Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Validation and usability of floating car data for transportation policy research

Han van der Loop[a] *, Marco Kouwenhoven[b], Peter van Bekkum[c], Henk Meurs[c] and Natascha Kijk in de Vegte[d]

[a]KiM Netherlands Institute for Transport Policy Analysis, P.O. Box 20901, 2500 EX The Hague, The Netherlands
[b]Significance, The Hague, The Netherlands [c]MuConsult, The Netherlands [d]Transpute, The Netherlands

Abstract

This paper describes whether Floating Car Data (FCD) are usable for policy research in the Netherlands based on validation criteria. The use of FCD for traffic information, traffic management and automated vehicles is however beyond the scope of this paper. Projects undertaken by the Netherlands Ministry of Infrastructure and the Environment reveal that for identifying bottlenecks on national, regional and local roads, FCD, owing to the spatial and temporal detailing of vehicle driving speeds, have considerable advantages over data from fixed measurement points. INRIX and TomTom annually publish traffic rankings of cities in the Netherlands, but they are not useful for policy, as their findings are inconsistent and largely incomprehensible. To determine whether FCD can be used to identify trends over succeeding years the KiM Netherlands Institute for Transport Policy Analysis (KiM) compared speeds from FCD 2011-2014 (HERE) and 2014-2016 (INRIX) with driving speeds based on induction loops. Our first conclusion is that over the years FCD elicit certain misrepresentations, because different sources of FCD are used, definitions change (e.g. in road segments), and data are filtered or substituted for missing periods of time. Our second conclusion is that it appears to be possible to monitor trends in hours of delay with a method we developed combining FCD with induction loop data. The use of mobile data for ex-ante and ex-post policy evaluations is currently in an explanatory stage in the Netherlands. Projects aim to improve the measurement of travel time from origin to destination in disaggregated traffic models.

Keywords: transportation policy; performance indicators; traffic measurement; traffic congestion; floating car data

1. Introduction

Floating Car Data (FCD) of various suppliers (HERE, TomTom, INRIX and Be-Mobile) have become available in

* Corresponding author. Tel.: +31 6 15359855
E-mail address: han.vander.loop@minienm.nl or hanvanderloop@gmail.com

the Netherlands in recent years. These data pertain to in-car navigation systems, mobile phones, smartphone travel apps, fleet management systems, and connected cars. FCD are by-products of gps-navigation and mobile phone provision. GPS (Global Positioning System) or GSM (Global System for Mobile Communications such as Vodafone) can determine the location of a vehicle.

This paper describes the extent to which FCD are usable for policy research focused on accessibility by car (travel time and congestion). Mobile data are especially used for current traffic information, traffic management and automated vehicle control. These applications are however beyond the scope of this study.

2. Method

Policymakers in the Netherlands need data pertaining to accessibility in the following stages of the policy process (Van der Loop and Mulder, 2001).

1. In the problem-identification stage, policymakers need detailed information about the bottlenecks in traffic on all roads: not only for main roads (arterials, main trunk road network), but also for regional and municipal roads (primary and secondary roads).
2. All stages of policy need information about how accessibility has developed over the years. For example, has the level of road congestion risen or fallen? What are the causes? Such information may contribute to policy decisions.
3. Prior to taking decisions, the expected effects of policy measures must be known (ex-ante evaluation). Knowledge of the actual effects of policy measures (ex-post evaluation) is required at the end of the policy process, and for testing the methods of the ex-ante evaluation.

For these three policy functions, this paper focusses on the following indicators:

- Travel time of persons and goods from place of origin to destination (O-D)
- Hours of delay

Hours of delay is defined as the extra hours a vehicle needs because the expected speed was not reached (vehicle hours of delay). Presently, hours of delay on national roads are calculated based on measurements of the number of vehicles and their speeds, as measured by induction loops situated approximately every 1 kilometre. To calculate hours of delay, the difference between the travel time at the driven speed on a road stretch and the reference speed is multiplied by the traffic volume (vehicle kilometres) on that road stretch.

To determine the usefulness of FCD for policy research in the Netherlands, a literature study and interviews with suppliers were conducted in cooperation with Transpute. Additionally, the research focused on whether congestion development could be determined by linking mobile data with data from fixed measurement points (induction loops, Bluetooth); for this, KiM conducted studies with HERE- and INRIX-data (MuConsult, 2016; Van der Loop et al., 2019). The applied methodology is detailed later in this paper.

The following criteria were starting points for validating the mobile data of the above-stated three functions of transport policy research.

1. Possibility of evaluating the quality (reliability and validity) of the data used: are documented and detailed source data available?
2. Reliability and validity of indices. Reliability indicates how consistent the measurements are (that is, whether no measurement errors occurred). Validity pertains to the indices' correctness in terms of the actual level of congestion.
3. Clarity pertaining to the nature of the information and manner in which it was obtained and processed (including information pertaining to the data's origin, obtained from which company, deployed using what instrument or methodology, and related documentation).
4. Spatial identification and coverage: can the information be linked to a certain network and is it capable of providing a true picture of the congestion on the entire road network (local and overall)?
5. Continuity and consistency: is it certain that the data will remain available for several consecutive years and can the data for each consecutive year be summarily compared?
6. Speed of supply: how quickly can the data become available and at what intervals (monthly, quarterly, annually)?

