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DESIGNING WHOLE JOURNEY, MULTIMODALTRANSPORT PROVISION

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My research has been within design departments, applying user-centred design to wicked problems in health, education, regeneration and transportation.
I have received grants in excess of £15 million, including research on the design of polysensory school environments for children with ASD, the involvement of children in the Building Schools for the Future Programme, the contributions of citizens to urban regeneration (VoiceYourView), and the development of patient held records (MyCare).
I have developed a user testing toolkit for SMEs (IDEAL-ALIP project) and decision support for SMEs in assistive technology (COMODAL).
I am theme lead for Future Cities in the Research Institute in Transport and Future Cities, looking at car safety and security of female occupants, the HMI of electric vehicles, a stakeholder analysis of an electric bus, and a review of social transport.
I led the FP7 project METPEX to successful conclusion in 2016, developing a Pan European tool to measure the quality of multimodal, end to end passenger experiences.
Currently I lead the 4 year H2020CIVITAS SUITS project, with 23 partners across EU. Our aim is to increase the capacity and capability of smaller local authorities to design and implement sustainable transport measures.
I also have an AHRC network bid looking at women's mobility problems in Malaysia and Pakistan

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My research interests have been in: CAD support for industrial design in the transport industry, socially aware design, and design pedagogy. The CAD work was driven by research grants in the 1990s, and the recent work on socially responsible design culminated in a book on design for transport. Through leading our Centre of Excellence in Product and Automotive Design I focused on design pedagogy, which I pursued further through leading the Design Pedagogy Special Interest Group of the Design Research Society for 9 years and producing a book on Design Pedagogy.

During the 1980s I was responsible for the establishment and development of transport design, which achieved international prominence. I was Dean of the Coventry School of Art

and Design for 18 years. During this time it doubled in size, achieving strong research rankings. I pioneered design research, contributing publications and holding a number of research council grants. The context for this work has been concept design in the automotive industry and developing techniques to support the design activity.

From 2007 to 2010 I was Director for Design, responsible for leading and coordinating design education and design research .I am now based in the Research Institute in Transport and Future Cities, contributing to a number of research projects.

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ABSTRACT

EU transport research is led by a vision of sustainable, accessible, inclusive, joined up transport services. The FP7 METPEX project developed a standardised tool for measuring the quality of multimodal whole journeys, to identify where public transport could be improved to attract more users, combatting the fragmentation which characterizes transport design and research. With 16 European partners in 12 countries, KPIs were developed articulating standards to ensure a satisfactory whole journey experience for different traveler groups. They framed the range of design opportunities and responsibilities, to embrace a holistic, inclusive, empathic approach. This broad case study of design integration, signals 4 design areas (infrastructure, information, system design and vehicles) involving 13 types of design specialist. The passenger is central to an integrated approach and there is a clear and timely need for a 'Passenger Champion' who can insure a user focus for an integrated design approach.

KEY WORDS

Sustainable transport, whole journey experience, key performance indicators, transport design, user champions, design integration.

INTRODUCTION

The Transport Research Knowledge Centre defines transport research as 'studies, technical development and demonstrations concerning passenger or freight transport by any mode, or a combination'. Ergonomics and universal design have influenced transport design; e.g. vehicle design, inclusivity, safety and a person-centred approach (Woodcock, in Tovey 2012b).

Bontekoning et al (2004) and Evans and Azmin-Fouladi (2005) have commented on the fragmentation of transport research across science, engineering, IT, design and planning, from initial planning to ex post evaluation. In a competitive industry, the mix of disciplines, stakeholders, transport measures, environmental contexts, regulations, service provision and funding mechanisms, the voice of the user is lost. Piecemeal approaches to funding lead to poorer user experiences and uneven provision. Additionally, local authorities (LAs) have concerns (Woodcock et al, 2019) that developments such as MaaS (Mobility as a Service) and C-AV (Connected and Autonomous Vehicles), whilst purporting to establish more user-centred, customizable journeys may not deliver inclusive services, disadvantaging vulnerable groups. Emphasising the user journey experience provides a way of integrating these diverse elements (Woodcock, 2012a).

METPEX

To address this, the METPEX project (Measurement of the Quality of the Passenger Experience) (anonymised) developed and validated a comprehensive, whole journey (origin to destination) passenger experience measurement instrument for use by LAs, operators and consultants to benchmark and reliably evaluate different aspects of service provision.

At the project's inception, traffic congestion in European towns and cities had an estimated cost of €80 billion annually, with 23% of CO2 emissions from transport coming from urban areas. The EU Commission's white paper "Roadmap to a single European transport area – towards a competitive and resource-efficient transport system" called for a 60% reduction in greenhouse gas emissions (COM, 2011). Additionally, EU road fatalities were high (some 28,000 in 2012) with 38% in urban areas and pedestrians particularly exposed. (EC, 2013). Combatting such trends requires changes in thinking, technology and usage patterns.

Carbon reduction targets can be met by increasing the use of public, shared and active forms of transport. However, public perception of public transport (PT) is generally poor with 32% using public transport weekly. It is regarded as unsatisfactory, detrimental to the overall quality of life and health, effecting obesity (Davis et al, 2008) and mental health (McCay et al, 2017). Fragmented approaches to transport design, planning, operation and evaluation make it difficult to understand, champion and prioritise the circumstances and needs of transport users.

