THE IMPACT OF STRATEGIC TRANSPORT POLICIES ON FUTURE URBAN TRAFFIC MANAGEMENT SYSTEMS

TITLE PAGE

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ABSTRACT

Urban traffic management and traffic signal control systems, denoted as Urban Traffic Control (UTC) systems, are used extensively worldwide by Local Government Authorities (LGAs) when implementing strategic transport policies. However, it is not clear how well the requirements imposed by LGA policy implementation will be met by UTC systems being developed for the future. Therefore, research was undertaken to analyse how delivery of urban transport policies over the next 5 to 10 years would shape LGAs' requirements for the next generation of UTC systems, and thereby to identify Key Performance Indicators (KPIs) to provide user-led guidance for future system development. A two-stage survey of LGA policy makers and implementers from around the world was conducted. The results produced consensus among the group of participants (n=16) on 17 KPIs, representing a synthesis of expert opinions on the desired features of future UTC systems from a policy implementation perspective. The research makes an important contribution in eliciting the wide-ranging breadth of issues associated with delivering strategic transport policies and understanding how these issues affect the requirements LGAs have for future UTC systems. Aligning future UTC system capabilities with LGAs' requirements will enable more effective implementation of strategic urban transport policies worldwide and allow the benefits to society associated with those policies to be realised.

KEYWORDS

Strategic transport policy
Local Government Authority
Urban traffic management
Survey
User requirements
Key Performance Indicators

1 INTRODUCTION

In general, responsibility for strategic policy at the level of cities and towns (i.e. urban areas) is delegated from national government to Local Government Authorities (LGAs), although local policies must be implemented in the context of any overarching national policies (Hooghe and Marks 2003; Hooghe and Marks 2009). Urban traffic management and traffic signal control systems, hereafter abbreviated to Urban Traffic Control (UTC) systems, are used extensively worldwide by LGAs when implementing strategic transport policies within their areas of administration. However, it is not clear how well the requirements imposed by LGA policy implementation will be met by UTC systems being developed for the future. Therefore, the aim of this research was to analyse how delivery of strategic policies for urban transport over the next 5 to 10 years would shape LGAs' requirements for the next generation of UTC systems, and thereby to identify Key Performance Indicators (KPIs) to provide user-led guidance for the development of future systems. The research was conducted in collaboration with Siemens Mobility (a well-established manufacturer of UTC systems) and was carried out as an international two-stage survey: (1) an interview survey with suitable experts from around the world; and (2) an email survey of the same experts to assess consensus on interview survey results.

LGAs are the typical users of UTC systems and expert participants were recruited therefore from policy makers and implementers employed by LGAs in different regions worldwide. Participants were encouraged to see the survey as an opportunity to describe the desirable features of an ideal new UTC system to meet their requirements, rather than the features of a new system being constrained as an iterative development of an existing system, i.e. the purpose of the research was to consider a next generation UTC system unconstrained by the legacy of how existing systems are designed and operated.

In order to maximise the information captured during the survey, it was desirable to allow the expert participants the freedom to raise any/all issues they thought were important and relevant within their own view of what constituted their strategic transport policies. Therefore, a pre-determined definition of strategic transport policies was not imposed on participants so as to avoid being prescriptive and to minimise any potential for experts to feel restricted.

A review of the literature concerning user requirements from future UTC systems is reported (Section 2), followed by a description of the methodology used to conduct the interview and email surveys of expert participants (Section 3). Results of the analysis of the data collected during the interview and email surveys are presented (Section 4) and discussed (Section 5), including setting out the final list of

KPIs that represent a synthesis of participants' opinions on the desired features of future UTC systems. Finally, conclusions are drawn from the study (Section 6).

2 UTC SYSTEM USER REQUIREMENTS: A REVIEW

The research literature regarding the development of future UTC systems, and the requirements that users (i.e. LGAs) have from these systems in the context of achieving their strategic transport policy aims, was reviewed. However, the vast majority of the literature on future UTC systems was found to be concerned with the development and evaluation of specific system features, rather than the requirements of users (i.e. a focus on supply of, rather than demand for, UTC system features). For example, recent studies of specific features included the incorporation of Artificial Intelligence (AI) into UTC systems. Paraense *et al.* (2016) found that applying an AI method to traffic signal control on a simulated (9-intersection) urban road network produced average travel time reductions ranging from ~13-21% compared to existing (i.e. non-AI) methods. Araghi *et al.* (2015) found that AI methods "show a higher performance compared to traditional controlling methods" in terms of minimising total delay when controlling traffic signals at an isolated intersection. Mannion *et al.* (2016) evaluated three AI methods, all of which resulted in similar improvements (average speed increases, and average queue length and average waiting time reductions) when compared to a fixed signal timing method.

Other specific features were the incorporation of connected and/or autonomous vehicles (CAVs) technologies into UTC systems. Rios-Torres and Malikopoulos (2017) reviewed research trends regarding the incorporation of CAVs technologies for vehicle coordination at intersections and highway on-ramps, finding that typical objectives were improving traffic flow and reducing accidents. Guler *et al.* (2014) suggested connected vehicles technology "could significantly improve the operation of traffic at signalised intersections", and Feng *et al.* (2015) showed signal control based on connected vehicles technology could produce reductions of up to ~16% in total delay compared to existing methods. Wang *et al.* (2015) and Kumar *et al.* (2018) investigated the development of route planning algorithms based on real-time traffic information obtained from connected vehicles technology, with both studies finding that their proposed algorithms out-performed existing algorithms in terms of reductions in average travel time and average waiting time. Research by Zhang and Riedel (2017) and Ahmad *et al.* (2018) considered the mechanisms by which the data exchange enabled by connected vehicles technology might best be implemented within UTC systems to improve road network performance. Regarding autonomous vehicles technology, a range of mechanisms for controlling autonomous vehicles in the context of ensuring safe and efficient passage through intersections were evaluated by Zhang *et al.* (2015).

Incorporation of traffic signal priority systems was considered by He *et al.* (2014) in a study that developed a priority system for buses and pedestrians, which was found (based on a 2-intersection simulation) to be able to accommodate priority requests, whilst also reducing overall average bus, pedestrian and car delays. Ahmed and Hawas (2015) developed a traffic signal priority system for buses, with comparative performance assessed as "quite satisfactory" based on a simulated (49-intersection) road network. Nellore and Hancke (2016) reviewed the techniques used to incorporate Wireless Sensor Networks (WSNs) into UTC systems, finding that the main objectives tended to be reduction of congestion, reduction of average waiting time at intersections, and to provide priority for emergency vehicles. Gaber *et al.* (2018) proposed a new model for the use of WSNs in UTC systems that was found to be particularly energy efficient (in terms of power consumed by the sensor network) and to provide longer sensor network lifetimes compared to existing models. Chao and Chen (2014) proposed a new method for UTC systems incorporating Radio Frequency Identification (RFID) vehicle tags (for traffic flow detection) in conjunction with a WSN that was found to reduce traffic accidents and total delay compared to existing methods. Sundar *et al.* (2015) also proposed a UTC system incorporating RFID vehicle tags, with the system designed to reduce congestion, provide traffic signal priority for ambulances, and detect and stop stolen vehicles (red traffic signal). Wang *et al.* (2018) and Yan *et al.* (2017) both proposed the incorporation of crowdsensing data into UTC systems whereby messages initiated by vehicle drivers or passengers (e.g. reports of congestion, accidents or road surface damage) were communicated to the UTC system. The crowdsensing scheme proposed by Yan *et al.* (2017) was based on communications via a smartphone app, and included an incentive mechanism to encourage participation based on granting participating drivers access to increasingly detailed information on real-time traffic conditions. Both Liu *et al.* (2017) and Kumar *et al.* (2018) suggested UTC systems should incorporate connections to advanced 5G high-speed mobile wireless networks so as to enable improved communications and more rapid response speeds.

One study that did consider (to an extent) how well UTC systems were able to meet the requirements of users in implementing current and future transport policies was a study by Hamilton *et al.* (2013). However, the main concern of the study was to provide a comprehensive review of the history of the evolution of UTC system technologies to date (of publication in 2013), and no systematic collection and analysis of expert opinions on user requirements from future UTC systems was carried out. In addition, the review was conducted over five years ago now and the technologies available for incorporation in the features of the next generation of UTC systems have advanced since then (e.g. a paradigm shift from an era of limited data availability to one of data abundance).