3. FCD to identify bottlenecks in traffic flows

Numerous articles were found in the literature comparing mobile data with other data sources, such as Bluetooth data (Omrani, 2012; Ho Lik Yu et al., 2013; Liu at al., 2012; University of Maryland, 2015; Morgul et al., 2014; Van den Haak and Emde, 2016). These comparisons were made for traffic management and travel information (for guidelines, see TTI, 2011), and always concerned specific times and places at a certain moment or for a very short period of time. No articles were found that specifically identified bottlenecks in traffic flows (see the following section for discussion of improving the matrices of trips from origin to destination in traffic models).

In preparing the Netherlands' 'Better Use' policy program, and the 2017 National Market and Capacity Analysis (NMCA), the amount of hours of delay on national, regional and municipal roads in the Netherlands in 2017 were estimated in a pilot (Ministry of Infrastructure and the Environment, 2017a). In Rijkswaterstaat's National Model System (LMS), INRIX mobile speed data were matched with the number of trips from zone to zone (1,400 zones) in the base year 2014. With the 2016 INRIX driving speeds per subsegment serving as the starting point, the speeds available for all subsections were linked to Open Street Map. To calculate the lost minutes per vehicle per segment, the difference between the average speeds during the evening peak hours (16:00-18:00) and the free-flow speed were determined. The free-flow speed per segment is the highest speed reached after the highest 20% of speeds are removed from consideration; these differences in driving speeds are then multiplied by the number of vehicles that use that particular road segment, as based on the number of trips undertaken on segments in the LMS. The number of trips in 2016 is interpolated from the base year 2014 and the LMS's medium-term matrix for 2021.

According to this NMCA calculation (which requires further validation), more hours of delay occurred on regional and municipal roads (75 million) in 2016 than on national roads (53 million). The most hours of delay occurred on roads in and around the Randstad's major cities (Amsterdam-Utrecht-Rotterdam-The Hague), and in Noord-Brabant and Gelderland (Table 1). According to the applied methodology, the findings can be considered as an initial indication of how many hours of delay occurred in the relevant areas. These hours of delay - as determined using INRIX - have not yet been sufficiently validated for use in monitoring and evaluation. Moreover, a simple allocation of driving speeds and intensities was applied, and the impact of the selected definition of free-flow speed remains unclear.

Table 1. Hours of delay on roads in the Netherlands in 2014 (x 1000) on an average workday during peak hours (16:00-18:00)(12)*.

	National roads	Within the built-up area	Outside the built-up area	Total
Region				
Randstad	31	24	13	68
Noord-Brabant and Gelderland	16	12	9	37
Rest	6	9	8	23
Level of urbanisation				
Metropolitan (5 cities)	9	10	1	21
Urban (17 cities)	5	11	3	20
Smaller towns	15	14	7	36
Rural	24	10	19	52
Total	53	45	30	129

* To compare the hours of delay with other countries: length of national roads is approximately 5,300 kilometres and length of all roads approximately 142,000 kilometres.

Owing to mobile data's large degree of spatial detailing and the fact that an approximation of speeds (eventually combined with stable road characteristics, such as number of lanes) is sufficient, mobile data is deemed suitable and useful for identifying national, regional and local bottlenecks in traffic flows (better and to a greater extent than is possible using fixed data, which cannot achieve such intricacy).

That mobile data does not provide information about the degree of the traffic flow means that bottlenecks can indeed be identified, but not how many vehicles are involved. Mobile data alone is therefore incapable of determining hours of delay, because this indicator is a multiplication of two indicators: the difference between the driving and free-flow speed and the traffic volume.

In the context of the ‘Better Use’ program, mobile data were used to measure hours of delay relative to a free-flow speed specific to this measurement. With a view toward interpreting the findings and comparisons with other studies, measuring using fixed reference speeds is preferred.

4. FCD to monitor trends in accessibility

No articles were found in the literature that examined the use of mobile data for monitoring developments in accessibility over multiple years (trends). This section first examines the use of congestion indices based on mobile data and then describes two studies for monitoring trends in hours of delay.

4.1. Use of congestion indices to monitor trends in accessibility

Based on mobile data, TomTom and INRIX annually publish (worldwide) traffic congestion rankings, including for the Netherlands. TomTom developed the so-called Traffic Index (TI), which measures travel speeds during the day: the peak hours are compared to the off-peak travel times (at night, during the free-flow), with the difference between the two expressed as an average percentage of the decrease in travel speed.

