A Vision of the Future Construction Industry of Hong Kong

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ABSTRACT

The Hong Kong construction industry has been a powerful engine behind the city's rapid urban development. It serves to improve the living environment and standards, create a connected society, promote Hong Kong's sustainable development, and enhance Hong Kong's long-term competitiveness. To tackle manpower shortfall and to enhance its efficiency, the industry also strives to become a leading techno-construction industry in the region. Being the coordinating body of the industry, the Construction Industry Council (CIC) is taking the lead in pushing the boundaries and bringing the industry's competitiveness to the next level. We ride the waves of change to anticipate and meet evolving challenges by promoting new initiatives such as modular design and fabrication, Building Information Modelling (BIM), renewable energy technologies, construction automation and robotisation. More initiatives like the above are needed to spur the industry to re-invent our construction processes and ensure that stakeholders in the value chain work in an integrated manner. This paper presents state-of-the-art R&D and technologies adopted in the Hong Kong construction industry, and highlights the challenges ahead of driving innovations in the industry. More importantly, an overarching vision of the construction industry is set to better serve the changing needs of the community. Innovative technologies and ideas are explored and exhibited to achieve the vision.

Keywords
Hong Kong, construction industry, innovation, R&D, future vision

Introduction

The Hong Kong construction industry has been a powerful engine behind the city's rapid urban development. Contributing around 7% of Hong Kong's GDP, it serves as a main pillar of the city supporting its economic and social development. Driven by the massive infrastructure developments and housing programmes, Hong Kong construction industry is now undergoing one of the peak periods of construction in our history, and construction activities are expected to remain at a high level in the coming 10 years [1]. However, a series of critical challenges must be tackled properly to meet the market demand and requirements.

The rising manpower demand, coupled with an ageing workforce and skills mismatch, is one of the most pressing issues facing the Hong Kong construction industry. Currently, we are short of approximately 10,000 skilled workers and this shortfall is expected to last in the foreseeable years if no immediate action is taken [2]. On top of that, construction activities in the building industry are still labour intensive in general which make the industry's productivity lagging behind. Exacerbating the situation, the industry found difficulty in attracting the young generation to join the industry due to the "4Ds" perception of the industry i.e. dirty, dangerous, demanding, and disorganised.

While a number of strategies have been initiated to improve safety performance of the industry such as "pay for safety" scheme, publication of guidelines, awareness campaigns, etc., the construction industry recorded highest number of fatalities and accident rate among all industries in Hong Kong. In 2013, 3,232 industrial accidents were reported in the construction industry, 22 of which were fatal [3]. Facing tight project schedules and physically demanding tasks within crisis-ridden environments, effective measures are crucial to raise site safety performance.

In addition, construction is recognised as an energy-consuming and carbon intensive industry. Buildings take up approximately 90% of the electricity consumed in Hong Kong, contributing 60% of the overall GHG emissions [4]. The energy use of all types of buildings (residential, commercial and industrial buildings) reached 195,458 TJ in 2012 [5]. Construction and demolition waste is another critical issue locally. At present, the amount of construction waste disposed is 3,300 tonnes a day, which accounts for 25% of total daily disposal while three local landfills are reaching

their full capacities in 2014, 2016 and 2018 [6].

Under the competitive global environment, elevating efficiency and promoting innovation for the Hong Kong construction industry are critical not only to resolve the above-mentioned issues but also to make the industry competitive in the global market. Modern construction methods and techniques, information technology as well as automation technology need to be adopted by the industry. Being the coordinating body of the industry, the Construction Industry Council (CIC) is taking the lead in pushing the boundaries so as to bring the industry to a new level. This paper presents state-of-the-art R&D and technologies that are currently adopted and promoted in the Hong Kong construction industry, discusses the challenges encountered during the implementation of innovative techniques, and more importantly conceives the vision and goals for the industry's sustainable development. Innovative technologies and ideas are explored and exhibited to achieve the vision

Technologies Adopted in Hong Kong

Prefabrication and Modular Construction

Being one of the most densely populated metropolitan cities in the world, Hong Kong's housing supply is definitely a key element of the sustainable urban development. Hong Kong Housing Authority (HA) is the main provider of public housing for about half of the Hong Kong population, which plans, builds, manages and maintains different types of public housing.