In summary, no recent study (i.e. within the last ten years at least) could be found that provides an extensive, system-wide, global analysis of expert opinions on the desired features for future UTC systems from the perspective of LGA users implementing and achieving the aims of their strategic transport policies. Instead, the literature is generally focused on reporting the technical capabilities of emerging technologies that have been (or could be) developed as UTC system features, without necessarily analysing the extent to which those features are aligned with the requirements of users.

Conducting a comprehensive study of user requirements is important because only when those requirements have been analysed and understood can the development of future UTC systems be truly guided by and focused on what users actually need to help them realise their transport policy ambitions. This is the research gap in the existing literature addressed by this study. Undertaking such a study at this time is particularly apt because a paradigm shift is occurring from an era of data scarcity to one of data abundance (and the computing power necessary to utilise that abundance effectively, i.e. the rapidly emerging field of analysis of large and complex datasets often termed 'Big Data') meaning the range of potential capabilities that future UTC systems could provide is expanding (Zhang and Riedel 2017).

3 METHOD

3.1 Establishment of the Expert Panel

The purpose of the survey was to elicit expert opinions on what the next generation of UTC systems should be able to deliver to achieve ideal outcomes for users in terms of implementing strategic transport policies, and to produce a set of KPIs that synthesised those expert opinions and described the desirable features of future UTC systems. The set of KPIs can then serve as guidance during development of the next generation of systems.

The emphasis on policy delivery meant that selection of the expert panel for the survey was focused towards recruiting participants who were responsible for formulation and delivery of LGA strategic policy for urban transport (i.e. policy makers and implementers), rather than towards participants who were responsible for the day-to-day operation of UTC systems; although this focus was not adhered to rigidly, and where a potential participant had the requisite strategic policy knowledge they were not rejected because their main responsibility happened to be day-to-day UTC system operations. In fact, including some participants with experience of day-to-day operations was beneficial because they could identify possible issues regarding the practical application of the next generation of UTC systems. A general hierarchy of posts in a LGA organisation is shown in Figure 1, illustrated by specific examples drawn from Transport for London (TfL)[1]. The posts assessed as having the appropriate knowledge to serve as expert participants (asterisk in Figure 1) were: Head of Surface Transport; Head of Road Transport; and Road Transport Strategy and Operations Manager.

The survey was an international study and experts were selected from a range of countries in different world regions, with the specific countries and urban areas dictated by the access available through Siemens to named contacts in appropriate posts. The named contacts were then approached independently about their willingness to participate. The survey was approved by the University's Faculty Ethics Committee (ERGO number 45848). Experts from urban areas of varying population and geographic sizes were recruited to capture any variations in opinions that may exist due to these factors. The total number of participants was restricted for reasons of practicality within the time available for the study. Interviews were generally conducted individually, but one interview was conducted jointly because two participants from the same LGA wanted to have an input to the research. Consequently, 15 interviews took place between November 2018 and February 2019, involving 16 participants. Each participant was re-contacted separately for the subsequent email survey, which took place in April and May 2019. Participants were drawn from LGAs distributed as follows: Africa (1), North America (1), East Asia (1), Australasia (2), mainland Europe[2] (3), and the UK (7). Thirteen of these LGAs have administrative areas that are predominantly urban with characteristics[3] as follows: populations ranging from ~140,000 to ~8,800,000; areas ranging from ~40 to ~2,300 km^2; and population densities ranging from ~1,000 to ~7,500 persons/km^2. The remaining two LGAs administer larger regions, containing both urban and non-urban areas, with characteristics as follows: populations of ~900,000 and ~1,700,000; areas of ~5,400 and ~4,900 km^2; and population densities of ~170 and ~340 persons/km^2.

[1] TfL is the LGA responsible for implementing the Greater London Authority's (GLA) London-wide transport strategy in cooperation with the individual London Borough Councils.

[2] One LGA from each of Austria, Germany and Italy.

[3] Characteristics were obtained from https://www.citypopulation.de/

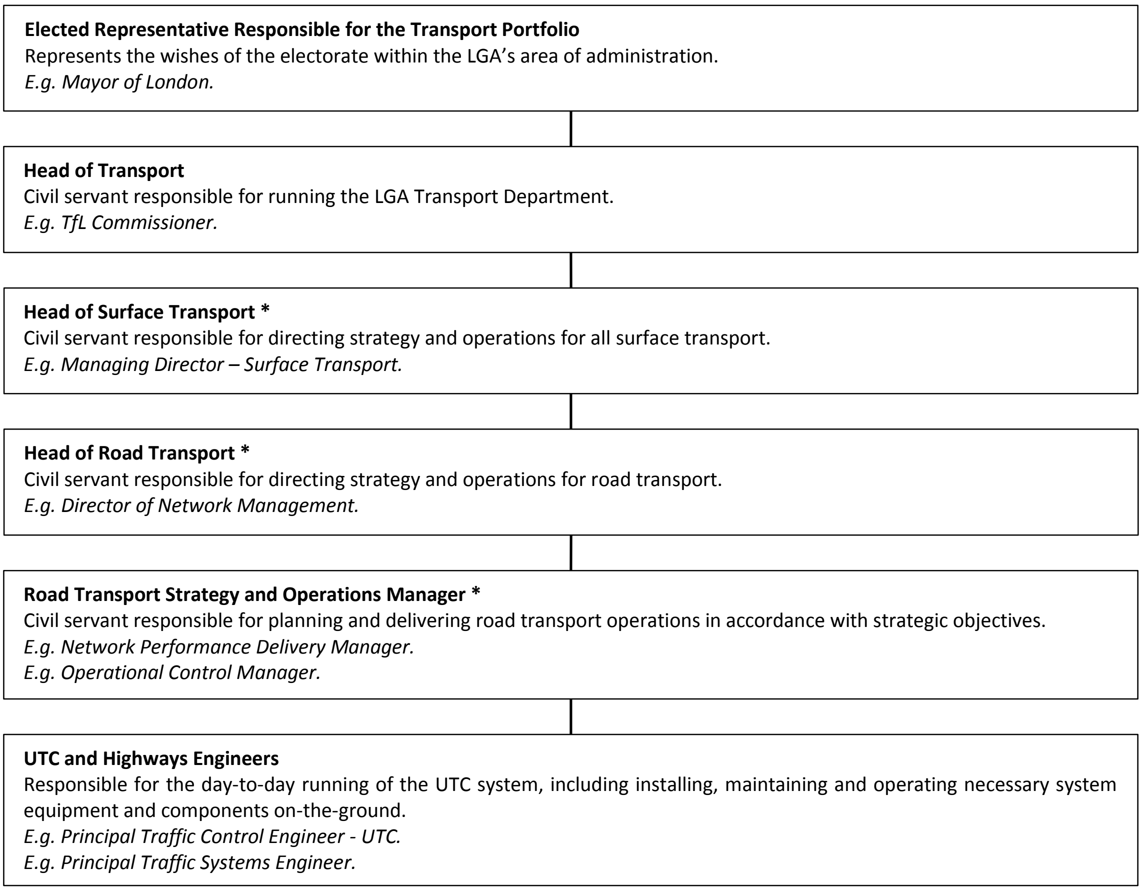

Figure 1: General hierarchy of posts in a large LGA organisation.
Examples of specific posts were obtained from information on TfL's organisational structure (TfL 2018a; TfL 2018b) and from personal contacts within TfL. * indicates posts assessed as having the appropriate knowledge to serve as expert participants in the study.

3.2 Delphi Technique

The survey was conducted using the Delphi technique, which has been widely used in many different contexts to elicit knowledge from a group of experts and arrive at a consensus to inform decision making or understand phenomena in greater depth (Brady 2015). The technique was appropriate because it has the necessary flexibility to accommodate the following features of the survey: (1) the participants were drawn from multiple geographically-distant locations, making face-to-face contact as a group impractical; (2) participants are in high-level management positions within their respective organisations, meaning flexibility was required to allow participation to fit around their busy schedules; and (3) the survey was designed to learn as much as possible from the participants in a relatively short time period (Brady 2015). The Delphi technique normally involves a series of rounds where information is fed back to participants to gain consensus (Keeney *et al.* 2001). The survey in the study involved two rounds (i.e. the interview survey stage followed by the email survey stage) after which consensus was reached.

