Digitally-Enabled Electric Vehicles As-a-Service: Exploring the 'Tri-Opt' of Novel Private Transport Business Models

***Abstract*—Three distinct trends are emerging to shake-up the dominance of privately-owned, combustion car transport in the UK. First is the emergence of the electric powertrain as an affordable means of transport; this carries the potential to address many of the pump-to-tire shortcomings, especially CO2 emissions, air and noise pollution. The second is the rise of new hire models of car ownership: the concept of paying for the use of a car per single leg of a journey, also addressing systematic impact such as residential parking and social division. Thirdly, the rise of 'smart city thinking', the concept that increased connectivity, data and smart grids can be harnessed to create value, especially in transport. We define the combination of the three as the 'Tri-Opt' of private transport – three disruptors that should not be considered in isolation but as interacting levers – an inflection of the 'Energy Trilemma'.**

In this paper, we apply systems thinking and utilise a mixed methodology of workshops, interviews and systems modelling drawing upon the UK city of Bristol's *Smart EV Transport Hub* project to identify concepts that positively combine two or more of these three 'Opts'. Subsequently, the use cases are evaluated qualitatively for their comparative value, and segmentation is undertaken to characterise and generalise groups of concepts to inform recommended stakeholder actions. We demonstrate that synergistic overlaps are many and they create significant value; thus the 'Tri-Opt' notion should be investigated further. Our data highlights that of the greatest value are those use cases that the current literature base has explored the least, and can be characterised as requiring significant public and private sector collaboration. It is highly recommended that public-private sector collaboration in private transport – within a context of digital innovation – electric vehicles, smart grids and mobility as a service model, is subject to further research and investigation.

I. Introduction

A. Problem Space

A GROWING corpus of research is gathering consensus on the view that the prevailing Western private transport paradigm has a finite lifespan; a transport culture that consists of overwhelmingly privately-owned internal combustion engine automobiles is unlikely to survive the next 50 years in its current form, in the face of economic, social, and environmental pressures [1]–[3]. Several distinct trends have emerged a as potential disruptors in existing research. Three in particular are identified and focused upon within this paper; firstly, the emergence of electrical motors as the primary alternate powertrain for private automobiles [4], [5]. Secondly – and more in its infancy – the trend of transitions to new car use models, which is regularly referred to within the collective term of 'Mobility as a Service' [6]. A third – the broadest and most in its infancy – the emergence of the smart city theorem. This capitalises on the use of systems that harness the opportunities increased data and connectivity present to provide value [7]–[9] where disruption to private transport, measured on any one of these individual trends is, at present, slow. Electric cars only make up a negligible share of the UK car market, with limited charging infrastructure outside of major urban areas [10]; short-term hire transport models have yet to be proved at a significant scale in the UK, beyond simpler transport situations, such as bicycles [11]; and smart cities are, in many cases, little more than a long term strategic aspiration, with some instances of demonstrators, most of which are too early in their lifetime to be able to provide any substantial conclusions about the value of data.

Some of the most successful disruptive private transport initiatives of recent times can however often be observed combining two or three of these opportunities. AutoLib, the Paris-based EV car hire scheme offers one-directional trips around the city and since 2011 has already grown to over 500,000 members and 4,000 cars. Tesla Motors have also heavily emphasised new business models enabled by data and the role of new ownership models in their latest corporate strategy release [12]. Existing literature has extensively examined each trend in its isolation, and to a limited degree there is exploration of combinations of two, but there is almost no consideration of triple-overlaps (see Figure 1), nor of the notion of synergy between the three trends as a principle. The idea of three significant issues needing to be considered in conjunction with one another is not a radical concept however, as seen in the inverse, but principally similar, 'energy trilemma' [13]. This paper – building substantially upon previous work [14] – will focus on investigating the manifestations of the overlaps of these three opportunities within the context of the city of Bristol in the UK.

B. Electric Vehicles

Electric vehicles (EVs) can offer an environmentally sustainable alternative to internal combustion engines (ICEs). EVs are powered by a battery which is charged through the electricity network. Alongside reducing carbon emissions, EVs can also improve noise and air quality, provide savings for consumers and reduce dependency on specific fossil fuels [15]. It is widely accepted that an alternate energy source is necessary for the UK transport network in the near future, and electrification is currently considered the most likely choice. The Department for Transport predicts that by 2020 there will be 1.5m EVs on the road in the UK [10].