City development over the last century has led to urban sprawl including many automobile dependent locations (Caraman, Panea and Tovey, 2017). Attempts to reduce car dependency include Transit Oriented Development (TOD), mixed-use residential and commercial areas maximising access to public transport, and discouraging car-ownership. New measures supported include bike sharing, shared spaces, incentives to use public transport (e.g. smart ticketing), disincentives to use private vehicles (e.g. congestion charging, parking levies). However, it may be argued that unless there is an overall improvement in the quality of passenger experience, people will continue to use private vehicles. The use and complexity of intermodal travel are widely recognised. Travel apps and smart ticketing have enabled smooth connections, smart payment and taken some of the uncertainties out of travel, saving time, money, energy and greenhouse gases. Seamlessness can refer to interoperable stations, more frequent services, real time information updates, integrated ticketing and charging systems. However, travellers may still favour personal automobiles over public transport, if the perceived quality of the journey is poor. A better whole journey experience requires an understanding of which factors are perceived as unsatisfactory, by which users on which transport modes and under what circumstances. A valid and reliable means of assessing where travellers experience low satisfaction in their journeys would enable, targeted investment to rectify problems and encourage the modal shift on to public and active forms of transport.

JOURNEY FRAGMENTATION

Typically, a journey is comprised of distinct parts (Woodcock, 2012b), many involving walking stages and changes to vehicle and transport modes. Such whole journey experiences are not typically measured, because they are inherently complicated involving different providers – so even if information is gathered, it is difficult to effect change on an area which is under the control of another commissioning agent e.g. in the UK, stations and stops may not be owned by the transport operator, transport operators are not concerned with the experience of passengers getting to stations. This may be further compounded by the dominance of economic and quantitative metrics. It is common practice to survey commuter journeys, leading to gender bias and a lack of understanding of how transport contributes to the wider life and well being. Few attempts have been made to survey the end-to-end, multimodal journey experiences from the perspective of different traveler groups.

Such analysis requires inclusive, reliable and validated measurement instruments to measure the quality of whole, multimodal journeys, quantifying and benchmarking the lived experience of travellers. Once levels of satisfaction have been measured robustly, investments can be focussed on those parts of the journey that are least satisfactory, thereby attracting more people onto sustainable forms of transport. Other research approaches such as shadowing users and journey blogs can have greater richness but may be regarded as simply providing anecdotal testimonies from which it is difficult to develop wider stakeholder buy in and influence policy.

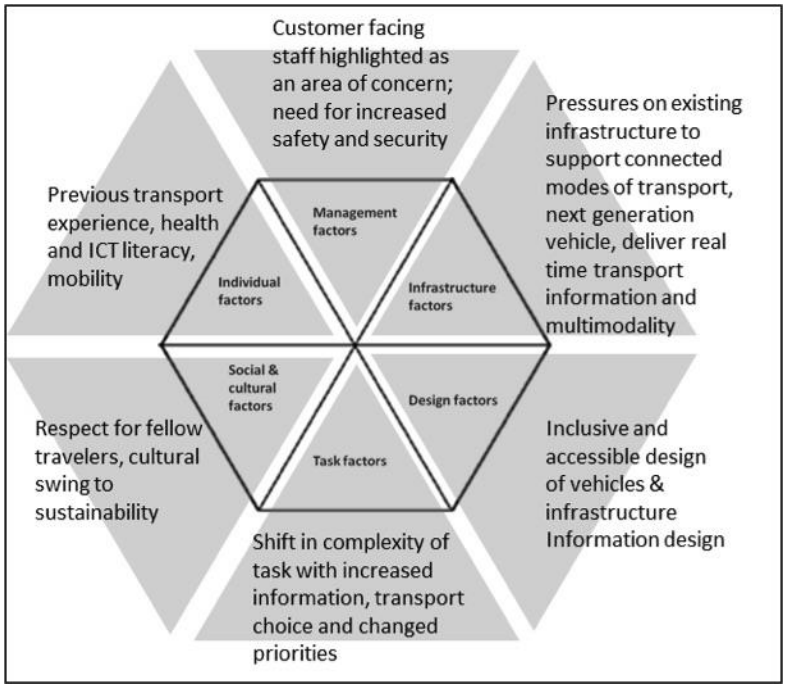
Key Performance Indicators (Parmenter, 2007) have emerged as a means of evaluating quality in a transport system. KPIs may address operating efficiency such as load factors or cost-per-vehicle-kilometre. They offer a technique appropriate for tackling the provision of transport, which is directed to meeting user needs by changing transport management, particularly when it is provided by several organisations (charitable, private, commercial and public).

METPEX developed a framework of validated and reliable, user-oriented indicators to measure end-to-end user experience (rider comfort, travel speed and reliability, affordability, integration and satisfaction etc.) to enable targeted investment in areas which passengers thought were needed (e.g. quality of customer service safety in stations). The indicators could form the basis of future surveys for use by organizations and authorities to measure the quality of the whole journey, or different parts thereof, for a wide range of traveller groups, including those from traditionally hard to reach groups. (Tovey, Woodcock and Osmond, 2017). The framework of indicators forms the basis for this case study.