The HA has been actively pursuing the mechanised prefabrication construction system in its public housing developments with an aim to upgrade building quality, improve construction safety, enhance environmental protection and increase cost effectiveness. Building elements such as facades, slabs, staircases, partition walls and beams are prefabricated in the construction of public housing blocks for better workmanship and to maximise construction efficiency (Figure 1) [7,8]. With over two decades of experience being the pioneer in the use of prefabrication in Hong Kong, the use of precast concrete in domestic blocks has reached about one-fourth of total concrete volume in a typical public housing project. With the prefabrication of volumetric precast bathrooms (Figure 2) for domestic flats in some of the projects, the ratio can increase to 35%. More recently, the HA piloted the construction of a precast roof water tank, and also began exploring the feasibility of precasting lift machine rooms, roof parapets, manholes and drainage channels, as well as prefabricating electrical trunking [10].

Figure 1 - Precast elements (facades, slab, and staircase) used in HA public housing [7]

Figure 2 – Volumetric precast components (bathroom and kitchen) used in HK projects [11,12]

The practices that the HA adopted for the construction of public housing exhibit significant success in the control of cost, quality and construction time. Previous study has demonstrated significant advantages of prefabrication compared with traditional construction in terms of reduction of construction time (20%), construction waste (56%), dust and noise on-site, and labour requirement on-site (9.5%) [9]. Worker safety is also improved dramatically since complex and labour-intensive construction processes on site are reduced. Use of precast components has also been actively explored and adopted in major infrastructures such as immersed tube tunnels, HKZM Bridge and Hong Kong Shenzhen corridor, etc. Private sector developers also started adopting precast concrete construction in 2002 when the gross floor area (GFA) concession was included. An offsite prefabrication yard for automated cutting and bending of steel rebar was recently awarded and production is anticipated to commence towards end 2015.

Construction IT

IT technologies such as Building Information Modelling (BIM) may help improve construction efficiency through better information management, construction process control, cross-disciplinary collaboration, internal coordination, problem solving, and risk management [13]. BIM is currently one of the

Hong Kong construction industry's key initiatives for enhancing the overall performance of the projects and the construction management.

Since 2006, HA introduced BIM in its development of public rental housing projects, more than 19 projects have already adopted BIM at various project stages, ranging from feasibility study to construction stage. To facilitate the BIM implementation process, HA has prepared its in-house BIM standards, user guide, library component design guide and references [14]. For infrastructure projects, Highways Department was the first to use BIM on the Central-Wan Chai Bypass and Island Eastern Corridor Link in 2009 followed by a number of complex public works. Apart from the public sector, majority of major developers have adopted BIM to different extents such as development project planning, setting the use of BIM as a mandatory requirement for the design of particular developments [15].

To harness this potential of wide BIM application in both public and private sectors of Hong Kong, it is needed to secure the commitment of senior management to invest in IT and to build up a critical mass of IT users within the industry. The CIC has taken the initiative to facilitate the implementation of BIM in Hong Kong's construction industry in a systematic and strategic way [16]. Currently, the CIC is working together with various industry stakeholders to set industry standards and develop a common data infrastructure. The CIC BIM Standards (CIC BIMS) are designed to enable a client to specify, manage and assess BIM deliverables by architects, engineers and contractors. The use of the CIC BIMS should ensure that project deliverables produced using the BIM processes achieve an agreed level of quality [17].

In addition, other BIM-based or IT-related research and technologies are being studied by researchers dealing with practical problems faced by the Hong Kong construction industry as well as the overseas. The Hong Kong Innovation and Technology Commission (ITC) has funded a research project which proposes to develop an RFID-enabled service-oriented BIM platform for enhancing prefabrication housing production in Hong Kong [18]. Location-based technologies for asset tracking and risk management system have been developed and tested in construction projects, including the application of Chirp Spread Spectrum (CSS) and RFID technology. With such system working on-site, the relative locations between workers and the danger zones can be detected real-time and thus generating warning signals to avoid accidents [19]. Other BIM-related studies, such as BIM-based system for estimation and planning of demolition and renovation construction waste linking to the Hong Kong government's waste charging scheme, distributed cloud-based social BIM framework which could support collaboration among project participants and information sharing, cloud computing integration with BIM technology in the construction, integrated 5D BIM for quantification of construction process emissions and accident identification, virtual prototyping framework for simulating construction process and so on, have also been developed or being studied in the local construction industry [20-24].

