VALIDATION OF FLOATING CAR DATA FOR TRANSPORT POLICY ANALYSIS AND TRANSPORT MODELS

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1. INTRODUCTION

Floating Car Data (FCD) has been available for policy research in the Netherlands since 2010, as provided by various suppliers (Here, TomTom, INRIX, BeMobile, Vodafone/Mezuro). These data pertain to in-car navigation systems, mobile phones, smartphone travel apps, fleet management systems (management of car fleets), and ‘connected cars’.

The percentage of vehicles whose driving speed is derived using these mobile data is increasing. Presently, suppliers indicate they measure approximately 5% of all vehicle movements via mobile data, and this percentage is rising alongside the increased application of floating car systems.

This paper describes the extent to which floating car data is available for policy research focusing on accessibility by car. However, the use of mobile data for current traffic information, traffic management and automated vehicle control is beyond the scope of this study.

2. METHOD

To determine the usefulness of floating car data for policy research in the Netherlands, we conducted a literature study and interviewed suppliers. Moreover, we examined whether congestion development could be determined by linking mobile data with data from fixed measurement points (detection loops); for this, KiM conducted joint research with MuConsult using Here-data from 2011-2014 (MuConsult, 2016), and collaborated with Significance using INRIX-data for 2014-2016 (Significance/KiM, 2017). The applied methodology is further described in this paper.

The following criteria were starting points for validating the mobile data for transport policy research.
1) Possibility of evaluating the quality (reliability and validity) of the data used: are source data available to a sufficiently detailed degree?
2) Reliability and validity of indices. Reliability is understood to include how consistent the measurements are (or conversely, a lack of measurement errors).

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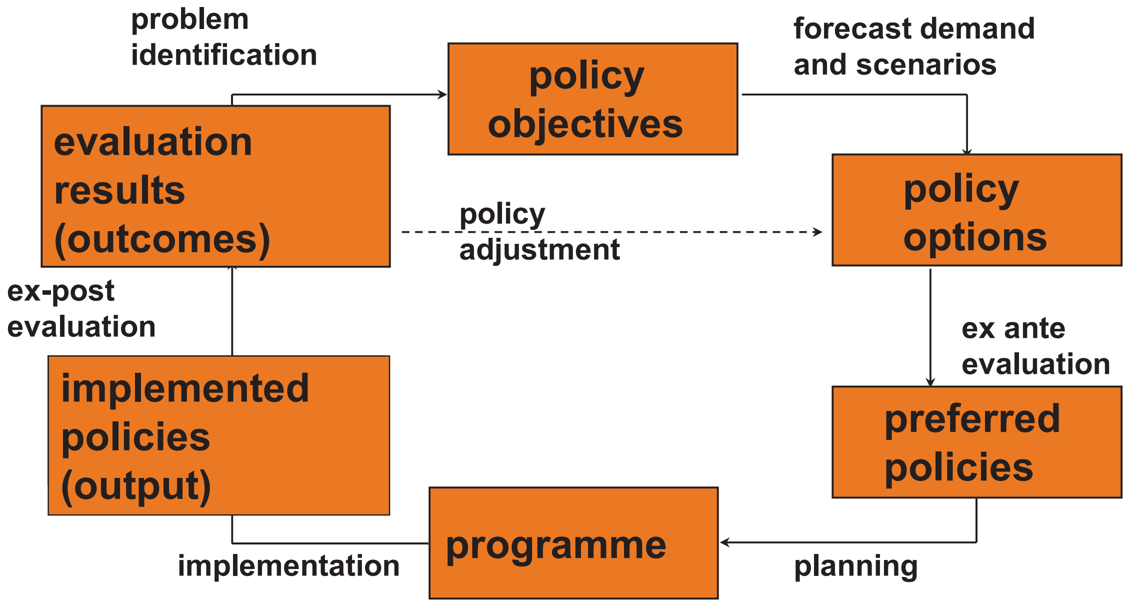
Validity pertains to the correctness of the indices and full representation of all aspects of the actual level of congestion.
3) Clarity of documentation in terms of the nature of the data and manner in which it was obtained and processed (including information pertaining to the data's origin, obtained from which source or company and deploying what instruments or methodology, related documentation).
4)Spatial identification and coverage: can the information be linked to a network and is it capable of providing a true picture of the congestion factors 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 from each consecutive year be summarily compared?
6) Speed of supply: how quickly can the data be made available and at what intervals (monthly, quarterly, annually)?

3. WHICH INFORMATION IS NEEDED FOR TRANSPORT POLICY?

With a view toward accessibility by car and policy processes (Figure 1), floating car data is useful for the following purposes:

1. Identification of the problem: determining the bottlenecks in the traffic flow at the start of the policy process.
2. Monitoring: determining trends or developments in accessibility over time (years).
3. Ex-ante and ex-post evaluation: data can help to identify possible effects of policy measures on the policy objectives (ex-ante evaluation). Knowledge of the realized effects of policy measures can play a role in adjustment of policy and testing and improving ex-ante evaluation methods.

