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Evaluation of the Suitability of Public-Private Partnership for Kowloon East Smart City Development Project in Hong Kong

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Abstract: Smart City has become increasingly popular around the world; Hong Kong is no exception. However, Hong Kong is currently lagging in smart city development, consequently, the government has launched a pilot project 'Kowloon East Smart City Development'. However, due to fact that the implementation of smart solutions requires a high level of technical and managerial skills and Hong Kong's public sector lack experience in the smart city, therefore, this study investigated the suitability of public-private partnership (PPP) for the pilot project. Analytic Hierarchy Process is adopted to quantitatively assess the positive and negative impacts of PPP on the smart city project. The pairwise comparison was conducted by interviewing local experts experienced in both smart cities and PPPs. The local weighting of each positive and negative factor and likelihood measurement of alternatives were carried out. Subsequently, sensitivity analysis is administrated to identify the critical factor that can affect the final decision. The results indicated that the PPP is a suitable approach for the pilot project. 'Greater benefit to the public' is found to be the most critical factor.

Keywords: Smart City, public-private partnership, PPP, Hong Kong, smart solutions, procurement

1. Introduction

The concept of a smart city (SC) has gained attraction among policymakers and researchers worldwide in recent years. SC is a sustainable approach to ensure that the environmental, economic, and social needs of the past and future generations are fulfilled within the city domain (Yang and You, 2019). This approach makes use of the Internet of Things (IoT) and other means to enhance the residents' quality of life and city traffic and energy management (Yang and You 2019; Smart City Consortium Policy, 2017). In the 2017 policy address, the Hong Kong government announced an ambitious SC plan and promised to invest US$6.5billion (approx.) towards technology-related initiatives (Chan, 2018). To further investigate the feasibility of the SC plan physically, the government has launched 'Kowloon East Smart City Development' as a pilot project.

Implementation of 'smart solution' requires a high level of technical and managerial skills; therefore, the idea of private participation in the form of public-private partnerships (PPPs) keeps floating among government officials. As a matter of fact, Hong Kong has a long history of PPPs such as the success cases of Cross Harbor Tunnel and Asia World-Expo. The Cross Harbor Tunnel is widely regarded as the most successful BOT (Build, Operate, and Transfer) type PPP for its timely completion and short payback period (Cheung et al., 2012).

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Despite the success, PPP strategy for SC development can, however, be risky due to the following reasons, 1) Hong Kong has never implemented SC-PPPs, 2) some of the past PPP projects have been criticized by the general public such as the West Harbor Tunnel due to an unreasonably high toll fee, 3) recent large infrastructure projects such as West Kowloon District and Hong Kong-Zhu Hai-Macau Bridge were opted not to procure through PPPs, and 4) as the main purpose of SCs is social welfare maximization, creating a balance between social welfare maximization and the private sector profit, in comparison to normal PPPs, would be nothing short of a challenge.

Considering these challenges, it has become absolutely necessary to investigate the appropriateness of PPPs as the viable procurement method for SC development in Hong Kong. This study, through the use of the Analytical Hierarchy Process (AHP), identified whether or not the PPP option is suitable for Kowloon East SC Development Project. For this purpose, firstly, an investigation is made to establish the connection between PPP and SC development in Hong Kong. Secondly, evaluation factors and methods are identified to construct the AHP structure. Thirdly, the AHP technique is administrated to analyze the suitability of adopting PPP in Kowloon East.

2. Background

2.1 Smart City Development

'Brains and creativity' have become a major driver for economic growth (IBM, 2010). SC plays a critical role in the development of 'brains and creativity' by focusing on four high impact areas: 1) streamlining and tailoring public service particularly education, 2) improving public safety and emergency response time, 3) reducing congestions in transport systems, and 4) enabling appropriate access to health data for better disease prevention. Cohen (2012) summarized six key aspects of SC: 1) smart economy, 2) smart mobility, 3) smart environment, 4) smart people, 5) smart living, and 6) smart government.

