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Transport survey methods - in the era of big data facing new and old challenges

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Abstract

This document presents an introduction to the ISCTSC Special Issue of Transport Research Procedia. It synthesizes the discussions held at the 11th International Conference on Transport Survey Methods, and describes the contents of the selected contributions. This conference has been held in different countries from all over the world, involving an increasing group of enthusiastic and generous specialists, willing to share their knowledge. This 11th conference was an opportunity to discuss the state of the art on transport survey methods, but also to question the way transport surveys are conducted in the era of big data. We took the opportunity to identify the main challenges, and the most important questions.

Keywords: ISCTSC ; transport ; survey methodology ; big data

1. Introduction

Quebec conference takes place in a long series of conferences from 1979 until now:

- **1979 | Grainau, Germany**
- **1983 | Hungerford Hill, Australia**
- **1990 | Washington DC, USA**

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- **1996 | Steeple Aston, UK**
- **1997 | Grainau, Germany**
- **2001 | Kruger Park, South Africa**
- **2004 | Playa Herradura, Costa Rica**
- **2008 | Annecy, France**
- **2011 | Puyehue, Chile**
- **2014 | Leura, Australia**
- **2017 | Estérel, Québec, Canada**

The conference has a similar organization since Grainau 1997. A large amount of time is always dedicated to workshop discussions with a limited number of oral presentations. Social activities always take an important place in order to facilitate and stimulate informal exchange. Lastly, the conference is always organized in a relatively remote location. All these dimensions play an important role to develop networking inside the international survey methods community. The relatively permanent structure and objective of the conference allows analyzing thematic evolution. An analysis of the conference titles, workshop titles and keynotes presentation gives some indication of the evolution of research preoccupations.

The first conferences were mainly dedicated to different technical dimensions of surveys like sampling, non-response, survey mode, interviewer impact, interviewee motivation, among other. All aspects devoted to increase survey quality. The 1997 conference book is titled "Transport Surveys: Raising the Standard", the fist keynote of 2001 conference was "Developing standards of Transport Survey Quality". The title of 2004 conference book was "Travel Survey Methods: Quality and Future Directions".

The 2008 conference in Annecy represents an evolution in conference content with the recognition that the world of survey methodology was evolving as indicated by the conference book title "Transport Survey Methods: Keeping up with a changing world". There was only one workshop on new technologies during the first conferences and two for the 2004 conference dedicated to web and non-web surveys. In 2008, we had three workshops dealing with the introduction of GPS surveys, electronic devices for surveys and mobile technologies. The focus on new technologies and surveys has then increased progressively as indicated by the number of workshops on those topics and the evolution of conference titles: in 2011 "Scoping the future while staying on track", in 2014 "Embracing technological and behavioral changes" and for the last conference of the series in 2017 "In the era of big data: facing the challenges".

Of course, the focus on the impact of new technologies on surveys has evolved with time. In 2004, we observe the first transport surveys using web media to collect data and we have some experimentations using GPS. In 2008, GPS become a media to collect data and more and more data are collected using electronic devices. In 2011, GPS surveys remain an active research field with the opportunity to both collect data through GPS devices or using smartphone apps. In 2014, there was a strong focus on big passive data such as telephone company data and smart card data. And, in 2017 some researches using social network data were presented.

We are at a stage where we have never had at our disposal a similar amount of data on mobility and transport. But we need to analyze the potential of these big data. Data quantity is huge but it does not mean that the data is representative of the population. There is also a question about data quality and data completeness. For example, socio demographic data is usually not available with big data, and when available, it is not possible to use it due to evident confidentiality concerns. Also, we have at our disposal more survey media than in the past. Traditional postal, face-to-face and telephone media are still available, but web, GPS devices and smartphone are also used. The challenges of traditional data are still present, and some of them are particularly important now. For example, response rates are decreasing, and in some countries they have reached so low levels that some researchers have questioned the logic of investing huge efforts to obtain random samples. The decline of response rates encourages the use of mix-mode surveys. New big databases encourage the development of data fusion methods. Data quality remains a strong preoccupation of ISCTSC conferences even though the word "quality" is no longer present in the conference titles. The objective is to develop methods to assess data quality and to identify the potential of new data sources to analyze mobility behaviors, develop models and assess transport policy impacts, rather than to develop quality standards to apply in survey. The on-going evolution of new technologies impose to permanently re-visit the question of quality in survey methods and data processing.

We have organized the Quebec conference with the aim of facing both the old and new challenges when developing

surveys, data collection protocols and data analysis methods.

2. Presentation of the 16 workshops in order to give an overview of the content of Procedia

The 11th International Conference on Transport Survey Methods was held during one week in September 2017 in a unique and remote location in the Laurentians region of Quebec, Canada. Everything was designed to create an opportunity for networking, collaboration, and sharing of knowledge. The conference was organized in the form of two workshop series with eight parallel sessions each, plus six plenary sessions and two poster sessions. The 172 participants included leading survey researchers and transport professionals from over 20 countries representing industry, government policy makers, as well as academic scholars and researchers.

