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Flying high: a human perspective of unmanned aerial systems in future cities

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ABSTRACT

The notion of advanced technology is predominantly portrayed in a positive light and discussed within a dialogue that delivers benefits to its users. The term 'smart city' has been used to convey this concept whereby technology can deliver an 'intelligent effect'. However, many instances of smart city concepts tend to focus on the technology more than the inhabitants who have to co-exist within this solution. This paper discusses these factors by highlighting a smart city project example, Flying High, a project that focussed on the use of unmanned aerial systems within the environs of a city. Use cases were generated via a stakeholder engagement that epitomised the benefits of adopting this technology within the city. Civil security, medical transit and intelligent transport were found to be key uses of smart technology specific to future cities. Key to the findings of these use cases for this technology within the city are discussed in terms of their perceived feasibility, suitability and both economic and social impact. These factors are discussed in relation to the use cases, whilst also highlighting the importance of human socio-technological issues such as governance and the effect of public attitude to the uptake of advanced technology.

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"With cities, it is as with dreams: everything imaginable can be dreamed, but even the most unexpected dream is a rebus that conceals a desire or, its reverse, a fear." (Calvino 1972, *p. 44)*

Relevance to Human Factors

This paper addresses the emergence of advanced technologies and highlights the need for the human element to be considered prior to conceptualizing how such technologies are used. The Flying High Challenge provided the focus of introducing unmanned aerial systems within our cities, but stressed the importance of addressing the human requirement and perception of these technologies. Under the West Midlands project of Flying High we examined several use cases that utilized small drones and explored stakeholder vie ws in terms of impact. This paper highlights the need to address not only the perception of these advanced technologies within our communities, but it raises the importance of taking a collaborative approach to addressing socio-technological issues – rather than simply focusing on the technology solution.

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The evolving city

Historically the story of humankind is told within the context of groups of people feeling the instinctual need to create a shared environment; individuals whom congregate and create a community. This is how humans fundamentally evolved into social beings, whereby following the Neolithic revolution humans slowly began to collect in settlements in order to pool their resources (Bocquet-Appel 2011). Early Sumerian civilisation can be put forward as heralding the first manifestation of a city, creating vast city-states around 6,000 years ago (Oppenheim 1977). This was then followed by what we recognise today in terms of the classic cities borne from the Egyptian, Greek and Roman civilisations. The footprint that these cities have left are still seen today, whether they are extensions of what we consider our modern cities or incomplete memories that remind of us of our past. Needless to say we can safely hypothesise that the need for humans to congregate and share a common habitat is not a newly formed behaviour, but simply part of the human condition. A city not only serves this instinctual desire to gather but also provides with it an associated logistical support structure that tends to be embedded within such complex environs. Beyond the physical structure of the city, Duranton and Puga (2004) state that the city exists as a means by which knowledge is shared and produced with others. Indeed, the nature of bringing individuals together in order to contrast ideas, which may in many cases have an economic value, was a philosophy proposed by the pioneer of Political Economics Adam Smith (Smith 1776). It is this act of congregating people together that fosters the sharing of ideas and experiences, whilst creating a stable environment for individuals to contribute and compete to a growing marketplace of ideas, products and services.

Beyond the simple manifestation of buildings is the need to centralise our sense of belonging and provide a degree of resilience and stability. Indeed, there would be little necessity for a city that lacked any degree of resilience and stability. However, the nature of modern cities would suggest the need for growth along both physical and non-physical dimensions. To a large extent the use of technology is often held up as the measure of a modern (and successful) future city. If technology is thus viewed as the catalyst for bringing life to a modern city then data must be viewed as being its lifeblood - for transporting, delivering and sharing information that represents and supports our very existence and state of being. Falco (2015) suggests that this focus on data rich analytics can even assist in building resilience through harnessing systems that may be empowered to make decisions on behalf of the human.

The need for vast amounts of data to be readily passed across a city network implies a high degree of connectivity. This is part of the driving ethos behind the internet of things (IoT), bringing together different technologies and protocols in order to facilitate such things as distributed sensing, adaptive and robust communication, and processing. Such components would lend themselves to the concept of a future smart city; in that any solution put forward within such an IoT paradigm would be viewed as possessing a high degree of service improvement for the citizens of the city. The ability for communication to exist within this smart city must be both centralised and governed by an acknowledged agency, but also allow for a common protocol for third parties to use the same network. Issues related to cyber security, privacy and safety must be paramount here - thus a common platform and protocol would most likely be overseen or regulated by a single city. Abiding to how this network is used not only allows other service providers to use the smart IoT infrastructure and through association perceived levels of trust and assurance to its users, but potentially will allow for other users to possess multiple choices of solutions they may wish to engage with. This not only provides choice for the consumer, but also promotes healthy competition and a growing economic market.