Three consecutive phases of an SC development for achieving the key aspects include 1) SC 1.0 driven by technology companies, 2) SC 2.0 driven by the city government, and 3) SC 3.0 driven by citizens (Cohen 2015). The majority of the leading SCs belong to SC 2.0 in which city administration actively seeks technological solutions for improving residents' quality of life. However, according to Smart City Consortium (2017), SC 2.0 might not be sustainable as it is highly dependent on city administration. SC 3.0, on the other hand, focuses on industry, government, and citizen co-creation.

2.2 Smart City Development in Hong Kong

Hong Kong ranked 35th globally in the Innovation Cities Index 2016-2017 (2thinknow 2017) and ranked 71st in terms of quality of life (Mercer, 2017). Whereas, the often called competitor city Singapore was ranked much higher in the same rankings. These figures portray that Hong Kong needs substantial improvement to reach high levels of SC development. Cohen (2015) stated that Hong Kong has the potential as the current advancement in the public transport system and e-payment has laid a perfect foundation for smart mobility.

Kowloon East Smart City Development Project: In 2015, the Hong Kong government announced a pilot project 'Kowloon East SC Development Project' to explore the feasibility of developing an SC. Three key objectives were identified: 1) making use of innovation and technology to address urban challenges, 2) enhancing city attractiveness to global businesses and talents, and 3) inspiring continuous city sustainable economic development. The proposed development framework contains three layers: 1) the inner layer of innovation-oriented platform aiming to encourage knowledge-driven collaboration, co-creation, and community engagement, 2) the outer layer of IoTs to be used as a tool to support SC initiatives, and 3) the middle layer of strategic aspects referring to areas which can benefit from SC initiatives such as governance, resources management, and mobility (Kowloon East Office, 2017).

2.3 Positive and Negative Aspects of PPPs for Smart City Development

As indicated by Smart City Consortium (2015), the government is considering adopting PPP for the construction of IoT network. However, decision-making for PPP implementation is a complicated process involving multiple stakeholders. To facilitate stakeholders, Li et al. (2005) summarized 15 positive and 13 negative factors, which are widely recognized in PPP literature (Chan et al. 2010; Ismail 2013; Liu and Wilkinson 2011). The positive factors include 1) transfer risk to private partner; 2) cap the final service costs; 3) reduce public sector administration costs, 4) reduce public money tied up in capital investment, 5) solve the problem of public budget restraint, 6) non-recourse or limited recourse public funding, 7) reduce the total project cost, 8) facilitate creative and innovation approach, 9) accelerate project development, 10) save time in delivering the project, 11) improve maintainability, 12) improve buildability, 13) benefit local economic development, 14) transfer technology to local enterprise, and 15) enhance government integrated solution capacity. The negative factors include 1) lack of experience and skills, 2) confusion over government objectives and evaluation criteria, 3) excessive restriction on participation, 4) high charges to the direct users, 5) fewer employment positions, 6) reduce project accountability, 7) high risk relying on the private sector, 8) higher project value, 9) very few schemes have reached contract stage, 10) lengthy delays caused by political debate, 11) high participation costs, 12) much management time in contract transaction, and 13) lengthy delays in negotiation.

Li et al. (2005) further classified these factors into 8 different groups. This research has used these 8-factor groups for evaluation purposes. 5 positive factor groups include

F1. better project technology and economy,
F2. a greater benefit to the public,
F3. public sector avoidance of regulatory and financial constraint,
F4. public sector saving in transaction costs, and
F5. reduce public money tied in investment.

Whereas, 3 negative factor groups include

F6. lack of experience with PPP,
F7. over-commercialization of projects and
F8. high participation cost and time.

2.4 Evaluation Models for Assessing Suitability of PPP Projects

PPP literature has reported several evaluation models from global and from Hong Kong perspectives. For instance, Cheung and Chan (2010) established an evaluation model to decide whether PPP procurement is suitable for a public service project. This model involved three stages: stage 1 to establish weighing of positive and negative factors; stage 2 to analyze the potential PPP project, and stage 3 to evaluate the decision for adopting PPP. Stage 1 involved conducting a questionnaire survey to collect feedback from professionals in Hong Kong using a Likert Scale. The mean score for each factor was calculated. Stage 2 was a thoughtful analysis of the selected project. Project information was matched to the list of factors from stage 1. Then, the mean score of each factor for the selected project was calculated. Stage 3 involved calculating the total score of positive and negative factors. The decision of adopting PPP procurement was based on the dominating side i.e. positive or negative. Ng et al. (2010) constructed the PPP feasibility evaluation model for Hong Kong considering technical factors, financial and economic factors, social factors, political and legal factors, other factors (staff issue and possible management action), and stakeholder's satisfaction. Similarly, a mean score ranking technique was used.