Around the theme "In the era of big data: facing the challenges", we discussed the latest advances in current and prospective transport survey and data processing issues while focusing on data quality and challenges associated with new data sources and survey methodologies. The question of big data and new survey methods or new data sources was discussed in all workshops. We acknowledged that big data is an important source of data with a high potential to analyse mobility behaviour and contribute to transport planning and policy. Some examples were given through paper presentations and discussions. Nevertheless, there is a strong agreement that big data should not replace "traditional" transport data collection system that already exists in many countries. "Traditional" surveys allow collecting at the same time socio-demographics, contextual and attitudinal variables, and mobility, thus allowing to better understand and model travel behaviour. There is consensus that "traditional" surveys have to evolve while taking into account the importance of temporal comparability, and that we need to develop methods to enrich big data with socio-demographics or contextual information. We have therefore discussed the new challenges we face in the era of big data and new data collection methods, but we have also discussed some of the old challenges that are still important while conducting transport surveys or processing data. The procedia volume is organised accordingly.
Section 1 presents papers and workshops mainly dedicated to big data analysis or new data collection methods using new technologies or media:

- Smart card data, new methods and applications for public transport;
- Passive and sensor data - potential and application;
- Use of social media, social networks and qualitative approaches as innovative ways to collect and enrich travel data;
- New developments in travel diary collection systems based on smartphones and GPS receivers;
- Web-based surveys, new insight to address main challenges.

Section 2 presents workshop mainly dedicated to old questions that were discussed in previous conferences. Of course, the evolution of methodologies and media to collect the data introduce new challenges for these "old" questions:

- Increasing survey participation levels without changing travel behaviour;
- Representativeness in surveys: challenges and solutions;
- Dealing with immobility and survey non-response.

Big data and new methods will not replace "traditional" transport survey at least at short term. However, "traditional" surveys have to evolve and to benefit from the existence of new data sources. Section 3 presents workshops that were mainly dedicated to articulate, combine, and fuse methods and database:

- Making the transition to new methods for travel survey sampling and data retrieval;
- Household travel surveys in an era of evolving data needs for passenger travel demand;
- Data Analytics and Fusion in a World of Multiple Sensing and Information Capture Mechanisms;
- New directions in experimental design.

Lastly, in section 4 we present workshops that were mainly dedicated to specific domains or questions:

- Measuring attitudes and perceptions in quantitative surveys;
- Surveys on long-distance travel and other rare events;
- Behavioural Changes in Travel – Challenges and Implications for their Identification and Measurement;
- Validation under "ground truth" in surveys.

128 papers were presented during the conference. Procedia contains a selection of papers organised by workshop with the workshop synthesis.

2.1. Big data analysis or new data collection methods using new technologies or media

Section 1 contains workshop mainly dedicated to big data or new technologies in survey.

The first workshop (Chandesris, Nazem, 2018) concerns new methods and applications for public transport using smart card data. Roulland et al. (2018) propose a general framework for looking at all the core elements of transit mobility in the various possible operational settings of public transport using operations data. Yeun-Touh et al. (2018) attempt to validate the trend of long-term usage of public transport based on the information of the smart card holder. Espinoza et al. (2018) compare different methods in order to measure, using smart card data, how much do public transport users change their behaviour through time. Workshop discussion highlights the high potential of smart card data while recognising that research is still needed to better qualify this potential. Participants insist particularly on the need to develop data fusion and aggregation methods from different data sources and owners, to develop standards format and to share them among community and to improve algorithms and visualisation tools to analyse the data.

The second workshop (Olaru, Tudela, 2018) deals with passive and sensor data. Kusakabe at al. (2018) develop a method to estimate staying duration at transit facilities by detecting Wi-Fi MAC addresses. Validation was performed through the comparison with a survey in one of the largest highway bus terminal in Tokyo, Japan. Bonnel el al. (2018) compare origin-destination matrices obtained from passive mobile phone data with household travel survey data in Rhône-Alpes region in France. Morency et al. (2018) propose clustering techniques in order to process data obtained from five different passive data streams to create a typology of typical days of usage of different mode of transport including new mobility services. Workshop discussion highlight the move from hypothesis testing and verification with traditional survey data towards more data-driven approaches that requires to develop new methods, especially to improve fusion and aggregation process. The definition of quality should move from survey quality standard to new validation frameworks and methodologies.