3.3 Interview Survey Stage

A qualitative method was used for the interview survey stage (i.e. the collected interview data were analysed qualitatively using thematic analysis) because this allows themes and questions to be explored, whereas a quantitative method is best suited for testing a pre-existing theory through statistical analysis. In addition, the purpose of the study was to ascertain, and achieve consensus on, all the important KPIs, rather than to quantitatively rank the KPIs in order of importance (McIntyre-Hite 2016); although an indication of quantitative ranking was provided as a secondary result of the email survey stage of the study (Section 3.4).

Prior to interview, participants were provided with: a Participant Information Sheet (PIS) that explained the research, including their right to withdraw from the study; a Participant Consent Form to be signed and returned to the researcher once the participant had read and understood the PIS; and a Terminology Guide (included as Appendix A) to help specify the meaning of certain terms that might be used during the interview, which was important to establish compatibility of responses between participants (Turoff 1970). Each interview lasted approximately 30 minutes (mean interview length was 26 minutes) and followed the same semi-structured format using the questions shown in Table 1.

The interview questions were designed to be open questions serving as prompts to guide discussions, whilst avoiding being overly prescriptive such that potentially relevant issues might be excluded. Several questions were used for both main subject areas (i.e. strategic transport policies and desirable UTC system features) to provide multiple opportunities for participants to comment, and therefore maximise the likelihood of capturing the full breadth of issues they might want to discuss. Questions 1 to 3 concerned strategic transport policies and encouraged participants to consider this subject from various different perspectives. Questions 4 and 5 concerned the desirable features of UTC systems and encouraged participants to consider this subject initially from the perspective of their current system, before expanding to the features of a system that would deliver ideal outcomes in terms of implementing their strategic transport policies into the future. The interviews were conducted face-to-face or by telephone, and the audio from each interview recorded and then transcribed for analysis.

Table 1: Semi-structured interview questions.

Question Number	Question Text
1	How would you describe the aims of the strategic policy for transport of both people and goods in your city now and over the next 10 years? In other words, what are you trying to achieve for transport in your city? And have the aims changed at all during the last 5 years?
2	Is what you are trying to achieve for transport: • Different in different areas or along particular corridors of the city? • Different for different modes of transport (e.g. road, rail, bus, cycling and walking)? • Different for the transport of people compared to the transport of goods? • Different for different times of day (e.g. peak, inter-peak and off-peak)?
3	In terms of your strategic transport policy: what are the things you are aiming to stop doing; what are the things you are aiming to start doing; and what are the things you consider important to continue doing?
4	In terms of your current Urban Traffic Management System: what are the things you are aiming to stop doing; what are the things you are aiming to start doing; and what are the things you consider important to continue doing?
5	What are the system features you would like to have in an Urban Traffic Management System for your city designed to provide you with ideal outcomes in terms of implementing your strategic transport policy over the next 5, 10, 25 years?
6	Following analysis of the initial interview results (likely to be a period of a few weeks), we would like to contact a small number of the original participants again to review the summary of findings. Would you be happy for us to include you in this review phase if selected?

The interview transcripts were analysed collectively to produce a synthesis of expert opinions for the participant group as a whole, with the transcripts analysed qualitatively using thematic analysis to identify patterns within the data. Thematic analysis is a flexible method appropriate for identifying, analysing and reporting themes within qualitative data (Braun and Clarke 2006; Fereday and Muir-Cochrane 2006), and was used to provide a description of the entire interview data set, allowing a sense of the predominant themes to be acquired. The transcripts were read carefully to identify and code meaningful units of text relevant to LGA strategic transport policy and the desired characteristics of the next generation of UTC systems to enable policy delivery, such that units of text dealing with the same topic could be collected together under the same code (Frith and Gleeson 2004). A particular unit of text could be included in more than one code. The codes were then grouped into the predominant themes. The themes were closely linked to the data because an inductive (i.e. data-driven) approach was used for coding, rather than a theoretical approach where the data are coded according to a pre-existing theoretical framework or analytic preconception (Braun and Clarke 2006). Within each theme, individual KPIs were then formulated by combining codes dealing with similar topics, which produced an initial list of KPIs that described LGAs' desired features of future UTC systems.

3.4 Email Survey Stage

The purpose of the email survey stage was to provide a quantitative (statistical) assessment of the extent of group consensus on the initial list of KPIs. The initial list (ordered randomly) was distributed by email to all participants individually to allow them to indicate their level of agreement with the interview survey results. For each KPI, participants were asked to insert a score ranging from 0 to 10, where 0 indicated a KPI completely unimportant to their organisation and 10 indicated a KPI of critical importance. A free-text box was provided where participants were encouraged to describe any other desired features that were important to their organisation, which they believed to have been omitted from the KPIs.

4 RESULTS

Results from the study are presented in three sections: Section 4.1 describes results from the initial interview survey stage, Section 4.2 describes results from the subsequent email survey stage, and Section 4.3 presents the final list of KPIs.

4.1 Interview Survey Stage

The codebook compiled during the initial reading of the interview transcripts and used for the thematic analysis of the interview survey data is shown in Table 2. No significance should be inferred from the code order in Table 2, with codes numbered as convenient during the thematic analysis. The prevalence of each code (i.e. number of occurrences in the interview data) is also shown in Table 2, along with selected examples of participant quotations, although the example quotations often relate to more than one code. The codes were grouped into the predominant themes shown in Figure 2. The initial list of KPIs, formulated by combining individual codes on similar topics within each theme, is shown in Table 3. Inspection of Table 2 demonstrates just how wide-ranging the interviews were and the sheer breadth of issues raised by the participants. The study therefore provides a broad research base encompassing all aspects of LGA strategic transport policy around the world over the next ten years.

Table 2: Codebook, example quotations and code prevalence from the thematic analysis of the interview data.

Code No.	Code	Code Description and Example Quotations	Code Prev.
1	Walking	**Promotion or prioritisation of walking.** "Walking and cycling is very important because it promotes health, but it also gets people out of cars". "We also seek operationally to lower the wait time for pedestrians [crossing roads] as much as we can".	27
2	Cycling	**Promotion or prioritisation of cycling.** "You started to see more transformative schemes happening in [DELETED] like the East-West Cycle Super Highway, like the various cycle super highways that have gone in over the last few years". "[For cycling, we are] putting in nearside signals, we are putting in detection systems, and we have got some dedicated cycle lanes and dedicated cycle facilities which we wouldn't have seen in [DELETED] two years ago".	27
3	Bus	**Promotion or prioritisation of bus use.** "What we are thinking about, is differentiating the priority for public transport depending on time of day or depending on the delay. For example, ….it's more efficient to prioritise [a bus] that's late, and not all of them". "We have had a strategy of putting in bus lanes for the last five years, that has been hugely successful, and the strategy is to continue to grow bus lanes out to other areas of the city that don't have them today".	27