Intelligent smart cities and unmanned aerial systems

It is difficult to create any sort of discourse about future technologies without using the term 'smart city'. The term 'smart city' is somewhat a vague and ambiguous label that fails to share an agreed definition (Albino, Berardi, and Dangelico 2015; Gil-Garcia, Pardo, and Nam 2015). Although this term often implies a coming together of technology-based innovation within the urban environment. With the rapid advances in technology we must consider the evolution of our cities as being perceived as 'smart' - in that data and information is seamlessly connected and shared, whilst offering benefits to those who exist within the city: the citizens. There are many examples of smart city projects that exemplify the application of innovative technologies in order to provide more efficient solutions. For example, Navvab, Bisegna, and Gugliermetti (2018) propose a method by which smart sensors could be integrated into street lights that would create an adaptive system that would change the level of visibility for passing pedestrians and drivers. This form of 'adaptation luminance' exemplifies the manner in which the use of technologies can be harnessed within an existing networked infrastructure in order to pass on benefits to the people who live there. We are seeing a number of new technologies being applied in this manner within our cities, with many now offering a degree of decision-making through intelligent agent-based systems. For example, Angelidou (2017) evaluated fifteen smart city projects and found that the primary focus was mainly around Information Communications Technology (ICT), and noted that there was a top-down approach to implementing technology (as opposed to more public/citizen bottom-up approaches). To allow for a wider public voice to be heard in such endeavours, Deakin (2014) proposed a means by which the public voice may be heard. This would be achieved by adopting a 'triple helix model' approach, whereby academia, private and public bodies are joined in partnership in order to provide an overarching level of governance. This would provide the means by which the public could gather a sense of control over what initiatives would be allowed to impact their environment and daily lives.

Whilst intelligent systems and autonomy are seen as key technology drivers within smart city concepts, the use of unmanned systems are beginning to offer solutions to many service-orientated activities within our cities. For example, the use of autonomous vehicles for refuse collection (Ferri et al. 2011), public transportation services (Shut and Kasyanik 2013), freight delivery (Boysen, Schwerdfeger, and Weidinger 2018) and even working collaboratively with humans in emergency scenarios (Blaya et al. 2009). These are a small selection of autonomous services being tested within cities. However, one of the fastest growing markets belongs to unmanned aerial systems (UAS) or as they are more commonly referred to - 'drones'. The use of UAS in smart cities has been discussed in terms of both inside and outside the city environ, focussing on operations such as agriculture, security, telecommunications, traffic management, surveillance, mapping, emergency services, weather monitoring, and environmental analysis (Barmpounakis, Vlahogianni, & Golias, 2016; Menouar et al. 2017). Although the foundation of this technology was borne within military applications, we are seeing the emergence of a very strong commercial market whereby smaller UAS are being designed for different operations. Many of these operational concepts are slowly beginning to migrate towards city applications. However, the integration of technology is just one component that must be considered with city application; as the acceptance of this technology is held solely by the inhabitants of the city. These are the very people that are identified as possessing the benefit of utilising these systems, but are seldom consulted as to the nature of deployment or use.

The use of small UAS (or sUAS)[1] has been shown to have a high degree of public and stakeholder acceptance (Flying High 2018) - both key factors in any emerging technology that may be perceived as somewhat disruptive. For example, in a study by Richards and Edgell (2017) they focus on the importance of attitude towards the acceptance of UAS operating in national air space (NAS) from a stakeholder perspective, finding differences in attitude across different stakeholders. Further to this, Richards and Stedmon (2018) report the importance of how the media can shape attitude when it comes to the acceptance of UAS, and the manner in which this technology is conveyed to the reader. We can infer that the perception that the public possess towards a given technology or concept will most likely have a direct effect on its acceptance. This is true of how UAS are conveyed in terms of operational scenarios. However, when we think of a traditional UAS operation, it conjures up a single operator (or pilot) staring at a handheld device (or ground station) as they manually input instructions to their (single) aerial vehicle. Normally we can expect a joystick or some other form of control input to be used to convey commands to the vehicle. However, advances in automation and highly capable sensors is rapidly changing this concept towards a more autonomous UAS that will perform sense and avoid functionality, demoting the operator to simply monitor the air vehicle.