Third workshop (Ampt, Ruiz, 2018) works on social media and social networks and qualitative approaches to enrich travel data. Guidon et al. (2018) develop egocentric social network analysis in order to study socially motivated leisure travel. Di Ciommo et al. (2018) define a needs-based theoretical framework for evaluating transport policies and investment focusing on the assessment of personal transport needs as a fundamental part of human rights and social inclusion. Participants in the workshop described issues related to the use of online social media in the context of travel surveys, and problems related to privacy and bias. Several methods of collecting social network data in the context of travel analysis and recent examples of related data collection efforts were discussed to identify their advantages and limits. The importance of integrating social media and social network data was emphasised. Future research needs were formulated as for example method to combine new social medial data with traditional data in order to enrich both databases, process to integrate qualitative and quantitative approaches and again the need for validation methods.

Fourth workshop (Prelipcean, Yamamoto, 2018) examines new developments in travel diary collection based on smartphone and GPR receivers. Ferreira et al. (2018) define usability parameters for post-processing automated generated trip data relying on task completion time, errors and success rate as well as subjective ratings of trip validation interfaces. Stopher et al. (2018) describe a study in which a smartphone app and dedicated wearable GPS devices were used in the same study, with processing done with the same software, providing an opportunity to determine the strengths and weaknesses of each media to collect the data. Gong et al. (2018) propose a two-step methodology -a density-based clustering algorithm in the first step and SVMs (support vector machines) in the second step- to deal with GPS data without speed or acceleration features. Prelipcean el al. (2018) offer an overview of the current state of travel diary collection using smartphone compare to traditional methods. Participants discuss different methodologies to extract semantics from GPS trajectory and auxiliary data. Methodological choices when collecting

GPS data have also been discussed like battery consumption, time intervals between GPS point, user experience and user interface to collect auxiliary data, GPS data accuracy… Participants insist particularly in the need to share experiences and to develop open source tools in order to capitalise from existing works.

Last workshop (Monzon, Bayart, 2018) deals with web-based surveys. Arroyo et al. (2018) develop a web based survey, which consists of several questionnaires to collect respondents' values and attitudes; a two-day activity-travel diary; information about social interactions; and socio-demographic characteristics. Zijlstra et al. (2018) analyse the impact of using smartphones, tablets or traditional devices to collect web data. Authors experienced that one third of respondent use a mobile devices. It is therefore important to develop adaptive or responsive web design in surveys for mobile respondents. Workshop participants discuss best practices for designing web-based surveys especially in terms of respondent recruitment to control the sample, survey design to reduce respondent burden especially using mobile devices. Web surveys are often used in mix-modes protocols. Methods to consider and correct comparability issues have been discussed. Participants recognize that all these questions still represent important challenges for researchers.

2.2. "Old" questions but new challenges

Section 2 presents workshops mainly dedicated to old questions that were discussed in previous conferences. Of course, the evolution of methodologies and media to collect the data introduce new challenges for these "old" questions.

First workshop (Bricka, Greaves, 2018) concerns methods or protocols to increase survey participation levels without changing travel behaviour. Scheepers and Hoogendoorn-Lanser (2018) contribute to the general understanding of how incentive strategies can best be used in longitudinal household surveys through analysis of literature and of the Netherlands Mobility Panel. Verzosa et al. (2018) explore the potential of gamification concepts to potentially make surveys more engaging and appealing. Their analysis is based on the development of a web survey in Australia. Workshop participants recognise that the evolution of travel survey methods has been closely linked to technological advances. New technologies can help make the data collection process more efficient and effective in terms of obtaining better quality data. At the same time, the newer technologies challenge us to not just improve processes but to explore and develop even better ways of collecting travel data, a prime example being the 'gamification' of travel surveys. Evidence from gamification are still sparse and inconclusive. Gamification offers new approaches to propose incentives in survey. At the same time, there is risks that some form of gamification impacts mobility behaviour and therefore survey results. Participants expect to find more research presentation for the next conference in order improve gamification and incentives toolbox.

Second workshop (Armoogum et al., 2018) discuss representativeness in surveys. Kagerbauer, Stark (2018) analyse whether the level of supervision influences quality of response and results of multi-day surveys. They compare a multi-day survey with children and high level of supervision in Austria with data of the same age group out of the Mobility Survey in the Greater Stuttgart Region. Ampt et al. (2018) present an analysis of response rates over a long time period, of a car use survey that incorporates GPS technology. They also discuss the use of focus groups to understand rbehaviour. Hoogendoorn et al. (2018) present the influence of non-random attrition on results external validity in panel survey. To correct this problem it might be necessary to recruit additional respondents between waves. But how to determine how many and which respondents to recruit? Authors introduce a new method for determining the sample's allowed deviation from the population, as based on the concept of inverted relative entropy. Workshop participants discuss the problem of representativeness through the usual segmentation of sampling frames coverage, non response mechanism and measurement errors. They discuss several methods to reduce the problem. They acknowledge the fact that the best way to reduce the problem is to tackle it upstream when designing survey methods (good sampling frame, follow-up with respondents, incentives, response facilitators, reducing respondent burden…). Nevertheless even with state of the art survey representativeness remains a concern and need a post treatment through various methods which were discussed.