INRIX publishes an annual Traffic Scorecard Report that indicates the number of hours of delay in peak hour traffic congestion during 240 business days, while also ranking the various Dutch cities, and the Netherlands as compared to other countries. INRIX calculates driving speeds per road segment at 15-minute intervals and compares them to a free-flow reference speed. The index is based on the peak hours (6:00-10:00 and 15:00-19:00) and relates to road length. Congestion is deemed to have occurred if the speed drops below 65% of the free-flow speed, which is considered as the speed of that road segment without congestion. Various articles published on INRIX's website broadly explain the methodology used for devising the INRIX Traffic Scorecard.

INRIX and TomTom’s published congestion indices seem to suggest that they are in fact descriptions of the actual development of congestion or of the traffic congestion in cities. Is that really the case? Neither of the indexes’ calculation methods are described in the explicit detail required for assessing what these findings exactly mean and whether any misrepresentation exists. The algorithms used remain unpublished. The development of congestion as published was not validated using other measurements of congestion development. Moreover, while comparisons are indeed made with the previous year, there is no examination of trends occurring over several years. One problem is that the borders of cities are unequally defined; consequently, the cities differ in degrees of urbanisation and specific urban planning characteristics.

The congestion indexes that use mobile data are based on large numbers of vehicles, but of a relatively small and selective segment. Analysis of HERE data reveals that the composition of selected vehicles changes from year to year (see next section). The TomTom and INRIX indexes do not clearly reveal if and how such shortcomings are accounted for. Based on the information gained to date using INRIX data, it appears that these data do not always reflect the actual speeds of the vehicles (see next section). Based on the available published information (e.g. TomTom, INRIX), it is also impossible to comprehend why one city scored higher than another. Moreover, the findings of the various companies are also contradictory (Table 2). The main problem is that the findings, and the differences that exist among the various findings, cannot be understood or explained by the published figures and definitions. For these reasons, the congestion indexes cannot be assumed to accurately reflect the development of congestion. Consequently, although the TomTom and INRIX indexes do appear promising, their findings have no value for policy and cannot be used in the policy process. Moreover, when interviewed, the companies indicated that this published information was primarily intended for marketing purposes.

Table 2. TomTom and INRIX congestion indexes for cities in the Netherlands in 2016 (Puylaert, 2017)

TomTom	City	Delay (compared with 2015)	INRIX	City	Delay
1	Haarlem	27% (+3%)	1	Maastricht	14%
2	The Hague	24% (+1%)	2	Amsterdam	9%
3	Leiden	23% (+2%)	3	Utrecht	8%
4	Groningen	23% (+1%)	4	Dordrecht	8%
5	Amsterdam	22% (+2%)	5	Haarlem	8%
6	Nijmegen	21% (+3%)	6	Rotterdam	8%
7	Arnhem	20% (+3%)	7	Arnhem	8%
8	Tilburg	19% (+2%)	8	The Hague	7%
9	Breda	19% (+2%)	9	Amersfoort	7%
10	Eindhoven	19% (+3%)	10	Groningen	7%

4.2 Use of FCD to monitor trends in accessibility

Instead of relying on the congestion indices published by companies, trends in hours of delay can be determined by combining basic information derived from mobile data with information from fixed measurement points. In the Netherlands, this has been tried using HERE and INRIX data.

HERE

HERE data were used to determine hours of delay from 2011 to 2014 as follows: the delays were calculated, based on HERE data, and multiplied by the traffic volume, as based on data from fixed measurement points (usually induction loops) managed by the National Data Warehouse for Traffic Information (NDW). The HERE data were available in the form of travel time data for 111,000 sections of a 16,500 km network (2014; mean length 147 meters). In the calculations, the quarterly average speeds were per workday per month (for example, the speeds measured from 6:00 to 6:15 on four Tuesdays in March 2014). In a geographic information system, the travel time data per stretch were linked to the locations where the numbers of vehicles (intensities) were measured. The network segments were then connected to each other, creating longer trajectories, and the travel time was calculated over those trajectories. The delay was calculated with reference to the free-flow driving time, and the hours of delay were derived by multiplying with the intensity. A methodology developed to identify the free-flow driving time accounted for the driven speed during off-peak hours and the maximum speed limit. INRIX data were used to further develop this methodology, as detailed below.

It appeared that the trend of hours of delay calculated with INRIX and other data differed from the trend on national roads based on only induction loops. Analysis of the intensity data revealed that the trend developed in a plausible manner. The average speed per year on the main roads managed by the state (Rijkswaterstaat, RWS) in Noord-Holland, Utrecht, Zuid-Holland and Noord-Brabant, as measured by RWS and HERE, were compared. According to the RWS data, speeds during off-peak hours (10:00-15:00) gradually increased by a total of 0.5% from 2011 to 2014. According to the HERE data, the driving speed increased by 7.6% during off-peak hours (Figure 1). Moreover, the speed gradually increased by 1% during the peak hours (6:00-10:00 and 15:00-19:00), according to the RWS data, while the HERE data revealed that from 2011 to 2013 the speed increased by 10% during peak hours, and decreased by 2% the following year. The changes in HERE data are regarded as unrealistic.

