75	74	China	CHC	Architectural	201434204H	LI	WEI HONG	李韋宏	B3	6	
76	75	Taiwan	NCKU	Architectural	Nil	YANG	CHEN-AN	楊宸安	B2	6	
77	76	Taiwan	NCKU	Architectural	Nil	ZHANG	XUE-CHENG	張學誠	B4	6	
78	77	Belgium	UH	Architectural	Nil	Lambrix	Sander	Nil	M1	6	
79	78	Hong Kong	CHC	Architectural	201234006H	AU-YEUNG	KWONG SANG	歐陽廣生	B4	7	
80	79	Hong Kong	CHC	Architectural	201234007H	PANG	LOK SEE	彭樂詩	B4	7	
81	80	Hong Kong	CHC	Architectural	201234208H	CHIU	TSUI TING	趙翠婷	B4	7	
82	81	China	CHC	Architectural	201234209H	YU	WANKUAN	余晚寬	B4	7	
83	82	Hong Kong	CHC	Architectural	201334002H	HO	KWUN CHEONG	何冠錩	B4	7	
84	83	Hong Kong	CHC	Architectural	201337002H	CHU	YING HUNG	朱映虹	B3	7	
85	84	Hong Kong	CHC	Architectural	201337201H	LAW	TSZ HIM	羅子謙	B3	7	1960's
86	85	Hong Kong	CHC	Architectural	201337601E	LIU	CHUN HIM	廖晉謙	B3	7	
87	86	Hong Kong	CHC	Architectural	201434008H	MOK	KA WING	莫家穎	B3	7	
88	87	Hong Kong	CHC	Architectural	201434009H	CHAU	CHRISTOPHER MAN-TAO	鄒文韜	B2	7	
89	88	Taiwan	NCKU	Architectural	Nil	LIN	WAN-CHIEN	林琬茜	B2	7	
90	89	Taiwan	NCKU	Architectural	Nil	YOU	YUAN-RU	游沅儒	B4	7	
91	90	Belgium	UH	Architectural	Nil	Rycker	Aarnoud De	Nil	M1	7	
92	Note CHC- Chu Hai College of Higher Education (Hong Kong); NCKU= National Chengkung university (Taiwan); DKU= Dankook University (Korea); UH=Hassalt University (Belgium)										

(Above) 'Vertical studio' – students of different years from the five universities were mixed up and formed design teams to facilitate cross cultural and intellectual exchanges

Programme Schedule and Events

Day 1- 23 Nov, 2015 (Mon)	
	
Lecture by Prof Brian McGRATH on Adaptive Urbanism	Lecture by Prof Joshua ROBERTS on Tsuen Wan Development
	
Visit up to the temples in the mountain to understand religious aspects and watershed of Tsuen Wan	Appreciating cultural custom of Hong Kong
Day 2- 24 Nov, 2015 (Tue)	
	
Lecture by Prof David Grahame SHANE on New Town development	Lecture by Prof Peter BONGAERTS on Tuen Mun New Town studies

	
Walk in Tsuen Wan to understand urban context	Studio workshop- from manual drafting to digital modelling
Day 3- 25 Nov, 2015 (Wed)	
	
lecture by Prof Eugènia Vidal CASANOVAS on infrastructural urbanism, Assembly Hall	Lecture by Prof Sylvia NGUYEN on New Town Transit Oriented Design, Assembly Hall
	
studio workshop- understanding mapping and diagramming techniques	Practising techniques in the studio

Day 4- 26 Nov, 2015 (Thurs)	
	
Site visit in Tsuen Wan city centre	Studio discussion and works
Day 5- 27 Nov, 2015 (Fri)	
	
lecture by Prof HSUEH Cheng-Luen Hseuh Urban Adaptive Re-use in Taiwan	
	
Studio workshop guided by guest professors at the studio	

Day 6 and 7- 28 Nov, 2015 (Sat) and 29 Nov, 2015 (Sun)	
	
Students’ design meetings and production at the studio	
Day 8- 30 Nov, 2015 (Mon)	
	
Final presentation showing the groups’ design visions of Tsuen Wan	Overall reflection, closing remarks and sharing

