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Factors influencing the consideration of Public-Private Partnerships (PPP) for smart city projects: evidence from Hong Kong

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Abstract

Smart cities are emerging in most parts of the world. The cost-benefit analysis of such initiatives should include an unbiased consideration of potential procurement modes, especially when a substantial investment is entailed to scale up projects to the city level. Despite the enticing trend of public private partnerships (PPPs), city governments should evaluate the available options using an objective approach such as Multi-Attribute Utility Analysis (MAUA). The technique takes into account prioritized assessment criteria (which are tailor-made for smart city projects) and the relative utilities of the procurement options in meeting the criteria.

The methodology of MAUA is demonstrated through a questionnaire survey and a focus group meeting involving public and private sector practitioners, and applied to 8 types of common smart city projects in Hong Kong, which is one of the metropolises earmarked to become a smart city by putting concepts into practice. Results show that not all projects are best suited to PPP and that there may be divergent views between the public and private sectors, with possibilities for a compromised decision which both sectors would accept.

Keywords: Smart cities; Procurement options; Public Private Partnership; Multi-Attribute Utility Analysis

1. Introduction

Due to the rapid pace of urbanization and the advent of Information and Communication technologies (ICTs), many smart cities utilizing them have sprang up in the world. Frost & Sullivan (2013) predicts that business opportunities in the smart city area will exceed US$2 trillion by 2025. Although smart city projects are usually spearheaded by the public sector due to the primary responsibilities of governments to look after the welfare of its citizens, such a big market is certainly within the radar reach of private corporations. In fact, the amount of investment needed for scaling up smart city projects is huge in most cases, which creates a burden to purely public sector budgets. Fishman and Flynn (2018) reckoned that only 16 percent of cities are able to self-fund their required infrastructure. Hence, most governments would look into the possibilities of engaging the private sector in smart city development. According to SCC (2018), India has been spearheading with 73 public-private partnership projects in their 100 smart-city plan, worth US$1.2 billion or 4 per cent of the total investment; with many more examples in China, Japan and Korea (DXC, 2018). In a snap shot, Jacobson (2018) identified over 45 asset-based and service-based smart city projects as candidates for PPP globally. On one hand, private sector finance may not be the cheapest to obtain, but the innovative capability and efficiency gains (especially in the ICT arena) to be achieved may be considerable. On the other hand, unlike some tolled infrastructure projects, smart city projects often produce intangible benefits, posing questions on financial returns to investment. Therefore, when carrying out a feasibility study or cost-benefit analysis of smart city projects, as advocated by Galati (2018), governments need to gauge the suitability of different procurement options, which, in the broad sense, may be classified into (i) public sector only; (ii) public-private partnerships (PPP); or (iii) private sector only. This broad classification is focused on the common investment sources for carrying out this research, although a plethora of other participation modes exist in particular situations (such as State-owned Enterprises or project coalitions). Indeed, a taxonomy of smart city extends the stakeholders from corporate-led to a commons-base as proposed by Niaros (2016) and public-private-people partnerships as proposed by Schaffers et al. (2011), which take into consideration the contributory roles of citizens as well. In some jurisdictions, e.g., mainland China, State-owned Enterprises may also participate actively in smart city development (Anthopoulos and Fitsilis, 2014). Inevitably, each city will have its own specific circumstances to take care of. Whilst not intending to preclude other possibilities, this study focuses on the 3 mentioned modes of procurement options only for the remaining of this paper, with PPP as the center of discussion. This is because a systematic evaluation of the suitability of PPP for smart city projects is not well covered in the literature. This research sets out to fill the knowledge gap.

As the title of the paper suggests, the first research question being addressed is: "What are the factors that would lead to the use of PPP in smart city development", amidst the prevalence of the traditional public investment approach, to achieve the goal of sustainable smart cities as advocated by multi-national bodies (Uraia, 2015). The latter is only possible when the right priorities are established with a clear set of factors underpinning procurement decisions. Hence, the second research question is: "Which options would give the best service whilst the uses of scarce resources and talents are optimized for a smart city project?" Aided by a weighing survey, a focus group meeting and Multi-Attribute Utility Analysis (MAUA), this study demonstrates how city governments worldwide can make a tactical or operational decision for adopting an appropriate procurement mode when implementing a particular smart city project, whereas other research (e.g., Anthopoulos, 2017; Schiavone, et al, 2019) mostly discusses about various possible business models.

Since the smart city movement takes place more vibrantly in developed economies, focus is also being put on them for the rest of this paper, whilst it is acknowledged that the issues of public-private partnership are also being discussed frequently in developing countries. Hong Kong is a case in point since it is an emerging smart city with a number of pilot projects on trial (yet to be scaled up). Based on Hong Kong's track record of PPPs in the infrastructure facility sector (including BOT tunnels and exhibition centers), it is expected that the government would open up opportunities for using this procurement approach for smart city projects.

Starting with a framework of theories and concepts in the following section, the assessment criteria for evaluating if PPP is suitable for smart city projects are distilled from the literature and weighted with a questionnaire survey, and these criteria form the backbone in the use of proven techniques (MAUA and Focus Group Meeting) for ranking possible procurement options. Data collection was carried out in Hong Kong, which is an emerging smart city similar to other jurisdictions making the same move. The projects are chosen to highlight the range of possible smart city project characteristics. Stakeholders in both the public and private sectors will be able to rank procurement options objectively by following the projects as examples.

2. Research Background

Smart cities have gone through an evolutionary path, from the technology-led front towards achieving more social objectives. The building of smart cities has also moved from the early day top-down utilization of innovations pioneered by governments to the present day bottom-up realization of startups' inventions (Ratti, 2016). In the former case, during the proof-of-concept stage, seed funding is provided by governments through research grants or subsidies, whereas venture capital supports the latter. At the beginning, technological risk is high and there is uncertainty as to the acceptance of users (e.g., privacy concerns associated with electronic road pricing). When technology maturity is reached for scaling up a smart city project, economic and social sustainability must be the aims of developmental strategy (Xu and Wu, 2012). Suitable means of financing a project from installation to operation and maintenance need to be secured. The procurement process should be aligned with the means of financing, e.g., by ensuring transparency in the use of public funding. City managers need to make the right choice from a wide continuum of procurement modes ranging from total public ownership, State-own Enterprises (if applicable), a coalition (e.g., PPP), to entire private ownership. The influencing factors hence become important considerations.

3. Theoretical and Conceptual Framework

Public goods used to be provided by the government using public coffers. In the past two decades, PPPs have been used as a common strategy (in the name of diversifying funding sources and improving efficiency) by governments around the world to provide public services, and there have been calls to develop an institutional framework of governance (Chou et al., 2015). With the emergence of smart cities, much of the ICT breakthrough has been achieved by the private sector, and it is only natural that the private sector has become the main driver of smart city advancement. Going back to fundamentals, the need for cities to be smart stems from increasing urbanization, scarce resources and the desire for human comfort, but the gap to bridge in fulfilling this need is wide in terms of available expertise and finance, so that collaboration seems to be the only way out for scaling up smart city initiatives (EIP-SCC, 2016). Anthopoulos (2017) classified the smart city as an extension of "ubiquitous" city from the functional base of digital and information city, with an emphasis on social infrastructure and people. As such, the desire and need for citizen engagement and hence collaboration has been increasing. In suitable circumstances, the public sector can benefit from interaction and collaboration with the private sector to experiment and develop smart city projects based on technologies and expertise of the latter, after establishing the need for the smart city services through public (including users) consultations.

On the private sector side, the motivation for profit, business growth and risk averseness affect its appetite for collaboration. On the public sector side, fairness and accountability are essential in the governance of any democratic state. Decision making on procurement choices need to be as objective as possible, and utility is an appropriate measure since it represents the degree to which an actor's goals are achieved (Simon, 2001), subject to the assumption of choices being made based on rationality. When a major smart city investment is contemplated, city managers have a strong need for a clear and robust evaluation mechanism to be used for ranking the alternative modes of goods and services procurement, taking into consideration the project characteristics and the maximization of utility based on the Theory of Rationality (Zey, 2001). Although more recent exposition of the theory reveals its limitations due to bounded rationality of human decision making, a suitable mechanism which does not rely on the assumptions of unlimited resources and perfect foresight is handy to use. Any proposed mechanism should amass the relevant criteria when considering available options, the relative importance weightings between these criteria and account for how well each option satisfies the criteria in a particular situation. With these being the requirements, this study demonstrates a plausible approach (MAUA) with an aim to maximize utility values in the context of smart city projects, which, unlike traditional projects, demand innovative business models to make them sustainable.