Third workshop (Madre, Lucas, 2018) deals with immobility and survey non-response. De Haas et al. (2018) present a research whose target is to assess whether the inclusion of initial nonresponse in a nested logit mode choice model leads to changes in parameter values and more adequate estimated probabilities. Erhardt, Rizzo (2018) examine the impact of the number days in a multi-day GPS household travel survey on the sample size to obtain a certain level of precision for mobility indicators. They provide a framework to correct the impact of the repeated measurement

problem. Bradley et al. (2018) examine the impact of growing non-response for young adults currently between the ages of 16 and 35 (often called “Millennials”). They explore the possibility that car use decrease observed for this age-cohort could be explained by non-response bias. Participants discuss mainly the problem of immobility that might be associated with what we called “soft” refusals. It is an “old” problem with abundant literature but still actual problem with research needs. They discussed some methodologies used in national surveys to identify the problem of immobility. They propose some solutions to limit the impact of bias associated with non-response, but recognise that most of the methods present some limits at least in terms of variance estimation. They also discussed the impact on model estimation and proposed some recommendations in order to limit possible bias. Workshop concludes with a research agenda because non-response and immobility problems seem to increase in most surveys.

2.3. Combining survey methodologies and data aggregation, fusion challenges

Big data and new methods will not replace “traditional” transport survey at least at short term. However, “traditional” surveys have to evolve and to benefit from the existence of new data sources. Section 3 presents workshops that were mainly dedicated to articulate, combine, and fuse methods and database

First workshop (Kuhnimhof et al., 2018) discuss the challenges associated with the evolution from “old” methodologies to new form of surveys taking benefit of the potential associated with new technologies while maintaining the comparability over time. Aschauer et al. (2018) report a comparison of the Austrian National Household Travel Survey (HTS) and Time Use Survey (TUS) with a 3rd survey format – the "Mobility-Activity-Expenditure-Diary" – to better understand the specific strengths and weaknesses of HTS and TUS in terms of quantifying travel and non-travel activities and their specific underreporting effects. Eisenmann et al. (2018) analyse the impact of a new mixed-mode design of the person’s willingness to continue participating in the consecutive survey waves of the German Mobility Panel. They try also to identify if there is a causal relation between data quality and completeness of survey repeaters and survey mode in the data collection stage. Bäumer et al. (2018) present the most current German VKT survey, Fahrleistungserhebung (FLE) 2014, which comprised two elements: a motor vehicle owner survey to measure national VKT and traffic counts to measure domestic VKT. Gruschwitz et al. (2018) analyse the survey mode effects observed in the recent German national household travel survey “MiD 2017 – Mobility in Germany” with focus on the observed mobility behaviour and survey mode preferences. In order to disentangle survey mode selection and survey mode measurement effects, multivariate regression models where used to control for socio-demographic factors. Bayart and Bonnel (2018) also analyse survey mode effect on number of trips and distance and travel time budget in a regional travel survey. In their analysis, they implement an endogenous selection model, allowing taking into account selection bias. De Abreu e Silva et al. (2018) test the effect of different contextualization, scaling, framing and formatting of environmental impacts and health benefits information on commuting mode choice using stated preference survey administered both online and face-to-face. Participants recognise the importance of survey methodologies evolution in order to benefit both from methodological advances and from new technology opportunities, but at the same time the need to maintain the comparability over time especially for all long series of surveys like national transport survey or some local surveys. Both objectives are contradictory. Participants recommend maintaining at least for a share of the sample “old” methodologies while proposing to the rest of the sample new protocols. It brings the challenge of first identifying and then eliminating mode effects when using the data. But it gives an opportunity to get more and more survey methodology comparisons in order to better understand survey mode effects in various survey contexts. The development of new survey media (like GPS receiver of smartphone for example) will increase the complexity of survey protocol in the future. It is therefore relevant to develop research for improving data integration and fusion methods.

Second workshop (Miller et al., 2018) focuses more precisely on the future of household travel surveys. Richard and Rabaud (2018) present methodological choices made to define the French household travel survey (HTS) methodology also called “Cerema standard” that is currently the standard data source for local mobility knowledge in France. Roider et al. (2018) present methodological solution and experiences developed within the cross-border project BRAWISIMO - "Region Bratislava-Vienna: study about mobility behaviour" - involving the two countries Austria and Slovakia. Hubrich et al. (2018) analyse strengths and weaknesses of household travel surveys (HTS) and individual travel surveys (ITS) based on a comparison of two surveys with similar survey methods, one conducted as HTS and the other as ITS. Workshop participants highlight that travel surveys have been an extremely successful

method for efficiently gathering standardized, high-quality information on passenger travel demand. However, changes in communications technologies and methodological issues are presenting increasing challenges to the conventional approaches used in travel survey. This workshop explored a wide range of needs and options for improved HTS design and analysis to exploit the potential of emerging new methods and to meet 21st Century transportation planning and modelling needs. A set of policy recommendations and research priorities which emerged from this discussion are presented. In particular, the need to develop methods to fuse different data sources or data produced by different methodology within the same survey has been identified. Core-satellite concept appears relevant to respond to the various survey objectives, or to survey specific segments but it needs to be further operationalised in different survey contexts. Open data and access to big data was also discussed.