Construction Automation and Robotisation

The Hong Kong construction industry has earned a reputation over the years in rapid construction of quality high-rise apartment blocks and office towers. The adoption of specialised construction techniques has made Hong Kong a regional leader. Faced with high labour cost, any machinery that could save labour usually will be welcomed by industry players. Thus, adoption of mechanisation in construction is one feasible and effective mean to achieve high productivity for the industry. Figure 3 shows the example of concrete pumping applied in the project sites which substitutes the traditional manual concrete lifting.

Figure 3 – Concrete Pumping in Hong Kong [25]

Machinery could enhance the efficiency of specific work trade on-site, but more desirable is the effective management approach for increasing productivity and project workflow throughout the entire development processes. The application of the aerial cinematography technology or Unmanned Aerial Vehicle (UAV) for site progress recording and monitoring (Figures 4 and 5) has been studied and tested in Hong Kong's real construction projects which could provide aerial overview at different stages of the site progress for site daily record [26]. The system could conduct volumetric survey, assist site logistic planning and energy simulation, and help generate conceptual 3D modelling

which saves the time and manpower as well as increases the productivity. To better control the as-built quality of projects, the laser scanning technology has been applied by Hong Kong contractors during the construction stage which provides more accurate project information and avoids multiple manual site visits for checking [26].

Figure 4 – Testing the UAV on-site [27]

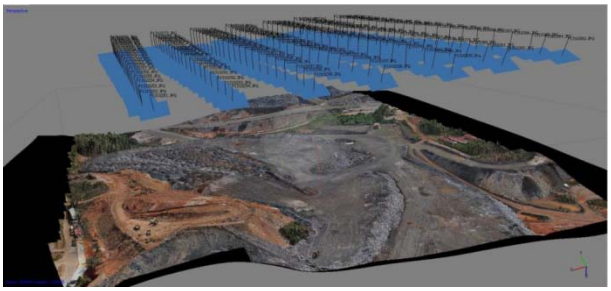

Figure 5 – 3D modelling based on aerial photos [28]

Robotic research and application is being rapidly developed in Hong Kong. The University of Hong Kong has established its Advanced Robotics Laboratory currently working on the development of robotics systems for operation in dangerous, degraded, human-engineered environments with the usage of available human tools, ranging from hand tools to vehicles, the outcomes of which are highly suitable to be applied in the construction industry. The Hong Kong University of Science and Technology (HKUST) is also developing the Robotics and Autonomous Systems (RAS) operating with high degree of autonomy which are desirable in various fields such as construction. In the aspect of practical application, the manufacture for precast construction elements has adopted the robotic arm in the production line as shown in Figure 6.

Figure 6 – Robotic for precast element production [29]

Challenges in the Implementation of Construction Innovation

The penetration of automated technology and innovation in the Hong Kong construction industry is lagging behind other countries such as the US, Japan, South Korea, etc. [31,32]. The substitution of capital for labour remained sluggish even when the building industry was facing an ageing pool of construction workers. This is inherently due to the fragmented industry with the presence of numerous small-scale contractors whose skills lie in extensive subcontracting and procurement of labour services and building materials, rather than mastering the building technology [33]. Investment in technology such as robotics for these SME might be luxury [34]. On top of that, risk implications, contract and standard requirements, and altering conventional practices are critical when adopting new technologies. Driving industry stakeholders in adopting new technologies is therefore challenging, especially when the cost effectiveness of the new technique has not been well-proven in real projects.

The industry also lacks incentives to adopt new technologies. Private developers who aim at lowest construction costs, as well as the public sector that has been unwilling to accept tenders that are not the lowest have indirectly promoted the use of more labour than machines [35]. Strong policy is always an effective mean to promote innovations in construction. The US requires mandatory BIM submission for government projects since 2008. Similarly, such mandatory requirement will also be in force in UK for public sector from 2016 onwards. Singapore started to comprehensively implement BIM nation-wide in 2011 and now requires mandatory use of BIM from 2015 onwards [15]. Riding on the technology from the

manufacturing industry and government support, Japan has been the leading role in the prefabrication and modular construction industry [30]. In Hong Kong, the HA and Development Bureau of the local government have recently introduced alternative procurement approach to promote innovation and creativity through tendering processes. The CIC is also taking the lead to implement practical initiatives that will benefit the industry such as the BIM implementation, adoption of Eurocode, etc.