Seminal works such as those by Jensen and Meckling (1976); Boyco et al (1996) have established agency theories on the possible efficiency gain in privatizing public enterprises. Whilst those theories are pertinent to PPP, this paper is not an appropriate place to discuss the theory of privatization (and hence the benefits and pitfalls) further. As an application of the theories, the lessons learnt from the previous involvement of the private sector in the provision of public services remind decision makers to be accountable for the achievement of value-for-money (World Bank, 2013). Although many such lessons have been well documented for common infrastructure like roads, schools, hospitals and rails (Bain, 2009), smart cities are relatively a new domain for investment decision making. When considering if PPP should be introduced at all in a jurisdiction, it is a tactical decision on a wide front. When individual project procurement modes are considered, the decision becomes an operational one (Tran et al, 2019). This type of decision is usually entailed during the scaling up phase of smart city projects. The right stage for making such decisions needs further research, but this paper contributes to the identification of the factors influencing the choice amongst broadly defined procurement modes (in particular PPP) and demonstrates the use of one of the practical evaluation techniques. Hong Kong is an emerging smart city with a high population density, relatively sound infrastructure and a hub of private investment. Although data collection for this study was carried out in Hong Kong, the survey and focus group meeting approach may be adapted in any other city to suit their own contextual requirements, such as modes of governance, economic and social structures.

4. Literature Review: Assessment Criteria for Decision

In order to establish the assessment criteria for the evaluation of suitable procurement options of smart city projects, a literature search using SCOPUS and Google Scholar databases was first conducted based on keyword search on publications from 2006 to 2018, filtering out those which relate only to procurement approaches for general construction works and their supplies only. Targeted readings included refereed journals, expert reports, books, and government review reports, etc. The bibliometric details are shown in Table 1. A constructivist approach was adopted in that the search and qualitative data organization was carried out keeping in mind the central core question of what a decision maker would consider in the context of a smart city project being launched. Since different countries used PPP at various times of their infrastructural development programs, the databases were searched using thematic order rather than a chronological order. Hence, the sub-section headings hereinafter are classified according to the assessment criteria which relate to the keywords being considered (with the capital letter "C" and serial numbering for subsequent use as abbreviations; with the keywords being shown in italic).

Table 1. Literature sources identifying the selected Assessment Criteria

Criteria	Variables	Selected Sources	No. of Related Papers
C1	Availability of finance (i.e., if there is a need to tap into private sector funding)	Acatel-Lucent, 2012 Shuja Tahir, 2017	10
C2	Availability of expertise (i.e., if there is a need to tap into private sector expertise)	DXC, 2018 EIU, 2016 Viitanen and Kingston, 2014	17
C3	Availability of needed data (directed, automated and volunteered) for providing smart city service (e.g., private car park vacancy info nearby)	Kitchin, 2014 Al Nuaimi et al., 2015	4
C4	Efficiency drive (to enable early start at procurement stage. Note that PPP may need negotiation)	Curristine et al., 2007 Cheung and Chan, 2009 Leiringer, 2006	9

C5	Efficiency drive (at operational stage)	Duffield et al., 2008 Lam and Javed, 2015	7
C6	Need to share risk	Larsen et al., 2016 Deloitte, 2017 Shen et al., 2006	16
C7	Rate of technology becoming obsolete (i.e., if too fast, private sector will not invest)	Triana, 2012 Villani et al., 2017	6
C8	Rate of technology diffusion (i.e., would it be faster if the private sector is involved? e.g., due to their marketing and distribution networks)	Reddick et al., 2017 Feeney and Brown, 2017 Meijer and Thaens, 2018	8
C9	Suitable business models can be devised to share income/saving	Anthopoulos, 2017 Frost & Sullivan, 2013 Lawther, 2005 *Schiavone et al., 2019	9
C10	Asset availability (as security for financing and/or having residual terminal value after the private sector completes its obligation or when the facilities are transferred back to the public sector for continued operation)	Weber et al., 2016 Meng and McKevitt, 2011 Iseki and Houtman, 2012	5
C11	Capable of measuring performance (for paying the private sector and monitoring quality)	Smith, 2007 CEPA, 2005 Liu et al., 2014	8
C12	Possibility of procurement by competition	World Bank, 2013 Lam and Fu, 2019	9
C13	Possibility to maintain transparency of procurement and monitoring of operation	Forrer et al., 2010 Rwelamila, 2017	6
C14	Complexity of coordination of government departments	Luo and Junkunc, 2008 PwC, 2017	7

(* Note: an addition after the main literature review to indicate the latest trend)

Globally, many governments believe that partnering with the private sector enables them to tap into the expertise (often patented) of the latter due to their hyper-specialization in the ICT arena, together with their resources and business network (Warner and Fargher, 2019). In respect of resources, some city governments would like the private sector to help finance their "smart" development, e.g., replacing streetlights with LED technology in Turin of Italy (Mangano et al, 2016). They also consider that the PPP approach which they used for traditional infrastructure may not suit smart city development needing continuous engagement and innovation. Hence, earlier on in France, the academia was drawn into the collaboration network for longer term smart city projects such as a living lab to benefit from the cutting edge university research (Dupont et al, 2015). In the case of Hong Kong, through the recent budget allocation, PPP will be fostered to engage the industry in using IT to improve public services (Hong Kong Government, 2019).

Kujala et al (2011) used several cases within a power plant supplier firm to identify factors influencing the choice of business models, and found that assessment needs to be taken at the specific solution level for project-based firms. Similarly, this present study firstly attempts to identify the assessment criteria affecting procurement options, with the suitability of PPP as a specific question in mind, and the criteria will be further prioritized through a survey in Hong Kong. Towards the end, the preferred procurement option is evaluated by a focus group for specific smart city projects. The assessment criteria are elaborated below with the associated literature support:-

C1: Availability of *finance* (i.e., if there is a need to tap into private sector funding)

With the ever-growing budgetary needs to satisfy a whole spectrum of city functions (to name just a few: housing, health care, education, etc.), governments need to exercise good judgment in the allocation of public funds, and with increasing citizen participation, they are closely watched in their spending. Apart from the traditional tax revenue, the availability of funds for capital and recurrent operating expenditures on public infrastructure (including smart city facilities) depends on the existence of well-tried and new funding channels, which may be limited in the public sector. In the US, non-tax government-based financing options for cities include general obligation bonds, revenue bonds, green bonds, social impact bonds, etc. (SCC, 2015). In the European Union, the Covenant of Mayors aiming at promoting energy efficiency amongst municipalities allows the use of funds from the European Investment Bank (Perrone, 2014). In the Asian arena, the depth of public bond markets is often not enough to finance smart city initiatives yet, and multi-lateral agencies are more eager to assist projects of basic human needs, such as water supply and power, than making a city smart.

By comparison, private sector funding channels are usually more varied, though not necessarily cheaper than public sources. There are potentially larger pools of private capital, which may be leveraged upon to improve livability and create long term impacts on the wellbeing and economy of a city (SCC, 2015). Sometimes, smart city projects are initiated by the private sector itself, which may pioneer with new technologies (Alcatel-Lucent, 2012) and prefer total control. Instead of purely private investment, some government involvement may play a pivotal or catalytic role in what is known as a Public-private partnership (PPP), which is defined as an arrangement between government and private sector entities for providing public infrastructure, community facilities and related services (Shuja Tahir, 2017).

Hence, whether or not funding is available, and in what form, may be an influential criterion in evaluating the mode of smart city project development.