The major changes revealed in the HERE data were likely primarily due to changes that occurred in the fleet composition (the share of commercial vehicles (relatively often trucks), and private vehicles (primarily passenger cars), vary per year), and also possibly partly due to the applied measurement methodology (MuConsult, 2016). Consequently, misrepresentations were found in the annual changes to HERE’s speed data.

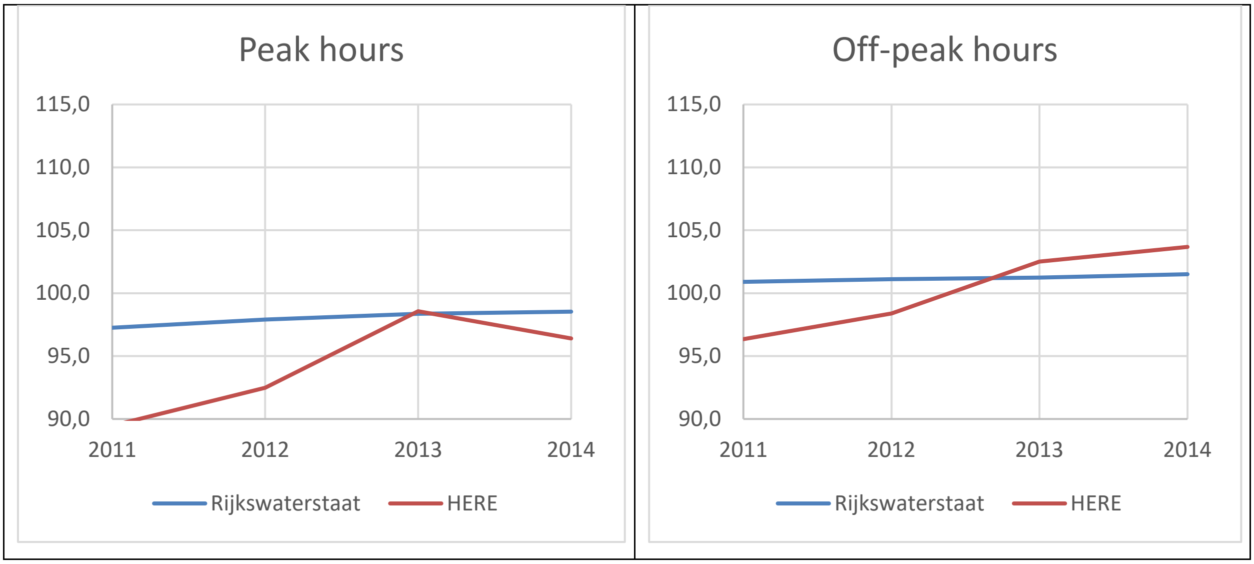

FIGURE 1. Development of driving speed (km/h) on the national roads per year 2011-2014, as based on the induction loops (RWS) and mobile data (HERE) during the peak (6:00-10:00; 15:00-19:00) and off-peak hours (10:00-15:00).

INRIX

In order to ascertain whether the annual development of hours of delay can be determined by linking delays measured with INRIX data to intensities from fixed NDW measurement points, this annual development of hours of delay was compared to the development of hours of delay, as determined by using both the delays and intensities from NDW (Van der Loop et al., 2019). For this comparison, a set of locations were selected where both NDW data and INRIX data were available for all months between 2014 and 2016 (except for the month of May 2014, which was excluded, due to numerous problems with the data). Owing to changes in INRIX's definitions of road segments and missing fixed data, 4,125 locations were ultimately identified in the dataset, of which 162 locations were situated on regional roads and 22 on municipal roads. INRIX data were available for every minute of each separate day. The length of the segments (called "subsegments") is approximately 100 meters.

The analysis was conducted for seven different road types: on the regional and municipal roads with local maximum speeds of 50, 60, 70 and 80 km/h, and on the national roads with local maximum speeds of 70, 80 and 100+ km/h. The reference speeds (or free-flow speeds) are based on the average speed during off-peak hours (10:00-15:00) on these seven road types: respectively 45, 50, 55, 60, 55, 80 and 100 km/h (2). This renders it possible to compare changes over time (years) in a comprehensible and consistent manner, and contributes to determining the measures' effects and comparing them with one another.

INRIX provides an average speed for a single road segment (up to a maximum distance of 1.6 km), as well as for the 16 subsections of each segment. The corresponding INRIX subsegment is determined for each detector. Subsequently, a comparison is made between the measured detector-speed and the recorded INRIX-speed for all 36 months between 2014 and 2016 and for each quarter of the day (insofar as data are available).

The speeds on the INRIX subsegments changed approximately 3 to 7 minutes later than those of induction loops. Moreover, the INRIX driving speeds were correlated for consecutive minutes, which was likely due to data being substituted for missing time periods. Both differences could be overcome by estimating the quarterly data and accelerating the INRIX data by 5 minutes.