Adapting new technologies by the industry is usually a lengthy process. Readiness of industry stakeholders depends on the interoperability of the technology with existing practice and operation system, personnel capability, etc. Challenges such as technological feasibility, cost and time benefits, user training, and safety considerations, etc also need to be addressed in the promotion and implementation of innovation in our construction industry. To allay the concerns of investment and risks of innovation adoption, the government provides financial support (e.g. Innovation and Technology Fund, New Technology Training Scheme, SME Funding Scheme, etc.) to those construction firms who would like to introduce new technologies. Such government support to some extent aids SME in investing the innovative techniques [36]. The CIC also invests around HK$10M (~US$130,000) each year to fund research projects to stimulate and promote innovation and technological development in the industry. In addition, the CIC Innovation Award 2015 has recently been launched which aims to spearhead development of new concepts to enable continuous enhancements in the construction industry in Hong Kong, the Mainland China and overseas. It is believed that in near future the significant benefits could be revealed through the promotion of such initiatives, thus gradually transforming the industry to a high-tech and high efficiency working environment.

Hong Kong Construction Innovation: Mission and Vision

Hong Kong's construction industry is indeed in the midst of an exciting transformation. With the driving force to meeting the increasing demands, we envisage that the industry will move towards "productive", "safe" and "green".

To achieve the Hong Kong's vision for cutting-edge construction productivity, we anticipate that the industry could be highly proactive and open in adopting innovative, cutting-edge technologies along design, construction, and maintenance. Standardisation through prefabrication and modular construction can greatly enhance efficiency of work execution. In Changsha, central China, a 30-storey building was constructed in 90 days by extensively adopting prefabricated modular structural system. This project demonstrates how the industry can move towards high productivity. In addition, BIM is expected to be fully implemented in the industry throughout the project lifecycle. For effective project modelling, visualization, simulation, monitoring and management, the BIM can be integrated with Radio Frequency Identification (RFID) tracking technology as a method of creating, sharing, exchanging and managing the building information throughout the lifecycle among all stakeholders (Figure 7). It is also anticipated that manual construction activities can be conducted by automated technologies and robotics, such as 3D printing technology, so as to improve efficiency, site safety and quality as well as to reduce construction waste.

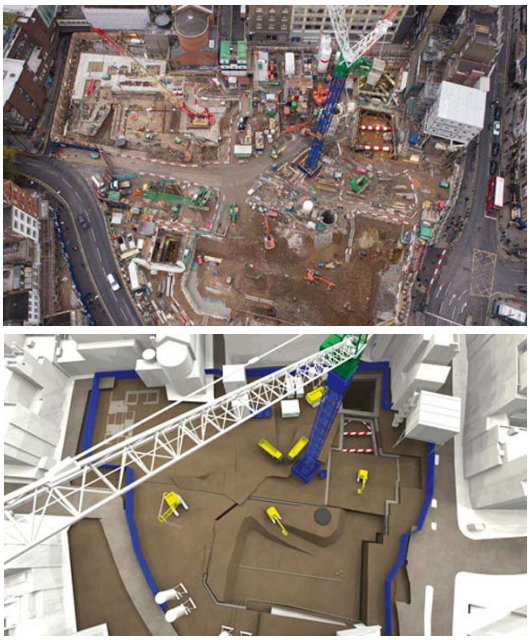

Figure 7 – BIM Integration with RFID [37]

Construction safety has always been one of the most concerns of CIC and the whole industry. Through the measures taken in the five aspects as shown in Figure 8, we anticipate that "Zero Accident" is not just a slogan but the reality. Training to frontline is the first and essential step towards the goal. Construction safety management should shift to a new paradigm to 'Construction Design and Management' (CDM) by identification of potential health and safety hazards, and mitigation measures at early stage of a project and early involvement and co-operation of all stakeholders through timely provision of relevant information. On top of that, advanced technologies such as real-time

localisation system, Internet of Things, should be adopted in the wider construction industry to manage safety. For instance, RFID tags containing pertinent safety information, including regular test records, could be attached to safety equipment such as slings, safety harnesses and belts, scaffolding and hardhats. In addition, tightening law related to construction safety is needed for a stronger deterrence effect on unsafe practices among project stakeholders. Ultimately, the industry should continue to invest considerable resource and effort in promoting safety-first culture.