Registration ID: 2304

Effect of Residential Tower Geometries on Urban Wind Environment

ABSTRACT

Since 1960s building typologies in Hong Kong demonstrated significant variations in their geometry and size responding to plot ratio amendments. Majority of residential buildings prior to 1990s were of square or rectangular plan form. Since mid-1990s under Comprehensive Development Area policy, "hyper podium tower" typology which consists of a 15m high podium with quasi-cruciform plan residential towers above was introduced. Our previous research indicates a reduction in wind speed from 2.97 m/s in 1950s to 2.27 m/s in 1990 (Authors et al. 2016). A sharp drop in the wind speed was evident from 2.27 m/s in 1990 to 1.88 m/s in 2000 which may be attributed to the emergence of "hyper podium tower" residential typology.

The study further investigates the impacts created by these quasi-cruciform towers on urban wind environments comparing them with three different residential tower geometries considering two factory estates in Tsuen Wan as prospective redevelopment areas. Hyper podium developments with square towers, cylindrical towers, cruciform towers and cruciform towers with balconies were examined for their impact on urban wind speed. Wind speed was measured at 2m, 30m and 50m heights using a three dimensional urban model of Tsuen Wan as of 2015 development scenario testing with Computational Fluid Dynamics ANSYS Fluent platform.

Cruciform towers and cruciform towers with balconies outperformed wind speed around square and cylindrical towers. Cylindrical towers indicate the lowest wind performance due to the laminar wind flow facilitated by the smooth building envelope. These findings also support the positive impacts created by balconies in residential buildings as a green feature promoting urban ventilation. Findings from this study provides references for designing sustainable and liveable neighbourhoods.

Keywords: Urban regeneration, Sustainable neighbourhood, building geometries, urban air ventilation

1. BUILDING TYPOLOGIES IN HONG KONG

Evolution of building typologies in Hong Kong is discussed generally and also taking Tsuen Wan new town as a case study. Tsuen Wan is one of the first satellite towns in Hong Kong which is currently undergoing rapid revitalization.

Hong Kong building regulations have been evolving responding to factors that promote health and well-being of citizens and therefore plot ratio amendments. In mid 1930s permissible depth of buildings were reduced to 10.7 m with building height capped at three storeys. In the early 1950s, public housing programmes were introduced to accommodate increasing influx of returning residents. Initial public housing typologies were massive blocks with increased floor area. Private developers entered the market in 1956 and building regulations were further changed allowing taller buildings up to 24.4m high. Realizing the increased density by the massive blocks and their consequences, new building ordinance in 1966 reduced the plot ratio to 8:1 with options to choose higher plot ratio with lower site coverage or lower plot ratio with higher site coverage. Podium & tower typology became a popular option due to 100% site coverage for non-domestic portion.

Since early 1980s, industrial areas in Hong Kong have been transforming from manufacturing to a service and knowledge based economy due to the decline in industrial sector's contribution to Gross Domestic Production. With the relocation of industrial estates to Pearl River Delta Region, most these factory buildings were adopted for non-manufacturing and residential purposes. In 1988 Hong Kong inherited approximately 12 million ft^2 of flatted factories (Colliers, 2011). Tsuen Wan developed as an industrial hub accommodating some of the largest factory estates that exist even to date. In the past fifteen years, Tsuen Wan has been undergoing rapid transformation of these industrial estates and old buildings built in the 1950s. With modified zoning requirements, stand-alone developments have been progressively replaced by mixed use large scale redevelopments which are classified as 'Comprehensive Development Areas (CDA)'. Out of 136 factory zones in Tsuen Wan 52 have been transformed into non-industrial zones (HKSAR, 2011). Old wide roads made for container vehicles and factory blocks were amalgamated and transformed into large blocks with development Plot Ratio of 5 to 6. These modifications to plot sizes and plot ratios adversely impacted on the urban porosity.