Most of the world's major automotive companies have released purpose-designed electric cars (as a opposed to 'engine-swap-out' models); some have gone so far as to make significant strategic investment in the concept by releasing an entire

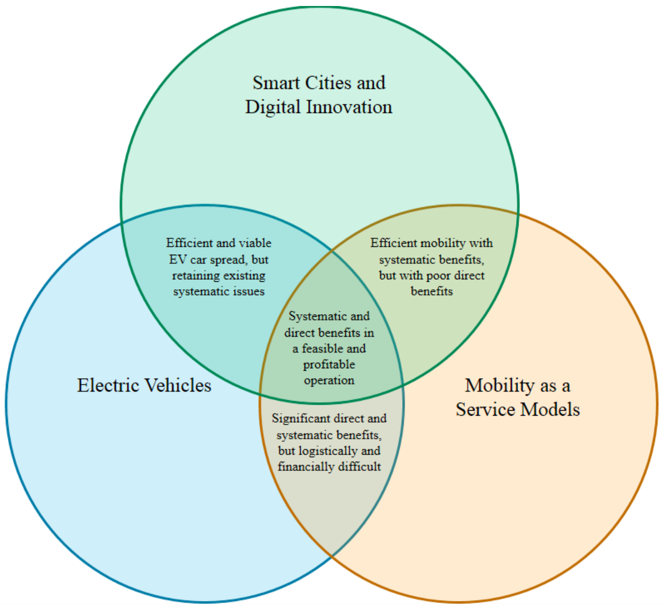

Fig. 1. The proposed 'Tri-Opt' of positive opportunities to disrupt the private sector transport paradigm in developed countries.

electric car range, for example BMW's i Series range. The direct 'pump-to-tire' environmental benefits of electric cars, lower particulate emissions, lower noise emissions and lower operational CO2 emissions, are highly significant. Legislation in many countries is acting in two ways: penalising internal combustion engine users, and incentivising the purchase of EVs. Electric cars bring with them several caveats, however: the capital cost of EVs, predominantly due to current battery technology, is yet to be comparable to an equivalent internal combustion engine car; the embodied carbon of EVs, again due to the battery component, is on average considerably higher than an equivalent internal combustion engine, and the generation of electricity to meet charging patterns is theorised to bring with it considerable logistical difficulties on national grids [16], [17].

There are a number of barriers to the adoption of EVs. Many of these are psychological, for example range anxiety; consumers worry that they may 'run out of juice' [18], [19]. However, 95% of all vehicle journeys in the UK are less than 25 miles (40km) [18], only a small proportion of existing EV's range. Other consumer barriers include: concerns over battery lifetimes, the risk associated with investing in a relatively new technology and the current, comparatively large capital investment required to purchase an EV. Personal vehicles and small commercial vehicles account for 13% of all UK carbon emissions [20]; by transitioning to EVs in these sectors, the overall volume of emissions could be significantly reduced. Due to the nature of UK car culture, fleet vehicles accounted for 63% of all new vehicle sales in the UK in 2011 and as such are a dominant influence on the type of cars for sale in the used market [21]. There is a growing trend for EVs in fleet vehicles, so it is likely a tangible used EV market will start to emerge in the next five years.

C. Digital Innovation and Smart Technologies

Smart technology is a new and rapidly growing concept; as such, a consensus of its exact definition has yet to be reached. Key stakeholders, including academics, policymakers and industrial experts have identified the fundamental, unifying theme as the use of data and connectivity to produce value [22]–[26]. The rise of interest in data-based possibilities for the built environment is regularly cited as being fuelled by three key developments:

1) *The rapid increase in the production of data.* Computer scientists have stated that many social trends, such as the rise of internet connectivity (specifically high-speed mobile Internet), and social networking, has caused an exponential increase in the production of data, especially big social data; the abundance of such a resource has spurred consideration as to its potential use.
2) *The rapid increase in the ability to collect specific data.* Improvements in sensor and communication technology have meant the installation of data collection devices is now both financially and spatially practical [7]. The development of mesh networks, the notion of deploying distributed sensors across a large area, can provide a high resolution or accuracy of data or the ability to track the movement of entities. Furthermore, the Internet of Things, the notion that with the deployment of connected sensors on existing everyday objects, interactions that are currently machine-human- machine could simply be machine-machine, allowing many such processes to be faster, cheaper and more convenient.
3) *Improvements in data storage and processing.* Following Moore's Law/Kryder's Law, storage is far cheaper than ever before, allowing this vast data to be stored. Processing power is also much greater, allowing complex trends from data on scales so vast as a city to be processed and actioned fast enough to be considered 'live'.