Third workshop (Cherchi, Bhat, 2018) was dedicated to data fusion. Eisenmann and Kuhnimhof (2018) present a multistage method for imputing car costs by cost item in a German national travel survey data set. Methods is based on combining different data sets and imputation models. Bourbonnais and Morency (2018) propose a travel datawarehouse using dimensional modelling for promoting a more understandable structure, generating comparable results, providing faster access to data and accelerating publication of highlights. Participants of the workshop explored and discussed a new landscape in which data from multiple sensing and information capture mechanisms may be gainfully combined to obtain richer, more comprehensive, and more representative information regarding human mobility patterns as well as human perceptions, attitudes, and lifestyle choices. The workshop discuss the exciting possibilities, some investigative and predictive analytics pathways forward in terms of methods, and the research challenges in this emerging landscape of data science.

Last workshop (Daziano, Farooq, 2018) discuss new directions in experimental design. Cherchi (2018) presents the use of eye tracking technology to explore how individuals process information in a stated preference experiment. Langbroek et al. (2018) describe and evaluate a stated adaptation instrument to investigate the effects of a transition towards electric vehicles on travel behaviour. Respondents were equipped with an “imaginary” electric vehicle with a specific range and were asked whether they wanted to make changes in an activity-travel schedule, they had previously registered. Bansal and Daziano (2018) conduct discrete choice experiments (DCEs) in New York City to measure welfare measures associated with the use of autonomous taxis. A method for pivot-efficient designs is proposed and tested that exploits the distribution of attribute levels. Alizadeh et al. (2018) present the development and deployment of a general data collection framework adapted for behavioural route choice studies. The main objectives of the proposed framework are to observe drivers’ route choices, and to identify important factors, including observable attributes and latent behavioural traits, affecting those decisions. Workshop participants discuss evolution of experimental designs in the context of the rapid changes and challenges that the transportation field is experiencing. Because an experimental setting in travel behavior analysis is quickly associated with stated preference methods, the workshop had a clear focus on the design of discrete choice experiments. However, one of the main conclusions is that we need an expanded notion of experiments to achieve diversity in the participation of experimentalists beyond standard stated preference analysts. Workshop also discuss the idea of “experiment design of the experiment design” meaning that we should control in a methodical way the parameters of the design so that analysts can assess and formalize design protocols, while also examining the combined use of conventional and new tools.

2.4. New perspectives in the era of big data for specific survey topics

Last section 4 is mainly dedicated to specific domains or questions which were little discussed in other workshops but still important for the transport survey community.

First workshop (Clifton, Carrasco, 2018) deals with measuring attitudes and perceptions in quantitative surveys. Stark and Hössinger (2018) present the research design of a survey, which served as methodological experiment measuring attitudes at different levels of aggregation: (A) basic personal values, (B) one-dimensional (unspecific) attitudes as typically used in TPB models, and (C) multi-dimensional (content-related) attitudes towards travel modes. Gerber et al. (2018) expose a research based on a mobility survey among Luxembourg cross-border workers. It yields a critical view about the specification of measurement indicators to be used for the survey of attitudes and beliefs and to test structural equation models as an exploration and data-mining tool. Berger and Dörrzapf (2018) gives an insight into the importance of bicycle-friendliness, also known as “bikeability” and its qualitative components like perception and emotions of the riders. The goal was to test new bio-physiological sensors (like EDA device, eye tracker etc.) to

develop a methodology on how sensor technologies can be integrated in the data collection processes and to discuss their practicability. Workshop participants discuss about issues in incorporating qualitative information, namely attitudes, perceptions, and other psychological-social factors into transport research and analysis. They first recognise the need to further develop our understanding of attitudes and perceptions. More thought is needed in the identification of the attitudes that should be measured on each context, with a more explicit consideration of the interests of policymakers. The state of the art is still very thin on understanding the stability and dynamics of attitudes and behaviour, and the interactions between attitudes, values, intentions, and behaviour. More comparative studies can provide the opportunity of testing methods and measurements, as well as comparing the influence of attitudes on behavioural intentions.

Second workshop (Gerike, Schulz, 2018) works on surveys on long-distance travel and other rare events. Aultman-Hall et al. (2018) describe a travel survey instrument that include social network contact locations for 110 participants in a convenience sample from three states in the USA. New types of measures were successful at capturing a range of unique annual travel behaviours and social network extent in relation with long-distance travel and tourism. Christensen (2018) presents a new Danish survey about journeys abroad with overnight stay(s). The survey is used to investigate if it is possible to collect long distance travel data by only asking for information about the latest journey. Workshop participants discuss suitable definitions for long-distance passenger travel. It became clear that equally precise but still applicable definitions of long-distance travel are essential for generating valid and useful data. The potential of new big passive data like mobile phone data was discussed. These promising new data sources and data collection methods should be integrated into travel statistics with care — in particular by allowing for transition periods with both the traditional and the innovative data collection running in parallel. Strengthened interdisciplinary research is expected to reveal new valuable insights.