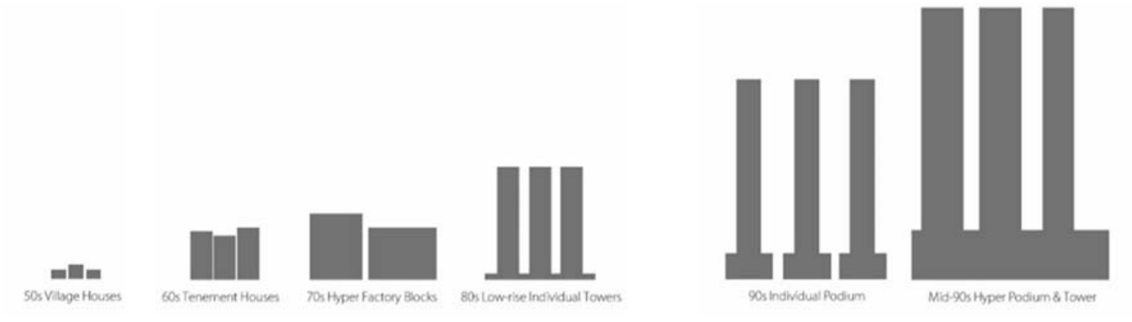


Figure 1: Evolution of building typologies in Tsuen Wan from 1950s to 2015 (Source: Authors, 2016)

In Hong Kong distance between building blocks is governed by the vertical light angle requirement of 71.5 for habitable areas with a minimum 10% glazing area out of the floor area. As a result, distance between buildings became narrower resulting on lack of air and light penetration into lower levels.

1.1. Emergence of cruciform and quasi-cruciform residential typologies

In private residential developments, in order to maximize the gross floor area within given plot ratios, residential typologies began to evolve into plan forms that deliver higher spatial efficiency and daylight & natural ventilation penetration. Hong Kong building regulations stipulate minimum perpendicular distance between windows of habitable rooms in different blocks within the same site. Cruciform plan form and its mutations were the most feasible option; staggering building envelope of cruciform plan eliminates perpendicular obstruction between towers although adjacent towers are closely built. Most these developments also consisted of external features such as protruding drying racks, bay windows, planter boxes etc.

Most developments adopted bay windows instead of balconies as bay windows were exempted from the gross floor area (GFA) calculations. In 2001, GFA exemption was granted for balconies; 50% of balcony area that is not less than 2 m^2 became a value added sustainable feature in many new developments (Buildings Department, n.d.). Majority of hyper podium residential towers in Hong Kong are of cruciform geometries in order to increase number of flat units per floor that have daylight access.

For the purpose of this study, we calculated building volumes of square, rectangular and cruciform plan tower developments in Tsuen Wan as of 2015. Figure 2 indicates the predominant presence of quasi-cruciform towers in Tsuen wan compared to square plan form and rectangular plan form building volumes. Cruciform developments consist of 19.16 million m^3 whilst square representing 5.6 million m^3 and rectangular plan form towers representing 12.6 million m^3.

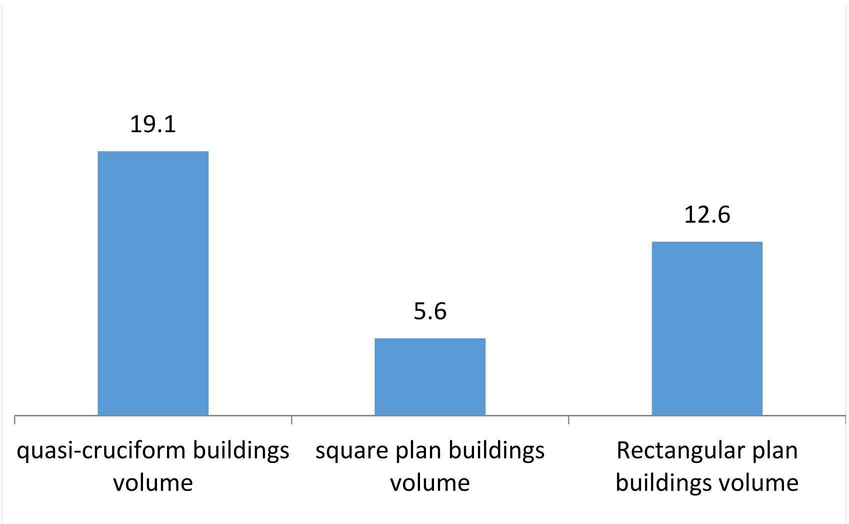


Figure 2: Building volumes three different building geometries in Tsuen Wan in 2015 in million m^3
(Source: Authors, 2016)