C2: Availability of *expertise* (i.e., if there is a need to tap into private sector expertise)

State-of-art technologies are deployed in smart city projects, and although governments nowadays spend an increasing budget on research and development, or make grants available to fund innovative projects, the pace of invention may not be compatible with the rapid progress being made in the private sector, presumably due to the commercialism at work in the latter. Onag (2017) quoted a partner of Frost and Sullivan (2013) as saying "cities [government] don't often have the skills or resources to deploy, let alone operate an advanced data capture and analytic architecture." Governments can tap on the speed, expertise and agility of the private sector to scale up ICT infrastructure and services (DXC, 2018).

Private sector companies were viewed as possessing cutting-edge ICT, so that they enjoyed an unrivalled position in influencing smart city experiments, and the hegemony of global technology firms was considered as being inflated (Viitanen & Kingston, 2014). Governments reacted defensively. Until recently, it was reported by one-third of the 615 executive respondents to a 12-city global survey that city governments tended to regard the private sector as service providers and suppliers, rather than as strategic partners (EIU, 2016). They opined that the governments' practice of buying products off the shelf was less of an interest to them, compared to putting the problem on the table and challenging them to solve it as a team. Fortunately, the same survey report also highlighted emerging ways of engaging the private sector and citizens in technology development, including hackathons, appathons and other competitive technology-oriented events, such as online crowd-sourcing challenges.

Government involvement, on the other hand, may be perceived as a ground of comfort to users of smart city technology, as concerns on privacy breach and data security loom when the private sector takes charge of ICT provisions. Government's ability to enact a robust governance framework on data collection and use would be a deciding factor on the trust which citizens can place on sharing data using technology (EIU, 2016).

Hence, the availability of technological and monitoring expertise is an important consideration affecting the mode of smart city development.

C3: Availability of *needed data* for providing smart city services

Smart city projects are made possible by the collection, processing and dissemination of vast amounts of data. Social data is generated by human activities, and the devices monitoring them (Batty, 2013). Physical data (e.g., geospatial features) is captured and converted into various useful forms through Geographic Information Systems (Choudhary, 2019). In terms of the generation process, smart city data can be classified into 3 types: directed, automated and volunteered (Kitchin, 2014). Directed data is generated by means of real-time surveillance, such as checking passport holders' features against stored databases. Automated data is generated as an inherent and spontaneous function of a capturing system, such as a device or smartphone recording transactions. Volunteered data is entered by the users themselves through their interactions through social media and posting of photos, etc. Whilst city managers are interested in data acquisitions through automated means monitoring traffic and citizen movement using the Internet of Things (IoT), businesses have collected vast amounts of data about their own operations and customers (Kitchin, 2014).

Many such entities are reluctant to share what they consider as proprietary data with others, including the government. They may be restricted by certain privacy conditions against transferring such data. In addition, much of the data is unstructured or collected in a variety of formats, making sharing difficult (Al Nuaimi et al., 2015).

In the opposite sense, some debates have been sparked as to whether private entities collecting data from the public should own the data and monetize from its use (Smartcityhub, 2017).

When a smart city project is being considered, the availability of the needed data for providing the services should be considered in light of the above data ownership situations, since they would impact on the appropriate business model. For example, for a carparking real time vacancy app developed by the public sector to be useful, it should embrace private carpark vacancy data as well. Private carpark operators may not contribute their data easily unless they are incentivized to do so. On the contrary, when the private sector wishes to use demographic data for electronic marketing or other purposes, it needs to obtain such data from authorities which are empowered to collect it, say, for taxation or census reasons.

When data ownership is on one side, and the technology/resource of processing it centrally is on the other, some forms of PPP would be necessary to make territory-wide smart city applications successful (e.g. dissemination of real-time car park vacancy information via smart phones).

C4: *Efficiency* drive (to enable an early start at the procurement stage)

In many developed countries, an ongoing challenge is to provide more public services with less public spending (Curristine et al., 2007). This may entail service re-design and the use of alternative delivery mechanisms. In the arena of smart cities, the objective is to improve the well-being of citizens and their quality of living. This target, coupled with the fast moving technological development globally and the benchmarking effects of neighboring cities, exerts a drive towards early implementation. An early start made possible is regarded as efficient from the points of view of the procurer and users.

Traditionally, public sector implementation of projects usually adopts a linear sequence of procedures, notably emphasizing the use of bidding to achieve transparency and enhance accountability. By contrast, private sector business practices are perceived to be more flexible if they have total control. Decision making is generally more streamlined, especially when market pressure of competition is present.

For smart city projects, it therefore depends on who the initiator is. For technologies which are developed entirely by the private sector, such as personal smart phone applications, or energy saving devices simply plugged into power sources, the private sector can take on project implementation on its own quickly. However, when there is an interface with public facilities, or when regulatory aspects are foreseeable, government involvement is necessary. PPP is often poised as a practical solution in the latter situation, since a public agency would help to get over some regulatory hurdles.

Despite much literature coverage of the perceived advantages of PPP as a procurement approach, some bitter experience has been gained in past projects, especially in terms of lengthy negotiation or bidding time (MoF, 2004; NAO, 2007). Cheung and Chan (2009) reported on the shorter take-off time made possible by the government-led procurement approach for a major bridge initially slated for a PPP scheme, especially when uncertain economic conditions are present. Sometimes, corruption allegations may protract a PPP scheme (Kanakoudis et al, 2007). Leiringer (2006) also questioned the often-cited innovative potential of PPP projects and called for caution in interpretation.

Therefore, a contextual analysis of a given project environment is necessary to ascertain if an early start and efficient technology utilization would be achievable when procurement decisions are made regarding smart city projects. Delays in deployment may lessen the benefits to citizens or even render the technology obsolete (see C7 below).

C5: *Efficiency* drive (at construction and operational stages)

Construction or installation is usually outsourced, whether or not the public or private sector takes on the development role. If the private sector is committed to a turnkey contract (especially with funding responsibility), construction is more likely to be fast-tracked, other things being equal (Duffield et al., 2008).

Once a facility is built or installed, its operational efficiency becomes a key concern of stakeholders. For smart city projects, life cycle cost aspects including energy consumption, connectivity, manpower deployment, need for updating, maintenance and repair, etc. come into play. For a governmental entity to undertake operation, a robust recurrent budget needs to be established and it has to absorb the risk of obsolescence. An alternative is to outsource operation to a private operator, with clear requirements of service standards to be stipulated at the outset.

To enhance operational efficiency under the PPP approach, an unambiguous output specification needs to be prepared by the client's team (Lam & Javed, 2015); a proper payment and deduction mechanism needs to form part of the contract (Ng & Wong, 2007) and reasonable provisions made for foreseeable changes (NAO, 2007). Yet, learning from past failure cases, the projects must not be technologically complex, as in a national physics laboratory, or facilities substantially interfaced with legacy systems plus a phased roll-out (CIPS, 2005; NAO, 2006).

With a carefully prepared contract, PPP may have its benefits for the construction and operational stages of straight-forward smart city projects, if time is sufficient for the bidding and negotiation.

C6: Need to *share risk*

Public sector projects had been prone to cost overruns and delays, partly due to the lack of commercial pressure for the project personnel. However, in today's tight budgetary and accountability reins, public work officers are under increasing political and social pressures to bring projects to fruition on time, to meet budget and quality requirements (Larsen et al., 2016). Risk management is now a standard procedure in large scale public works. A maxim of risk management is to allocate risk to the party most able to control it. Actually, in a typical work contract between the public client and a private contractor, the former is often in a better position to control risks as far as the exercise of regulatory powers is concerned. In the context of smart city projects, a significant exposure to market risk would prevent a private developer from initiating what would otherwise be beneficial to the public at large, especially when an innovative service is going to be provided free of charge to users (not necessarily free to the government). Paradoxically, at this point, the government must intervene in providing a suitable risk environment for the private sector, who may own the technology.

In PPPs for smart cities, the abovementioned maxim would find its truth, in that private technology developers are better in controlling and hence, bearing, technology risks, but then the government may share the market risk (e.g., by paying a shallow price for the use of the technology). A new type of risk (i.e., cybersecurity) needs careful consideration to balance the interests of public users versus private sector (Deloitte, 2017). Here, governments play a pivotal role in the protection of privacy under the inevitable drive of the private sector towards the growth of big data, which has an increasingly high commercial value.