The average speed, as measured by INRIX, closely corresponds to the average speed as measured by NDW (Figure 2). However, deviations exist for driving speeds below 30 km/h, and above 110 km/h. The speeds above 100 km/h are unimportant in determining hours of delay (up to a reference speed of 100 km/h). The induction loops are known to identify stationary or slow moving vehicles less often and therefore overestimate speeds below 30 km/h. Because the speeds of INRIX are higher below 30 km/h, this cannot explain the difference. It may be that INRIX's fusion engine eliminates low speeds. For high driving speeds on segments with variable maximum speeds, the INRIX-speeds occasionally assumed strange patterns, which was perhaps due to the INRIX-fusion algorithm being optimised to indicate the possible speed instead of the driven speed (Van der Loop et al., 2019).

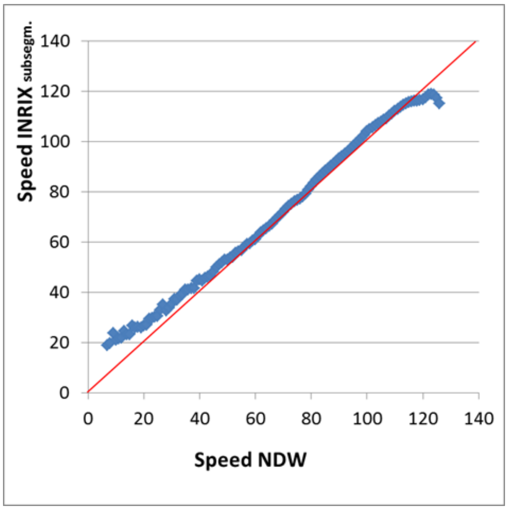

Figure 2. Relation between speeds of INRIX and NDW on 3600 INRIX subsegments per 15-minutes (blue dots) on national roads with a maximum speed limit of 100 km/h in December 2016 compared with perfect correlation (red line).

The problems that the INRIX-data encounter at higher speeds also ensure that differences exist between the two sources in terms of average speeds during peak and off-peak hours. Although the differences vary with each month, no trend seemingly emerges in which the differences become increasingly larger or smaller (Figure 3). The agreement between the development of hours of delay of INRIX/NDW and NDW-only supports the assumption that the difference existing between the average speeds is primarily caused by INRIX's problems at higher speeds, and that there is substantial agreement between both data sources in the speed interval where hours of delay occur (between 30 km/h and 100 km/h).

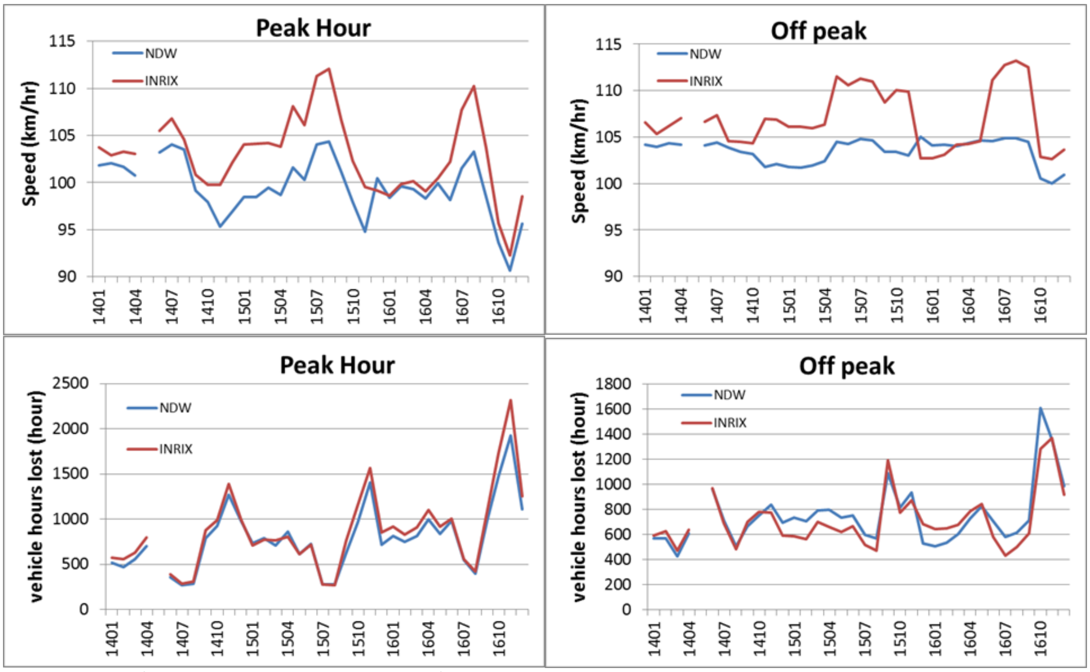

Figure 3. Development of driving speed (km/h) and hours of delay on the national roads per month 2014-2016, as based on INRIX/NDW at peak (7:00-9:00; 16:00-18:00) and rest of day.