THE WHOLE JOURNEY EXPERIENCE

The METPEX project was based on a systematic, user centred design approach described by Woodcock (2012b), through the application of the hexagon – spindle model (Benedyk, Woodcock and Harder, 2009; Woodcock, 2017). Placing user interactions in the transport system at the centre of the analysis was fundamental to understanding of the complexity of the factors which effect their experience (e.g. from design of infrastructure to vehicles, to quality of customer support) and the need to address individual differences. Typically, current measurement instruments evaluate experience only for the part of the journey that an operator is interested in (such as a bus). Where more integrated surveys do exist it is not always possible to drill down into the data, or trace back the validity of items being measured. Passengers have diverse requirements e.g. a passenger with a disability may need advanced information of station layout and the ability to book assistance. Information may need to be presented in different formats to compensate for perceptual and communication difficulties. A central belief for ergonomists and designers is that if you optimise the quality of experience for those with the most challenging needs, everyone will benefit. Thus all travellers would benefit both from a knowledge of the design of a station to ease their movement through it and the presentation of essential information in a clear manner in different modes. This approach was core to the project.

Figure 1: H-S model related to passenger experience



DEVELOPING THE KEY PERFORMANCE INDICATORS (KPIs)

Candidate KPIs (described in Tovey et al, 2017) were derived from desktop research which identified over 1,000 user, travel mode and context specific indicators. Multi Criteria Analysis (MCA) was used to weigh the indicators. 600 questions were selected and distributed into the five sections of the survey relating to individual attributes (i.e. socio-demographic, mobility behaviour), attitudes (i.e. travel preferences, mobility-related opinions), contextual variables (i.e. temporal, weather conditions, trip purpose, subjective well-being indices), specific user group and travel mode issues, travel experience factors (e.g. availability, travel time components, information provision, reliability, way-finding, comfort, appeal, safety and security, customer care, price, connectivity). A multilingual dynamic survey tool was developed (Liotopoulos, 2017) to select and generate surveys of 50-75 questions, targeted to specific user groups and travels. These were presented to respondents in either focus groups, on–line, real time and retrospective formats or paper-based surveys.

User groups surveyed included communication impaired travellers (i.e. those with hearing impairments, visual or speech and communication impairments); commuters (those who commute regularly); low income travellers (those with below average income); over 64 year olds; rural dwellers; travellers with children; travellers with dependents; under 24 year olds; visitors; female travellers. The transport modes included were: bicycles; demand responsive transport; mobility vehicles; pedestrians; private vehicles; public transport, rail, road, tram and underground; waterborne vehicles. Data were also considered in terms of journey, purpose, number of legs and overall satisfaction.

The survey tools were deployed in 10 different languages, i.e. English, French, German, Spanish, Italian, Greek, Swedish, Lithuanian, Polish and Romanian. Two rounds of a back translation among experts and survey coordinators ensured consistency across different languages. In total, 6,360 completed responses were collected. After the data had been cleaned and double checked for consistency and reliability across different sections, the total number of valid samples was 5,275 (See Table 1 below). Of these 984 responses were derived from the pen and paper survey, 3,394 responses from the on-line web survey, 231 responses from

the bespoke on-line app (Liotopoulos, 2017), 414 responses from the game app (Woodcock et al, 2014) and 252 responses from the focus group method.

City	Comm. Impaired	Commuters	Low Income	Mobility Restricted	Elderly	Rural dwellers	Travelling with children	Travelling with dependent	Under 24	Visitors	Women
Bucharest	11	76	49	19	21	21	20	2	32	31	83
Coventry	9	67	11	5	16	16	7	1	58	44	74
Dublin	8	209	40	9	10	24	5	3	45	7	78
Grevena	2	8	35	12	38	28	31	0	56	20	35
Rome	8	165	115	22	40	44	4	5	143	32	129
Stockholm	9	110	76	55	31	13	54	3	109	9	151
Valencia	9	62	113	19	49	4	14	2	32	29	127
Vilnius	9	33	31	9	20	3	15	1	22	4	76
FIA networks	150	221	197	57	44	133	29	25	106	157	356
TOTAL	215	951	667	207	269	286	179	42	603	333	1109

Table 1: Distribution of valid responses by socio demographic characteristics

The 5275 valid observations provided immediate information regarding the quality of travellers experience in each of the cities, against mode and user type (Susilo et al ,2017). From this data, KPIs were derived using multivariate analyses (mainly principle component) which captured the crucial experiences of different user groups, at those stages of the journey which would most effect their satisfaction (Diana et al, 2017). The KPIs do not privilege one traveller group, or transport mode over another. However, the modular approach allows interested parties to select different sets of indicators, depending on the study they wish to undertake.

The final research instrument comprised of a ready-to-implement evaluation, method which would measure quality and accessibility in the transport system (Diana et al 2016). The KPIs would:

- Help policy makers tailor measurement instruments to their needs by defining the extent of the quality evaluation exercise
- Summarise derived information to improve communication among stakeholders, by giving a synthetic and quantitative evaluation on quality and accessibility-related issues from the traveller's perspective
- Benchmark the performances of the service, transport mode or journey phase from the viewpoint of specific user groups with the performances that were measured
- Signal what was needed to revise and replace existing provision through designing improvements and new products, systems and arrangements.