Figure 1. The policy cycle (Van der Loop, et al., 2001)



The following indicators are used for these three policy functions:

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

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- 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 measured with induction loops, managed by the Dutch Ministry of Infrastructure and the Environment. To calculate hours of delay, the difference in travel time by the driven speed on a road stretch and the reference speed is multiplied with the traffic volume (vehicle kilometres) on that road stretch.

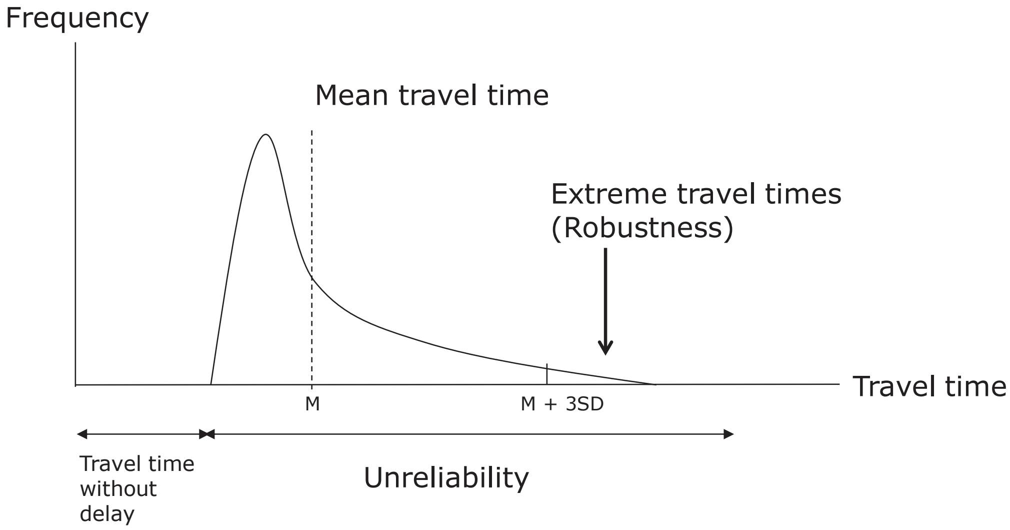
- Travel time unreliability

According to OECD recommendations (OECD, 2010), unreliability of travel time is defined as the extent to which the travel time is longer or shorter than the amount of time the traveller anticipated (Figure 2). This definition includes both the large and small daily variations in travel time, as well as the more incidental minor and major disruptions. The measure in which unreliability can be expressed is the standard variation (SD) of the division of travel time, in minutes. The advantage of this measurement is that all variations in travel time are expressed in it.

- Extreme travel times and robustness

An element of unreliability pertains to relatively extreme travel times, which, for example, stem from incidents or heavy traffic. In such situations, the network may appear to be insufficiently robust. From the traveller’s perspective, robustness is considered as the extent to which extreme travel times are prevented. Extreme travel time loss is deemed to be the hours of delay that are more than three times the standard deviation (SD) of the average travel time (M). This pertains to 8% of all hours of delay on the national roads.

Figure 2. Schematic rendering of the unreliability of travel time and extreme travel times (KiM, 2016).



4. FCD FOR IDENTIFYING BOTTLENECKS IN TRAFFIC FLOWS

Numerous articles were found in the literature comparing mobile data with other data sources, such as Bluetooth data (for ex. Omrani et al., 2012; Ho Lik Lu, et al., 2013; Liu, et al., 2012; I-95 Corridor Coalition Vehicle Probe Project, 2015; Morgul, et al., 2014: Van den Haak et al., 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 a very short period. No articles were found that specifically identified bottlenecks in traffic flows (for improving the matrices of trips from origin to destination in traffic models, see section 6).

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 (NMCA, 12). INRIX mobile speed data were matched with the number of trips from zone to zone (1,400 zones) in the base year 2014 in Rijkswaterstaat's National Model System (LMS). 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 (16-18 hours) 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. This is 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 calculation for the NMCA (that needs further validation), more hours of delay occurred on regional and municipal roads (75 million) in 2016 than on the 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 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 (see section 6). 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. First indication of hours of delay on roads in the Netherlands in 2014 (x 1000) on an average workday during the evening peak hours (16:00-18:00). Source: Mobility scan, MOVE Mobility, 2017.

	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

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Mobile data's large degree of spatial detailing, and the fact that an approximation of speeds is sufficient, render mobile data 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 still be identified, but not how many vehicles are involved. Mobile data alone is therefore incapable of determining hours of delay and thereby bottlenecks, because this indicator is a multiplication of two indicators: the difference between the driving and free flow speed and the traffic volume. The same conclusion applies for the other indicators.