For the above-stated reasons, and owing to minor differences between both developments, the combination of INRIX and NDW is regarded as suitable for a reasonable determination of the development of hours of delay. They are suitable for determining annual changes in hours of delay on main roads, regional and municipal roads. Reliability could be improved if the above-stated, relatively minor misrepresentations are clarified and avoided.

The development of hours of delay on national, regional and municipal roads was determined on all INRIX subsegments (> 20,000) that were available over the course of the entire 3-year measurement period and for those segments whose definition did not change (or not significantly) during this period. An average intensity was determined per road class in the (previously linked) NDW data for every quarter of each separate day in the measurement period. The lost vehicle hours were then calculated by combining the INRIX speeds, the average NDW intensities, and the reference speeds.

Based on this analysis, the development of hours of delay on national roads (Figure 4) closely corresponds to the development of hours of delay on the national roads, as calculated by the Ministry of Infrastructure and the Environment and published in the Mobility Monitor (KiM, 2016). Some discernible differences exist, but this could be due to a slightly different selection of road segments. The development of hours of delay on regional and municipal roads shows a similarly rising trend to that on the national roads. However, on regional and municipal roads, the gradual increase primarily occurred between January 2014 and April 2015, while the increase on national roads was more explosive, especially since September 2015.

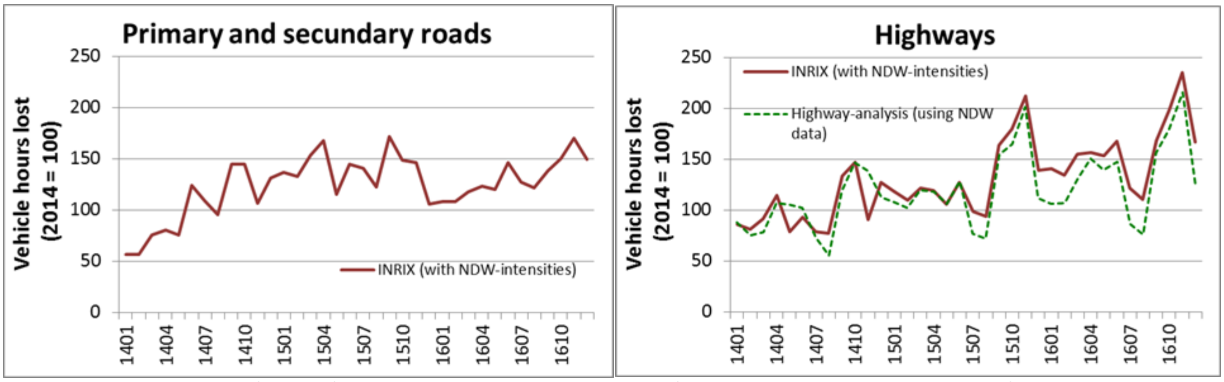

Figure 4. Development of hours of delay on roads per month 2014-2016 of INRIX/NDW and on national roads of RWS (2014 = 100).

5. FCD for policy evaluation

In the literature pertaining to the use of mobile data, two studies were found for improving information in an O-D matrix in the base year of a transport model. For the transport models of Leicester County (UK), Tolouei et al. (2015) compared Telefonica data with other sources according to trip characteristics, concluding that generally a reasonable level of agreement existed between the GSM data and data from roadside interviews. Restrictions on mobile phone data are such that no distinctions could be made between vehicle types, motives, and the spatial distribution required for a transport model. Allos et al. (2014) compared GPS data from Trafficmaster and Telefonica (obtained via INRIX) with data from roadside interviews, in order to improve the O-D matrix on an average weekday in October 2006 in Cambridgeshire’s transport model (UK). They concluded that the new information did indeed improve the matrix, but not by enough, owing to the complexity and demanding interpretation. No literature sources were found pertaining to the use of mobile data for ex-post evaluation.

5.1 Ex-ante evaluation

Transport models, such as the Rijkswaterstaat’s National Model System (LMS), require a detailed description of the travel behaviour of persons in a base year. Information is needed about travel times and hours of delay from origin zone to destination zone (O-D). Mobile data could potentially be used to improve this description. At present, FCD suppliers only provide speed data on road segments. For insights into usable O-D information, to date such data have primarily been provided for specific detailed research on a project basis. Little is known about the data’s quality and usability.

Currently in the Netherlands, NDW, users and suppliers, are exploring the possibilities of conducting pilot projects using FCD, in order to bolster information about trips on the O-D level. This is not a question of determining complete national or regional matrices, but rather of determining smaller-scale applications, such as traffic flow distributions at an urban road network intersection and at a junction on the national roads (whereby it is possible to make comparisons with visual observations), and of determining a selected link in national roads (compared with information from license plate research) and the distribution of traffic flows, for example, on main/parallel roads. Pilots should subsequently examine the usability.