Table 2 continued

4	Rail	**Promotion or prioritisation of rail use.** "The trams run on the road network as well as their own network and all the trams have full priority at all times of the day". "We passed a bond a few years ago to extend our light rail….and so that's a major policy that's going to provide a lot more access into and out of the city".	12
5	Public Transport	**Promotion or prioritisation of public transport use without specifying which mode in particular.** "In the next ten years…., we would look to promote, actively promote public transport". "It is very usual to have public transport priorities, or as we call it public transport acceleration, at the traffic signals".	22
6	Shared Transport	**Promotion or prioritisation of vehicle sharing, i.e. travellers sharing vehicles either simultaneously (e.g. lift sharing) or over time (e.g. car clubs or cycle hire schemes).** "Our plan is to push in relation to the sharing mobility, ….car sharing, bike sharing, scooter sharing".	9
7	Travel Plans	**Promotion or prioritisation of Travel Plans.** "There is a lot of publicity going on about....travel plans, we have got officers who are working with local businesses, the schools, ….trying to change the behaviours of people in how they travel".	1
8	Park & Ride	**Promotion or prioritisation of Park & Ride schemes.** "Certainly a Park & Ride has gone in recently, and actually now has been expanded as a second bus service going to a different part of the city".	4
9	Shared Road Space	**Promotion or prioritisation of schemes designed to encourage shared road space between modes, i.e. pedestrians, cycling and motor vehicles.** "Shared [road] space, ….that can work brilliantly well".	1
10	MaaS	**Promotion or prioritisation of Mobility as a Service (MaaS), i.e. a shift away from personally owned transport to consumption of transport as a service from public/private providers.** "We were not able to reach the climate goals with a new kind of private car, we have to give up this idea that everybody has his own machine to realise the mobility".	1
11	Private Car	**Discouraging private car use.** "In the last five years a seismic shift from the old traditional 'the car is king'…., to the cyclist and pedestrian and other modes". "Certainly, we're trying to get more people out of their cars, trying to stop people coming into the city centre [by car] as much as possible".	23
12	EV	**Promotion or prioritisation of Electric Vehicle (EV) use.** "A move to electric vehicles is potentially quite positive, in terms of reducing the use of diesel vehicles, petrol vehicles, improving air quality".	7
13	AQ Emissions	**Improvement of Air Quality (AQ) through reducing polluting emissions from vehicles.** "In this sustainable mobility plan, we have also introduced a policy creating a low emission zone". "It's generally pollution, we have one of the highest PM_{10} concentrations in the whole of Europe…. and therefore we have to reduce it".	23
14	GHG Emissions	**Tackling climate change through reducing Greenhouse Gas (GHG) emissions from vehicles.** "To reduce pollution and….greenhouse gases".	3
15	Sustainable Road Freight	**Promotion or prioritisation of sustainable road freight operations, including restricting movements and operations of goods vehicles.** "We should be able to have, for example, at peak times have no freight vehicles". "I think we have to stop letting everyone deliver goods at every time to everywhere. We can't just let every single parcel and Amazon delivery be transported to the door within the historic city centre".	15
16	Freight Consolidation	**Promotion or prioritisation of freight consolidation to reduce goods vehicle movements.** "If you are dropping deliveries to a building, you are only going to a building once a day or twice a day, rather than 30 or 40 times a day". "We do get a lot of freight traffic and at the moment there are no projects specifically for freight aside from a freight consolidation centre for city centre deliveries, which has been running for years and is really, really good".	4
17	Congestion	**Reduction of congestion on the road network and maximisation of network throughput.** "We recognise the economic importance of keeping the road network moving". "We are very interested in the use of technology to try to improve [road network] capacity".	30
18	Journey Time Reliability	**Improved journey time reliability.** "I've been looking at things like journey time reliability". "Increasing our reliability of the transit service, so having dedicated right of way for buses".	2
19	Accessibility	**Improved accessibility and inclusivity of the transport network.** "You need to make sure that everybody, as much as possible, is included...., so that everyone can travel…., no matter what the choice of mode". "What we want to do more is transport accessibility, so transport for all. That means people with walking difficulties and disabilities".	4
20	Transport Safety	**Reduction of transport-related accidents.** "Road safety, always high on the agenda, very, very important". "[We have a] target that nobody is killed or seriously injured in the road network by 2041, with a subset of that to be that nobody is killed or seriously injured by buses on the network by 2030".	9
21	Compliance	**Enforcement measures to ensure compliance with rules and restrictions placed on road users.** "There's a lot of driver non-compliance with rules of the road". "People don't obey yellow boxes [box junctions] properly, and it causes congestion, it's that kind of enforcement stuff".	8

Table 2 continued

22	Expertise	**Reduction of the expertise, and associated training demands, required to operate UTC systems.** "There's a massive skills shortage in the industry". "A traffic specific problem of a brain drain of experienced staff…., which means [UTC systems] need to be more user-friendly". "Their expertise and their time, frankly, that's the most expensive thing that we've got, people's time. It needs to be better spent than having to tinker down in the weeds of obscure command line level stuff".	27
23	Manpower	**General lack of manpower, and reduction of the manpower required to operate UTC systems.** "I can never see an authority of our style being heavily resourced in staff, in manpower".	9
24	Funding	**General lack of funding, and reduction of the funding required to operate UTC systems.** "[In] the last three years I've concentrated on cost reduction and running the systems I've got as cheaply as possible, keeping them near the latest versions with the limited funding I have....; we've turned off a lot of systems that we didn't believe we were getting financial benefit from". "Virtually none of it's working anymore, because of austerity, everything's been switched off, not being used".	17
25	Maintenance	**Reduction of the maintenance required to operate UTC systems.** "From a maintenance perspective…., it can be quite onerous". "Keeping the [vehicle] detection active is a problem because of maintenance….[and] constant road repairs".	12
26	Network Monitoring	**Easy and reliable monitoring of transport network performance.** "Trying to pull that data out and having a nice interface to look at that data and say 'this is what's going on here'". "I want to also understand what the impact is on the modes…. We don't know that we're giving benefit to the buses over pedestrians, over cyclists, over vehicles. I have got no kind of dashboard, or any kind of stats to show me what's happening in terms of the traffic control".	14
27	Remote Working	**Ability to use remote/mobile working when operating the UTC system (e.g. using laptops away from the UTC control room).** "I'd like to see the technology keep pace for remote working…., you can have a mobile control room almost".	1
28	AI/Autonomy	**UTC systems with the ability to autonomously and intelligently react and seek optimal solutions in accordance with targets defined by operational personnel.** "It's got to be machine learning…., an adaptive system…., so it learns". *Interviewer:* "You could give it a simple target and the system would be able to work towards that target itself?" *Respondent:* "Yeah, exactly, exactly, so then from the user point of view, you don't need to be highly technical to be able to use these systems because the system will do a lot of it itself".	17
29	Real-Time Modelling	**UTC systems with the ability to model the outcomes of potential interventions in real-time.** "Modelling the whole network online…., real-time online modelling". "Real-time modelling and real-time prediction of what is going to happen in the next ten minutes".	7
30	Off-Line Modelling	**UTC systems with the ability to model the outcomes of potential interventions off-line.** "[At the moment], we can't model what's the proposed impact of this proposed scheme? How are we going to make it fit in with the wider network? What are queue lengths going to look like?". "When a new [shopping mall] opens we have no idea, how do you model what is going to be the impact? ….and then how do we build a transport network to support that?".	4
31	Usability	**Simple, user-friendly interface allowing desired UTC system targets/objectives/outcomes to be easily specified, set and adjusted by operational personnel.** "Having something that's a little bit more user friendly, ….[where] you don't have to go and learn a foreign language to dive into what's going on". "Usability at the moment, because it's very old, if you look at the technology behind it, it's very old, very mature, so it's not the easiest of systems to use; we certainly want something that's a bit easier to use than the current one". "[Ideally], if you wanted air quality, you would set it for air quality; if you wanted bus priority, you would set bus priority; if you wanted pedestrian priority, you would set pedestrian priority".	17
32	Incident Response	**Reduction of the time taken to detect and respond to incidents.** "We can be three hours before we know of an incident".	2
33	Cycle/Stage Flexibility	**UTC systems with flexible traffic signal cycle timing and stage ordering.** "The main [restriction] is that SCOOT has a cycle time. The way it optimises from one set of signals to another is the cycle time". "You've got this stage-based antiquated way of managing traffic".	2
34	Smart City/Region	**Integration into smart city/region schemes, i.e. innovation and technology to improve all aspects of area management (e.g. mobility, environment, government, economy, living space).** "I think the UTC system has to be part of the Smart City strategic development". "Another important measure we introduced in our sustainable mobility plan is to integrate all the mobility systems we have in our city. Public transport, all the sharing mobility, the tram lines, the train lines and so on, and we are working to create a bigger mobility service system".	9
35	CAVs	**Incorporation of Connected and Autonomous Vehicles (CAVs), including two-way data exchange with UTC systems.** "You have got to have a system which is capable of connecting to the vehicles, informing the vehicles, and providing them with information". "We need a method of traffic control that will utilise vehicle connected technology because if we can start to pick up the actual connected vehicles positioned in the network and feed that into SCOOT, we would no longer need to maintain detectors. And once that happens that will change the industry greatly because right now slot cutting [for Inductive Loop Detectors] is the biggest bill we pay and it's the biggest thing that goes wrong, and it's the hardest thing to have budget to fix".	17
36	Mobile Network Data	**Utilisation of Mobile Network Data (MND), i.e. tracking of mobile telephones based on a device's location relative to network base stations (cell towers).** "I would want it to be able to consume, obviously anonymised mobile phone data, vehicle data, occupancy data from vehicles".	1