Many such sources refer to data as a raw material (perhaps even an emerging fifth 'utility', joining electricity, gas, water and telephone networks), creating the notion that data can and should be used as an input to a business model that is then translated to value. In recent years the practicalities of collecting and processing a vast quantity of high value data of a system, as discussed, has developed significantly [23]. Such a system could be a house, business or city, with data being the movement of containers in a factory, the journeys of cars across an urban network, or the use of electricity residentially. Increasingly, this also represents the pressing focus on whole-life environmental impacts of ICTs [27]. The sheer volume of data available for such a large range of systems has led to the term 'big data' now commonly used to refer to a datastream large enough to make smart value-producing systems feasible [28]–[30]. This may involve taking data across traditional 'silos' [31], [32]. 'Creating value' can be interpreted in many ways, including the translation of a process to be:

- *Faster:* for example, using traffic data to update signs in real time, rather than the slow, reactive methods by which traffic is informally advised against taking certain routes.

- *Fairer:* for example, demand-based pricing for grid electricity, whereby data from the national grid is used to charge those who use electricity when demand is highest (when the cost of generation is highest), a cost that is reflective of the cost to supply the electricity to them, and vice versa in periods of low demand.
- *At lower cost:* for example, flow sensors in water pipes can be used to deduce the exact location of leaks when they emerge, rather than expensive and time-consuming visual inspections [33].
- *Without human interaction:* for example, when an inspection robot is automatically sent to the site of a machine malfunction in a factory, rather than a human noticing the fault and piloting the robot manually. This can improve instances of both human error, hesitation and subjective judgment (for better or for worse).

While there is acknowledgement that it is not without ethical and societal concerns [34], [35], there is an extensive literature base documenting the potential impact of digital innovation, through these improvements, in the transport sector [36].

D. New Ownership Models

'Mobility as a Service' has grown to be a concept that is specifically appreciated in modern transport dialogues [6]. It is best defined as a transition from a paradigm of relying on a product that is purchased to provide mobility functionality, to a service where the outcome of moving from one location to another is provided, disassociated from any requirement for asset ownership, and typically arranged on a journey-by-journey basis.

In other modes of private transport in the UK, particularly bike use, an increasing number of users are opting to participate in short term hire models of use, particularly in urban contexts. Rather than bearing the capital and logistical cost of owning a bike, individuals hire the bike for a nominal fee from a given node near their origin, complete their journey, and return the bike to a node near their destination. In essence, they are purchasing mobility per-leg of their journey, or 'as-a-service'. Once seen as radical, examples such as Londons cycle hire (a.k.a. "Boris Bike") scheme demonstrated not only the feasibility of the business model, but also the efficacy of the indirect benefits, illustrated by significant increase in cycling in the city bringing health benefits, but also the notion of these as a substitute for car journeys. A range of drivers have been suggested for the emergence of this paradigm:

- *Changing societal values:* whereby evidence has suggested a decrease in the cultural value placed on car ownership; conflict with an increased desire to live in vibrant urban areas within walking distance of workplace and other amenities and the spatial restrictions of car ownership in such scenarios [37].
- *Changing economic situations:* increasing costs of car ownership, particularly in insurance (particularly for young individuals) and fuel cost.
- *Changing effectiveness of privately-owned car transportation:* an increasing frustration with congested transport systems and an increasing desire to travel to A-to-B reliably, regardless of the specific comfort of one's 'own' motor vehicle.
- *Proof of concept:* Driven by commercial ventures showing the viability of alternate private transport paradigms. Traditional car hire companies in particular are beginning to explore short-term, distributed 'car club', return journey ('A-to-A' journeys) offerings, whereas emerging start-ups are offering entire by-leg services, such as the aforementioned Autolib.

II. Methodology

A. Objectives

This paper sets out to achieve the following objectives:

1) To explore a range of use cases for how the opportunities in the aforementioned 'tri-opt' overlap in the UK's private transport, in combinations of two or three, to produce value.
2) To understand, to a qualitative and relative degree of accuracy, the varying value perceived by our stakeholders to be presented in the identified use cases.
3) To segment the use cases, considering a combination of their characteristics and value potential, with a view to forming recommended policymaker actions.