The Ministry of Infrastructure and the Environment (2017b) examined whether Vodafone GSM data could be used to improve the O-D matrix. Mezuro, a company specialized in mobile data, translated the GSM data into trips, showing that it is indeed possible to improve the O-D matrix in parts (for example, at airports, traffic to and from abroad, and trips longer than 10 km, except those by train). Further research will be conducted to determine what quality improvements can be made to GSM data, in order to compile O-D matrices for car traffic in LMS.

In the coming years mobile data is expected to provide improved knowledge of traffic situations, bottlenecks and the causes thereof, especially on regional and municipal roads; for example, bottlenecks arising on municipal roads and continuing on regional and national roads, or vice versa. Other improvement options for LMS include: using FCD door-to-door travel times as input when estimating choice behaviour and when assessing the quality of model allocation in the base year, and particularly in comparing travel times on provincial and municipal road segments. FCD data is already used to test and improve the allocation of car traffic. Various problems still must be solved.

- One problem with devising O-D matrices based on mobile data is the sample's selectivity. Will the construed O-D matrix be representative for all trips? How should we handle the possible underrepresentation of certain trips, such as short trips? How can the O-D matrices be weighed or enhanced if necessary?
- Another problem is whether transport modes (cars and public transport) and vehicle types (passenger and freight or transport) can be differentiated. Distinctions between the various trip motives are also needed.

5.2 Ex-post evaluation

To determine the actual impact that policy has had on traffic congestion and other aspects of accessibility (ex-post evaluation), the same clarity and quality of traffic data is required as for identifying trends (no discrepancies between consecutive years). Here the problem also arises that trends in driving speeds and travel times can be misrepresented and are also often found to be based on different (and over time inconsistent) data sources. If the composition of the population of travellers to whom the data pertains is always changing, the subsequent measured difference cannot be ascribed to the introduction of a measure. Mobile data suppliers could find ways to take this into account when processing the data. Additionally, in order to determine the extent of congestion in terms of hours of delay, intensities are required from other data sources (fixed measuring points, such as induction loops, Bluetooth, traffic lights).

6. Conclusions and future developments

In recent years FCD have become available for policy research, as a by-product of GPS navigation and mobile phone provision. Research in the Netherlands leads to the following conclusions about the usability of FCD for three functions in policy research: identify bottlenecks in traffic flows, monitoring trends, and policy evaluation.

6.1 Conclusions

1. Identifying bottlenecks in traffic flows

- Due to spatial and temporal detailing, and because an approximate speed is sufficient, mobile data are highly appropriate for identifying bottlenecks in traffic flows on the national, regional and local road networks (more than is possible with fixed data, which cannot achieve so much spatial detail).
- Because mobile data do not provide sufficient information about the size of the traffic stream, the number of vehicles confronted by bottlenecks cannot be determined. Mobile data alone are therefore insufficient to determine travel time loss, because this requires two indicators: driving speed and traffic volume. If data for more vehicles become available and sufficient methods are developed, in future mobile data might be able to identify the amount of traffic.
- With a view toward the comparability of various studies, the preference is for measurement of delay relative to reference speeds that remain equal in succeeding years.

2. Monitoring trends

a) Use of the TomTom and INRIX traffic congestion indexes.

Currently, the congestion indexes published annually by TomTom and INRIX, ranking congestion in countries and cities, cannot be used for policy, because these indexes' findings cannot be comprehended or verified based on the published figures and definitions. The findings are inconsistent with other sources, as well as with each other. It is impossible to ascribe an unambiguous policy interpretation to the findings of TomTom and INRIX's congestion indexes.

b) Use of mobile data to measure indicators.

Although the congestion indexes are unusable for policy, the underlying data can be used to supplement the current data available from fixed measurement points.

- Mobile data provide insights into driving speeds on a much more spatially detailed level than the fixed road systems.
- The consistency of data over the years appears to differ among suppliers. Consequently, the consistency must be checked before applying mobile data for monitoring. Mobile data cannot necessarily determine changes in speed or travel time over time, and this may be caused by several factors, including changes in the composition of the population of vehicles over time, changes in definitions (e.g. in road segments), and changes in data being eliminated or substituted for missing time periods. The combined use of INRIX with data from fixed measurement points demonstrates that the shortcomings of mobile data can be overcome.
- Currently, traffic volumes cannot be determined with mobile data. The number of measured vehicles (probes) remains too low (around 5%) and insufficiently representative.

3. Use of mobile data for ex-ante and ex-post policy evaluation

Applications of mobile data for ex-ante and ex-post policy evaluations provide new opportunities (e.g. to improve O-D matrices). Analyses of HERE, INRIX and Vodafone data in the Netherlands reveal that these data do not always reflect actual speeds (e.g. lack short trips) or trends in speeds for identifying changes over time. The examples of INRIX and Vodafone demonstrate that these data already can contribute to ex-post and ex-ante evaluation if these limitations are recognised and solved using new methods. Moreover, the situation might improve over time if the suppliers' mobile data improve and users gain more experience in determining the strengths and weaknesses of these data.