Table 2 continued

37	GPS Data	**Utilisation of GPS data, i.e. tracking of GPS enabled devices.** “[The UTC system] needs to be GPS based [for sensing vehicle positions], and it needs to have that map spatial element so that it can properly understand the queues”. “You can buy [GPS data from Google Traffic] as a real-time feed, if you pay the money”.	4
38	Wi-Fi Data	**Utilisation of Wi-Fi data, i.e. tracking of Wi-Fi enabled devices.** “Units in the city which have Wi-Fi, basically like Wi-Fi readers, and so we can….calculate travel times throughout the city”.	1
39	Bluetooth Data	**Utilisation of Bluetooth data, i.e. tracking of Bluetooth enabled devices.** “It’s taking whatever data we have, be it car data, be it measured data from Bluetooth, ….and using them to give us a good picture and finding out exactly where the problems are at the moment”.	2
40	Video Analytics Data	**Utilisation of video analytics data.** “Certainly video analytics is looking quite good at the moment, ….you would have video analytics, which is looking at vehicle types, classification, cyclists, etc.”.	1
41	Weather Data	**Utilisation of weather data.** “We know when it’s a cold, wet morning, ...they’re all going to take their kids to school in the car, we can really predict where the problems are going to be….; our UTC [system] doesn’t know it’s a wet day”.	5
42	Pedestrian Data	**Utilisation of pedestrian count data.** “You would never really know which way to set up the network [signal timings] that benefits the most people. Bearing in mind there could be ten people on a bus, but there could be 50 people on a bus. And there could be 100 people waiting to cross the road, or there could be one or two people waiting to cross the road”.	5
43	Cyclist Data	**Utilisation of cyclist count data.** “Knowing that you’ve got cyclists coming, how you’d adapt and change the intersection maybe, because you’ve got cyclists coming”. “We have data around [passenger counts on] buses. What we are struggling to catch up on is reliable data around pedestrian counts and cycle counts”.	5
44	Passenger Data	**Utilisation of public transport passenger count data.** “If you’ve got connected vehicles you can say, ‘I am a bus’, and if it’s connecting to the ticket machine you can say, ‘with 27 passengers’”.	6
45	Goods Vehicle Load Data	**Utilisation of goods vehicle load data.** “There’s a desire to understand the goods traffic, ….how much value of goods go through that junction per hour”.	1
46	Toll Collection Data	**Automatic processing and collection of toll charges.** “We would also like the UTC system linked up to some sort of automatic toll collection….system”.	1
47	Data Feeds	**Ability to receive and fuse data feeds from any/all sources relevant to the transport network, i.e. Big Data compatibility.** “A lot more information [inputs]…., whatever they might be”. “I would call it some Big Data approach. Being able to incorporate external data which gives me a way of, or a possibility to, foresee some of the situations that could happen”. “It’s all the other data sources, like pedestrian numbers, cycle numbers, air quality, wind, weather, all this kind of stuff. Somehow, I want to be able to mash that in”.	32
48	Information Outputs	**Outputs to disseminate reliable information (e.g. travel information, route guidance, transport network performance, air quality) to citizens/travellers/policy makers in easily digestible formats (e.g. clearly presented information via apps and mobile devices).** “I’d like the UTC system to be able to influence behaviour. So, say simplistically, to tell a sat nav, don’t go down that road. Or tell a sat nav, send some down that road, some down that road, some down another road”. “Things that we want to do more is to make use of technology to give more information to the commuters. For example, to get real-time information on bus arrivals and bus loading and unloading so that they can choose the best time to travel”. “We intend to utilise the transport data a lot more so that we can start to say [for example] when this corridor was closed last time this was the impact of it. Are you [the policy makers] really happy allowing this to happen again?”.	24
49	Open API	**Open Application Programming Interface (API) for use by third parties.** “It definitely needs to be open source”. “It should be that there’s some form of API that anybody can subscribe to”.	2
50	Interoperability	**Interoperability with UTC system components supplied by other manufacturers.** “Manufacturers maintaining proprietary code on their equipment which is not compatible with other manufacturers, but if....another manufacturer [then supplies UTC system components] for your city you need the codes to be compatible or else you’ve got a problem”.	2
51	Cloud Computing	**UTC systems that can be hosted on cloud-based servers.** “Ideally everything will move to cloud-based”.	3

MaaS is Mobility as a Service; EV is Electric Vehicle; AQ is Air Quality; PM_{10} is Particulate Matter (≤10 µm); GHG is Greenhouse Gas; AI is Artificial Intelligence; SCOOT is Split, Cycle and Offset Optimisation Technique (a UTC system); CAVs are Connected and Autonomous Vehicles; and API is Application Programming Interface.

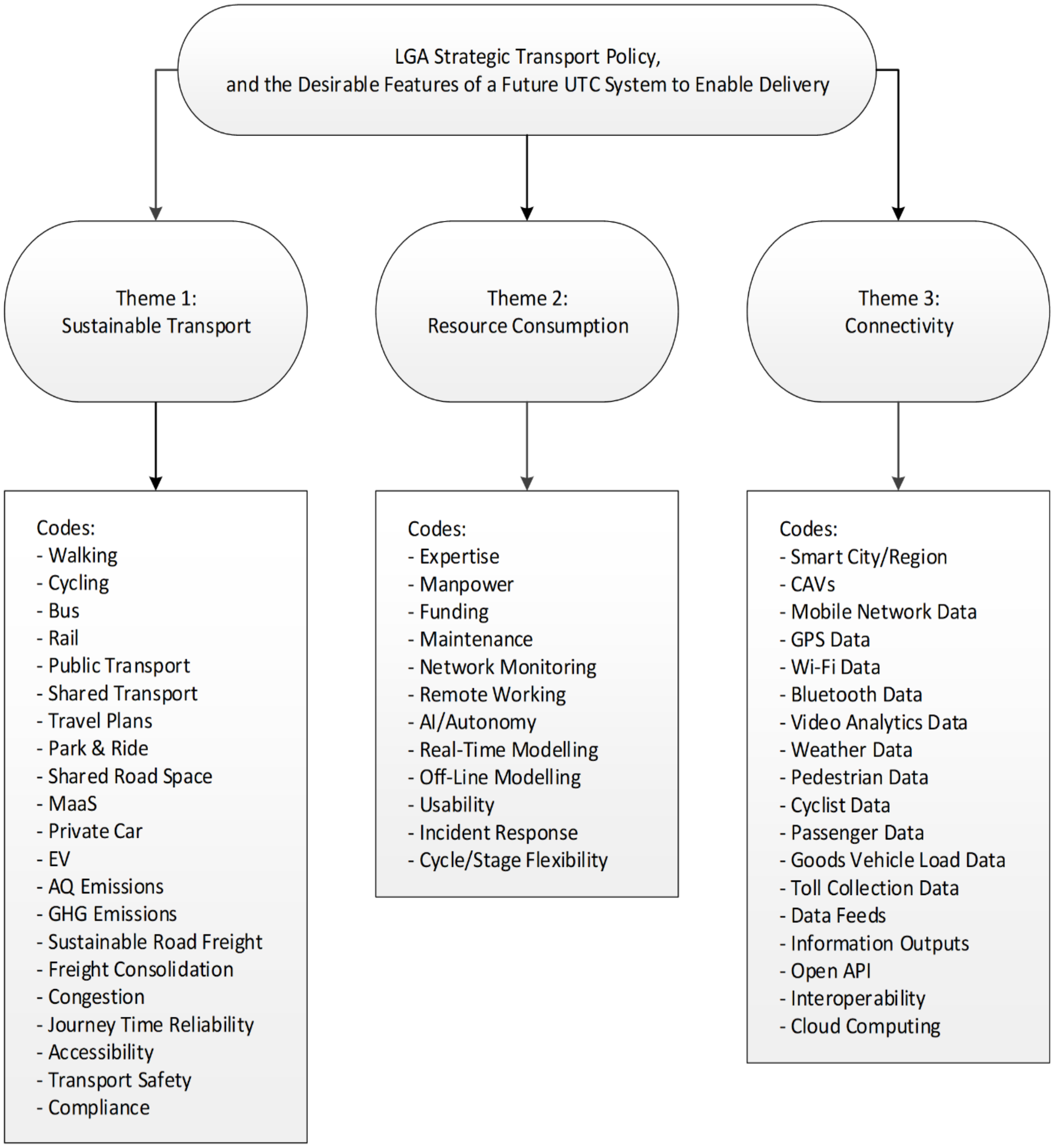

Figure 2: Diagram of the themes and codes for LGA strategic policy and the desired features of future UTC systems. Refer to Table 2 notes for abbreviation expansions.