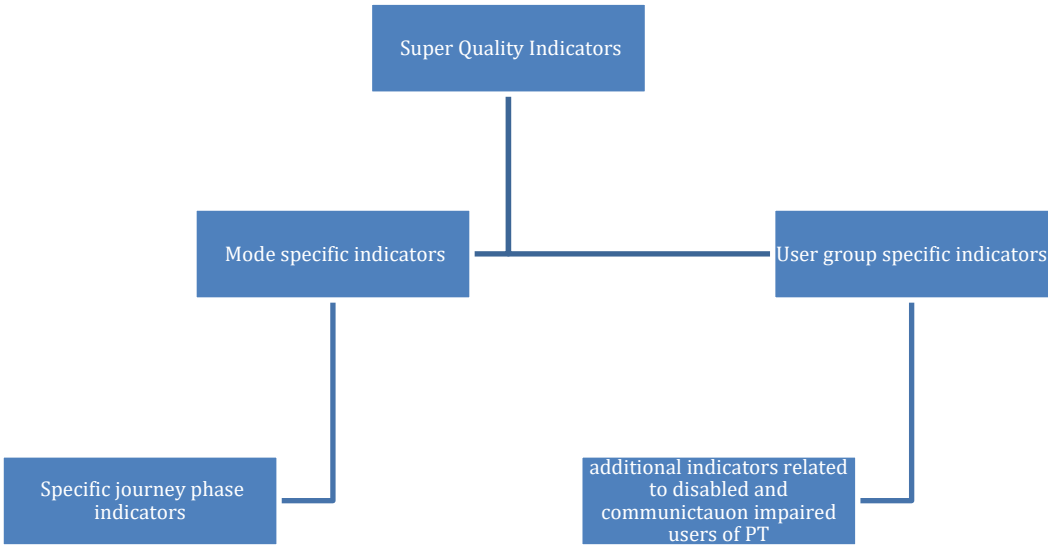


Figure 2: Relationship of Key Performance indicators

Super Quality Indicators are concerned with a high level of evaluation at city or operational level. Mode specific indicators related to rail, cycles, buses, trams, metros and underground, and cars. The list of additional indicators for a wide range of specific user groups is significant and novel. This includes visitors, women, young people, rural dwellers, people with children, commuters, low-income groups, communication impaired, older people, the mobility restricted and pedestrians. Bespoke surveys can be tailored for specific traveller profiles using a combination of KPIs. Each KPI consists of a number of validated variables (Tovey et al, 2017). It is noteworthy that METPEX provided the level of transparency in the derivation of indicators, missing in most studies. The KPIs and their associated variables were as follows;

1. Design of transport stations, including issues related to their character and atmosphere of stations, layout, provision of seating and other amenities; temperature, air flow and routes; accessibility, signage, cleanliness and maintenance and presence of staff.
2. Design of transport interchanges, including layout, accessibility, safety and security measures, layout, relationship with other transport modes, multimodality of information, provision of seating and other amenities;
3. Design of transport stops. Nearness, accessibility for those with dependents, and in wheelchairs, multimodality of information, safety and security, design for free flow of people, cleanliness and maintenance, shelter, ease of boarding an egressing vehicles.
4. Quality of road and rail crossings, e.g. suitability and safety, adequate time provided to cross, location, multimodality of adequacy of speed restrictions
5. Physical interaction between modes including separation between different transport modes, levels of prioritisation given to non-motorised traffic on roads and junctions, designated parking spaces and adherence to parking regulations, barriers to protect vulnerable road users from traffic
6. Nondiscriminatory services and protection of data also including privacy, passenger charters and protection from operators failing to meet their liabilities;
7. Accessibility of transport vehicles, infrastructure, information and ticket purchasing for different user groups including tactile pavements, ramps and drop down kerbs, (pre-trip) information available in different formats, availability and accessibility of lifts, escalators and station personnel levels, easy administrative processes to gain travel cost reduction.