Acceptance of unmanned aerial systems within the city

Although there are many potential applications of sUAS within the confines of a city, they must all be able operate within the challenges that constitute an enclosed urban environment. Current regulations for using sUAS dictates a high level of constraints in terms of communication protocol and operating limitations. Across many countries this confines routine sUAS to line of sight operation, working during daylight hours, and limitations relating to the distance the vehicle can operate near buildings, infrastructure, other vehicles, and crowds of people. Major advances in sensor technology are beginning to address a number of these issues and leading towards a safe and efficient capability. Alongside this remains the question relating to the attitude of the general public, who may soon be the unexpected bystander who is confronted with a sUAS that has the potential to compromise their own perception of safety, and also the individual's rights in relation to privacy.

This again suggests the importance of seeking public acceptance before new technologies are sought to address societal needs. While technology is put forward as the harbinger of what defines a smart city, the manner in which technology solutions are integrated into our society is somewhat haphazard and lacking in any meaningful formal framework that other technology vendors can follow. Furthermore, the people who decide whether a technology should be embraced or trialled can almost be viewed as disenfranchising the very citizens that must live alongside the solution being offered. Dameri and Benevolo (2016) argue that solutions that may be considered for any smart city should be processed via a structured stable governance framework. The lack of such governance could very well alienate the citizens of the smart city and compromise the very effect the solution has been designed to address. Copus (2015) suggests that local governance networks tend to possess complex networks of public and private bodies that tend to rely on a number of individuals to drive policy decisions. The rapid emergence of telecommunication technologies can be viewed in such a light; with the active deployment of the next generation mobile communication (5 G) across several countries. For example, within the United Kingdom several cities are trialling this technology through initiatives within the local council (e.g. Salford, Birmingham, Bristol, Cardiff, Glasgow, Liverpool, Manchester and London). Governance in such instances must be shared by stakeholders and government agencies - who can often hold opposing views in relation to the technology and application being proposed. For example, the 5 G test bed being trialled in the West Midlands (Birmingham, Coventry and Wolverhampton) of the United Kingdom has been promoted as the UK's first 5 G test area, with £75 m Government investment. While the benefits of providing a more robust and efficient communications network has been suggested to provide huge benefits to our social infrastructure across our cities - allowing improved traffic flow, emergency service coordination, health services, construction (BBC 2018), there is little discussion of the perceived health effects, disruption, or value for money in such an investment (Di Ciaula 2018; Russell 2018).

Traditionally the public voice within the process of governance is often not central to such decisions, although there is evidence that this stance is slowly changing - as will be discussed in the following example.

Case study: the flying high challenge

During 2018 a competition was ran by the National Endowment for Science, Technology and the Arts (Nesta) within the United Kingdom. Nesta is a charity that sets a number of societal challenges that promote innovation across different sectors, but with the aim of influencing investment and policy within the UK. There is significant interest in this domain based on the rapid growth of associated technology and the market opportunity it is projected to possess. For example, it is projected that by 2030 the Unmanned Aerial Vehicle (UAV) market will contribute £42bn to the UK gross domestic product (GDP)[2]. To address this opportunity Nesta initiated the Flying High Challenge whereby Cities were asked to put forward a case for selection as a UAS test city. The Flying High Challenge focussed specifically on the rapid growth of the UAS market. While the development and application of drones has predominantly focussed on military uses traditionally in the past, many other uses have been demonstrated. For example, the use of drones for precision agriculture, oil and gas infrastructure inspection (onshore and offshore), monitoring civil unrest, ensuring border security, and so on. These clearly have compelling business cases that indicate a marked cost-benefit for use, but also an increase in efficiency and in many instances can be seen to remove the human from risk. For example, the task of working at height whilst inspecting a wind turbine. The cost, time and manpower required for this operation using equivalent capability (which may include a manned helicopter or an inspection team) equates to a marked increase in cost and risk to the individual conducting the task.

At the centre of the Flying High competition was the focus on providing the general public and key city stakeholders the opportunity to shape the manner in which UAS are deployed within their city.

Following the selection process, five UK cities were chosen to investigate the application of UAS' within the confines of the city. These cities included London, Southampton, Preston, Bradford and a partnership between Birmingham and Coventry (a consortium referred to as West Midlands). All Cities were tasked with identifying key use cases for the use of drones in their region, and then deciding on a single use case to represent the specific concept of operation for that City. All Cities were tasked to focus on key characteristics that were more associated with their unique requirements. Many use cases employing UAS were somewhat common across the Cities, but some unique examples cases were identified through a series of dedicated workshops conducted by each individual City team. The identified key use cases are illustrated below:

- **London** – Rapid delivery of urgent medical products across the city
- **West Midlands** – First response to traffic incidents and co-ordination of Emergency Services
- **Southampton** – Medical delivery service between city and Isle of Wight
- **Preston** – Provision of aerial imagery for managing/monitoring construction services/activities
- **Bradford** – Supporting Fire and Rescue Services in managing and monitoring fire incidents

This paper will focus on the research activity conducted within the West Midlands team, whilst examining some of the key themes that were discussed before arriving at a single use case. A community-based participatory research (CBPR) approach was adopted in order to facilitate the 'translational process' between the wider stakeholder community and those that study it (Hacker 2013).