Table 3: Initial list of KPIs resulting from the interview survey stage of the study.

KPI No.	KPI [and Codes Included in the KPI]	Combined Code Prev.
	SUSTAINABLE TRANSPORT THEME	
1.1	A UTC system that enables the prioritisation and promotion of a range of modes (e.g. walking, cycling, public transport, EVs) as alternatives to petroleum-based private car use. [1, 2, 3, 4, 5, 11, 12]	145
1.2	A UTC system that reduces congestion and maximises throughput on the road network. [17]	30
1.3	A UTC system that prioritises improvement of air quality and the reduction of adverse climate effects through reducing vehicle emissions. [13, 14]	26
1.4	A UTC system that promotes the sharing of urban space, safely and in compliance with regulations, by users of a transport network easily accessible for all regardless of mode. [9, 19, 20, 21]	22
1.5	A UTC system that enables the prioritisation and promotion of sustainable road freight operations. [15, 16]	19
1.6	A UTC system that supports shared transport, travel planning, Park & Ride, and MaaS as travel options. [6, 7, 8, 10]	15
1.7	A UTC system that improves journey time reliability. [18]	2
	RESOURCE CONSUMPTION THEME	
2.1	A UTC system that operates with reduced requirements for manpower and maintenance (e.g. network performance monitoring, incident detection). [23, 24, 25, 26, 27, 32]	55
2.2	A UTC system that has a high degree of usability, requiring less expertise and associated training for operational personnel. [22, 31]	44
2.3	A UTC system that incorporates Artificial Intelligence that autonomously seeks to achieve targets defined by operational personnel. [28]	17
2.4	A UTC system that has the capability to model the outcomes of potential transport network interventions before implementation. [29, 30]	11
2.5	A UTC system that has a high degree of flexibility in configuration (e.g. traffic signal cycle timing and stage ordering). [33]	2
	CONNECTIVITY THEME	
3.1	A UTC system that can fuse information from any/all relevant sources (e.g. traditional traffic monitoring and emerging data sources). [36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 50]	66
3.2	A UTC system that can disseminate reliable information to citizens, travellers and policy makers in easily digestible formats. [48]	24
3.3	A UTC system that can communicate with Connected and Autonomous Vehicles. [35]	17
3.4	A UTC system that has an open Application Programming Interface (API) (e.g. allowing use by third-parties and integration into wider smart cities). [34, 49]	11
3.5	A UTC system that can be hosted on cloud-based servers. [51]	3

4.2 Email Survey Stage

All of the original sixteen participants responded to the email survey. Results from the statistical analysis of importance scores are shown in Table 4, with a higher mean score (range 0 to 10) indicating a more important KPI. Mean importance scores are all greater than 5 (the mid-point), which indicates that, on average, every KPI was regarded as important to some extent. Response scores were found to be non-normally distributed for some KPIs, and a Friedman test (Friedman 1937) was appropriate therefore to determine if the observed differences in participant responses to the different KPIs were statistically significant (Field 2009). Results of the test showed there were no statistically significant differences ($p<0.05$) between the responses to the KPIs, which means (statistically) the KPIs were all regarded as equally important. The implications of this are discussed further in Section 5. Friedman test mean rankings are shown in Table 4. There are 17 KPIs in total, so ranks can range from 1 to 17, with a higher ranking indicating a more important KPI.

Table 4: Friedman test mean rankings and mean importance scores for KPIs in the initial list.

KPI No.	KPI	Friedman Mean Rank	Mean Importance Score
1.1	A UTC system that enables the prioritisation and promotion of a range of modes (e.g. walking, cycling, public transport, EVs) as alternatives to petroleum-based private car use.	11.28	8.25
3.4	A UTC system that has an open API (e.g. allowing use by third-parties and integration into wider smart cities).	10.47	7.88
1.2	A UTC system that reduces congestion and maximises throughput on the road network.	10.28	7.75
2.5	A UTC system that has a high degree of flexibility in configuration (e.g. traffic signal cycle timing and stage ordering).	9.97	7.63
2.2	A UTC system that has a high degree of usability, requiring less expertise and associated training for operational personnel.	9.88	7.63
3.1	A UTC system that can fuse information from any/all relevant sources (e.g. traditional traffic monitoring and emerging data sources).	9.72	7.81
1.7	A UTC system that improves journey time reliability.	9.63	7.63
1.4	A UTC system that promotes the sharing of urban space, safely and in compliance with regulations, by users of a transport network easily accessible for all regardless of mode.	9.44	7.33
2.3	A UTC system that incorporates Artificial Intelligence that autonomously seeks to achieve targets defined by operational personnel.	9.31	7.50
1.6	A UTC system that supports shared transport, travel planning, Park & Ride, and MaaS as travel options.	9.06	7.31
1.3	A UTC system that prioritises improvement of air quality and the reduction of adverse climate effects through reducing vehicle emissions.	8.22	6.94
3.3	A UTC system that can communicate with Connected and Autonomous Vehicles.	8.19	7.06
2.1	A UTC system that operates with reduced requirements for manpower and maintenance (e.g. network performance monitoring, incident detection).	7.78	7.00
2.4	A UTC system that has the capability to model the outcomes of potential transport network interventions before implementation.	7.75	6.50
1.5	A UTC system that enables the prioritisation and promotion of sustainable road freight operations.	7.59	6.94
3.2	A UTC system that can disseminate reliable information to citizens, travellers and policy makers in easily digestible formats.	7.25	6.25
3.5	A UTC system that can be hosted on cloud-based servers.	7.19	6.47

n=16. KPIs are ordered according to Friedman mean ranks, which is slightly different to the order of mean importance scores, because Friedman test results provide a better indication of how participants ranked the importance of each KPI relative to the other KPIs.

In ten (63%) of the sixteen email surveys returned, participants did not insert any remarks into the free-text box designated for describing omitted KPI features, indicating there were no desired features thought to have been omitted and therefore no additions or adjustments to the KPIs were necessary in response. Six participants did insert remarks and their comments typically concerned: (1) further explanations of scores (e.g. that scores represented the LGA's short/medium-term position, but could change slightly if viewed from a longer-term perspective); (2) fine-tuning of the wording of the initial KPIs (e.g. explicit mention to be included in the KPIs of a desire for UTC systems with reduced requirements for financial resources); or (3) requests for very specific features that were already included in a more general sense by the initial KPIs (e.g. a desire for UTC systems that provide clear information about (and log) the impact of signal timing decisions on different modes, which is covered generally by the network monitoring aspects of KPIs 2.1 and 3.2 in Table 3). Remarks in (1) and (3) were also taken to indicate there were no desired features thought to have been omitted because (1) concerned explanations of scores rather than omitted features and (3) concerned specific features already included more broadly, and therefore no additions or adjustments to the initial KPIs were necessary in response. Remarks in (2) did require some adjustments to the initial KPIs in response, but these were only very minor adjustments (e.g. a few instances of minor re-wording), which are shown in the final list of KPIs in Table 5. One other remark suggested an addition to the initial KPIs in the form of an overarching aim for future UTC systems of having “complete flexibility over what is controlled and how”, enabling the system to respond to any/all future strategic transport policies even if they are currently undefined.