8. Social dimension of services including non-discriminatory transport and practices on grounds of race and ethnicity, acceptance of guide dogs, extent to which transport provision takes into account the needs of children, young people and those living in less affluent areas.
9. Provision of universally designed multimodal information on arrivals and departures and the clear presentation of accurate, reliable information (e.g. audible public announcements, well lit, written information) across many modes (including mobile phones and internet) and knowledgeable staff.
10. High quality public transport staff able to deal with incidents, uphold restrictions (e.g. quiet carriages) who are helpful, attentive and knowledgeable, and empathic to the needs of vulnerable transport users. This extends to vehicle drivers, on board and call centre staff,
11. Quality of travel information during journey. This overlaps with 9, but specifically relates to the clarity and reliability of information provision during travel, e.g. for onward movement and journey planning; clarity and ease of use of maps and directional information; Clarity of warnings and hazards during journey such as information announcements and updates in stations/transport stops; en-route information on mobile devices and provision of information in different languages and formats.
12. Quality of pre-trip information. Accessibility, comprehensiveness and accuracy of pre-trip information relating to fare information, timetabling and route information, especially for those from vulnerable groups, including ease with which seat reservations can be made and transport staff spoken to in advance of a journey; Level of information relating to connections and planned service disruption
13. Overall quality of transport infrastructure so that is fit for purpose including effectiveness and design of dedicated lanes and pavements, maintenance, cleanliness, upkeep and level of investment.
14. Levels of vandalism and graffiti on route ways and vehicles
15. Quality of ride including temperature, ventilation, vibration, speed and smoothness of ride, seat comfort and level of crowding.
16. Safety and security while travelling from parking, to waiting in stations and at stops and in vehicles; design of safety features such as adequate lighting, provision of handrails, CCTV and security staff on; management of safety and security incidents and regulation of behaviour of other passengers; Safety of travellers with additional needs; Level of crowding; Protection of baggage against loss and damage.
17. Support for intermodal travel. This overlaps with 11, but also includes ease of trip chaining, transfer to different modes, knowledge of staff, length of time available to make connections; location, design and clarity of real-time information for connections; smart ticketing and design of integrated transport system.
18. Motorized vehicle users' needs including ability to plan and organise journey in advance; adequacy of directional signage, design of traffic flows so that private vehicles can progress at an acceptable speed, level of prioritization, parking.
19. Ticket regulations and flexibility. This covered the whole purchasing system, ticketing regulations/flexibility/availability and smart ticketing.
20. Practical aspects relating to ticketing. Ability to buy tickets in vehicles, at retail outlets, in stations, and the ability of staff to correctly inform you of most appropriate ticket
21. Reliability and on-time performance including resilience of system to recover from planned and unplanned events (e.g. extreme weather, tourism, large events); its reliability and punctuality (e.g. to make guaranteed connections); operational performance e.g. frequency of delays and cancellations, concurrence between actual and planned travel time Length

of weight for services; Information on the risks of journey delays before the departure; (Real-time) information on disruption or delay of service.

22. Service availability e.g. Coverage, directness of the journey (e.g. number of changes); extent to which transport services fulfil personal mobility needs, frequency, capacity and predictability and suitability of service.
23. In-vehicle ergonomics.
24. Design for specific user groups e.g. through universal design or adaptation of vehicles and infrastructure
25. Previous transport experience, mobility, health, ICT literacy.
26. Value for money of services.

Figure 2 shows the distribution of these validated KPIs in the H-S model. This clearly shows that the quality of the passenger experience is poor across a range of factors. This means that there may not be one magic solution that would immediately improve the experience for all (though clearly dramatically reducing costs and increasing coverage and reliability would go a long way to improving experience). From the list, four things are clear:

- Problems are not the responsibility of one agency
- Many problems have a significant design or user experience component
- None of the problems is intractable, or even costly
- A lot of people are suffering every day because of poor transport provision, design and planning.