2. RESEARCH DESIGN PARAMETERS

A factory estate within Tsuen Wan that has prospects for redevelopment was considered as the experimental site: this existing factory estate was hypothetically replaced with eight podium developments that consists of 37 towers. These towers represented four variations of building geometries that were simulated for wind performance. These four variations are: square plan towers, quasi-cruciform plan towers, cylindrical towers and quasi-cruciform towers with balconies (Figure 3). Wind performance at 2m pedestrian level, 30 m and 50 m height above ground level was measured. All buildings were approximately similar in floor plate area and distance between towers.

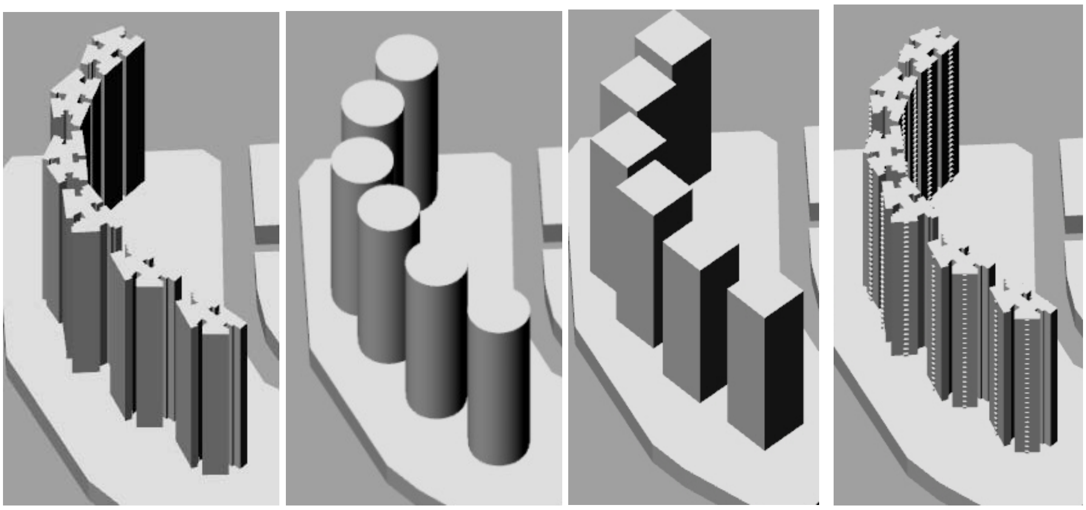


Figure 3: Four different building geometries tested for their impact on urban ventilation (Source: Authors, 2016)

2.1. Wind simulation parameters

All protocols stipulated in Hong Kong Air Ventilation Assessment Framework were followed in setting parameters. Simulations under seven strongest wind directions (E, ESE, ENE, NE, SE, S, and SSW) that represent over 76% of annual wind frequency were carried out for each case.

Inflow wind profiles are adopted from RAMS data from Hong Kong Planning Department's website. Inflow turbulent kinetic energy profile and corresponding dissipation rate profiles are estimated using the following equations where u* is the frictional velocity, Cμ =0.09 and κ=0.4.

$k = \frac{u_*^2}{\sqrt{C_\mu}}$ $\varepsilon = \frac{u_*^3}{\kappa(z+z_0)}$

Computation Fluid Dynamics ANSYS FLUENT solver (Fluent Inc., 2006) with the Realizable k-e turbulence model was used for wind simulation adhering to the parameters described in Hong Kong Air Ventilation Assessment framework. Strength of the Reynolds number is referred to explain laminar and turbulence air flows. The model spans a distance of 2700m with inflow wind velocity of 6 m/s at boundary layer height, as for the formula of Reynolds number

$$Re = \frac{UL}{\gamma}$$

In which, U=Length Scale (Order of 102 to 103) for Tsuen Wan district, the length scale is around 2700 meters for our study area.

L=Flow Velocity (Order of 100) from our wind velocity profile, around 6 m/s for inflow wind velocity at boundary layer height.