C7: Rate of *technology* becoming *obsolete*

The core technology of smart cities is that of ICT, which is being developed at leaps and bounds, both in terms of hardware and software. ICT comes within the realm of short life cycle products, which are characterized by a demand occurring for a short period, after which they become obsolete (Triana, 2012). The up-to-dateness and obsolescence of technology are the concerns of all partners in a co-operative governance model (Villani et al., 2017). Whilst a government may favor the trial and adoption of a new design concept favored by its citizens to showcase the city's "smartness", a private sector developer may take a more prudent approach since whatever it does, cost recovery and a profit element must be achievable within the life span of the technology to be launched. Taking renewable energy as an example, there is a plethora of new technologies being wheeled out frequently from laboratories, but when it comes to private sector participation and implementation on a market scale, only the well proven solar plant and wind farms (and to some extent, biomass) are financeable to-date on a commercial scale, and even so, it must be done under conditions conducive to capital recovery.

It follows that the choice of procurement mode for smart city project needs to take into consideration the life spans of the facilities versus the developers' expectation of pay-back periods. Public sector clients would normally value intangible benefits more than the private sector (Andersson & Johansson, 2016), and this may be an influential factor in smart city projects. Again, both sectors may complement each other using PPP to create win-win situations (e.g., public funding plus private operation on a unitary charge basis).

C8: Rate of *technology diffusion*

Whilst marketing of new technology has been common in private sector entities, government and social service agencies were not used to the idea of marketing until the mid-late 1970s (Lamb, 1987). A fundamental change of mindset enhances the potential contribution of marketing to public service delivery (Laing, 2003). Although Kuusisto (2017) describes that public organizations were shifting into web 2.0 world, Roman and Miller (2013) criticized the benefits obtainable by the government from its use of digital assets is still one-sided, in that information provision is more prevalent than dialogue-making.

Rogers (2003) defined technology diffusion as "a process in which an innovation is communicated through certain channels over time among the members of a social system". For this to happen, a two-way process is more efficient. Studies by Reddick et al. (2017) as well as Feeney and Brown (2017) found that governments would be able to advocate and educate their citizens by communicating electronically with them through social media, and thus modify their social behaviors and attitudes. However, this has only begun recently with government officials setting up Facebook or blogs in developed economies, but mostly used for justifications of their policies, seldom creating a participative platform for smart city building.

By contrast, the private sector can be more flexible in its approaches to market innovative products to achieve a faster rate of diffusion. Private entrepreneurs are apt to advertise and gather feedbacks from users through a multitude of channels. In situations where the public and private sectors complement each other, PPP may offer win-win propositions. A good example is the street lighting improvement works in Eindhoven of the Netherlands, where technology has stimulated public and private collaboration. The local authority aims to improve streetscape and reduce crime rates, whereas the private sector wants enhanced business opportunities and real estate gains (Meijer & Thaens, 2018).

C9: Suitable *business models* can be devised to share income/saving

Whilst government has a constitutional responsibility to see to the well-being of its citizens, private businesses exist for making profits to reward their owners and shareholders. If the private sector is to participate in the making of smart cities, sufficient incentive must be provided, and most of the time this incentive is financial, although the exercise of corporate social responsibility such as environmental sustainability would enhance the companies' image, which can be an intangible attraction if such opportunities arise. A business model refers to the way "a business creates and delivers value to customers" (Teece, 2010). In the context of smart cities, value for the citizens may be interpreted as gain (e.g., clean air enjoyment) or reduced spending (e.g., medical or energy bills). For the smart city service providers (which may be the public sector alone, the private sector alone, or PPP), the cost structure and revenue structure are the essential parts forming their business models (Anthopoulos, 2017).

Earlier, in a study of transportation information system, Lawther (2005) used a continuum of models with Public-control or Private-control as the extreme forms. More recently, Frost and Sullivan (2013) adopt four generic types of Smart City Business Models as follows:

Build-Own-Operate (BOO) – the city government builds the smart facilities or provides the smart services using its own resources;

Build-Operate-Transfer (BOT) – the city government entrusts an appointed partner (through a concession or contractual arrangement) to build the smart facilities or provide the smart services in return for a fee within an agreed period, after which the facilities and operation are reverted back to the government;

Build-Operate-Manage (BOM) – similar to BOT, except that the city government does not take back the facilities;

Open Business Model (OPM) – Qualified private entities are allowed to build smart facilities or provide smart services, under some regulatory constraints established by the city government.

Variants of the above types exist and choice depends on the nature of the smart city facilities or services to be provided. It is also possible that these models will evolve from one to the other to suit the needs of different projects (Lawther, 2005). An important distinction is whether revenues are collectible from the users, or provided by the city government on a subsidized basis. As "urban smartization" continues, more innovative business models will evolve (Schiavone et al, 2019).

C10: *Asset* availability (*as security* for financing and/or having residual terminal value)

Depending on the nature of smart city projects, the generation of valuable physical assets may be a relevant consideration during their financing from the lender's security viewpoint. The transferability of such assets will also dictate their values, especially in the private sector's perspective (Weber et al, 2016). Together with the rates of depreciation and useful life spans, bankability will be a pertinent issue for private sector financing (Meng & McKevitt, 2011). It remains to be seen if the intangible data generated by IoT will be recognizable as an asset due to its transient nature (Kubler et al., 2015).

In the public sector, social benefits may be the predominant consideration and asset value, important as it is as a capital expenditure, may be more for accounting purposes.

In the case of PPP, the residual value may turn into a negative figure in the eyes of the subsequent public owner, since maintenance and repairs to upkeep the facilities handed back from the private sector concessionaire would become their responsibility. Iseki and Houtman (2012) described solutions such as the specification of residual life standards and requiring a handback reserve fund for bringing the facilities to the specified standards.

For smart city projects, the ICT element may need updating, both in terms of the hardware, software and its licenses, to enable compatibility with evolutionary state-of-art systems. IoT, for example, needs careful consideration in terms of its design, deployment and feedback in its life cycle management as part of a smart city platform (Yamakami, 2017).

C11 Capable of *measuring performance* (for paying the private sector and monitoring performance)

For any contracted out service, in order to properly incentivize the contractor for quality service and monitor his performance, measurements need to be undertaken (Smith, 2007). This is especially important if the contract allows for deduction of payment due to slacks in performance, as in the cases of shortfalls in the output required under a PPP contract (CEPA, 2005). Liu et al. (2014) addressed the inadequacies of *ex-post* evaluation of performance in traditional contracts and called for the use of a life cycle evaluation framework, particularly for PPP types of procurement, taking service response time into consideration.

For smart city projects, performance measurements of outputs may not be a straightforward task, since the benefits which users obtain are usually intangible (e.g., convenience and well-being). At the service provider side, case-based measurements may not be appropriate, since data fed into ICT systems is transmitted instantaneously on a Business-to-Customers basis. For some systems, access or downloading counts within a pre-defined period may help. It may be possible to align payment mechanisms to suit such measurements in the form of Key Performance Indicators.

In case measurement is not commercially practicable, it may be sensible to use the stage payment schedule, or revert to public sector's in-house service provision to avoid possible disputes or accountability issues.

C12 Possibility of procurement by *competition*

For transparency and accountability reasons, it is customary for a city government to award contracts by tendering. However, for smart city projects with innovative solutions as selling points, the intellectual property right involved may preclude tendering. Often, there is a lack of like-with-like comparisons.

When traditional tendering is not practicable, a design and build approach may be adopted, either through launching design competitions, or conducting negotiation with pre-qualified entities. PPP has been criticized for being a black-box in many previous instances (Hall, 2015), so care needs to be taken in choosing this route. In some countries, value-for-money needs to be established either through Public Sector Comparator, subject to the caveat that over-reliance on this quantitative approach may lead to sub-optimal decisions due to the many assumptions involved in the process (World Bank, 2013). Increasingly, smart city ideas are generated by innovative startups, which may work their way up the city ladder through pitching exercises to attract the attention of venture capitalists to scale up their products or services (Lam & Fu, 2019). This may be the beginning of a private-sector led venture, or PPP if the government is willing to remove some obstacles along the way.