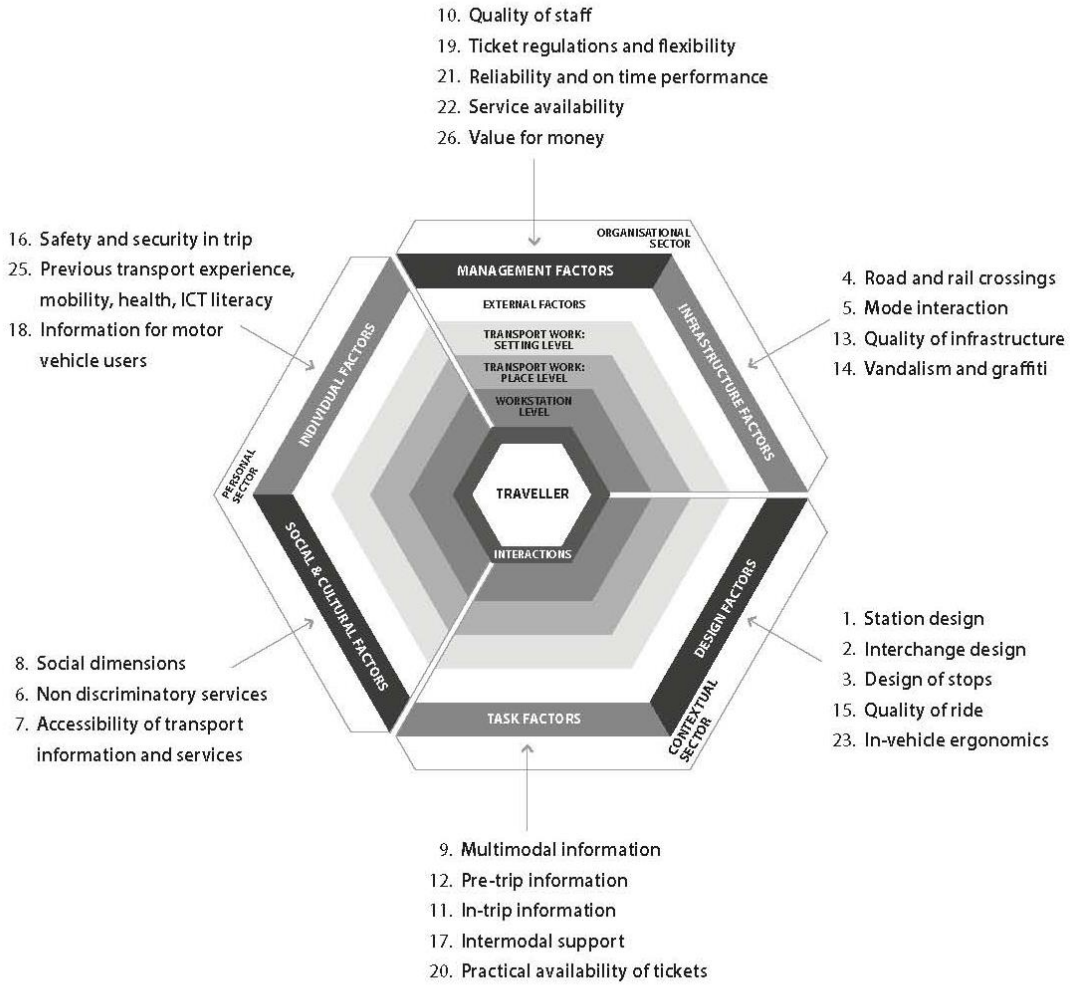


Figure 3 : The KPIs mapped on to the H-S model

Smart and intelligent transport underpinned by 4G and 5G technologies are seen as providing solutions to transport problems in the near to midterm with the arrival of Mobility-as-a Service (MaaS) and connected autonomous vehicles (CAV). In all likelihood their introduction will cause more transport chaos and transport inequalities. The question which the paper now seeks to address is given what we know about the current problems transport users experience, how we can build in safeguards to ensure that the current issues will be resolved, and not exacerbated in future transport provision?

DESIGN RESPONSIBILITIES

Emphasising the end-to-end user journey experience provides a way of integrating diverse elements which have a bearing on the passenger experience (Woodcock, 2012a). In this approach, the role of different design agents is central to ensuring an inclusive approach to developing high quality environments, vehicles, services and experiences. Opportunities for transport design activities and leadership exist in:

- ensuring a holistic approach is taken to the user experience and the design of future transport solutions

- communicating to the design community significant scientific breakthroughs
- using latest research to inform course development to ensure that design creativity is directed towards transport solutions, and not just vehicle design
- joining up and applying research coming out of the sustainability and regeneration sectors.
- providing tool and methods for engagement, codesign and cocreation with transport users
- championing transport users at local authority, operational and policy making levels
- user experience design

In this representation of transport, designerly approaches go beyond the design of vehicles, to look at service design and quality, user experience design, accessibility, and urban design. Leading transport innovation teams with designers could enable a reframing of the problem to focus on three elements (a) how the design process will proceed, (b) what needs and opportunities the design will address, and (c) what form the resulting design will take (Edelson, 2002), moving from a solution to a problem led approach. Such an approach is in line with Willetts' (2011) statement for the UK that "*Design can help organisations transform their performance, from business product innovation, to the commercialisation of science and the delivery of public services.'* Practicing designers have to move into key positions where they can influence transport policy and design educators need to ensure that future graduates are equipped to design new transport futures.

The METPEX project illustrated the shortcomings of current transport provision for all user groups, at all stages of the journey, for all journey types. For many, public transport provision is of low quality and has inbuilt barriers to inclusion, thereby reducing accessibility to opportunities. This case study project was one of the first to provide a comprehensive breakdown of KPIs for 'traditionally hard to reach groups' and for active forms of travel. Considering the METPEX SQIs, it is possible to see many significant areas of design responsibility as illustrated below. Each of them will require a combination of the holistic mind-set implicit in the whole-journey concept and the attention to the granular detail, which a user-centred approach requires.

Table2 Design Areas

Design area	**Examples of areas of work drawn from METPEX project**			
	Design of transport infrastructure	Design of information	System design and management	Vehicle design
Urban planners/city design	X		X	
Design engineers	X			
User centred and universal design	X	X	X	X

User experience design	X	X	X	X
Graphic design	X	X		X
Transport design	X			X
Service design	X	X	X	
Vehicle designers		X		X
Systems designers	X		X	
Street designers	X	X	X	
App development and usability design	X	X	X	X
Product design	X	X		X

Table3: Areas of design intervention against the original set of SQIs

Design of transport infrastructure

SQI	Examples of design challenges	Design/research methods and activities
Design of transport stations (1)	Accessibility and universal design, empathic design, user experience design, which accommodates the needs of all user groups; design for efficient whilst giving a high-quality experience	Envisioning future scenarios, visual representations, universal design approaches; design for safety and user experience design; empathic modelling
Design of transport interchanges (2)	Enabling the efficient and comfortable flow of people; multi-modal information provision when and where needed; design of space for ease of access to all areas for people with different mobility needs	Empathic modelling, architectural, interior and product design.
Design of transport stops (3)	Transport stops which provide safety, security and comfort: presentation of multimodal transport information; sustainable lighting and power; use of sustainable, cleanable and vandal proof material	Use of new materials and forms of multimodal presentation for different ability groups; culturally and environmentally sensitive design; design to meet higher level needs
Accessibility for different user groups (7)	Employing universal and accessible design across all journey stages: for those with mobility and communication difficulties and for vulnerable users (women, elderly and those with hidden disabilities).	Empathic design; co and participatory design with different types of end users
Overall quality of transport infrastructure (13)	Infrastructure to enhance the quality of the journey: design of roads, pavements and cycleways to ensure safety, security and quality of active forms of transport; seating provision, green and open spaces. Planning for safer streets rather than privileging motorised transport	Urban and street design; co and participatory design methods; envisioning techniques for new transport scenarios; designing crime out; tactical urbanism