The West Midlands team within Flying High was composed of not only academic partners, but also key stakeholders across Industry and Government, Using this group of individuals, a non-probability sampling method was employed (via voluntary response) for the planned workshop All partners across the team (N = 64) were invited to take part in a 1-day workshop that would discuss the use of drones across the West Midlands urban environ. This approach was approved by the Coventry University Ethics Panel and the conduct of the workshop in terms of ambiguity, withdrawal, etc. aligned with the British Psychological Society code of conduct (British Psychological Society 2018). Participants that were interested in taking part were sent further details and an agenda for the day. It was made clear that participation was voluntary and no record of names of attendance or comments attributed to any single person or affiliation would be made. In total 22 participants we recruited for the workshop, including individuals from industry (N = 8), local councils (N = 3), combined authority and public bodies (N = 5), academia (N = 4) and Emergency Services (N = 2). At the start of the workshop all participants (N = 22) were asked to consider several possible use cases that would focus on the use of drones for a number of different operations. These scenarios were briefly introduced and an outline of an example operation was attached to each use case. The themes that were to be used for consideration for the workshop were core use cases as defined within the wider Flying High program, and thus each Flying High Partner City were tasked to explore these defined themes and to examine

Table 1. Themes associated with UAV urban scenarios.

UAS Theme	Code	Outline of use case
Civil Security	*CS*	The application of a UAV that can be used to assist the Police in their routine activities such as: crowd monitoring, observing known trouble hotspots, monitoring anti-social behaviour and assisting in finding missing persons.
Intelligent Transport	*InT*	The use of UAVs to provide real time monitoring of major/minor road arteries and transport network across the City. This is viewed as a key enabler of active transport management as a service provision to Transport Control.
Fire Response	*FR*	The ability to respond to fire incidents through applying UAVs in order to monitor/assist the Fire Services. This would include active monitoring of an incident, providing 'eyes on' updates and investigatory inspection as an incident unfolds.
Monitoring Air Quality	*MAQ*	The ability for a UAV to dynamically source air quality samples across the City and thus provide up-to-date air quality measurements. This may also provide a service to respond to potential incidents such as traffic congestion hotspots, or incidents such as gas leaks.
Intelligent Data Monitoring	*IDM*	A number of UAVs could be used to act as a dynamic network nodes that may collect/relay data across the City. This may be part of an existing networked infrastructure capability or in response to a specific requirement where the network is degraded.
Infrastructure Monitoring	*IM*	The ability for UAVs to be used in order to assess the growth of the urban landscape and effectively plan for future growth. This may also include the security of active construction sites within the City, or associated with the transport network.
Medical Transit	*MT*	The use of UAVs for rapid response in terms of medical transportation of medical products between designated sites in the City. This may include blood derivatives, tissues, organs, pharmaceuticals, etc. Primary locations would be inner-city hospitals, but could expand to other areas based on emergency demand.

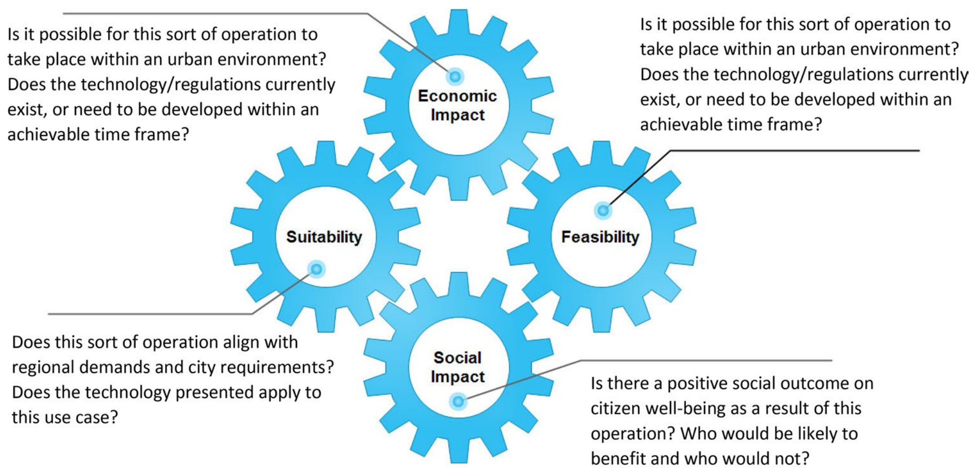

Figure 1. Main factors for considering scenario use cases.

which were best aligned to their region (based on local stakeholder views). These included the following seven themes for consideration, as outlined in Table 1.