The above-mentioned evaluation models adapted the factors of Li et al. (2005). Li et al. (2005) established these factors for the UK but were found suitable for Hong Kong. Moreover, these models share a similar ideology that PPP is suitable only if the adoption provides significant overall benefits.

3. Research Methodology

In line with the past research, this study evaluated the suitability of PPPs for the Kowloon East SC project by comparing the positive and negative impacts of PPPs. However, this research introduced the use of the Analytical Hierarchy Process (AHP) for this purpose. The process began by conducting a literature review to reveal the evaluation factors and ideology to be adopted in the AHP (sections 5 and 6). Based on that, the AHP structure was constructed and then experts' interviews were conducted for pairwise comparison of each factor. The pairwise comparison was followed by the calculation of local weighing and likelihood measurements of factors. Afterward, the final values of each alternative (adopt PPP or not) were obtained. The alternative with the highest score was selected as the best alternative. Lastly, a sensitivity analysis was done to identify the critical factors. The research framework is given in figure 1.

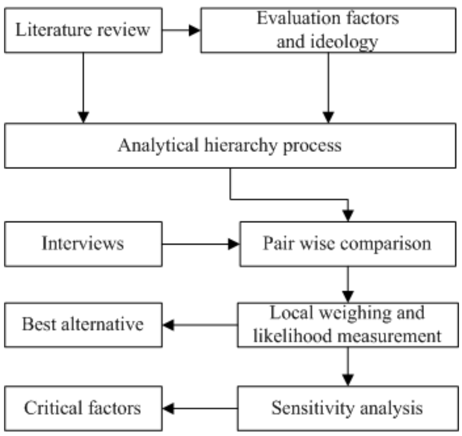

Fig. 1 - Research framework

4. Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) is based on the theory of measurement with an absolute scale to derive relative priorities of factors under consideration for decision-making (Saaty, 2001). Before the measurement, a hierarchical structure is constructed to represent the problem which includes goals, criteria, and alternatives. Goals represent the key issues that need to be solved. In this study, the goal was to decide whether or not PPP is suitable for Kowloon East SC-Project i.e. positive impact outweighs the negative impact or not. Criteria represent the factors under consideration i.e. positive and negative factors of PPP adapted from Li et al. (2005). The third element of the hierarchical structure is alternatives referring to the possible outcomes of the decision i.e. to adopt PPP or not, in this study.