γ= Kinematic Viscosity of Air (1.72* 10-5). Therefore, the simulations were carried out under high Reynolds number of order of magnitude of 109

Unlike in a building scale AVA study, in a city scale study it is important to adopt a practicable and reasonable resolution and a scale for simulation. Typically recommended 8million cell resolution did not facilitate smooth operation of the software for this city scale analysis warranting an increased resolution of 15million cells. Selection of an appropriate turbulence model is crucial in CFD simulation studies. RANS k-ε family steady turbulence model are commonly practiced for carrying out parametric studies on wind flow problems. Out of the three variations of RANS k-ε models, 'Realizable k-ε model' proposed by Shih et al. (1995) were adopted due to its ability in predicting more physically realistic turbulence properties with a varying model coefficient of C_μ which modifies the turbulent viscosity term. Following the recommendations in CFD guidelines (Franke, 2007; Tominaga, et al. 2008; Mochida et al., 2002), the study adopted a rectangular computational domain with symmetric boundary conditions at the two side boundaries and the upper boundary. For our computation, the inflow boundary condition is set as the velocity inlet boundary condition and the outflow boundary as the outflow condition. Unstructured tetrahedral cells of approximately 8-15 million with maximum expansion ratio were created in the mesh with other settings as referring to the COST Action C14 (Franke et al., 2011) and the Architectural Institute of Japan (AIJ) guidelines (Tominaga et al., 2008; AIJ 2007).

3. EFFECT OF BUILDING GEOMETRIES ON WIND SPEED

3.1. Urban ventilation trends from 1960 to 2015

This study examined the effect of building geometries on urban wind speed taking into consideration three different plan form variations and one variation with balconies. In order to establish a rational and scope, this study also developed historical wind profiles from 1960 to 2015 considering urban fabric changes in every ten years and historical wind profiles from 1997 to 2015 to verify results with every three-year development changes in Tsuen Wan city centre (Figure 4).

Progressive developments in Tsuen Wan new town resulted in the reduction in urban porosity from 51% unbuilt area in 1960 to 6.1 unbuilt area in 1990 negatively impacting on the pedestrian zone wind speed. Weighted average scores from fifty strategically placed test points within the study area reported a decline in pedestrian wind speed in parallel to reduction in unbuilt areas. However, the reduction in wind speed was 0.7 m/s from 1960 to 1990 in parallel with approximately 45% reduction in urban porosity, compared to the sharp drop in the wind speed from mid 1990s onwards (Figure 5).

Two significant development typologies attributed to this noticeable decline in the wind speed; a decline from 2.97 m/s to 2.5 m/s with the introduction of 'hyper factory blocks' in the 1970s followed by another sharp decline from 2.27 m/s to 1.88 m/s with the introduction of 'hyper podium & tower' developments in mid 1990s. Approximately 1.1 m/s reduction in the wind speed can be observed in the year 2000 compared to 1960s (Figure 5). Alarming impacts from hyper podium developments calls for attention to the way we design buildings.