Third workshop (Chlond, Eisenmann, 2018) is dedicated to Behavioural Changes in Travel. Von Behren et al. (2018b) aim to capture effects of an office relocation in Karlsruhe, Germany. A survey approach, including longitudinal elements, has been developed to capture short- and long-term effects of the employees' and their household members' travel behaviour. Nazem et al. (2018) analyse the travel behaviour changes due to medium-term disruption on public transit networks by using smart card data, as a potential substitute to before-after surveys. The case studies are metro station closures in Montreal, Canada. Wittwer et al. (2018) develop a method for ex-post harmonising mixed-method, cross-sectional household travel surveys. The harmonisation includes the areas of survey coverage, survey definitions, and survey methods. The harmonisation method is developed for five European capital cities: Berlin, Copenhagen, London, Paris, and Vienna. Von Behren et al. (2018a) present a comparative analysis of car dependence in three conurbations: Berlin (Germany), San Francisco (USA) and Shanghai (China). Wielinski et al. (2018) present the comparison of multiple data streams in the assessment of trip type distribution for free-floating car sharing service. Workshop participants began to exchange to find a comprehensive definition of behavioral change. Based on this definition, methodological approaches have been discussed and distinguished from each other and methods for the identification and measurement of behavioural changes by use of different methodological approaches have been revealed. Workshop concludes that continuous form of data collection approaches should be promoted to better identify and analyse behavioural changes.

Last workshop (Sammer, Chu, 2018) works on the idea of validation under "ground truth" in surveys. Harms et al. (2018) compare time-use diary surveys and activity-travel diaries and report on travel behaviour using data from the 2014-2015 UK Time Use Survey and highlight additional data that are available, such as secondary activities and levels of enjoyment associated with travel. Sammer et al. (2018) examine the problem of underreported trips in transport surveys. They first try to estimate the importance of the problem by comparing GPS data with traditional survey. Then they discuss methods to correct the bias by imputation. Workshop participants discuss definition of "ground truth" in surveys. They recognise that theoretical definition can be proposed but they have to face the problem of operationalisation in order to be used in "real" survey world. Comparison with independent data sources from the survey is recognised as an important dimension. Passive data appear promising data sources even if we still need "validation" researches to better understand what can we do with these data. The development of this kind of comparison to "ground truth" also allow to better identify the bias of available data.

There was a plenary session (Habib et al. 2018) dedicated to present a large data collection project currently being conducted in Canada. The declared purpose of this project is "to develop the next generation of passenger travel survey methods". The authors present preliminary results of different survey media, and discuss methods, with a focus on the

core-satellite approach.

3. What can we learn from Quebec Conference?

With 128 papers or posters, 16 workshops and 6 plenary sessions, it is not possible to make a detailed synthesis of all discussions. We prefer to focus on some dimensions that highlight important results of the Quebec conference. The selection is obviously partial, but we are convinced that these dimensions will generate new research and that most of these questions will continue to be discussed at the next conference in 2020 in Portugal.

All workshops recognize that in the era of big data we still need "traditional" surveys. We are convinced by the fact that big data represent an enormous potential but also an enormous challenge in order to better understand what can we do with these data. Big data generally does not contain socio-demographic information, either because it is not available or due to privacy concerns. It is sometimes possible to impute some socio-demographic information and those methods will most probably progress in the future. However, when we want to develop mobility behavior analysis, create models that take into account personal characteristics, analyze the policy impacts on different population segments, we need to have at our disposal mobility data and personal characteristics. We have therefore not reached the end of the survey era. Surveys allow to collect mobility data and at the same time socio-demographics or contextual data to better understand mobility behavior and mobility change. Traditional survey challenges remain important and even more, as we need to combine data sources, to face response rate decline, and often survey cost reduction.

3.1. Does Survey media affect mobility responses and how to combine survey media?

Traditional survey media are still used in many countries, including postal, telephone and face-to-face surveys. But we observe more and more the use of new media like web, GPS or smartphone devices to collect data on mobility. The development of new media gives new opportunities for survey analysts, but it also brings new challenges. The problem of data comparability is not new when different survey media are used. In previous research, an important distinction has been made between media administered by interviewers and those without interviewer, such as postal or web surveys. There is a vast literature discussing the respective advantages of each survey media, but also on their potential impacts on interviewee response. With GPS and smartphone based survey a new distinction is introduced between surveys which need active participation from interviewee and those which require limited participation because it is the device which records the mobility data (mainly GPS traces). Bigger differences, at least for trip number, are often reported with these new media, but results still appear controversial because they seem to be dependent on technical aspect of data collection. More research is necessary in order to better understand the potential impact of survey media to collect mobility data.