C13 Possibility to maintain *transparency* of procurement and *monitoring* of operation

In a published case study on a major infrastructure project in Hong Kong, Cheung and Chan (2009) stated the importance of avoiding allegation of public and private sector collusion when considering Build-Operate-Transfer, which is a form of PPP. Benjamin and Jones (2017) opined that there was an erosion of democratic accountability in the UK since the complex nature of PPP projects precluded public scrutiny, and that commercial confidentiality would undermine public access to information such as pay and staffing levels as well as contractors' performance.

To mitigate against such allegations, Forrer et al. (2010) emphasized the importance of demonstrating accountability through a clear definition of roles and responsibilities. Ng et al. (2013) added "people" to PPP (making it "P4") to highlight the importance of a process framework for engaging citizens. Rwelamila (2017) advocated transparent communication and dissemination, including the general public as an important stakeholder in any partnership involving the private sector. Hence, in a large cultural district development project put in the hands of the government after an initial resisted attempt to involve private sector developers in the early period, a 3-stage public engagement exercise was conducted over 25 months in Hong Kong (WKCDA, 2019). This is followed suit in the smart city pilot development project in Kowloon East. In other developed cities, similar engagement of the public in the planning stage is common.

A similar level of transparency is beneficial for the public to be involved in monitoring the performance of private sector operation in a PPP project after completion (Rwelamila, 2017). To a certain extent, this practice is now promoted for public-only and private-only investment. Examples of the latter include private utility or transport companies being put on watch by the public, which may affect renewal of these companies' licenses.

C14 *Complexity of coordination* of government departments

In a smart city project involving cross-disciplines and multiple public departments, such as the provision of integrated public information, or services requiring various interfaces, it may be beyond the capability of the private sector to handle with efficiency. An example would be the provision and maintenance of essential services such as water and gas utilities. For such piped services buried under streets and buildings, smart installations monitoring their conditions would involve the highway department, transport department, buildings department, survey and mapping office, water supply department, etc. in providing the necessary access.

Bureaucracy seems to hamper entrepreneurship more in emerging economies than in developed economies, where the rules of games between the public and private sectors are better defined. Luo & Junkunc (2008) expounded on this issue and postulated that the vulnerability of private firms (with concomitant increase in transaction cost) to bureaucracy is largely determined by their postures in entrepreneurial orientation, newness (age of establishment), and governance. Their study found that private firms cannot avoid bureaucratic barriers and need to adapt by investing time in engagement (obtaining information) and exerting influence to a limited extent in overcoming self-centered motivation of public agencies, despite prevailing central policy to the contrary.

In the domain of smart cities, it was proposed that a central coordinating body (e.g., a smart city program office) should be set up to help public and private innovators in manoeuvring between government departments, drawing resources from relevant agencies for cross-departmental projects where necessary (PwC, 2017).

To summarize, the above literature review has identified a comprehensive set of relevant factors which need to be taken into consideration when city managers decide on a suitable procurement option for smart city development. On one hand, the inclusion of these factors mitigates against the agency problems associated with traditional public service provision. On the other hand, the chance of private entities exploiting the public for profit needs to be guarded against.

As a critical reflection of the literature review, the above grouping of factors may be refined to take into account features of particular smart city projects. For example, for projects involving health informatics, the asset is not physical (hence availability as loan collateral is irrelevant in C10), but due to its highly sensitive nature, privacy requirements may replace this factor.

5. Methodology

5.1 Justifications for Multi-Attribute Utility Analysis

MAUA is a proven method to derive the ranking order of available alternatives. The method was used to evaluate a number of construction procurement strategies (Skitmore & Marsden, 1988) and Build-Operate-Transfer proposals (Walker & Smith, 1995). The Multi-Attribute Utility theory provides decision makers with a tool to "cost out" performance in one criterion for performance in another, and its advantages were expounded in the management literature (Butler et al., 2001). In essence, this approach allows good performance in one criterion to compensate for poor performance in another when a holistic view is taken, having assessed the relative importance of the criteria and the level of satisfaction which a certain choice provides towards the criteria.

According to Zhao and Ying (2019), within the toolbox of multiple criteria decision making, another common technique for ranking alternatives is the Analytical Hierarchy Process (AHP) as developed by Saaty (1980). Similar to MAUA, a complex decision task is decomposed into a hierarchy of components parts, each prioritized according to a set of attributes relevant to the component in question. Pairwise comparisons are made based on a ratio scale to establish the priority of one attribute over another. There has been continuing debate as to the relative merits of the MAUA and AHP as a ranking method (Belton, 1986; Dyer, 1990). However, from the point of view of the evaluators, AHP is more tedious since they may find it hard to remember their own comparisons when asked to do them repeatedly based on a ratio scale (how many times A is better than B), unlike the intuitive linear scale (e.g., 0-10 or 20) as in the case of MAUA. For example, in the demonstration which follows, for each evaluator, the numbers of pairwise comparisons needed for each project type (there are 8 cases in this paper) using AHP would be: 1st level between the assessment criteria ($_{14}C_2$ =14x13/2 = 91) plus 2nd level between each criterion and the 3 procurement modes (14x3 = 42), totaling 133. A proprietary software such as "ExpertChoice" is usually required with a large number of participants to ensure consistency of their pairwise comparisons in many rounds of iterations. In the case of MAUA, for each project type, an evaluator completes 14 ratings for the assessment criteria and 14x3 = 42 ratings for the 3 procurement modes vs each criterion, totally 56. In terms of ranking results, Lockett and Stratford (1987) had performed a simple experiment indicating that the two methods yielded similar results given that the evaluators were consistent (more difficult to achieve in the case of AHP). Other multiple-criteria decision making techniques such as ELECTRE and

PROMITHEE also rely on pairwise comparisons of alternatives, entailing similarly tedious procedures (see Table 2). Hence, MAUA is chosen for this demonstration to illustrate its practical applications in the industry. The manipulation is straightforward and does not rely on computer assistance.

Table 2: Comparison between different Multi-Criterion Decision Making Tools

Comparison Items	MAUA	AHP	ELECTRE	PROMITHEE
Pairwise comparison	No	Yes	Yes	Yes
Sorting requirement	No	No	Yes	No
Limited no. of alternatives	Yes (generally up to 3)	Yes (generally up to 15)	No	No
Iterations of calculation	Low	High	High	High
Checking measure	Not available, but good for up to 3 alternatives	Coefficient of Consistency	Credibility Matrix	Net ranking flow

Note:
MAUA: Multiple Attribute Utility Analysis
AHP: Analytical Hierarchy Process
ELECTRE: Elimination and Choice Translating algorithm (Translation from French)
PROMITHEE: Preference Ranking Organization Method for Enrichment Evaluations

5.2 Research Design

Before a smart city project is to be launched, it has to pass through the proof-of-concept stage if a new technology is involved (regardless of whether it is developed by the public or private sector). To implement it at the city scale, an appropriate procurement mode needs to be decided by the responsible city government. In the use of MAUA, different utility levels (i.e., a measure of intangible satisfaction) attributable to the three main procurement routes (public-only; private-only and PPP) under specific project scenarios are evaluated, alongside a set of prioritized assessment criteria evaluated by relevant stakeholders.

To demonstrate the viability of MAUA in determining the most suitable procurement mode for specific smart city projects, a two-prong method was employed in the following scenario. Since Hong Kong SAR government has earmarked the Kowloon

East area as a testing ground for smart city projects (the project features being enlisted in Table 3), data collection for demonstrating the applicability of the methods was carried out in Hong Kong. The method may be repeated elsewhere in the world.