Figure 8 – Potential Measures to Achieve the Vision of Construction Safety

As a responsible service provider and contributor to the city and the community, the construction industry should take the lead to improve the environmental performance in terms of energy and resource conservation, pollution control, carbon reduction, waste reduction and recycling. Starting from green construction of an individual project by utilizing green design methods, green materials, green building facilities and energy-efficient operational measures, renewable energy technologies, incentives schemes such as energy performance contracting, tax rebates, should be initiated to transform our construction activities and facilities to green. We anticipate creating a green community with enhanced green awareness of residents, and further to build a green city to benefit all Hong Kong citizens.

The Hong Kong construction industry has been dedicating in enhancing its overall performance and the competitiveness. The outstanding achievements and the international reputation in past decades have proved its excellence. At the turning point of the industry transformation, it is believed that we shall be more open minded on the adoption of innovation, to foster a culture with proactive attitudes towards the application and implementation of advanced technologies, and to work together to engineer our future Hong Kong with innovation and excellence for all to benefit.

References

[1] Construction Industry Council. Construction expenditure forecast for public and private sectors. On-line: http://www.hkcic.org/info/expenditureGraphic_2014.aspx, Accessed: 28/01/2015.

[2] Construction Industry Council. Striking the right balance. On-line: http://www.hkcic.org/eng/about_cic/EDBlogNews.aspx?langType=1033&NewsDate=12.03.2014, Accessed: 28/01/2015.

[3] Labour Department. Data obtained through email enquiry (4/9/2014 for 2013 data).

[4] Hong Kong Green Building Council. Market drivers for transformation of green buildings in Hong Kong (Executive Summary). On-line: https://www.hkgbc.org.hk/upload/HK3030/Home/roadmap_31OCT2014_preview.pdf, Accessed: 28/01/2015.

[5] Electrical & Mechanical Services Department. Hong Kong energy end-use data 2014. On-line: http://www.emsd.gov.hk/emsd/e_download/pee/HKEEUD2014.pdf, Accessed: 28/01/2015.

[6] Environmental Production Department. Introduction to construction waste. On-line: http://www.epd.gov.hk/epd/misc/cdm/introduction.htm, Accessed: 28/01/2015.

[7] Hong Kong Housing Authority. Prefabrication in housing blocks. On-line: http://www.housingauthority.gov.hk/en/business-partnerships/resources/prefabrication-in-housing-blocks/, Accessed: 28/01/2015.

[8] Mak Y.W. Strategic implementation of prefabrication and modular construction & some experience sharing of Hong Kong Housing Authority. In Second Construction Technology Forum: Construction for Sustainability, Hong Kong, 2013.

[9] Jaillon L. and Poon C.S. The evolution of prefabricated residential building systems in Hong Kong: a review of the public and the private sector. Automation in Construction, 18: 239–248, 2009.

[10] Hong Kong Housing Authority. Annual Report 2012/2013 Public housing growing from strength to strength On-line: http://www.housingauthority.gov.hk/mini-site/haar1213/en/index.html, Accessed: 28/01/2015.

[11] Hong Kong Housing Authority. Green construction: use of prefabricated building elements. On-line: https://www.housingauthority.gov.hk/hdw/en/aboutus/events/greenestate/sec4_6_1.html#2, Accessed: 28/01/2015.

[12] Yau Lee Holdings Limited. Concrete precast units: volumetric bathroom-cum-kitchen. On-line: http://www.yauleewah.com/eng/qualityproducts/products2.htm, Accessed: 28/01/2015.

[13] Construction Industry Council. BIM: Fact sheet – Strategic implementation of Building Information Modelling (BIM) in Hong Kong's Construction Industry. On-line: http://www.hkcic.org/WorkArea/DownloadAsset.aspx?id=10628&langType=1033, Accessed: 28/01/2015.

[14] Hong Kong Housing Authority. Building Information Modelling. On-line: http://www.housingauthority.gov.hk/en/business-partnerships/resources/building-information-modelling/, Accessed: 28/01/2015.

[15] Construction Industry Council. Final draft report of the roadmap for BIM strategic implementation in Hong Kong's construction industry. On-line: http://www.hkcic.org/WorkArea/DownloadAsset.aspx?id=13011&langType=1033, Accessed: 28/01/2015.