Motorised vehicle users' needs (18)	The project took place prior to CAV and alternatively fuelled vehicles. Addressing the needs of transitioning populations (Woodcock, 2014) and future vehicle users will be key.	Mobility as a Service (MaaS); vehicle and HMI design

Design of Information

SQI	Examples of design challenges	Design/research methods and activities
Provision of information on arrivals and departures (9)	Relevant, reliable and current information to travellers to assist their decision-making. Poor system design, legacy systems and operational issues reduced the reliability of information.	Graphic and information design for people with differing abilities/languages; multimodal information.
Quality of travel information during journey (11),	Universal design needs to be applied to the design of real time journey information.	Design and testing of mobile apps, real time information for those with different abilities. Compliance with relevant standards
Quality of pre-trip information (12)	Provision and usability of journey planners for those with differing needs and ensuring that those without access to It are not further disadvantaged.	As above

System Design and Management

SQI	Examples of design challenges	Design/research methods and activities
Support for intermodal travel (17)	Piecemeal development of transport services has reduced ease of intermodal travel. Issues include access to different forms of transport and smart ticketing.	User experience design and quality of end to service, at each customer touch point. Communication and information design. Wayfinding and design of intermodal exchanges.
Motorised vehicle users' needs (18)	Information provision and parking. Design opportunities for MaaS and CAV represent a clear opportunity for ergonomists, urban and vehicle designers.	Information design and presentation of signage; design of journey and route planners. User trials and simulations; design of HMI and hand over routines. Urban design.
Ticket regulations and flexibility (19) ;Practical aspects relating to ticketing (20)	Smart ticketing; design of service provision and ticketing to ensure non-discrimination; design of tickets and machines; staff training.	Product, information and instructional design. User testing and piloting for different user groups. Empathic design for staff.
Quality of crossings (4)	Issues for pedestrians and vulnerable road users, audibility, clarity of crossing markings, placement and design of crossings; lack of compliance of motorists '	Empathic design and ethnography or shadowing to understand experience of vulnerable road users. Urban design to improve current systems and testing of new designs,
Physical interaction between modes (5)	To reduce urban road fatalities better protection of vulnerable road users through enhanced pedestrian protection in vehicles (the EuroNCAP), road lay out and urban	Vehicles design – passive and active safety, use of materials, autonomous vehicles. Transport modelling /ethnography leading to safer street design'

	planning, separation of pedestrians from other road users or speed restrictions.	
Non-discriminatory service and protection of data (6) and social dimension of services (8)	. All travellers should be guaranteed equivalent levels of service. Reference needs to be made to the needs of vulnerable groups and those living in less affluent areas.	Empathic design of services, products. Co and participatory design to understand requirements of travellers from vulnerable groups.User experience design Universal design and vehicular adaptations.
Public transport staff (10)	Vulnerable travellers felt that staff were sometimes not helpful, knowledgeable or understanding. Travellers feel that they are not valued and have poor perception of public transport are reduced.	Empathic design and modelling. Universal, user experience and customer service design.
Vandalism and graffiti (14)	Graffiti, tagging and vandalism are expensive to address and deflate the traveller's spirit.	Design out vandalism and crime through environmental design' co and participatory approaches whereby local community can have buy in.
Reliability and on-time performance (21)	A major issue for passengers and operators: stations and stops are not adequately designed to provide travellers with the comfort and security they need when delays occur.	Design issues which may be relevant here relate to vehicle and service design to ensure that services and vehicles can operate within extreme weather conditions, area low maintenance and easy to maintain.
Service availability (22)	Public transport can be patchy, with services not always available or running to schedule, a major problem for those who rely on public transport (e.g. to get to work, education or health services)	Empathic design to understand the social impact of limited availability. Design of vehicles to ensure that the journey is safe and comfortable, with adequate provision of seating for travellers with dependents, or disabilities.
Value for money (25)	Fare structures need to be fair, transparent and consistent, offering value for money and travel choices. Groups also reported fear of being caught with the wrong fare and difficulties in making claims.	Issues about communication and information design so that travellers understand the tariffs. A holistic, systems approach needs to drive plans to implement Mobility as a Service, and user experience design to address fears of having incorrect tickets.

Vehicle Design

SQI	Examples of design challenges	Design/research methods and activities
Quality of ride (15) and ergonomics (23)	Poor ride quality on public transport related to the design of the vehicles and the way in which they were driven	Ease of ingress/egress; seating provision and comfort; windows; air conditioning; ride quality; and maximising space on overcrowded vehicles.
Safety and security while travelling (16)	Public transport: perceived safety and security.	Vehicle, station and infrastructure design. Designing out crime at stations and stops. Lighting design
Design for specific user groups (24)	Vulnerable groups: the design of the ticket area, boarding area, grab rails, luggage space,accommodation of wheelchairs and buggies.	Vehicle and universal design

EMPATHIC INTEGRATION

The table indicates the SQI identified areas where design interventions and design methods could lead to more inclusive travel provision. Design is a crucial ingredient both in improving current transport provision and in ensuring that future transport is more enjoyable and inclusive. However, the fragmentation is problematic, as it is left to individual agents to ensure that each component is optimised for all users. In previous discussions of the H-S model, no attempt has been made to address the wicked problem of cross-institutional championing of the transport user. Indeed it may be argued that the reductionist approach reinforces the separation, which needs to be overcome. It lacks any empathy with the situation and experience of users of the transport provision.