Table 3. Examples of smart city projects in Hong Kong

Smart city project		Features[2]	Trial Period	Expected User Groups	Stakeholders for PoC[1] trials
Project I	Smart crowd management system	The system utilizes surveillance cameras, sensors and video analytics to capture crowd flow and the number of vehicles, and spot abnormal conditions, for improving the efficiency of crowd management. With the use of equipment installed at key locations along the route and public transport queuing points, it assists event organizers in monitoring crowd flow, enabling swift actions and support when and where needed.	Jan. 2017	Marathon participants; Concert goers Firework viewers	Gov't outsourced to system developer and equipment providers*
Project II	Easy walking App	This App makes use of artificial intelligence to cater for the preference and needs of the users to suggest personalized routes, e.g. sheltered paths and barrier-free paths. The self-guided tour function recommends interest walking routes to suit users' persona and preference. Augmented reality and virtual reality (AR/VR) technologies are embedded in this App. Collaborating with major shopping centers, this App enables users to position themselves indoor using their smart phones through Bluetooth Low Energy (BLE) devices installed by the shops.	Jan. 2017-ongoing	Tourists Local visitors	Gov't sponsored laboratory*
Project III	Intelligent parking information system	Apart from parking vacancies, this system provides real-time information to drivers via a phone App or a website for computers, e.g. alternative parking spots around the destination, driving routes to the car parks as a suggested option, etc. A GPS-based intelligent parking information system applies wireless positioning technology to identify the available parking vacancies, which helps balance the supply-and-demand for them.	Mar. 2017-ongoing	Car drivers using smart phones	Gov't IT Dept; Public carparks; Private carparks*
Project IV	Energy efficiency data management system	Participants can track their real-time energy consumption at home on mobile gadgets and participate in a reward scheme for energy saving. This project may help the participants improve their power consumption habits, raise public awareness for conserving energy and promote low-carbon living.	May 2018-ongoing	Willing public housing residents	Utility co; Telecom co; Housing Dept*
Project V	Smart recycling bin system	The overfilled waste bins affect cityscape and need extra resources for monitoring. Through the application of artificial intelligence, this smart recycling bin system can arrange the waste collection optimally. The sensors will detect the fill levels of waste separation bins and their fill-up time can be estimated automatically. The workload of frontline collection staff will be alleviated at busy districts.	July 2018-ongoing	Public depts. (e.g., Food & Env)	Gov't*
Project VI	Multi-purpose lamp post	The multi-purpose lamp posts provide all-in-one locations to accommodate various sensors for real-time data collection and sharing (e.g., on air quality, temperature, and traffic flow), together with various wireless data transmission technologies. Wi-Fi receivers and information display panels may also be installed for interaction with citizens.	June 2018-ongoing	Transport Dept; Highway Dept; Env. Protection Dept	Gov't outsourced for procurement & installation*

Project VII	E-government portal	The e-government portal: *GovHK* is an integrated online service in Hong Kong. Transactions can be handled on this integrated website conveniently and for a variety of purposes, e.g., paying tax, renewing driving license, visa application, public facility booking, etc. E-government may provide open data platforms (users may use machine-readable data for a variety of purposes using APIs).	Mid-2016 - Ongoing	Office of Chief Info Officer; all gov't depts	Government
Project VIII	Bicycle-sharing system	The bicycle-sharing system provides public services for transit connectivity in urban areas. As an alternative to motorized transport for a short distance, it may connect users to public transit networks. The nearest available bikes can be located by the users via an App. The users are allowed to use the bicycles after payment (e.g. electronically via scanning the QR code). After use, bicycles can be returned anywhere and locked conveniently.	Dec. 2018-ongoing	Visitors to West Kowloon Cultural District (WKCD)	WKCD Authority outsourced to operator

Notes: [1]PoC: Proof of Concept; The overall population of Hong Kong is estimated at 7.5 million in 2019.
[2]The features stated in this table are based on the smart city projects in Hong Kong and extracted from different sources (EKEO, 2019; HKSAR, 2018; LegCo, 2018; PwC, 2017).
*Coordinated by the Energizing Kowloon East Office – a specially dedicated unit under the Development Bureau of the HKSAR Government)

(i) A questionnaire survey was conducted to establish the priorities of the above-mentioned 14 assessment criteria. An online survey form was designed and pilot-tested with 4 professionals (2 in each of public and private sectors) to ensure correct understanding with fine-tuning before mass distribution from Sept to Nov., 2018. Part A of the questionnaire requests respondents to choose an appropriate Importance Score (ranging from 1 to 20 to allow for a wide spread) for each criterion in their consideration of the suitability of PPP for smart city projects. Part B contains demographic questions about the respondents. Based on professional directories and government officer directories, approximately 450 invitations were sent by emails to experienced (at least 3 years) public and private sector built environment professionals (of roughly equal numbers) requesting them to complete the online questionnaire (see Appendix now, *an URL to be inserted after double-blind review due to the institutional domain name*) on an anonymous basis. Public officers were sampled from works departments in the government telephone directory (showing their job titles), and private practitioners were sourced from professional body directories and universities. In total, 92 replies were received (44 from the public sector and 48 from the private sector), representing a response rate of 20.4 percent. Their profile is presented in Table 4, showing their general familiarity with smart city projects.

Table 4. Profile of survey respondents

Variables	Classification	Frequency	Percent (%)
Working Experience (in years)	Under 5	14	15.2
	6~10	13	14.1
	11~15	9	9.8
	16~20	6	6.5
	Above 20	48	52.2
	Others	1	1.1
	Missing	1	1.1
Highest formal education level	Certificate	1	1.1
	Diploma	3	3.3
	Undergraduate degree	35	38
	Postgraduate degree	52	56.5
	Missing	1	1.1
Type of organization working in	Public sector	44	47.8
	Private sector	48	52.2
Nature of your work	Project management	29	31.5
	Marketing/sale	9	9.8
	Customer service	3	3.3
	Academic	5	5.4
	Contracting	4	4.3
	Consultancy (including engineering/surveying)	26	28.3
	Finance and Accountancy	1	1.1
	Others (e.g. planning)	14	15.2
	Missing	1	1.1
Familiarity with the "Smart City" topic	None	10	10.9
	Heard of it	28	30.4
	Thought about it	11	12
	Read about it	35	38
	Work on it	6	6.5
	Missing	2	2.2
Sample size		92	

(ii) When the 14 assessment criteria were prioritized through the above survey, a focus group meeting was arranged by inviting 3 senior public sector officers (Group A) and 3 senior private sector practitioners (Group B) to help evaluate the relative utilities of the respective procurement routes vis-à-vis 8 types of smart city projects undergoing proof-of-concept tests in Hong Kong. In essence, a focus group meeting is a carefully planned discussion, designed to obtain the views of the group members (5 to 12 relevant participants) on a defined area of interest, and the process is facilitated by a moderator (Langford & McDonagh, 2003). A profile of Group A and Group B members is depicted in Table 5, showing their rich experience in construction projects of their respective sectors. Their long-standing involvement with their own sectors makes them representative of the sectors' mindset, and their organizations have worked on projects using the 3 options. There is no overlap between the respondents of the survey and participants of the focus group meeting.

During the focus group meeting, which took place in March, 2019, a pre-briefing was conducted by the facilitator informing the participants of the purpose of the exercise, and the types of responses expected from them. The mean scores of the prioritized assessment criteria were also presented to the groups to seek their agreement with the order, which was unanimous. A set of 8 typical smart city projects was presented to the groups with explanations on their functionalities (see Table 3). Then, the 2 groups were seated separately to avoid hearing each other. A coordinator was elected each from Group A and Group B for recording the discussion amongst the groups on the proforma provided. Individual members of each group of 3 were requested to allocate utility scores (between 10 to 110 to avoid the mathematical complication of zeros in multiplication) towards the three alternative procurement modes (public-only; private-only; and PPP) versus each smart city project. After the evaluation by individual members was completed, each group was requested to agree on a single set of utility scores amongst its members through internal discussions for each project type. Then the Coordinators of Group A and Group B were requested to arrive at a compromised set of utility scores for a particular smart city project (i.e., the smart lamp post chosen due to its multifarious attributes including data collection, wireless transmission and display functions, seemingly making all 3 alternative procurement modes possible) as a demonstration of the result of possible negotiation between the public and private sectors. The entire focus group meeting lasted for 3.5 hours in a Saturday afternoon with a short break in-between, which was considered as the maximum attention span possible amongst the participants.