[16] Construction Industry Council. Building Information Modelling. On-line: http://www.hkcic.org/eng/news/BIM/OurInitatives.aspx?langType=1033, Accessed: 28/01/2015.

[17] Construction Industry Council. CIC BIM Standards - Building Information Modelling - Project Execution Plan. On-line: http://www.hkcic.org/WorkArea/DownloadAsset.aspx?id=12735, Accessed: 28/01/2015.

[18] The University of Hong Kong. RFID-enabled service-oriented BIM platform for enhancing prefabrication housing production in Hong Kong. On-line: http://www.autom.hk/bimp/, Accessed: 28/01/2015.

[19] Li H. Proactive construction management system: location-based technologies for asset tracking and risk management. In the LSCM Logistics Summit 2014, Hong Kong, 18 September, 2014.

[20] Cheng J. C. P. and Ma L. Y. H. A BIM-based system for demolition and renovation waste estimation and planning. Waste Management, 33:1539-1551, 2013.

[21] Das M., Cheng, J. C. and Kumar, S. S. BIMCloud: A distributed cloud-based social bim framework for project collaboration. In Proceedings of 2014 International Conference on Computing in Civil and Building Engineering, pages 41-48, Orlando, Florida, United States, June 23-25, 2014.

[22] Cheng, J. C. and Das, M. A cloud computing approach to partial exchange of BIM models. In Proceedings of the 30th CIB W78 International Conference, pages 9-12, Beijing, China, 2013.

[23] Wong J.K.W., Li H., Chan G., Wang H., Huang T. and Luo E. An integrated 5d tool for quantification of construction process emissions and accident identification. In Proceedings of the 31st ISARC, pages 393-397, Sydney, Australia, July 9 – 11, 2014.

[24] Huang T., Kong C. W., Guo H.L., Baldwinb A. and Li H. A virtual prototyping system for simulating construction processes. Automation in Construction 16 (5): 576-585, 2007.

[25] Shriro Group of Companies. Shriro Machinery Ltd. On-line: http://www.shriro.com/index.php?option=com_content&view=article&id=93:shriro-machinery-ltd&catid=54:technical&Itemid=107, Accessed: 28/01/2015.

[26] Wong, R. Virtual design & construction: an innovative approach to fulfil life cycle management. In the CIC Conference 2014, Hong Kong, 28 November, 2014.

[27] Swarm UAV. Why drone aerial photography is coming to construction sites. On-line: http://aerial.swarmuav.com.au/blog/aerial-photography-with-drones-construction-site, Accessed: 28/01/2015.

[28] Micro Aerial Projects L.L.C. Geospatial services and solutions anywhere in the world with micro aerial projects and the V-Map system. On-line: http://www.microaerialprojects.com/services/, Accessed: 28/01/2015.

[29] Program Contractors Ltd. Production center: structural steelwork production line. On-line: http://www.program.com.hk/en/productioncenter/structuralsteelwork, Accessed: 28/01/2015.

[30] Linner T. and Bock T. Evolution of large scale industrialisation and service innovation in Japanese prefabrication industry. Construction Innovation, 12 (2): 156 – 178, 2012.

[31] Tse R. Y. C. and Choy L. Is IT training in construction industry useful? Journal of Construction Research, 6(1): 1-13, 2005.

[32] Hasegawa Y. Construction automation and robotics in the 21st century. In Proceedings of the 23rd ISARC, pages 565-568, Tokyo, October 3-5, 2006.

[33] Chiang Y. H., Tang B. S. and Leung, W. Y. Market structure of the construction industry in Hong Kong. Construction Management and Economics, 19(7): 675 – 687, 2001.

[34] Fung K.H. and Rowlinson S. The adoption of advanced technologies in the Hong Kong construction industry. Surveying and Built Environment, 17(1):15-26, 2006.

[35] Chiang Y. H. and Tang B. S. 'Submarines don't leak, why do buildings?' Building quality, technological impediment and organization of the building industry in Hong Kong. Habitat International, 27(1): 1 – 17, 2003.

[36] Government of the Hong Kong Special Administrative Region. Government Funding Schemes. On-line: http://www.gov.hk/en/business/supportenterprises/funding/, Accessed: 28/01/2015.

[37] CIOB CM Newsletter. Adventures in time and space. On-line: http://www.construction-manager.co.uk//features/adventures-time-and-space/, Accessed: 02/03/2015.