Response rates are decreasing all over the world. Face-to-face surveys that often present the higher response rates are costly and it becomes more difficult to access some areas or buildings. Telephone surveys have to face the continuous decrease of landline in population. Postal surveys are not conducted in numerous countries due to very low response rate. Acceptability of GPS and smartphone surveys is still limited both for technical reasons and for privacy concerns. Except on specific context, we can hardly observe high response rate for survey with single media. It is common to observe response rate in a range of 25-50% in Europe and even less in North America. We know for a long time that individuals might have preferences to respond with some media rather than other. Sometimes they might be available to respond but without having the presence of an interviewer. It would be more efficient to leave interviewee decide which media suit more for them if we want to increase response rate and reduce interviewee burden. But we need to control for potential impact of the survey media on mobility indicators. We need to analyze the impact on population coverage and representativeness to develop adequate weighting procedure. More experiment is necessary in different context in order to produce some recommendations especially to be able to merge the data from different survey media.

3.2. Representativeness and statistical inference

Statistical inference require some form of random sampling. Quota method might produce good quality data,

especially for small sample surveys, but it is not possible to infer results with statistical confidence intervals for the entire population. But response rates are decreasing. Several methods have been developed to encourage people to participate in surveys. With random sampling, weighting methods allow to correct for some socio-demographic biases, but we need to postulate that in average an individual with some demographic who does not respond to the survey has the same behavior than the individuals who have the same socio-demographics but do respond to the survey. We know that the hypotheses might be problematic especially when we know that the response behavior might be correlated with mobility behavior.

The decrease in response rates become so strong in some countries with in some cases a few per cent of response rate especially in US mobility surveys. Even if some form of random sampling methods are used to build the sample, can we consider that with low response rate respondents are representative of the whole target population in order to apply statistical inference? In US some researchers recommend abandoning random sampling in favor of other sampling methods. This recommendation appears controversial and most researchers especially from countries where response rates are higher strongly disagree because inference is very important in mobility analysis. We clearly need more research in order to assess data quality and representativeness in case random sampling are not used.

The question of representativeness has been discussed also for big data. Even with huge quantity of data, we need to analyze the representativeness of data. Passive data are generally not recorded for the objective of mobility analysis, which is a derive output. In general, data is generated in relation with some form of consumption, like for mart card data or mobile phone data. It is therefore not possible to postulate that the data are representative of the whole population. With these data we generally do not have socio-demographics at least for privacy reasons. It became therefore important to identify possible bias in the data. We recognize that the number of researches dealing with representativeness of big data is still too limited. Important researches are needed both to identify bias and then to correct them. Is it possible to move from socio-demographic analysis of representativeness to other methods? Regarding the absence of socio-demographics, is it possible to move to some kind of "ground truth" validation? Even if we obtain similar results for some mobility indicators than other data sources, is it enough to validate the data? The problem might be even more difficult when we work with pre-processed data because we do not know which methods and which data are used to construct the big data. We might validate the big data against "ground truth" while big data might be built with the same data used to define "ground truth"… It might be case for example using google data.

3.3. New methods to analyze data

"Traditional" travel surveys were cross sectional. Data was collected most often for one day and sometimes for few days until a whole week. Even if some surveys, like Canadian survey or Dutch national travel survey might have big sample in comparison with others, the number of observations is very small in comparison with some big database where we can have more than a billion of observations. These new data require new methods to analyze and process the data due to their size.

The content of the data might also be different. Big data is generally obtained in a continuous form. It became possible to analyze day-to-day variability, weekly variability, seasonality, the impact of specific event (weather, strike, major disruption…)…. Big data often contain location dimensions that are more or less precise depending on the kind of data. The number of observations available over a time-period (hours, day, week…) allow to construct itinerary or complex and/or multidimensional chain. We need to develop adequate methodology in order to treat these new forms of data and to respond to new questions. Some authors propose new metric definition to take into account some form of multidimensionality allowed by the size of the data for example to build classifications. Others propose to use methods coming from disciplines where high dimensionality or big size of data are common like in physics, biology, genetic, medicine…. More researches are needed in order to better understand the relevance of the different methods to respond to these new questions. We also need to question the results that are produced by these new methods. How can we transform these results for example some form of regularity or some form of clustering… into better mobility behavior understanding and into transport policy recommendations.

Big database are generally produced for other purpose than mobility analysis. They generally do not contain trips as defined in travel surveys. Even with data produced with a mobility analysis perspective, data might be collected in a form that is different from the one of "traditional" survey. It is the case for example of GPS data or transit smartcard data. We therefore need to develop methodology to transform the data into trips segment and to extract semantic from

the data like transport mode, purpose, number of persons traveling together… Some tools are available, but few are open source. It is therefore difficult to build methodologies which can be applied in different context and that are recognized by the research community.