The authors assume that the conclusions about the FCD data also apply to other countries. Only the availability of data for fixed measurement points differs: in the Netherlands, the national roads are equipped with fixed measurement points (on average every kilometre), and consistent data on intensities and speeds have been available since 2000. Recently, traffic light systems also provide data on passing vehicles, and this may serve to further improve the data for transportation research.

.

6.2 Future developments

The question is whether mobile data's current disadvantages – such as inconsistencies between years and lack of representativity – are structural or solvable. Perhaps in future not only will data about more vehicles become available, but the clarity might also be improved.

Mobile data is currently made available by several providers. Each provider uses other sources and its own algorithms. There are no sufficiently detailed insights into how the data were calculated from the original sources, nor what its composition or variation over time is. This complicates its use in policy research. As a result, anyone who uses these data sources for policy research must first check for potential discrepancies. Mobile data suppliers will perhaps find opportunities for providing more information about the sources, the algorithms used for computing speeds from probes, the status (based on probe signals, extrapolated or estimated) and/or the composition (e.g. person-freight) of their mobile data.

If changes in the measurement of FCD are introduced, a period of transition with old and new computed data should be established, in order to estimate trend breaks. Ideally, the data should be of such quality that no corrections for errors or trend breaks would be necessary. As methods for recognizing patterns in the available data improve, the information available from the data pertaining to total traffic volume might also improve over time. Nevertheless, if mobile data do not represent all passing traffic, certain distance classes, time periods, vehicles, motives, etc., can still be over- or underrepresented. For the time being, fixed measurement points remain necessary for determining traffic volume.

References

Allos, A., Merrall, R., Smithies, R., Fishbum, R., Bates, J., Himlin, R., (2014), New data sources and data fusion. European Transport Conference.
Ho Lik Lu, Goran Nikolic, Reza Omrani, 2013. Alternative Data Collection Technologies. ITS Canada Annual Conference and General Meeting.
KiM, 2016. Mobility Report 2016. KiM Netherlands Institute for Transport Policy Analysis (KiM), The Hague, The Netherlands (www.kimnet.nl).
Liu, X, S. Chien, K. Kim, 2012. Evaluation of floating car technologies for travel time estimation. Journal of Modern Transportation, Vol 1, pp. 49-56.
Ministry of Infrastructure and the Environment, 2017a. National Market and Capacity Analysis 2017 (NMCA). The Hague, The Netherlands.

Ministry of Infrastructure and the Environment, 2017b. *Gebruik GSM-data voor Landelijk Model Systeem*. Pilot study. Powerpoint. The Netherlands.

Morgul, E.F., Yang, H., Kurkcu, A., Ozbay, K., Bartin, B., Kamga, C., Salloum, R., 2014. Virtual Sensors: A Web-based Real-Time Data Collection Methodology for Transportation Operation Performance Analysis. Transportation Research Board's 93rd Annual Meeting, Washington, D.C.

MuConsult, 2016. *Reistijdverlies op provinciale en stedelijke wegen 2011-2014*. Methodology development. Commissioned by, and in collaboration with KiM Netherlands Institute for Transport Policy Analysis. Amersfoort: MuConsult B.V.

Omrani, R., 2012, Alternative methodologies for travel time studies. Final report.

Puylaert, G., 2017. *De file top10 vanuit ander perspectief*. *Verkeerskunde*.

Tolouei, R., Alvarez, P., Duduta, N. (2015), Developing and verifying origin-destination matrices using mobile phone data: the LLITM case. European Transport Conference.

TTI, 2011. Guidelines for evaluating the accuracy of travel time and speed data. Texas Transportation Institute (TTI), 2011.

University of Maryland, 2015. I-95 Corridor Coalition Vehicle Probe Project, 2015. Validation of HERE Data. Validation of INRIX Data. Validation of TomTom Data. Reports for New Jersey (#13), November 2015.

Van den Haak, W.P., Emde, M.F., 2016, Validation of Google floating car data for applications in traffic management. TNO.

Van der Loop, H., Mulder, M., 2001. "To Measure = To Know": Results of a Transport Policy Monitoring System in the Netherlands. Paper, Seoul, South Korea, WCTR.

Van der Loop, H., Francke, J., Jorritsma P., Moorman, S., 2017. *Bruikbaarheid van floating car data voor beleidsonderzoek*. KiM Netherlands Institute for Transport Policy Analysis. The Hague, The Netherlands.

Van der Loop, H., Kouwenhoven, M., Willigers, J., 2019. *Het bepalen van het reistijdverlies op rijks-, provinciale en gemeentelijke wegen in Nederland 2014-2016*. KiM Netherlands Institute for Transport Policy Analysis, in cooperation with Significance, The Hague, Netherlands, 2019.