4.3 Final List of KPIs

The final list of KPIs is provided in Table 5 in accordance with the importance order (within each theme) determined by the Friedman test mean rankings, and Figure 3 is provided as a graphical representation of the information. The final list has been re-ordered compared to the initial list (which was presented in prevalence order in Table 3). With the exception of KPI S.1 (originally KPI 1.1) which topped both lists, there appears to be very little correlation between how many times a topic is mentioned (i.e. code prevalence) and the importance of a topic to the participants. The Pearson linear correlation coefficient between code prevalence and Friedman test mean ranking values for the KPIs (excluding KPI S.1/1.1) was found to be only 0.07.

Table 5: Final list of KPIs.

KPI No. (see notes below table)	KPI
	SUSTAINABLE TRANSPORT THEME
S.1 *(1.1)*	A UTC system that enables the prioritisation and promotion of a range of modes (e.g. walking, cycling, public transport, EVs) as alternatives to petroleum-based private car use.
S.2 *(1.2)*	A UTC system that reduces congestion and maximises throughput on the road network.
S.3 *(1.7)*	A UTC system that improves journey time reliability.
S.4 *(1.4)*	A UTC system that promotes the sharing of urban space, safely and in compliance with regulations, by users of a transport network easily accessible for all regardless of mode.
S.5 *(1.6)*	A UTC system that promotes shared transport, travel planning, Park & Ride, and MaaS as travel options.
S.6 *(1.3)*	A UTC system that prioritises improvement of air quality and the reduction of adverse climate effects through reducing vehicle emissions.
S.7 *(1.5)*	A UTC system that enables the prioritisation and promotion of sustainable road freight operations.
	RESOURCE CONSUMPTION THEME
R.1 *(2.5)*	A UTC system that has a high degree of flexibility in configuration (e.g. traffic signal cycle timing and stage ordering).
R.2 *(2.2)*	A UTC system that has a high degree of usability, requiring less expertise and associated training for operational personnel.
R.3 *(2.3)*	A UTC system that autonomously (e.g. via Artificial Intelligence) seeks to achieve policy-led targets defined by operational personnel.
R.4 *(2.1)*	A UTC system that operates with reduced requirements for financial, manpower and maintenance resources (e.g. easy network performance monitoring, rapid incident detection).
R.5 *(2.4)*	A UTC system that has the capability to model the outcomes of potential transport network interventions before implementation.
	CONNECTIVITY THEME
C.1 *(3.4)*	A UTC system that has an open Application Programming Interface (API) (e.g. allowing use by third-parties and integration into wider smart cities).
C.2 *(3.1)*	A UTC system that can fuse information from any/all relevant sources (e.g. traditional traffic monitoring and emerging data sources).
C.3 *(3.3)*	A UTC system that can communicate with Connected and Autonomous Vehicles.
C.4 *(3.2)*	A UTC system that can disseminate reliable information to citizens, travellers and policy makers in easily digestible formats.
C.5 *(3.5)*	A UTC system that can be hosted on cloud-based servers.

Initial KPI numbers from Table 3 are shown in italic brackets alongside the final alphanumeric labels, demonstrating how the KPIs have been re-ordered.

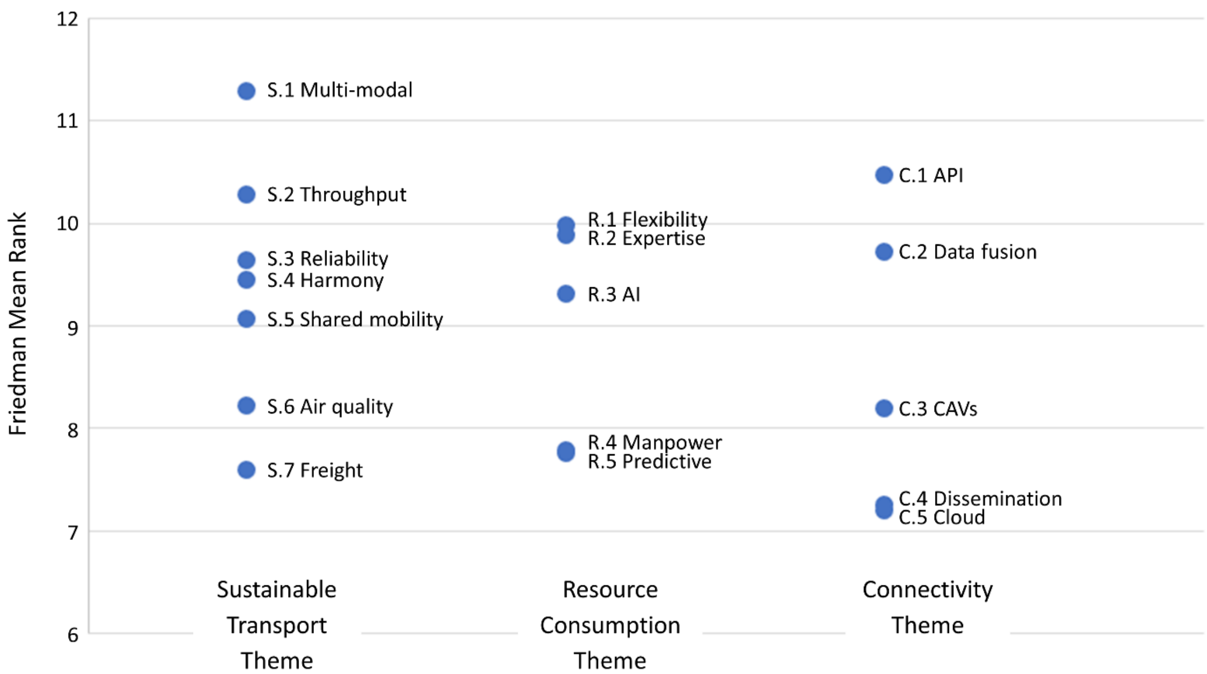

Figure 3: Friedman test mean rankings for final list KPIs.
Refer to Table 5 for full descriptions of the KPIs. Refer to Table 2 notes for abbreviation expansions. Higher Friedman mean ranking values (ranks can range from 1 to 17) indicate higher importance.

5 DISCUSSION

Results of the interview survey (Section 4.1) showed that the features LGAs desire in future UTC systems to enable the delivery of their strategic transport policies can be grouped into three predominant themes: (1) the Sustainable Transport theme groups codes associated with transport provision in accordance with the widely used definition of sustainable development, i.e. the three pillars of economic, social and environmental benefits; (2) the Resource Consumption theme groups codes associated with the desire for UTC systems to have a high degree of usability, reducing the resources required to run the systems and minimising the burden placed on LGAs' resource budgets, which are often very limited (Lowndes and McCaughie 2013); and (3) the Connectivity theme groups codes associated with the desire for UTC systems to have good connectivity, being able to utilise data from, and disseminate information to, a multitude of modern, interconnected technological systems and devices, both now and emerging in the future. It could be argued that the Resource Consumption theme is a sub-theme of the Sustainable Transport theme, encompassed by the economic pillar of sustainable development. However, the particular issue of resource consumption by UTC systems was raised on many occasions during the interviews, and it was therefore assessed as warranting a separate theme.

Results of the email survey (Section 4.2) showed that all the KPIs were seen as important to some extent by the group of participants (mean importance scores all >5). The lack of statistical differences found between the KPIs supported the notion that all the KPIs were important, and showed that no KPIs particularly dominated importance or were particularly irrelevant (i.e. all KPIs were statistically as important as each other). In addition, the results showed a general lack of participant remarks in the free-text box regarding desired features believed to have been omitted from the list of KPIs. In combination, these three aspects of the email survey results (mean importance scores, lack of statistical differences and lack of free-text remarks) indicated that group consensus had been achieved on the desired features of future UTC systems. The addition to the KPIs of an overarching aim of complete system flexibility to enable responsiveness to future, as yet undefined, strategic transport policies was considered in response to the relevant free-text remark (Section 4.2). However, this over-arching aim was not ultimately added to the final list of KPIs because such an open-ended aim would be difficult for a UTC system manufacturer to deliver in any practical sense. The final list included some minor re-wording of KPIs to incorporate participants' free-text remarks in response to the email survey (Section 4.2). However, the adjustments were only very minor ensuring consistency was retained with the initial list of KPIs on which group consensus was achieved.