B. Philosophy

This paper will take a systems thinking perspective to divergently consider the instances of when these trends create double and triple overlaps. With respect to the definition and measurement of value, due the broad scope of this paper, value will be considered qualitatively, with an emphasis on a use case's relative value compared to other identified use cases. Value will be considered to all stakeholders within the system boundary – in this case the city of Bristol, UK. To add rigor to this process, during engagement with stakeholders, the framework shown in Figure 2 was used, combining three approaches for considering value.

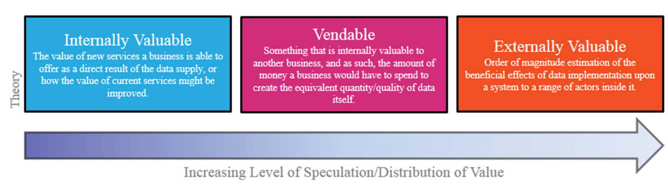

Fig. 2. Valuation methods

C. Methods

This paper implies a mixed methods approach, primarily but not exclusively – focused around a joint Bristol City Council and Bristol University research study into the potential of a 'smart electric vehicle transport hub' – a development that combined the three proposed trends on a physical site offering both public (bus and 'park and ride') and private (as-a-service electric car hire) transport services. The methods used are as follows:

- Five two-hour workshops with the presence of senior Bristol City Council staff, senior University of Bristol academics, and consulting engineers from built environment consultancy Arup;
- Ten semi-structured one hour interviews with a range of transport stakeholders in the city of Bristol, including bus operators, policy legislators, legal and financial professionals, all providing insight anonymously;
- A survey of 48 citizens of Bristol subscribed to Source West, an independent non-profit organisation representing the interests of citizens using electric vehicles;

III. Results

A. Individual Uses Cases

1) Car Component State (Smart/MaaS): In the traditional car hire industry, it is practice is to operate a maintenance regime that involves inspection above the recommended frequency, designed to reduce the time between inspections when the car may suffer from a freak failure. Freak failures are defined as those whereby there was no indication at the last inspection that the car would fail before the next testing. Using health and usage monitoring sensors attached to key components in the car, an operator of cars-as-a-service offering could gathering insight on a car's mechanical state close to the quality of that offered by a human inspection, in real time. This could drastically reduce the rate of freak failures in such a service that may have extremely fast turnarounds between regular and short customer uses. If the sensor coverage was sufficient enough, potentially allow cut backs in human servicing.

2) Live Air Quality Management (Smart/MaaS): Bristol City Council currently monitors air quality by semi-permanent installations at specific areas around the city. In a typical UK urban environment, particularly one with no major industry, air quality is primarily determined by road transport emissions. As such, if it was possible to understand the overall distribution of vehicles in the city at any one point in time, it is a reasonable hypothesis to believe it is possible to estimate, with relative accuracy, the air quality throughout the entire city. At present, in some areas of the city, car flow is monitored by car-recognising cameras. These however are sparse and expensive to install. Cars-as-a-service are likely to use the same roads to the same intensity of other cars on the road at that time. In other words, their road routing behaviour is likely to be very similar, if not identical, to the rest of the cars on the road at that time. As such, a critical resolution of hire cars is necessary to deduce an estimate of the wider car resolution. A particular opportunity with a MaaS model is to directly affix air quality sensors on to cars, gathering primary air quality data directly.

3) Live Accident Reporting (Smart/MaaS): Cars-as-service can also be fitted with impact sensors, altering the MaaS management system that a car has suffered a serious crash, allowing them to contact the authorities. Due to the significant improvement in road safety regulations, mobile phones have already improved road transport since the mid-2000s, and the relative rarity of isolated crashes, it is unlikely the value case here can be made from a practical improvement in fatality rates from car hire use. Instead, it is probable that the main benefit of such a system would be perceptual improved piece of mind for the customer that a system will be in place to constantly evaluate their safety, as well as pre-warning a traffic control system of potential disruption.