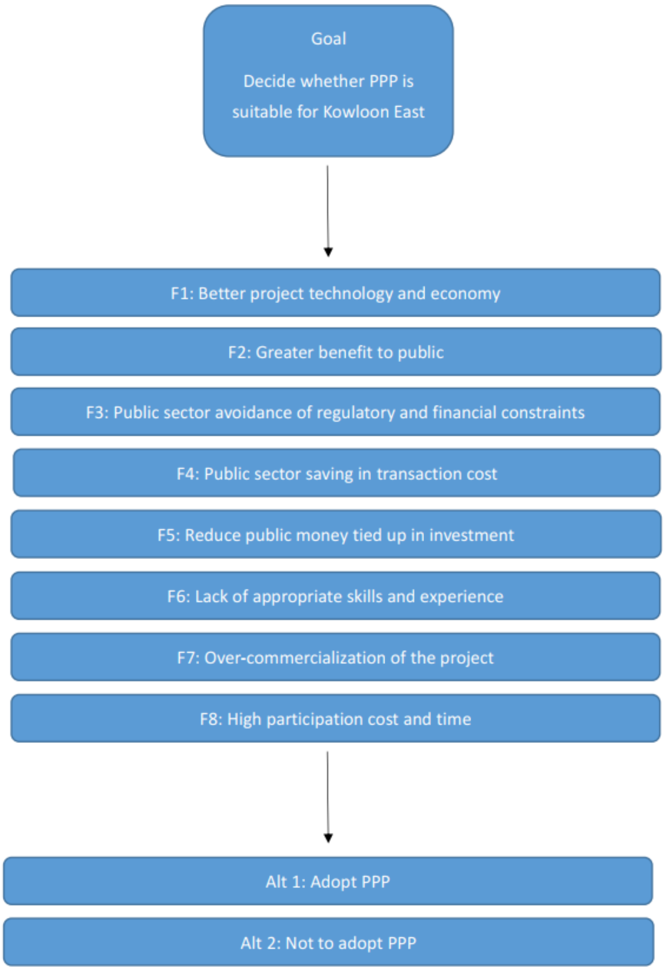

Fig. 2 - AHP structure

5. Data Collection

5.1 Experts Interviews

The interview aims to collect feedback from industry practitioners experienced in PPPs and SC development. For AHP analysis, a smaller sample size can be used as long as the experts have sufficient knowledge of issues under consideration. For this research, two highly experienced professionals were invited to provide opinions on the factors and the pairwise comparison of the AHP structure. The first expert was from Hong Kong Construction Industry Council and had plenty of experience in Kowloon East SC. She was also responsible for promoting the SC Exhibition. She also had sufficient knowledge about exhibitors and had a great familiarity with SC appliances. The second expert was an architect with several years of project experience in PPPs. She also had sufficient knowledge in SC as she was also associated with the SC development project.

During the interview on 10th October 2019, experts were requested to conduct the pairwise comparison on an AHP scale of 1 to 9 and to provide explanations on their judgments. The scale represents the extent of the importance of one factor over the other. The fundamental scale is given in table 1. Pairwise comparisons were divided into two parts, with the first part revealing the relative importance of each factor, and another part identifying the likelihood of each factor regarding two alternatives.

Table 1 - Absolute AHP scale adapted from Saaty (2001)

Intensity	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

5.2 AHP Computation

AHP computation results are given in Table 2. A stepwise procedure is given as follows.

1. Pairwise matrix A of (8x8) was obtained from each expert (F1 through F8).
2. The next step was to normalize the matrix to obtain the local weighing of each factor to determine the rankings of each factor. This involved the calculation of summation (Sn) of each matrix column and dividing each cell in the column by that summation to form the normalized cells. Following this, the weighing of each factor (Fn) was then calculated by taking the average of each row of the normalized matrix. The values were used in forming a local weighting matrix of factors (Alocal).
3. Then, consistency ratio (CR) was calculated to reflect if the pairwise comparison was consistent and the results of local weighing of factors were acceptable. The threshold value of CR was taken as less than 10% (Saaty 1994). Firstly, a weight sum matrix was formed by multiplying pairwise matrixes (A) by local weighing matrixes Alocal. Secondly, the consistency factor (λ) was calculated which was followed by the calculation of the consistency index. Thirdly, the consistency ratio was calculated as CR= (λ-n)/(n-1)/RI, where n is the number of factors in the pairwise comparison and RI is the random index whose value is 1.4 for n=8.
4. Afterward, likelihood measurement on alternatives i.e. ‘adopt PPP’ or ‘not to adopt PPP’ was calculated for each expert. This was done through a pairwise matrix of each factor separately as (Pn) and then combined in a matrix (P). This matrix P was necessary to calculate the final value (step 5) of each alternative to make the final decision.
5. The final value of each alternative was calculated using the residual probabilities method i.e. multiplying the P matrix with local weighing matrix [Alocal]T. The alternative with a higher value was accepted as the final decision.
6. Lastly, a sensitivity analysis was applied to determine the most critical factor (the most sensitive factor) i.e. the final rankings of alternatives can be altered by changing this factor alone. Sensitivity analysis was a long process, for a detailed procedure please check (Triantaphyllou and Sanchez, 1997). In summary, firstly, minimum change in absolute scale that can lead to the change in rankings of alternatives were identified. The changes in a factor were rejected if adjusted values come out to be greater than 1 or less than zero, and then sensitivity coefficients were calculated. Secondly, threshold values were calculated to determine the amount of change in the likelihood measurement of each alternative with reference to each factor. Similar to the first step, rejections were made, and sensitivity coefficients were calculated.