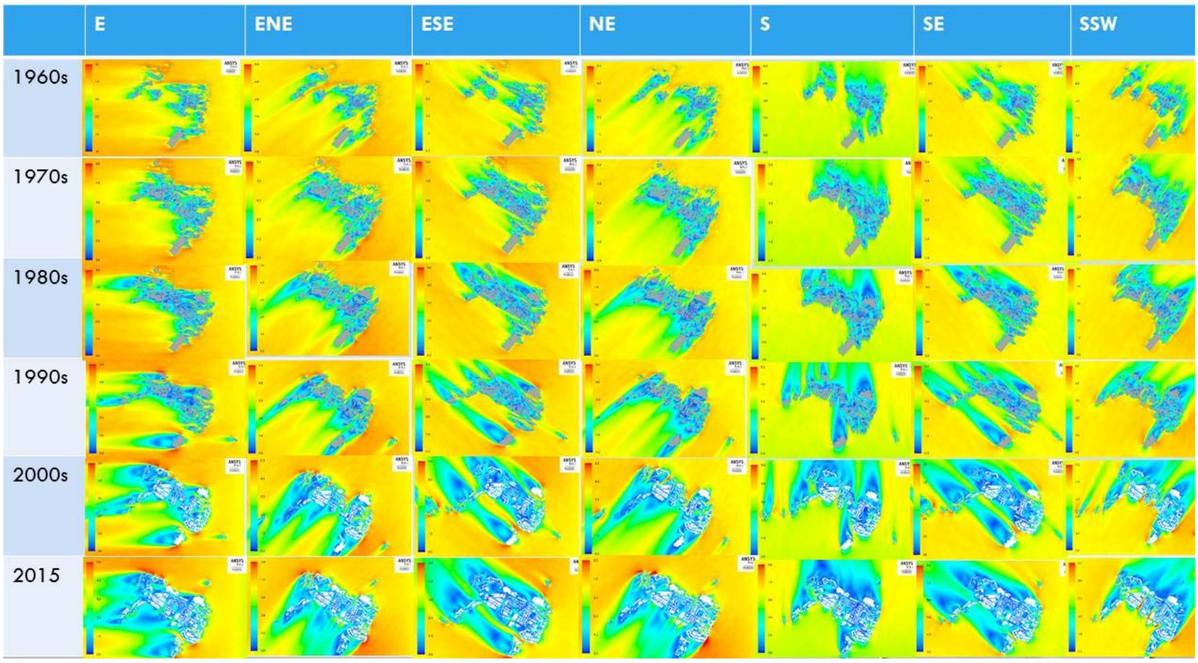


Figure 4: Ten year interval historical wind profiles from 1960 – 2015 (Source: Authors, 2016)

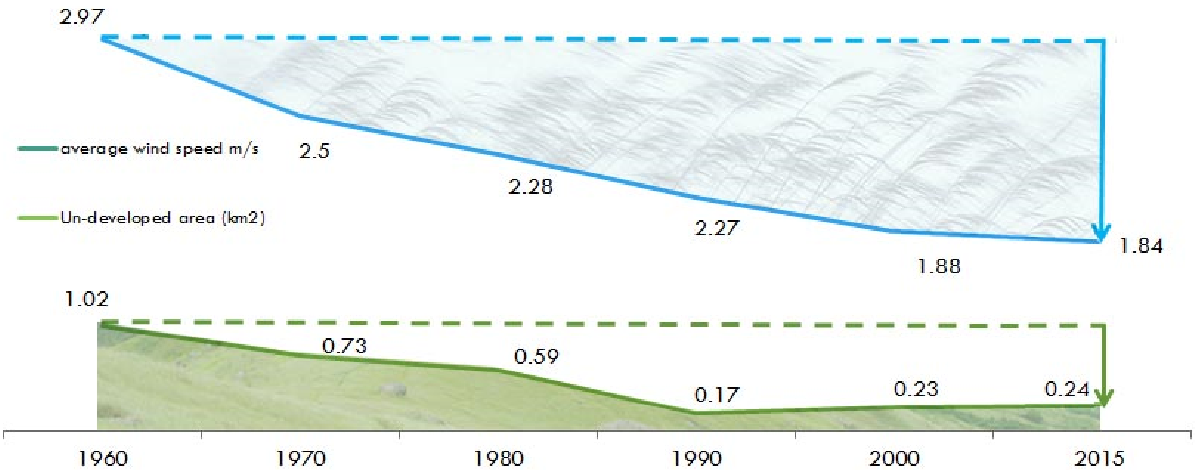


Figure 5: Correlation between pedestrian level ventilation and reduction in undeveloped land area in Tsuen Wan from 1960 – 2015 (Source: Authors, 2016)