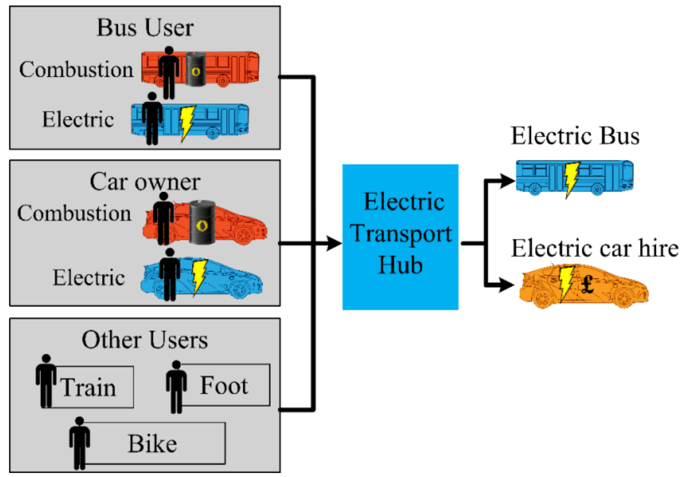

Fig. 3. An overview of the functionality of Bristol's Smart Electric Transport Hub, structured by input transport modes (left) and output transport services

4) User Journey Data (Smart/MaaS): Many retail and advertisement companies using big data have demonstrated that advertisement conversion rates (the percentage of individuals who act on an advertisement they have seen) can be greatly increased by accurate targeting of the advert to the correct recipient. Traditionally, this would be done by geographical area or age group. More recently however, with the ability to better express to the world your other preferences and personal situation through social media networks, it is possible to advertise to people of a specific relationship status, group affiliation or fans of similar services. Facebook and Spotify are prime examples of how specific demographic, geographic and chronological conditions are set to not only able to return high conversion rates, and thus, higher-priced advertising to customers, but also, as a result, able to vend smaller advertising exposures as a tangible product. This means a greater number of clients, and thus a more robust business model.

In a cars-as-a-service model, two potential avenues of value creation are possible. Firstly, information on the journeys of car hire individuals alongside the time they drive and their personal characteristics, could be vended in a data package to companies in retail and leisure industries. These companies would have otherwise had to undertake expensive customer research, thus the value is clear. However, this is very likely to suffer from extremely low consent rates, as it would perhaps be the most invasive form of personal data harvesting currently in existence. Alternatively, consent rates may well be much higher if the data was instead used to form targeted advertising at point of booking. This way, organisations could offer discounts to individuals it feels it may be able to convert to using their business on the trip, incentivising them to consent to the scheme. Furthermore, this could be done dynamically through the common advanced display systems that are available in modern automobiles. The revenue stream here will be twofold: the advertising organisations will pay for the in-car advertising rights, and individuals would be more inclined to travel through the MaaS model if special offers would be available as a user.

5) Demand-based Pricing (Smart/MaaS/EV): An alternate method to control congestion is to bring economic forces to bare on when an individual chooses to travel. In practice, a MaaS could include an additional influence based on the expected congestion of the roads at point of travel, attempting to deter travel that would exacerbate the congestion. Ultimately, this requires the highest critical resolution of hire cars of all the use cases addressed here. Furthermore, many ethical dilemmas exist. It might be extremely unpopular that the most sustainable cars are essentially 'taxed' into staying off the roads, while the unsustainable private transport is free to do as it wishes.

However another interpretation is around the ability to better control demand for the service, a key consideration for electric vehicles due to the fact that, even in the increasing affordability of fast chargers, EVs require considerably longer than ICE cars to transition from zero to full range capacity. Thirdly, this can also be used to manage car supply and demand between different nodes of car collection. For example, the following situations within a booking could threaten the ability to service later bookings:

1) *Inclement driving conditions:* EVs are susceptible to have sizeable variation of energy use per mile depending on driving conditions. Cold weather can have negative effects on electric torque. Additionally, heaters in EVs are unable to use the waste heat that a combustion car generates, so additional power from the battery is required; as much as 15% in certain circumstances [10]. Live battery data can allow the car hire management system to know the exact power use of a journey.
2) *Congestion:* Traffic can significantly decrease the efficiency of the EV, although the effect is less than compared to a combustion car as EV engine can turn off and on seamlessly. More significantly, congestion greatly increases the journey time. Car speed data and GPS location data can inform the booking management system when a car is stuck in traffic.
3) *Satellite navigation:* If an individual decides to take a longer route home, or even a route of the same duration of time but a greater use of charge (such as a longer motorway route compared to a slower trunk route). Live satellite navigation data can inform the booking management system the minute the drive has this intention.