Table 2 - AHP computations

No.	Steps	Expert 1	Expert 2
1	Pairwise comparison A	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & \\ 1 & 1/4 & 7 & 6 & 9 & 4 & 8 & 8 & F1 \\ 4 & 1 & 8 & 9 & 9 & 6 & 9 & 9 & F2 \\ 1/7 & 1/8 & 1 & 1 & 1 & 1/5 & 1 & 1 & F3 \\ 1/6 & 1/9 & 1 & 1 & 1/3 & 1/3 & 3 & 4 & F4 \\ 1/9 & 1/9 & 1 & 3 & 1 & 1/6 & 1 & 1 & F5 \\ 1/4 & 1/6 & 5 & 3 & 6 & 1 & 5 & 5 & F6 \\ 1/8 & 1/9 & 1 & 1/3 & 1 & 1/5 & 1 & 1 & F7 \\ 1/8 & 1/9 & 1 & 1/3 & 1 & 1/5 & 1 & 1 & F8 \end{bmatrix}$	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & \\ 1 & 1/3 & 4 & 5 & 5 & 2 & 1 & 1/2 & F1 \\ 3 & 1 & 6 & 7 & 6 & 3 & 3 & 2 & F2 \\ 1/4 & 1/6 & 1 & 3 & 2 & 1/3 & 1/4 & 1/5 & F3 \\ 1/5 & 1/7 & 1/3 & 1 & 1 & 1/4 & 1/4 & 1/3 & F4 \\ 1/5 & 1/6 & 1/2 & 1 & 1 & 1/2 & 1/3 & 1/2 & F5 \\ 1/2 & 1/3 & 3 & 4 & 2 & 1 & 2 & 1/3 & F6 \\ 1 & 1/3 & 4 & 4 & 3 & 1/2 & 1 & 1 & F7 \\ 2 & 1/2 & 5 & 3 & 2 & 2 & 1 & 1 & F8 \end{bmatrix}$
2	Local weighing matrix A_{local}	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0.25 & 0.41 & 0.04 & 0.06 & 0.05 & 0.14 & 0.03 & 0.03 \end{bmatrix}^T$	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0.15 & 0.31 & 0..05 & 0.04 & 0.04 & 0.12 & 0.13 & 0.16 \end{bmatrix}^T$
3	Consistency ratio CR	8.74%<10%	5.27%<10%
4	Likelihood measurements on alternatives P	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & \\ 0.80 & 0.83 & 0.75 & 0.80 & 0.88 & 0.67 & 0.17 & 0.33 & Adopt\_PPP \\ 0.20 & 0.17 & 0.25 & 0.20 & 0.13 & 0.33 & 0.83 & 0.67 & Not \end{bmatrix}$	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & \\ 0.86 & 0.89 & 0.67 & 0.25 & 0.25 & 0.80 & 0.67 & 0.20 & Adopt\_PPP \\ 0.14 & 0.11 & 0.33 & 0.75 & 0.75 & 0.20 & 0.33 & 0.80 & Not \end{bmatrix}$

5	Final Value	$\begin{bmatrix} 0.75 & Adopt\_PPP \\ 0.25 & Not \end{bmatrix}$	$\begin{bmatrix} 0.66 & Adopt\_PPP \\ 0.34 & Not \end{bmatrix}$
6	Sensitivity analysis		
	Sensitivity coefficient on the local weighing of factors	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0 & 0 & 0 & -0.0006 & -0.0007 & -0.0023 & 0 & 0 \end{bmatrix}$
	Sensitivity coefficient on likelihood measurements of factors	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0 & 0.01 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$	$\begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 \\ 0 & 0.011 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

6. Discussions

The results of the AHP computation of both experts indicated that PPP is a suitable procurement method for Kowloon East SC development. The sensitivity analysis revealed that 'greater benefit to the public' is the most critical factor.