Following discussions around the nature of possible urban scenarios using UAS, participants were asked to classify each of the scenarios in turn, whilst considering four key factors; see Figure 1.

The participants were arranged in groups of four/five with a balanced composition of Industry/Government/Academia members. Each group (composed of approximately 5 or 6 participants) were asked to evaluate all presented use cases in relation to the four factors as outlined in Figure 1. Participants discussed all scenarios and through discussion within

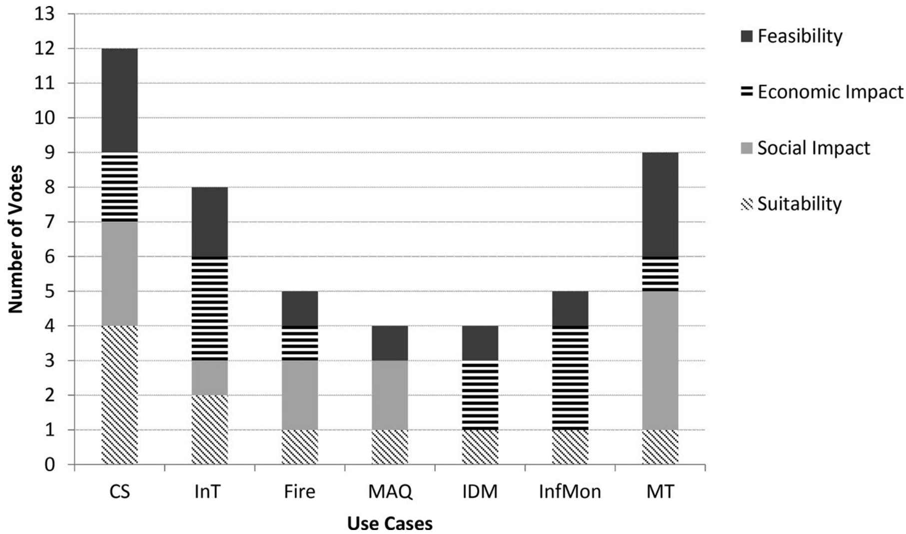

Figure 2. Plot of factors against different use case scenarios for Urban UAS operations.

the group arrived at agreement in terms of which of the four factors could be attributed to each of the scenarios. Participants were in essence being asked to assign (factor) points to share amongst the use cases; in essence they were voting in terms of which factors were important to each of the different use cases.

The results of this exercise, in terms of the tally of factor votes against use cases, are presented in Figure 2.

The majority of participants tended to focus on three main use cases; that of Civil Security (CS), Medical Transit (MT) and Intelligent Transport (InT). The other use cases were considered in turn, but did not seem to generate as much discussion or support as the other three use cases. However, both CS and MT generated the majority of votes cast amongst the groups of participants (respectively 12 and 9 votes), with InT finishing a close third (with 8 votes). CS was voted as having the highest feasibility in terms of existing technology and appropriate regulatory guidance to perform different operations. Economic impact for CS involved the comparison of using a manned asset rather than a UAS solution - in terms of rapid deployment and response, cost of operation, and acceptability due to less intrusive noise. Related to this, CS also scored the highest in terms of social impact - with the ability to provide instant support to the citizens as being perceived as outweighing negative attributes of the use case.

Some of the use cases did not generate a great deal of discussion or raise contentious issues. For example, the use of UAS for IDM and MAQ, while considered as being beneficial across the regions cities, were not considered to deliver huge impact direct to its citizens. Although MAQ was perceived as possessing a greater social impact than IDM from a health and well-being perspective. During the workshop there was a high degree of agreement that the use of UAS, and more so intelligent UAS, as potentially providing marked benefits for citizens. Across the CS and IT themes in particular, it was viewed that these scenarios could be merged to provide flexible and persistent capability.