Empathy is defined as 'the intuitive ability to identify with other people's thoughts and feelings – their motivations, emotional and mental models, values, priorities, preferences, and inner conflicts' (McDonagh 2008).

Effective human-centred design seems to require empathic qualitative approaches to inform and inspire designers to help them understand the personal experience and private context of the 'other' (Mattelmäki and Battarbee 2002; Fulton Suri 2003). This concurs with Koskinen, Battarbee and Mattelmäki (2003) - designers needed empathy, an emotional connection with the user, understanding their situation and why certain experiences are meaningful to them. This could be tackled by a range of approaches such as immersion in the life of the users, design probes, and imaginative projection. However most importantly in this context it needs a champion of the users who is obliged to adopt the whole journey perspective as an integrated entity. What this case study illustrates is that each of the design specialists needs an adjustment in approach both to ensure a user-centred mind-set and to be part of the integrated approach which the whole-journey approach demands.

THE ROLE OF LOCAL AUTHORITIES AND PASSENGER CHAMPIONS

Organisations most likely to be interested in the whole journey experience are the Local Authorities, providers of door to door services e.g. MaaS providers, bespoke, travel services (mostly high-end boutique providers), larger organizations championing sustainable travel planning (e.g. SUSTRANS), those using end-to-end journey mapping to improve the user experience (e.g. travel and hospitality industries - airports, online travel agencies, airlines). Customer experience management is concerned with the full end-to-end experience and is used to develop brand and customer loyalty (Virgin, Burberry, Amazon, Audi and BMW). Such an approach is needed here. However, it is difficult to translate into practice across a supply chain with multiple actors responsible for different aspects of transport. MaaS may become an integrator especially if strategic alliances are made with new vehicle design and manufacture (as with CAV and electric vehicles). Adopting customer experience management processes may improve the user experience of those services for all users. However, even though standards may rise as a result, inclusivity and user centred design are used as a means of increasing brand loyalty and profits, not because it is the ethical and moral.

The aspiration of the (UK) government supports accessibility for all in public transport and is in line with UN Sustainable Development Goals to provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in

vulnerable situations, women, children, persons with disabilities and older persons by 2030. (Tovey, ibid)

However, there is concern at governmental and local authority (LA) level that new technologies and service provision may result in greater transport inequalities without due consideration and consultation. Where new services breakdown or fail to meet the needs of local communities (e.g. because routes are nonprofitable), the LAs may have to step in to redress shortcomings. This will become more of an issue with MaaS where transport and mobility becomes more fragmented and services will be more disrupted as companies fail.

There is a need an integrator within LAs or MaaS operations who look after passenger needs and take responsibility for the quality of the whole , multi modal journey experience especially for hard to reach groups. The outstanding need is for an agency to act as the passenger or traveller champion to consistently monitor the diverse design inputs and intervene to modify them towards achieving the whole journey viewpoint, thereby integrating all aspects shown in Figure 3.

This role of Passenger Champion needs to be seen as both monitoring the various design activities and coordinating them so as to ensure the whole journey approach. This study shows quite starkly how crucial it is that such a mechanism be used to facilitate a user-centred integration of the various design inputs. It will not be easy as the forces to fragmentation are powerful.

CONCLUSIONS

The METPEX project arose out of the need to increase sustainable transport and reduce carbon emissions. One way of achieving this is by increasing the number of users of public and active transport. The development of an overall description of what is required to make this possible employing KPIs has facilitated the shift from a segmented and demarcated approach to a whole journey perspective.

Such an approach involves both a holistic method, but also one with sufficient detail to maintain its integrity. The creation of the measurement tool and the identification of the areas of responsibility for addressing the issues, are directed towards creating solutions. This has involved employing a design-focus, so that all of the analytical work can inform the creation of a user-friendly holistic vision for transport provision.

It has been useful to identify the agencies, which will be needed to put this in action. It has become clear that such an overall solution is only possible through the engagement of specialists such as designers and ergonomists, and that they are crucial in bringing about what is required. In this paper we have identified the many and various design functions and design roles, which are necessary in delivering solutions. The range of types of designers is large, including 13 design specialisms in four areas (information, information, system design and vehicles). Such designers will need to embrace a deeply empathic approach to attempt achieving the necessary user-centred mind-set. More

significantly a design integration approach is essential to ensure that the forces of fragmentation are resisted.

In this case study we identify the need for a Passenger Champion to ensure that the effective user-centred perspective is articulated and given powerful authority. This is the key to achieving an integrated approach. We conclude by confirming and reinforcing the essential role of the Local Authorities as the official bodies who have both an overview and a responsibility for ensuring this integrated approach emphasising the whole journey user-centred perspective. They need to ensure that there is a Passenger Champion to address the user needs and journey integration which are essential components in overcoming the fragmentation of demarcated design roles and separated service providers, and ensuring an integrated approach.

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