Table 5: Profile of Focus Group Members

Group A (**public officers**)	Group B (**private practitioners**)
Maintenance Surveyor (30) in a public housing body	Senior Quantity Surveyor (38) of an engineering consultant firm
Chief Property Services Manager (32) of a public client body	Director (25) of a project consultancy firm
Senior Project Manager (32) of a health authority	Associate Director (20) of a project consultancy firm

(Brackets indicate years of professional experience)

With MAUA, the prioritized score of each assessment criterion is normalized to a value between 0 to 1, and multiplied to the utility score of a procurement mode (the compromised group score is used in this demonstration, taking the public sector group and the private sector group in turn). The summation of the respective products indicates the weighted total utility of that procurement system for a certain smart city project, as perceived by each group. Hence, the 3 procurement systems can be ranked by their weighted total utility values. Equation (1) below summarizes the procedures.

$$S = \sum_{i=1}^{n} (RPR_i * U_i) \tag{1}$$

where S denotes the result, which is the weighted total utility of a procurement option for ranking purpose. RPR_i is the Rationalized Priority Rating for Criterion i (0 to 1), which has been obtained through the mentioned survey on PPP assessment criteria. U_i denotes the utility (ranging from 10 to 110) assigned by an expert (or group of experts) regarding how well the procurement option satisfies Criterion i and n is the total number of assessment criteria. Since each type of smart city project has its own characteristics affecting the choice of procurement mode, a series of 8 cases (Table 1) were tested out using the above MAUA method. Each of these cases has a different set of utility values versus a procurement option, but the assessment criteria remain unchanged.

6. Analysis of Results

6.1 Survey Findings

Descriptive statistics of the questionnaire survey are shown in Table 6 (Private Sector) and Table 7 (Public Sector).

The test of reliability on the questionnaire yields Cronbach's Alpha values of 0.907 (Private Sector) and 0.779 (Public Sector), representing "excellent" and "acceptable" internal consistency respectively within the replies to all questions on the 14 assessment criteria (Nunnally, 1978). The standard deviations of the associated mean scores (ranging from 13.1 to 16.64) for all questions in both the public and private sectors are within the range of 0.44 to 0.83, which means the dispersion amongst the respondents is relatively low.

It can be seen that in the Public Sector, the criteria having the top three Importance Scores are: *(1st) C3: Availability of needed data for providing smart city service; (2nd) C2: Availability of expertise; and (3rd) C13: Possibility to maintain transparency of procurement and monitoring of operation*. In the Private Sector, they are *(1st) C13: Possibility to maintain transparency of procurement and monitoring of operation; (2nd) C14: Complexity of coordinating government departments; and (3rd) C2: Availability of expertise*. Hence, in terms of the ranking order of the mean scores, both sectors are not much different regarding the relative importance of the top assessment criteria. When each individual criterion is compared between the two sectors, it was found that apart from *C7: Rate of technology becoming obsolete,* the public sector means are larger than the private sector means for all the other thirteen criteria. It implies that out of all the assessment criteria, the private sector pays particular attention to the possible obsolescence of smart city technology, which makes their investment risky. Another interesting finding is that all mean scores in both sectors are higher than 10 (the mid-point) before normalization, indicating that the assessment criteria are to the point in considering about PPP projects.

When triangulated with the literature, transparency in procurement (C13) is upheld as the foremost governmental policy (World Bank, 2016). The criterion C3 reflects the trend of big data, which is increasingly regarded as a resource of smart city development (Kitchin, 2014; Schiavone et al., 2019). Governments are counting on the expertise of the private sector (C2) in scaling up smart city services and infrastructure, and often solutions are provided by citizens or startups to city officials (DXC, 2018; EIU, 2016).

Considering the backgrounds of the survey respondents, who are almost equally distributed between the public and private sectors, their vast working experience (more than half with above 20 years) in project management and consultancies (each about 30 per cent), their replies are consistent with the trends in the literature. One possible caveat is their limited working experience in smart city projects, which may be due to the primary stage of developing smart city in Hong Kong, although about 68 per cent had heard or read about pilot projects being carried out.

Table 6. Summary of relative importance scores assessed by private sector survey respondents

Variables	Mean	Std. Err.	95% Conf. Interval	
Availability of finance	13.81	0.63	12.54	15.09
Availability of expertise	**14.48**	0.60	13.28	15.68
Availability of needed data for providing smart city service	14.46	0.54	13.38	15.54
Efficiency drive (to enable early start at procurement stage	13.60	0.52	12.56	14.65
Efficiency drive (at operational stage)	13.35	0.51	12.34	14.37
Need to share risk	13.10	0.60	11.89	14.32
Rate of technology becoming obsolete	13.85	0.54	12.77	14.93
Rate of technology diffusion	14.21	0.54	13.12	15.30
Suitable business models can be devised to share income/saving	13.85	0.52	12.82	14.89
Asset availability	13.73	0.49	12.74	14.72
Capable of measuring performance	13.69	0.64	12.41	14.97
Possibility of procurement by competition	13.81	0.64	12.53	15.10
Possibility to maintain transparency of procurement and monitoring of operation;	**14.79**	0.58	13.63	15.96
Complexity of coordination of government departments.	**14.67**	0.57	13.51	15.82
No. of observations		48		

[1]Cronbach's Alpha: 0.907.

Table 7. Summary of relative importance scores assessed by public sector survey respondents

Variables	Mean	Std. Err.	95% Conf. Interval	
Availability of finance	14.20	0.83	12.53	15.88
Availability of expertise	**16.20**	0.48	15.23	17.18
Availability of needed data for providing smart city service	**16.64**	0.47	15.69	17.58
Efficiency drive (to enable early start at procurement stage	14.41	0.50	13.41	15.41
Efficiency drive (at operational stage)	14.95	0.44	14.07	15.84
Need to share risk	13.43	0.54	12.35	14.52
Rate of technology becoming obsolete	13.11	0.59	11.92	14.31
Rate of technology diffusion	14.66	0.52	13.61	15.71
Suitable business models can be devised to share income/saving	14.27	0.66	12.94	15.60
Asset availability	13.98	0.58	12.81	15.15
Capable of measuring performance	15.07	0.45	14.15	15.98
Possibility of procurement by competition	14.18	0.60	12.97	15.39
Possibility to maintain transparency of procurement and monitoring of operation;	**15.41**	0.58	14.23	16.58
Complexity of coordination of government departments.	14.14	0.65	12.82	15.45
No. of observations		44		

[1]Cronbach's Alpha: 0.779.

6.2 Focus Group Findings

A summary of the individual assessment of the 6 participants is shown in Table 8, which depicts the arithmetic mean of the individuals' weighted total utilities *S* (see Equation 1) of the 3 procurement modes versus each of the smart city projects. An example of the calculation process is given as Table 9 for Project I only, since all other calculations are similar.

Table 8. Summary of the individual assessment at Focus Group Meeting

Smart city project		Arithmetic mean of weighted utilities		
		Public	PPP	Private
Project I	Smart crowd management system	64.73	62.53	**64.92**
Project II	Easy walking App	61.34	65.64	**72.71**
Project III	Intelligent parking information system	66.92	**68.03**	65.58
Project IV	Energy efficiency data management system	54.28	66.76	**74.19**
Project V	Smart recycling bin system	65.51	64.09	**65.79**
Project VI	Multi-purpose lamp post	**78.50**	68.55	60.20
Project VII	E-government portal	**87.26**	60.69	38.67
Project VIII	Bicycle-sharing system	55.21	71.57	**74.49**

In Table 8, the highest mean weighted total utility for each project type is highlighted in bold font. It can be seen that PPP is considered the most suitable for Project III (Intelligent parking information system) on the basis of assessment by individual participants. This makes good sense in that a region-wide car park vacancy information system should ideally combine the data from both public and private carparks for dissemination to users. Other projects show different preferred procurement modes (either public only or private only).

The compromised results of the public group are shown alongside those of the private group in Table 9. Here, it shows that in the compromised perspectives of public officers, PPP becomes the most suitable procurement mode for Project I (Smart crowd management system), Project III (Intelligent parking information system), Project V (Smart recycle bin system) and Project VI (Multi-purpose lamp post). For the private sector group, they could not reach compromise on any project suitable for PPP.