Consensus within the groups was reached after discussion regarding each of the factors for the individual use cases; although each participant would on occasion propose more importance on factors relating to their organisation. For example, CS would evoke discussions on benefits to safety and security from the Government representatives, with a focus on technology, application and regulations raised by Industry, and privacy and trust raised by Academia. Each use case would evoke a different discussion around the table before arriving at agreement on voting. A key factor in all discussions was the impact to everyday public life and well-being.

Results from this workshop would go on to feed into the wider Flying High project and the West Midlands use cases chosen as best reflections of the regional cities were put forward as Civil Security and Intelligent Transport. Medical Transit scored higher than InT, but due to the unique regional opportunity across the West Midlands (which as viewed as an Intelligent Transport hub) this was taken forward by one of the other five Cities (Southampton) for further analysis.

There was a clear consensus across the other Cities taking part in Flying High that there was a clear enthusiasm for utilising UAS across the urban landscape. The advancing UAS technology, whilst viewed as tangible benefit, was perceived as having to overcome significant regulatory constraints - that at times were somewhat unclear. Results from the combined City analysis suggest that key benefits of utilising UAS included:

- **Cost and Time Savings** - Across Government, Emergency and Health Services in order to respond faster and to deliver an effect in harder to reach places.
- **Health & Safety** - Using UAS to do tasks that would traditionally use humans that could put them in harm's way (e.g. working at height, hazardous environments).
- **Environmental Impact** - From monitoring air quality to congestion build up, UAS can assist in identifying trends before significant impact is realised. The use of UAS for monitoring the cityscape is also seen as a key capability in assessing the encroaching urban footprint.
- **Economic Impact** – The UAS market is growing at a strong pace and presents the opportunity for the creation of jobs in this area. Beyond this, the indirect use of UAS is also viewed as providing businesses with a wider reach in terms of flexibility and endurance, which provides more widespread economic benefit in the region.

Alongside these benefits many of the Cities shared the same concerns in embracing UAS. Concerns around the lack of clarity within the current regulations was often raised, and more so with how the regulations would evolve to take into account the growing need of users to adopt new UAS technologies; these included sense and avoid, beyond visual line of sight operations, airspace management, automation and autonomy. Only through closer and proactive engagement with the regulatory authority could these issues be addressed moving forward. There were also several other key concerns shared across the City partners:

- **Safety** – The resilience of the UAS and sub-systems would need to achieve a very high level. Evidence of this safety would need to be provided in order for the systems to be used in close proximity with the general public (and associated city infrastructure).
- **Security** – Associated also with Safety in terms of robust communication networks between the user and the UAS, but also in terms of hacking of data or control of the UAS (or its sensors).
- **Privacy** – It is highly likely that all UAS will be equipped with sensors that will be able to gather data from the environment. In many instances assurances must be made to

ensure this data collected from the system is managed and treated in an appropriate manner (that is agreed by all concerned).

- **Presence and Acceptability** – The routine use of UAS could potentially create a disturbance in terms of noise and general disruption that may affect the covenant that outlines the individual's *right to quiet enjoyment*. Also related to this is the reason for why a UAS has been put forward for use, as opposed to other means of operation. Trust will therefore be a key driver in shaping public acceptance.

Many of the issues above were discussed within the workshop, and also in the context of stakeholder acceptance and ultimately whether the general public would see the value in adopting this technology as matter of routine. This was a recurring theme discussed by all partner Cities. This is very much akin with what a significant review of (simulated agent-based) UAS applications in civilian operations carried out by Mualla et al. (2019), where they found significant issues surrounding autonomy, explainability [*sic*], security, flight duration, regulations, and validation and verification of agent-based UAS simulator models.

Discussion

We have seen significant changes in the architectural landscape of our cities over the centuries, with the resulting features we recognise today as being formed as a result of varying innovations (through the use of innovative processes, materials, and technologies). There is nothing new in this, even as we examine human history and our migration from small wooden dwellings to more permanent fortifications, to the recognisable metropolis we view as a typically modern city. These are testimony to not only the nature of discovery and exploration of humanity, but are a product of humanity's bold strides in advanced technology. Beyond the structures and materials there is a more significant driver amongst our future city conceptualisation facing us – and soon. Advances in complex automation technology and artificial intelligence have brought us to the point where we now possess capability that delegates control to a number of systems that possess a high degree of autonomy. This is evident in terms of the work being carried out with how humans delegate control to and from autonomous cars and autonomous UAS (e.g. Richards and Stedmon 2016). Both autonomous aerial and ground systems are emerging as the next significant challenge to how our city will look in the coming years. While the use of such technologies has tended to be led from the military, there is an increasing interest in how we can particularly utilise UAS within a civilian context (see Mualla et al. 2019).