3.4. Data fusion

Data fusion is an old research challenge, but still require research development. Data fusion consist to enrich a database from other data sources. Traditionally methods have been developed using availability of common variables in two or several database. These common variables are used in order to allow the transfer of information from one base to the other while respecting some statistical rules. These methods are possible because most of database were produced from survey and therefore were containing some socio-demographics. With big data, sociodemographic variables are most often not available. Is it possible to build new common variables which are construct from available data which could be some form of mobility indicators, some spatial information, some temporal information… or a combination of these information?

The development of surveys using several media for whole target population or for some specific groups requires also some form of data fusion. We have already mentioned that media used could affect data collected. The objective of these multimedia methods is generally to propose a unique database representative of the whole population (even if we keep the information of the media used for each observation). Methods exist to identify potential bias of each media for one mobility indicators like selection bias methods for example, but the analysis become much more complex when we want just to merge the database in order to build various mobility indicators. Researches are needed in order to better take into account the various mobility indicators that need to be built.

3.5. Core-satellite concept

Werner Brög has introduced the core-satellite concept during the Grainau conference in 1997. It has been developed and formalized by Kostas Goulias in 2011 at the Chilean conference. It has been discussed again to face contradictory survey requirements. Data precision requires higher number of observations in survey but survey budget rarely evolves in this direction. At the same time more complex models and new policy questions require more data for each surveyed individual or household with again not increasing budget. Core-satellite appears like a possible solution in order to combine these contradictory requirements. Some experimentations now exist. It is possible to develop operational methods based on core-satellite concept. But research is still needed in order define more precisely which questions should be in the core or in the satellites in relation with different survey objectives. Links between core and satellites should also be specified in order to develop fusion methods to enrich the complex database produced by core-satellite surveys. Questions have also raised from a data quality perspective. Sample size of satellite survey is generally small. Precision is therefore smaller. Is it possible to use higher sample size of the core survey in order increase the precision obtained from satellite data?

3.6. Data comparability over time

In some countries or in some conurbations, series of cross sectional surveys are available. Observing the evolution of behavior is in this case an important objective. But tension remains between maintaining the comparability over time and exploiting the “latest tools on the block”. Survey methodology is evolving and there is strong pressure to take advantages of these evolutions in order to benefit from innovation or methodological advance. But we always have to question if the mobility evolution observed between two surveys is the results of real behavioral changes or the results of methodological changes.

There is always strong pressures in order to maintain survey protocols in time using comparability argument to justify this choice. Discussion recognized the fact that keeping the same methodology does not mean we completely neutralize survey protocols potential impact. Response rate evolves with time, perception of survey media also evolves. The local context of interviewer fieldwork often evolves. Weather might be different even if we control for potential season effects. Interviewee expectation regarding survey tools might change with technological change. For

example interviewee expects now that interviewer use computer or electronic devices to collect the data that was not always the case in the past. We recognize that "identical" survey methodology or protocol does not mean strict comparability of outputs. It is therefore always important to question the meaning of the observed evolution between two surveys. We also acknowledged the fact that survey documentation is very helpful when cross sectional data analysis is performed over time.

Continuous survey or continuous passive data appears more favorable in order to analyze behavioral change or the impact of some policy (transport supply evolution, new policy regulation, pricing evolution…). Nevertheless, several challenges have been identified. Technological changes are more and more rapid for some data producers like for example social networks or mobile phone companies. Data production is generally not their first target and technical operation optimization might alter the data like for example the choice of antenna and the modification of location area in real time for mobile phone companies. The context of big data might also evolve (transport supply evolution, pricing evolution, specific events, weather…). Again, we made the conclusion that data documentation, context documentation and archiving is too often neglected that limits seriously the potential of data analysis over long period.

3.7. Need to understand the data

More complex models are used in order to improve their capacity to integrate human behavior complexity or to respond to new questions. Several researches have also highlighted the importance of attitude or perception to understand mobility behavior and decision process for example for new mobility services or transport policies. We also recognize that it is complex to collect attitude/perception variable in quantitative surveys. There exist some question series to build attitudinal variables like for example environmental attitude that might affect modal choice. But the status of these set of questions is not enough recognized which limits their use. We have also question the relevance of these set of questions regarding cultural differences within population or between countries, the problem of translation in different languages… We conclude that we need more research to identify best methods, indicators and measurements in travel surveys.

With big database, we do not have the possibility to introduce new questions to measure attitude or perception. Is it possible to impute these dimensions or in some cases to extract information which could help to measure some attitude or perception dimensions? We clearly need more research to respond. In case of social network data, the problem is somewhat different due to the nature of potentially available information. Some researchers have worked with these data in order to extract some mobility semantic or indicators, but at our knowledge not for attitudinal or perception variables. There is probably a new area of research which might be interesting to explore.

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