Pre-warning of any of these unforeseen circumstances can allow immediate shifting of the booking system to reflect increased hire duration or increased charging duration. This will prevent people booking in a time when the car will now be driving/charging. The value from this system comes from improved reliability of the car hire service. A simulation exploring the potential impact of demand-based pricing on revenue and variance of booking density, for a designed node of an smart EV MaaS node, can be seen in Figure 4.

As can be observed, it is possible to create a scenario where both total revenue is increased and bookings are more evenly

$$Price\ (per\ hour) = Mean\ Price\ (per\ hour) * \left(\frac{Relative\ Popularity}{Average\ Popularity}\right)^{Smart\ constant}$$

distributed. This mechanism could be made stronger – or seen to be more of a 'carrot' than a 'stick' strategy by the use of reduced parking costs in non- or limited-nodal MaaS systems.

6) Driving Styles and Usage Habits (Smart/EV/MaaS): As a high growth market, the EV market is currently undergoing heavy R&D investment. As a distinctly different driving experience, automotive designers are particularly interested in how users interact with the vehicle [38]. Such data is not currently commonplace and as such; to create this car manufacturers spend capital on customer surveys, on-road testing and other investments.

A similar situation can be observed in the in the car insurance industry; at present relatively few car insurers offer cover for EVs due to a poor understanding of their risk. Those that do offer prices above the ICE equivalent average 16-26% more. It is unclear if EV owners drive in an identical manner to combustion car owners, or if they are at a higher risk of collision due to lower noise and potential higher accelerations than combustion cars. Furthermore, many fundamental components of the EV have yet to come close to their expected end of life, so it is risky for insurers who do not know if the vehicles will reach their rated life.

Similar to the understanding of how individuals operate electric cars, the UKs National Grid would be interested in how individuals charge their EVs, as this will heavily influence how the grid develops in the next 50 years. Although typically our EV's have predetermined charging patterns, EVs that are taken on multi-day rentals will most likely require charging to address the specific needs of the hirer. This provides a valid insight into the charging habits of EV users [39], [40]. The value from this system comes from the created market of vending charging habits to the UK's National Grid. It is reasonable to assume there is value in these data sets to the operator of an EV MaaS system, through external sale, if a data strategy was in place to collect and store the insight.

7) Dynamic Traffic Routing (Smart/MaaS): Understanding the average speed of a road's cars allows the city's transport management to predict the related areas of congestion. The necessary resolution of this is much lower i.e. the speed of a given stretch of road is largely similar for all vehicles driving along it. Knowing such information in real time, the city transport management can employ data-based traffic management techniques. One of the most common of these is the notion of dynamic traffic rerouting. Road users are directed to the fastest route to a given location by being mindful of congestion. The car hire scheme takes this concept one step further, as it will be possible to understand where individuals are planning on driving in advance. With this information, mitigation actions that would previously be considered to have too long a lead time even in the 'live' mode can be implemented. For example, higher use of contraflow lanes that can be dynamically adjusted to allow for the particular nature of the rush hour traffic, increased public transport frequencies

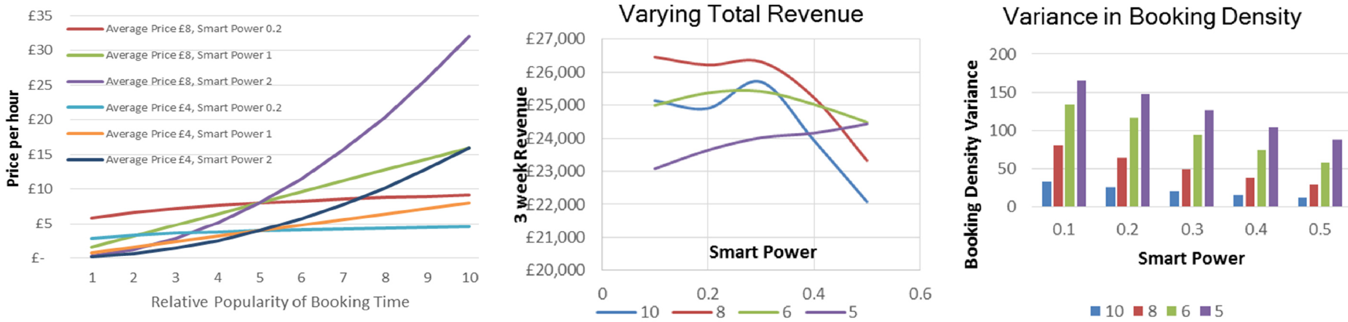

Fig. 4. Data regarding price sensitivity, customer flexibility and estimated footfall collected during the *Bristol Smart EV Hub* project.

to help move demand off the roads, or variable speed limits to maximise flow rates and relieve bottlenecks.