The operation of sUAS within the confines of a city present many challenges, and technology can certainly appear to address a number of these issues. To be able to operate (and react) to dynamic and complex surroundings, it is likely that the UAS will require high levels of automation. And in some instances autonomy may be seen as the means to achieve assured safe operation within an urban environment (Pereira et al. 2019). However, the operation of UAS within the smart city has tended to focus on the hardware/software aspects, with a particular emphasis on connectivity (Mualla et al. 2019).

If we are to witness advanced systems seamlessly integrated into our cities it is clearly important to consider critical technological factors such as cloud-based computing, connectivity, data infrastructure, etc. A critical technology that could address important safety-related aspects of multiple UAS operations within a complex environment is the application of intelligent systems. This may take the form of advanced automation, autonomy or varying degrees of artificial intelligence. Further to this, the use of intelligent agents may be situated on the vehicle, within the environment, or even form part of a wider traffic management network. These would primarily serve as assisting the human in managing the system in a safe and efficient manner. As such intelligent systems should not be perceived as a tangible black box that resides on a physical entity. The closer we get to understanding the application of intelligent systems, the more holistic an approach is required in terms of how they are used. Indeed, several studies have shown that hierarchical agent-based systems can be applied to small environments, to a wider orientated system that encompasses a far larger setting (Marsa-Maestre, Lopez-Carmona, and Velasco 2008). And further to that, how autonomous resource management agents can be applied to cloud services across distributed systems, rather than a single localised focus (Fagernes and Couch 2018). Associated UAS technologies have progressed over the past twenty years, such as advanced guidance systems, control technologies and sensors used for navigation (Suzuki 2018). These areas are fundamental components of a typical UAS. However, less traditional or drone-specific technologies have equally seen an upsurge in development an application. In particular the requirement for operating the UAS beyond visual line of sight (BVLOS) requires not just new control and sensor technologies, but the ability to allow the vehicle to navigate autonomously to some extent (Bircher et al. 2018) and more so when considering an urban environment (Neogi 2017). If the delegation of control is possible, then the potential may exist for a single operator to monitor/control multiple UAS (Richards and Stedmon 2017), affording a potential cost and efficiency saving for UAS commercial operations. Areas that are typically not associated with UAS per se are now being examined as enabling key technologies for future UAS operations. Mazur and Wisniewski (2016) conducted a market analysis for future UAS and identified the key research and development areas to be Artificial Intelligence (AI), sense and avoid, control and communications, image processing, and battery capacity. Each of these areas have already progressed outside of the UAS domain, with developments in AI holding potential to transition into the UAS domain. There are many examples where intelligent systems are being adopted as a UAS solution; such as the use of computation intelligence (reinforcement learning and neural networks) to train the system to recognise potential air traffic conflicts (Zhang et al. 2018). Furthermore the use of service-orientated computing has been examined for providing efficient middleware architecture that will facilitate collaborative UAS operations (Mohamed et al. 2014). A service-orientated approach could indeed provide significant advantages in simplifying what may very well be a complex UAS; but sharing common architectures and interfaces across different use cases.

However, the human element tends to be a secondary consideration that tends to be lost amongst these more tangible problems that require solutions. We must continue to ask ourselves how we feel about delegating authority of such systems, or how the city population will perceive, interact and use the systems being designed for them. Although the technologies that make up a smart city are viewed as providing tangible benefits in terms of quantifiable measures (such as cost savings or efficiency), the perception and attitudes held by the inhabitants of the city possess a significant factor that requires an equal hearing. This public and stakeholder voice must be heard early in the technology design process, or else the solutions will become contentious, unused or even alienated and become contentious uses of technology. Directly measuring the attitude of the general public alongside the proposed uses of technology must be considered as a natural development of any UAS urban application. Without designing the technology with all users in mind we could see the smart city citizens become disenfranchised. Factors relating to social and economic impact are key enablers of whether the general public will readily accept a potentially disruptive technology. These factors are closely aligned to the feasibility of the solution being offered, and more importantly whether the solution 'fits' the human requirement within a given context.

Technology currently exists (and has done for some time) that would allow for many of the UAS use cases cited within this paper to be carried-out. Therefore opening the airspace to routine use of urban operations by UAS does not need significant developments in technology. The only way we will see UAS truly integrated into the five nominated Cities is by marrying both technologies and regulations alongside acceptable use cases. Initiatives like the Flying High challenge in the United Kingdom allow us to bring these factors together, to not simply provide a solution to operating UAS in an urban environment, but to define the problem space exists in this area. Similar initiatives are being trialled in other countries at this time - in particular the ten identified Cities in the United States of America have begun developing specific use cases that will allow a closer step to using UAS in urban scenarios. A key facilitator to these projects is the understanding of UAS regulations and discussions with the regulators in order to be flexible for UAS operations to take place in a safe manner. In January 2019 the United States Department of Transportation announced proposed waivers to the Federal Aviation Administration (FAA) rules (Part 107) that would allow UAS to fly overnight, beyond line of sight, and relaxing the rules for flights over people.