Table 9. An example of the calculation process (the public compromise of Project I)

Criteria	Rationalized Priority Rating[1]	Public-only		PPP		Private-only	
		Utility-1	Result-1[2]	Utility-2	Result-2[2]	Utility-3	Result-3[2]
C1	0.07	60	4.20	100	7.01	30	2.10
C2	0.08	10	0.77	60	4.59	100	7.66
C3	0.08	100	7.76	80	6.21	40	3.10
C4	0.07	80	5.60	40	2.80	110	7.70
C5	0.07	30	2.12	60	4.24	100	7.07
C6	0.07	10	0.66	50	3.32	90	5.97
C7	0.07	20	1.35	70	4.73	110	7.43
C8	0.07	40	2.89	80	5.77	100	7.22
C9	0.07	40	2.81	90	6.33	110	7.73
C10	0.07	100	6.93	80	5.54	30	2.08
C11	0.07	100	7.18	70	5.03	40	2.87
C12	0.07	100	7.00	60	4.20	20	1.40
C13	0.08	110	8.31	90	6.80	10	0.76
C14	0.07	110	7.93	70	5.05	20	1.44
Total	1	65.51		71.61		64.53	
Rank Order		**Second**		**First**		**Third**	

[1]Rationalized Priority Ratings have been calculated through a completed survey and normalized to be fractions of 1.

[2]Result: S = Rationalized Priority Rating $*$ Utility.

Discussions with the respective groups of participants revealed the following rationale in support of their evaluation (participants emphasizing that these were their personal views) for each of project:

Project I: Group A felt strongly that PPP would help the government to source the state-of-art video analytic equipment and software to detect movement patterns. However, Group B considered that crowd management should be a public management function and hence belong to the “public-only” realm.

Project II: Both Group A and Group B preferred the private sector to handle this task, since it would provide more attractive features for pedestrians using apps to guide their shopping, or visiting to places of interest. This view prevailed both in individual and group assessments.

Project III: Group A held the strong view that a regional car park vacancy information system should be jointly developed via PPP since the coverage should include public and private car parks to avoid the information island syndrome. The private sector, however, seemed to favor their own systems. This is evident in that shopping mall developers operate their own car parking information systems to enhance patronage to their premises in Hong Kong.

Project IV: There is almost unanimous view that energy efficiency data management systems should be installed and operated by the private sector, since wireless telecommunication networks are being used to transfer the data from households to private utility companies in Hong Kong, at least in the trial scheme being carried out.

Project V: Group A thought that smart recycling bins are mostly located in private residential premises, whereas central trash collection is a city government function, hence making PPP a desirable model. Group B, however, believed that a recycling scheme would be implemented better by the government, since sufficient outlet channels would more likely be available.

Project VI: Due to the significant funding needs creating pressure on public budget, Group A preferred PPP, whereas Group B believed strongly that street-side lamp posts were controlled by the government, and hence should be owned and managed by the public sector.

Project VII: It was a strong consensus amongst groups of both sectors and the individuals that e-government portal should be owned and operated by the public sector, since the data originates from them.

Project VIII: Bike-sharing systems, being mostly of business-oriented nature, were unanimously agreed by both groups and individuals to be owned and run by the private sector. User rental would become a good revenue source, as experienced in Europe and the US.

In order to test the effects of possible negotiation between the public and private sectors, the two groups were requested to agree on the scenario of Project 6 (smart lamp posts being selected due to its multi-faceted features) by jointly evaluating the relative utilities of the 3 procurement modes versus the 14 assessment criteria. The overall results are shown at the right most column of Table 10. It can be seen that the highest total utility value was obtained for the public-only mode, followed by PPP and then private-only.

Table 10. Compromised results of the groups at Focus Group Meeting

Smart city project	The arithmetic means of weighted utilities								
	Public group			Private group			Both groups' compromise		
	Public-only	PPP	Private-only	Public-only	PPP	Private-only	Public-only	PPP	Private-only
Project I	65.51	**71.61**	64.53	**66.16**	52.98	65.77			
Project II	60.87	74.44	**77.91**	58.51	58.06	**70.92**			
Project III	70.29	**81.31**	64.89	60.66	57.38	**61.97**			
Project IV	50.85	74.95	**81.92**	47.05	57.88	**79.28**			
Project V	63.33	**68.72**	65.33	**66.67**	51.52	60.44			
Project VI	76.80	**77.72**	58.26	**88.32**	53.11	46.64	**85.17**	70.68	50.95
Project VII	**99.47**	57.84	24.98	**90.46**	57.15	25.26			
Project VIII	51.73	69.99	**84.08**	49.52	68.08	**74.63**			

This set of results is consistent with the mean individual assessment on total utility values (public-only: PPP: private-only at 78.50: 68.55; 60.20) and the compromised group assessment of the private participants (public-only: PPP: private-only at 88.32: 53.11: 46.63), showing a clear preference towards public-only. By contrast, the public participants compromised on PPP with the marginally highest utility (public-only: PPP: private-only at 76.80: 77.72: 58.26)

This comparison was not continued for the rest of the other project types due to time constraint (for the 2 groups to negotiate on 7 other projects) and the achievement of the demonstrational purpose. Since the most important assessment criteria for considering PPP were quite similar between the public and private sector groups (having 2 out of the top 3 criteria being similar), it is plausible that compromise can be reached without difficulty for the other seven projects. For real smart city deliberations, it would be sensible to achieve consensus between the public sector and private sector, before a decision is made to go ahead with a particular procurement mode having the highest compromised total utility value.

7. Conclusion and Recommendations

Smart city development across the world is augmented by the rapid advancement of ICT and other technologies. Before these projects are contemplated at the city level, their costs and benefits need to be evaluated with an understanding of who is going to provide the capital and undertake the operation. When it is decided to implement certain projects, the appropriate procurement method should be chosen with objectivity. Following the success of the collaborative economy, PPP has become increasingly credible alternatives for implementing smart city projects (e.g., energy efficiency improvement, etc.), especially when proper consultations have been carried out with citizens. Hence, from the investment decision perspective, the three broadly defined options studied here are: public-only; PPP; and private-only, bearing in mind that there are options outside this classification scheme (e.g., State-owned Enterprises in some economies). In seeking to address the first research question of "what are the factors that can lead to PPP for smart city development", a list of relevant factors have been identified through literature review and weighted through a survey. They may form the assessment criteria when evaluating if PPP is suitable for a particular smart city project. In this study, both the public and private sectors came up with broadly similar rankings for these criteria, especially on the availability of expertise (as smart cities are based on innovations) and the need for transparency in the procurement process as well as operation monitoring.

Since different types of smart city projects have their own characteristics, a focus group meeting well represented by the public and private sectors was set up to obtain individualized and group-compromised utility values of the three procurement options across eight types of pilot projects in Hong Kong. Answering the second research question of which procurement option suits a particular smart city project, the results indicate that the public sector participants are keen to implement smart parking app and smart lamp posts using PPP, whereas private participants seem to prefer to carry out smart city projects by their own, or the government to take on the responsibilities. For the smart parking app, the Hong Kong government is actively seeking collaborations from private carpark operators, and the number is increasing. For the future smart lamp posts, since 5G and Wi-Fi services would be provided, private sector operators are envisaged. The government is, however, trying to mitigate citizens' concerns on privacy issues, before the private sector will be involved. Public engagement exercises are also being conducted to collect feedback from potential users of all smart city services. This research also introduces a practicable method (MAUA) for a systematic and objective evaluation of the most preferred procurement approach for implementing particular smart city projects. As demonstrated in this study, a compromised solution between the public and private sectors is plausible using this method. The current progress of pilot tests in Hong Kong gives a good indication of the desirable features of the smart city projects, but the actual procurement choices are still contingent on deliberations and negotiations of the government and the private sector during the prospective scaling up of the projects. Further research may be needed to follow up on the latest development then, including the effects of involving citizens in the focus group as part of the decision making body.

When city managers follow the procedures outlined in this study, due regard must be given to the nature of the smart city projects being contemplated, since they have diverse characteristics ranging from transport, utility services (e.g., water, power, etc.) to health issues. It has been demonstrated clearly in this study that the assessment criteria may need refinement to suit specific smart city projects and that PPP is not a panacea. In order to find the optimal procurement mode, an appropriate representation of the stakeholders is essential, suiting the features of the smart city projects in question. With these caveats in mind, the approach presented in this paper may be adapted elsewhere to aid decision making before implementing smart city projects.

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