Much of the infrastructure necessary to facilitate this has already been tested at scale: dynamic lane direction has proven successful in Birmingham and the M25 has extensive supporting evidence about its dynamic speed limit interventions. This infrastructure could be improved in effectiveness from data that was faster and more accurate than existing, predominantly analogue sensing techniques. A criticism of this concept might be that such data sets are currently collected by digital firms such as Google. Such data however is not readily available to cities, and when it does, it typically comes with a substantial cost. A MaaS service would have access to this data and could provide it to the city's transport team.

8) Grid Balancing (EV/Smart/MaaS): Grid balancing is a generalised term for the concept of taking action to mitigate for surpluses or shortages in a region or nations electricity generation. In some definitions, balancing involves transferring power into the grid, but many techniques of simply avoiding drawing power (aka. 'shedding') are considered balancing by the UK Government [41]. The challenge of balancing the network is becoming much larger with more distributed generation and larger power demands. Many stakeholders in the UK's energy industry are increasingly providing financial incentives for these services and view it as an important challenge of the future.

This is increasingly relevant to EVs as they represent a growing load on the grid; some studies have suggested even moderate uptake of EVs might increase national power demand by up to 23% in some areas by 2021. However, of greater concern is how EVs will increase the variation (essentially the peakiness) in grid demand, a quality that is harder to service than total demand. However, at the same time their potential to be used as charge storing devices enables a situation whereby rather than being a burden on the grid which needs to be minimised, they can be a positive asset to provide charge to meet demand at peak times. Typically batteries have a very quick response rate to grid requirements, something other balancing solutions can lack. This would be exacerbated in a MaaS offering, whereby the value of the charge to the grid at that time is factored into the cost of someone instead using that charge to drive the car. The cars could then be used as grid balancing charge storage in periods of lower demand.

IV. Use Case Value Comparison

A. Workshops/Interviews

It is clear there is great variation in the perception of value in the identified use cases, and the certainty to which we understand this value and the path to realise it. These are presented in Figure 5. From observation of the results, three categories can be generalised:

- *Segment 3*, those that have by far the greatest benefit but are also the most uncertain. Typically these require highest critical masses and require the considerable, cross-sector stakeholder buy-in. However, their potential value could be described as extreme. Discussion highlighted how these, typically have the most diverse forms of value, spanning environmental, social and economic value, beyond simply financial benefits. While due to the substantial barriers, there is little probability that this group will be implemented in the short term, the significant potential cannot be ignored.
- *Segment 2*, with moderate benefit whose uncertainty is somewhat less and who enjoy good overall value/certainty ratio. These are typically mechanisms that involve the collection, management and external vending of data. How UK law changes with respect to data use, as well as how contract culture changes with respect to data transactions will have a great influence. Many local governments or devolved city regions, including Bristol, are aspiring to wider open data initiatives, a system where similar data sets are freely available (and reusable), and the data is realised through the new businesses that open as a result. There is an ongoing debate about how data monetisation strategies, such as these, are compatible with open data philosophies.
- *Segment 1*, with relatively low value but relatively high certainty. This group are best characterised as 'operational' changes, and as such require relatively little collaboration across stakeholder groups.

Graphical approximations of these characteristics across the three segments can be seen in Figure 6.

V. Conclusion

There is clearly synergistic value within the overlaps of the proposed 'Tri-Opt', confirming the original hypothesis.