Within the United Kingdom there have been several initiatives that have examined the integration of UAS within all classes of airspace (e.g. Autonomous Technology Related Evaluation and Assessment – the ASTRAEA project, 2006-2012). Beyond this £62 m collaborative industry program, future projects have tended to look at the technology that is required to overcome barriers to operating UAS (such as beyond line of sight sensing, autonomous decision making, and unmanned traffic management). While these 'pathfinder' projects focus effort in some of these areas, more recently the United Kingdom Research and Innovation (UKRI) public body launched the Future Flight Challenge. This £125 m program will examine not only sustainable aerospace technologies but has importantly raised the importance of drones and the need for public acceptance of UAS operations. In essence treating public opinion as an equal stakeholder in the design and operation of this emerging technology (Richards and Edgell 2017).

We are seeing a shift in these programs in that they are highlighting not only the importance of the general public in embracing these new modes of operation, but they are becoming an equal research challenge alongside the more traditional projects that tend to focus on the technology solution. The only way that UAS are going to be realised and truly integrated is if due consideration is given to how the general public feel about how the technology is being used and whether they will accept the routine use of such systems in their city. It is only then that technologists will be allowed to focus on a defined environment that would represent a realistic operating environment. Continuing to allow the public to be a stakeholder within this process will surely bring this technology a step closer, and identify potential barriers prior to implementation.

Conclusion

A city is more than the physical manifestation of its parts, but more an aspiration of the civilisation we strive to become. Just as past civilisations before us harnessed the use of new materials and minerals, we in turn embrace the advancement of technologies to create our own distinct mark on history. As advances in technology become more ubiquitous and pervasive we step ever closer to the promise of what some refer to as a 'smart city'. One branch of this technological tree encompasses the use of unmanned aerial systems that are likely to adopt variable levels of autonomy. However, rather than focussing solely on technology, it is critical that the use of UAS within any urban environment must be considered on several levels – as opposed to merely focussing on whether the technology is fit for purpose.

Traditionally Human Factors has been viewed as providing the user focus for the design of the system being developed; such as the physical rendering of the displays within the ground control station, the ground operations, training requirements, etc (Richards 2016). However, focussing primarily on these aspects, important as they are, should not detract from the importance of how Human factors extends beyond the user of the system. A true user-centred design approach will go beyond the end-user and consider the wider stakeholder community; in this instance including the end-users and operators, the regulators, the infrastructure operators (e.g. air traffic controllers), users of a service provision (e.g. drones operated on behalf of a company), and of course the public.

By adopting a stakeholder perspective it is possible to ask important questions about the nature of UAS and the manner in which such systems may be integrated into our everyday lives. As with all novel emerging technologies there are challenges and hurdles to overcome. These tend to be tangible and easy to quantify; such as the need for technology to make systems more reliable and safer, or the infrastructure that is required to facilitate its use. However, it is almost impossible to create a use case that demonstrates how these problems may be solved or even be shown to be beneficial, without considering the most vital of audiences that are asked to adopt a symbiotic relationship with such things: the general public and wider stakeholder community.

The Flying High Challenge has highlighted the need for a different perspective when considering how technology may enrich our lives. When developing examples of how this technology can be of benefit to wider society, the stakeholders must be considered as jury to this evidence. It is only by adopting a well-balanced stakeholder approach to creating use cases that demonstrating UAS concepts begin to gain support by the wider non-UAS community. Failure to seek advice or views on the perceived benefit versus cost from the stakeholders and general public within the city is not advised. Thus any concept of a future smart city would require a proper governance system for connecting technologists, stakeholder and general public to create an open discourse. This will create shared knowledge which, in turn, will lead to beneficial socioeconomic and environmental impact.

Notes

1. A small UAS is typically an air vehicle that weighs less than 20kg (without fuel) and also covers the smaller drones that are commercially available to purchase and fly recreationally.
2. Calculation taken from report by Pricewaterhouse Coopers: https://www.pwc.co.uk/issues/intelligent-digital/the-impact-of-drones-on-the-uk-economy.html

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No potential conflict of interest was reported by the author(s).

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