6.1 The Relative Importance of Factors

From the data collected, F2 'Greater benefit to the public' came out to be the factor with the highest importance i.e. local weighing of 0.41 by both experts (figure 3). However, both experts have a disagreement on the factor with the second-highest relative importance. Expert 1 ranked F1 'better project technology and economy' second with a local weighting of 0.25 while expert 2 ranked F8 'high participation cost and time' as the second most important factor with a local weighing of 0.16.

As mentioned earlier that the concept of SC emphasizes more on social welfare maximization, therefore 'greater benefit to the public' has the highest relative importance in pairwise comparison with other factors. In experts' opinion, adopting PPP will create job opportunities not only for the suppliers of the SC appliances but also for the local residents for the operation and maintenance of the facilities. It will also speed up the provision of SC appliances in which Hong Kong is currently lagging behind Shanghai, Singapore, and Tokyo. As per expert 1, 'better technology and economy' has the second most importance as great expectations are typically placed on the PPP project-level performance. She believed that the increase in private involvement will improve the cash flow and will advance technology for better quality and faster installations. Expert 2 has also ranked this factor higher at 3.

Both experts' perception of factor 8 'high participation cost and time' was significantly different as expert 2 ranked it 2nd and expert 1 ranked it last. Expert 1 stated that the SC project is different from normal infrastructure projects in terms of scale, investment, and profitability. SC projects are more flexible as once the appliances of a particular area are installed, the services may start operating and generating profits. Moreover, the way of generating revenue might vary such as through advertising and sales of goods, instead of traditional fee collection directly from the end-users. Therefore, the participation restriction might be lower than traditional projects. This allows the potential entry of small and medium-sized enterprises to the PPP project.

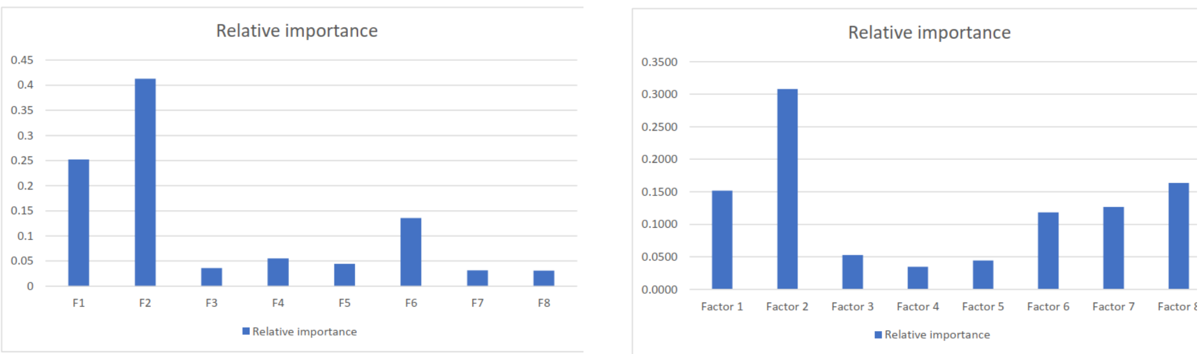

Fig. 3 - The relative importance of factors - expert 1 (left) expert 2 (right)

6.2 Likelihood Measurements

In terms of likelihood, experts 1 results showed that all five major positive impacts (factor 1 to 5) are achievable (figure 4). The government would benefit from the monetary advantages such as free up capitals for other public services of the highest priority such as public housing and enhance cash flow by minimizing the expenditure for operation and maintenance and maximizing regular payment from the private sector. In regards to the negative impacts, both factor 7 'over-commercialization of projects' and factor 8 'high participation cost and time have less probability due to the flexibility of SC projects. However, expert 1 showed less confidence in factor 6 'lack of appropriate skills and experience' as Hong Kong does not have any experience in SC.

Expert 2 believed that factors 1,2, and 3 are highly likely to achieve. However, the likelihood of factors 4 and 5 is relatively low. The reason is that the Kowloon East SC project is not likely to consume much money in comparison with traditional infrastructure projects. Therefore, the monetary advantage does not seem to have a significant impact. Similar to expert 1, expert 2 also believed that factor 8 'lack of appropriate skills and experience' is a huge concern for an SC project.