3.2. Creating sustainable neighbourhoods with better urban ventilation

Thermal comfort is a key consideration when designing liveable and sustainable neighborhoods. Poor air quality, urban heat island effect and extremely high humidity levels are some of the factors attributed by stagnant urban ventilation levels effecting liveability in urban Hong Kong. Effect of building geometries have been studied as a means of manipulating urban ventilation (Norberg, C.1987, Williamson, C. 1996). Findings reported distinct wind behavior patterns around these four building geometries with cruciform towers and cruciform towers with balconies reporting higher wind speeds around them compared to cylindrical and square towers. Results were consistent at 30m height and 50m height. These findings are supported by a study conducted by Montazeri, H. et al. (2013) which reports the contribution of uniform second skin façade to equalize wind pressure in balconies in high wind zones. Cylindrical forms facilitate more steady streamlined flow or laminar air flow around the surface. Whereas cruciform geometries facilitate erratic air flow around the edges due to resistive forces thereby creating air turbulence increasing wind speed around the buildings. In cruciform geometry, the envelope is rougher and therefore the friction between air and the envelope is higher; greater the friction between the layers, greater the drag. Results also indicate improvement in wind performance at upper zones compared to lower zones due to ground level friction which behaves differently from building envelope friction. Wind speed at the pedestrian zone can be unpredictable due to urban roughness variations; however, wind speed results at 2m high zone is seemingly consistent with 30m and 50m high zones.

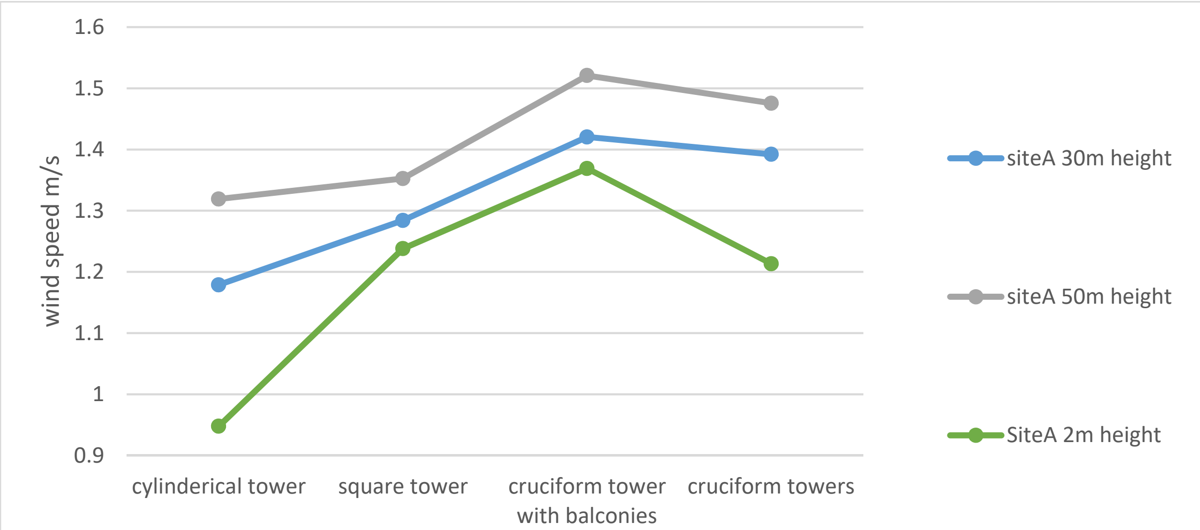


Figure 6: Building geometry impact on wind speed at different height zones (Authors et al. 2016)

4. CONCLUSIONS

This study established a correlation between urban porosity and urban wind speed and the impact from various building typologies on wind speed since 1960 until 2015. Wind simulation results in the year 2000 indicated adverse impacts on wind environment by hyper podium tower developments emerged in mid 1990s. Adverse impacts were also notable around massive podiums due to wind amplification on the windward side. Cruciform towers reported better wind movement around them, however the gap between these towers influence ventilation levels.

This study contributed to the advancement in built environment knowledge by developing historical wind profiles from 1960-2015 and identifying the effect of development trends and building typologies on urban ventilation. Results from 3 year interval analysis and 10 year interval analysis confirm the adequacy of 10 year interval analysis for development of historical wind profiles at city scale. These findings may serve as a reference for future development of sustainable and liveable neighborhoods with improved outdoor thermal comfort.

Findings from this study established the contribution from cruciform towers and balconies as a green feature in improving urban ventilation speed thereby their creating sustainable neighborhoods. Findings also call for review of residential development and CDA policy in order to create desirable pedestrian wind environments and thermal comfort levels.

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