Fig. 5. Results from workshop exercises on assigning qualitative value scores to use cases (note: log scale)

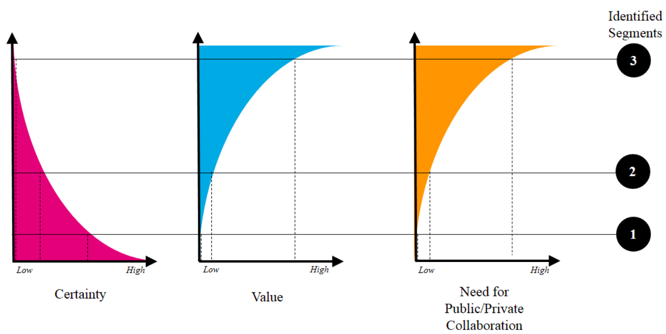

Fig. 6. Generalised relationships across identified segments

However it appears the specifics of this are somewhat different to initial speculation. The findings suggest concepts that combine MaaS offerings and digital innovation are the main focus of value creation which was favoured over MaaS, EV and digital tri-overlaps. While we can still conclude that the notion of the triple overlaps exist as an area to be considered, the original equal status hypothesised is incorrect, and that EVs are perhaps considered as a significant development that is set within the context of two more transformative opportunities of MaaS and digital innovation. Reviewing the concepts that have emerged through our methodology, value appears to span a wide range, but is overall significant. Certainty is also variable but generally averages at a lower point.

With respect to recommendations that can be inferred from the findings within this paper:

- *Segment 1* should be considered good operational practice for smart, MaaS EV services. However they are not transformative, and generally provide limited value, so should not be considered high priority focuses.
- *Segment 2* should be considered as positive additional revenue streams for smart, MaaS EV services. In particular, they may be beneficial for improving business cases to the degree that such services can attract investment and be launched, so releasing the individual benefits of each "Opt". While offering good value for relative certainty, they are not transformative in and of themselves and should not be considered end goals.
- *Segment 3* can be considered long term strategic focuses that have transformative value, and have underlying mechanisms that span beyond transport. Currently highly uncertain, understanding these, conceptually, should be a long term, pan-city, high priority aspiration.

It is important to note that this paper does not set out to define the value cases of the individual "Opts" themselves – such as reduced sunk-cost-induced car use in a MaaS model – and is designed to be a study of interaction of the three opportunities rather than appraisal of each concept by itself – of which there is extensive literature already in existence as explored in Section I. These recommendations however should be appreciated within the context of the individual benefits of MaaS, smart cities and digital innovation and electric vehicles.

Our results suggest that there are significantly more barriers than enablers at play in these double and triple overlapping concepts. Of most significance in the eyes of the participants, and of most relevance to the highest-value segment of use cases, is the need for public and private sector collaboration. It seems reasonable to presume this is a barrier for 'as-a-service' and digital innovation concepts across a range of city services.

VI. Future Work

For application beyond transport, it is recommended that the underlying generic mechanisms at play that create value are explored. The particular emphasis on MaaS and digital innovation suggests 'digitally-enabled innovative business models' may be the best starting point for considering these. Taking away the transport context, several can be observed in our research: including sharing of data to mutual benefit (e.g. driving habits), supporting new service delivery models that bring public benefit (e.g. dynamic car routing) and assistance of delivering public policy (e.g. demand-based pricing to reduce congestion).

Little or no research could be found that defines a framework of these mechanisms and there is a significant evidence base that private sector participation in city digital initiatives is a regular criticism by the public sector [42], thus it can be hypothesised there is value in understanding this issue better. Related to this, digitally-enabled public and private collaboration needs to be understood better, as it currently stands as the major barrier. The distribution of value/risk/investment identified as part of this, and articulated in a simplified causal loop diagram in Figure 7, need to be further investigated.

Acknowledgment

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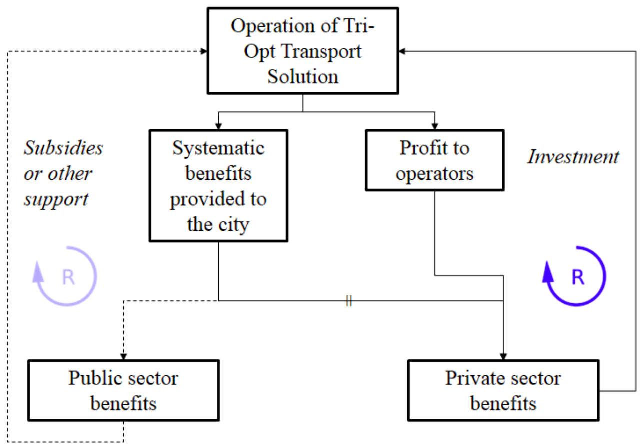

Fig. 7. A causal loop diagram articulating the investment/value dilemma of some tri-opt transport solutions.

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