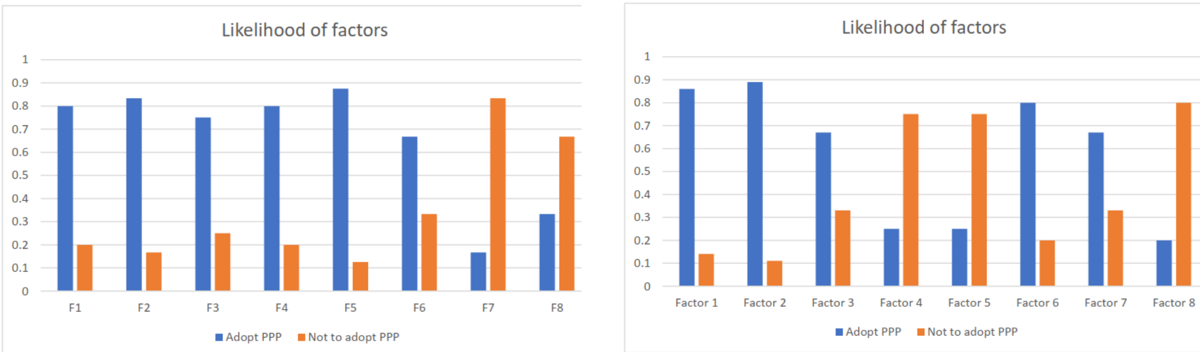

Fig. 4 - Likelihood measurement of factors regarding alternatives - expert 1(left) expert 2 (right)

6.3 Sensitivity Analysis

Regarding the sensitivity analysis on data by expert 1, the relative importance of all the 8 factors is found to be insensitive implying that the preference of the alternative 'adopt PPP' will not change by any fluctuation in the relative importance of factors. From the data of expert 2, the relative importance of factors 4, 5, and 6 are found as sensitive with a coefficient of -0.00055, -0.00071, and -0.00228, respectively. Among these factors, factor 6 came out to be the most sensitive. It requires an increase of 437.75% to normalized the importance of 0.60 to cause a change in the rankings of alternatives. This uncertainty of factor 6 was confirmed by both experts in interviews.

The sensitivity of the likelihood of each factor regarding the alternative came out to be sensitive only for factor 2 which has a sensitivity coefficient of 0.10 (expert 1) and 0.11 (expert 2). In other words, if the score of likelihood in factor 2 of alternative 'adopt PPP' reduces its value by 94% (expert 1) and 92% (expert 2), then the final ranking of alternative will be reversed, meaning adopting PPP will not be the preferable option then. This result again confirms that public benefit is crucial when considering PPPs. Overseas cases such as LinkNYC have demonstrated such a public benefit by providing free-of-charge smart city services to the citizens.

7. Conclusions and Limitations

This study investigated the suitability of PPPs for the Kowloon East SC project in Hong Kong. Firstly, a literature review was conducted to investigate the background of SC and the relationship between PPP and SC. Secondly, the evaluation factors and methodology to be adopted for this study were identified by reviewing various evaluation models for PPP suitability. Thirdly, a pairwise comparison of evaluation factors was carried out using the experts that are experienced in both SC and PPPs. AHP analysis was performed to find the most suitable alternative 'adopt PPP' or 'not to adopt PPP'. Local weighing of each factor and the likelihood measurement of each alternative were conducted. Lastly, through sensitivity analysis critical factor that might change the final decision was disclosed.

The results indicated that PPP is a suitable approach for Kowloon East SC-Project. 'Greater benefit to the public' is found to be the factor with the highest relative importance and the sensitivity analysis confirmed that.

SC is rather a new concept in Hong Kong, therefore, industrial professionals have limited knowledge in SC which led to only a handful of experts being interviewed. However, both experts were from Hong Kong Construction Industry and were directly involved in the SC project, therefore, the data and information received are considered valid and a similar methodology can be adopted for other future SC projects.

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