A secondary result of the email survey stage (Section 4.2) was an indication of the order of importance of the KPIs based on Friedman test mean rankings, as shown in the final list of KPIs in Table 5 and graphically in Figure 3. However, the importance order is only indicative (i.e. no statistically significant differences were found) and a larger sample size than was practical in this study is likely to be required to provide a definitive importance order that can be generalised to the wider population. Based on this indicative order of importance, it appears that, even when encouraged to consider strategic plans extending 5-10 years into the future, participants still displayed a slight tendency to shorter-term attitudes. For example, a highly useable (KPI R.2) and flexible (KPI R.1) UTC system that reduces congestion and maximises throughput (KPI S.2) was ranked highly, whereas a UTC system that prioritises reducing AQ and GHG emissions (KPI S.6) and can communicate with CAVs (KPI C.3) was assigned lower priority. A slight tendency towards shorter-term attitudes was not unexpected and is probably unavoidable to an extent when eliciting opinions from experts who may be predisposed to this way of thinking because immediate judgment of their performance (e.g. throughput of traffic on a day-to-day basis) tends to take (perceived) precedence over longer-term judgments (e.g. impacts on climate change). However, this possible tendency to shorter-term attitudes is a caveat to the study results.

The discrepancies between the orders of the KPIs in the final list (indicative statistical importance order in Table 5) and the initial list (prevalence order in Table 3) highlight the earlier point that prevalence of mentions by participants is not necessarily a good indicator of importance (Section 4.3). For example, a lot of work may have been done by a LGA on various schemes to encourage bus travel, which are described on multiple, discrete occasions throughout the interview; whereas a general lack of monetary funding may be a more important factor for the LGA, but is simple to express and mentioned on relatively few occasions. Consequently, despite the lack of statistically significant differences, the Friedman test mean rankings are likely to be a better indicator of the definitive order of KPI importance, and therefore the final list of KPIs (Table 5) was presented in accordance with the importance order (within each theme) determined by the Friedman test results. However, in general, it is important to remember that order of importance should not be given undue emphasis or attention because the order was only indicative. The more noteworthy aspect of the results to emphasise is that group consensus had been achieved on the desired features of future UTC systems, described by a set of KPIs all viewed as important by the group of participants.

It is not possible to be completely certain what was in participants' minds during their responses to the interview and email surveys. A potential issue with the study results therefore is a degree of uncertainty about whether responses were reflective of individual-level or organisational-level attitudes to the desirable features of future UTC systems. The aim of the study was to elicit organisational-level attitudes because formulation and delivery of LGA strategic policy for urban transport occurs through organisational decisions, rather than decisions made by individual employees. This issue was minimised by ensuring participants understood they had been selected as representatives of their LGAs for the interview survey, and by asking participants to provide scores to indicate the importance of KPIs to their organisation during the email survey.

The study sample size (n=16) was relatively small; although the Delphi technique does not have any strict guidelines for sample size (McIntyre-Hite 2016), and n=16 was within the range of participant numbers (3 to 98) for typical Delphi expert panels found in a meta-study by Rowe and Wright (1999). In addition, there was an over-representation of participants from the UK in the sample (7 out of 16), meaning potential bias towards the attitudes of UK LGAs was a caveat to study results. Every effort was made within the practical constraints of study resources to maximise the sample size and obtain a geographically even distribution of participants, and the constitution of the expert panel ultimately recruited reflects the difficulties associated with gaining access to senior personnel at LGAs around the world willing to find the time in their busy schedules to participate.

6 CONCLUSIONS

This was a two-stage study. During the first stage, interviews were carried out with key personnel (i.e. policy makers and implementers) from LGAs around the world in order to understand the requirements that LGAs have of the next generation of UTC systems in the context of implementing their strategic transport policies over the next 5 to 10 years. Thematic analysis of the interview survey data resulted in the formulation of an initial list of KPIs that synthesised participants' opinions. The KPIs were categorised according to the predominant themes of the interview data, which were sustainable transport, resource consumption and connectivity.

During the second stage, an email survey was used to allow participants to comment on the initial list of KPIs and to assess quantitatively the extent of group consensus. Analysis of the email survey results indicated that group consensus had been achieved on a final list of 17 KPIs as a description of the desired features of future UTC systems from a LGA policy implementation perspective, with the group of participants rating all KPIs as important to their organisations. The final list (Table 5) was presented according to Friedman test mean rankings as the best available indicator of relative importance, although importance order should not be given undue emphasis because it was only indicative.

Drawbacks of the study were the relatively low number of participants (although the sample size was within the range for typical Delphi expert panels) and an over-representation of UK LGAs. Prospective further work could address these issues through conducting a larger study, which recruited a greater number of participants more evenly distributed across global regions. This would reduce the likelihood of bias towards a particular country, and allow a definitive order of importance for KPIs to be produced.

The research elicited the wide-ranging breadth of issues associated with delivering strategic transport policies and analysed how these issues affect the requirements LGAs have for future UTC systems. These were important and necessary first-steps if the development of the next generation of UTC systems is to be conducted under user-led guidance informed by policy implementation. The list of KPIs produced by the study allows system manufacturers to take note of what LGA users of their products actually want, and act accordingly when developing the capabilities of future systems. The research was particularly apt at a time when the emerging era of data abundance (and the computing power necessary to take advantage of that abundance) means that the range of potential capabilities that systems could provide is expanding. Aligning future UTC system capabilities with LGAs' requirements will enable more effective implementation of strategic urban transport policies worldwide and allow the benefits to society associated with those policies to be realised.

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APPENDIX A

Table A.1: Terminology Guide distributed to participants in the interview survey.

Term	Meaning
IMPORTANCE (Priority or Relevance)	
Very Important	– a most relevant point – first order priority – has direct bearing on major issues – must be resolved, dealt with or treated
Important	– is relevant to the issue – second order priority – significant impact but not until other items are treated – does not have to be fully resolved
Slightly Important	– insignificantly relevant – third order priority – has little importance – not a determining factor to a major issue
Unimportant	– no priority – no relevance – no measurable effect – should be dropped as an item to consider
CONFIDENCE (Validity of argument or premise)	
Certain	– low risk of being wrong – decisions based on this will not be wrong because of this “fact” – most inferences drawn from this will be true
Reliable	– some risk of being wrong – willing to make decisions based on this but recognising some chance of error – some incorrect inferences can be drawn
Risky	– substantial risk of being wrong – not willing to make decisions based on this alone – many incorrect inferences can be drawn
Unreliable	– great risk of being wrong – of no use as a decision basis
DESIRABILITY (Effectiveness or Benefits)	
Very Desirable	– will have a positive effect and little or no negative effect – extremely beneficial – justifiable on its own merit
Desirable	– will have a positive effect, negative effects minor – beneficial – justifiable as a by-product or in conjunction with other items
Undesirable	– will have a negative effect – harmful – may be justified only as a by-product of a very desirable item, not justified as a by-product of a desirable item
Very Undesirable	– will have a major negative effect – extremely harmful – not justifiable
PROBABILITY (Likelihood)	
Very Probable	– almost certain to occur – strong indications of this happening
Probable	– better than a fifty-fifty chance of occurring – some indications of this happening
Either Way	– fifty-fifty – could go either way
Improbable	– less than a fifty-fifty chance of occurring – some indications of this not happening
Very Improbable	– almost certain not to occur – strong indications against this happening
FEASIBILITY (Practicality)	

Definitely Feasible	– no hindrance to implementation – no R&D required – no political roadblocks – acceptable to the public
Possibly Feasible	– some indication this is implementable – some R&D still required – further consideration or preparation to be given to political or public reaction
Possibly Infeasible	– some indication this is unworkable – significant unanswered questions
Definitely Infeasible	– all indications are negative – unworkable – cannot be implemented
PROBLEM TYPE	
Public	– relating to the public and its attitudes and reactions to government actions
Political	– relating to the decision making process in government at national or local level
Technical	– relating to actual implementation questions
Economical	– relating to the problem of funding
TIME	
Now	– can happen or take place this year
Soon	– one to five years
Near Future	– five to ten years
Future	– ten to twenty-five years
Far Future	– over twenty-five years
COST	
Insignificant	– accommodated in the annual budget without concern
Small	– minor effect on the annual budget
Moderate	– effect on budgets over several years
High	– major effect on budgets over 5 to 10 years
Very High	– major effect on budgets over more than 10 years

Source: adapted from Turoff (1970).