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

5. FLOATING CAR DATA TO MONITOR TRENDS IN ACCESSIBILTY

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

5.1 Use of congestion indexes to monitor trends in accessibility

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

INRIX publishes an annual Traffic Scorecard Report, which indicates the number of hours of delay in peak hour traffic congestion during 240 business days, while also ranking the Netherlands as compared to other countries, and ranking the various Dutch cities. INRIX calculates driving speeds per road segment every 15 minutes, and compares this to a free flow reference speed. The index is based on the peak hours (6:00-10:00 and 15:00-19:00) and related 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. But is that really the case? Neither of the indexes' calculation methods are described in the explicit detail required for assessing what their 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 paragraph). The TomTom and INRIX indexes do not clearly show 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 speeds of the vehicles (see next paragraph). 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 admitted that this published information was primarily intended for marketing purposes.

Table 2. TomTom and INRIX congestion indexes for cities in the Netherlands in 2016 (Source: Traffic Engineering, 2017)

TomTom	City	Delay (compared with 2015)	INRIX	City	Delay
1	Haarlem	27% (+3%)	1	Maastricht	14%
2	Den Haag	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	Den Haag	7%
9	Breda	19% (+2%)	9	Amersfoort	7%
10	Eindhoven	19% (+3%)	10	Groningen	7%

5.2 Use of floating car data to monitor trends in accessibility

Instead of the congestion indices published by the companies, the basic information derived from the mobile data can be combined with information from fixed measurement points to determine trends in hours of delay. In the Netherlands, this has been tried with Here and INRIX data.

HERE

Here data were used for determining hours of delay from 2011 until 2014 by means of calculating the delays, as based on the Here data, and multiplying these with the traffic volume, 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 the various network sections. 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 of the measurements of the amount of vehicles (intensities). The network segments were then connected to each other to create longer trajectories, and the travel time was calculated over these 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 for the free flow driving time took into account 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 of both sources 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 3). Moreover, the speed gradually increased 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.

These major changes revealed in the Here data were likely largely due to changes that occurred in the fleet composition (the share of commercial vehicles, relatively often trucks, and consumer vehicles, primarily passenger cars vary per year, see Figure 4), and were possibly partly due to the applied measurement methodology (MuConsult, 2016). Consequently, misrepresentations were found in the annual changes to Here's speed data.

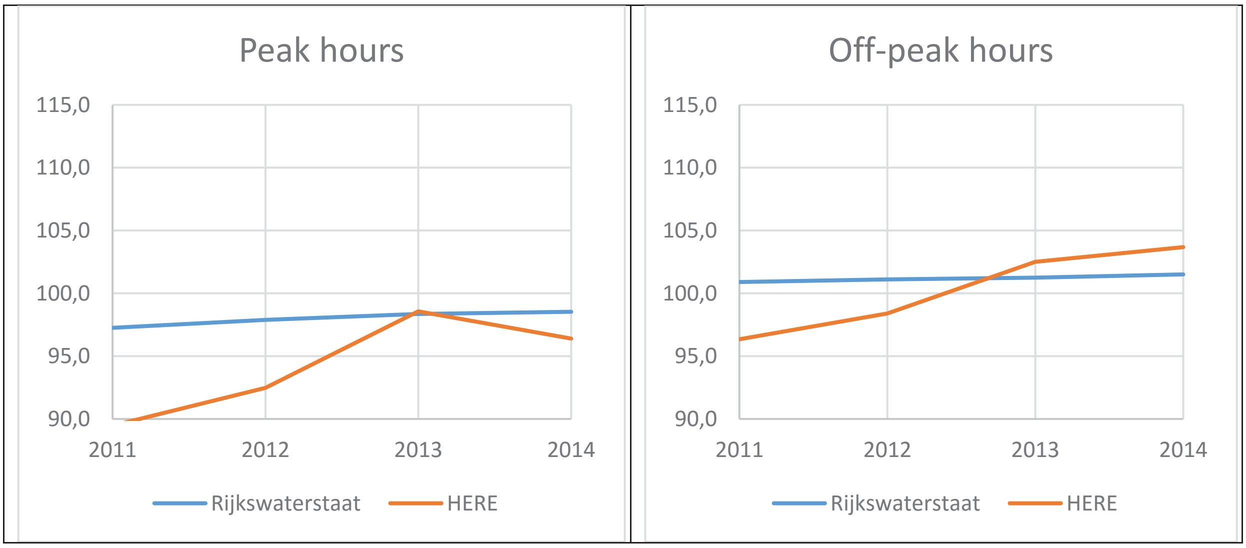

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Figure 3. Development of driving speed (km/h) on the national roads per year 2011-2014, as based on the induction loops (RWS) and mobile data (Here) during the peak (6:00-10:00; 15:00-19:00) and off-peak hours (10:00-15:00).

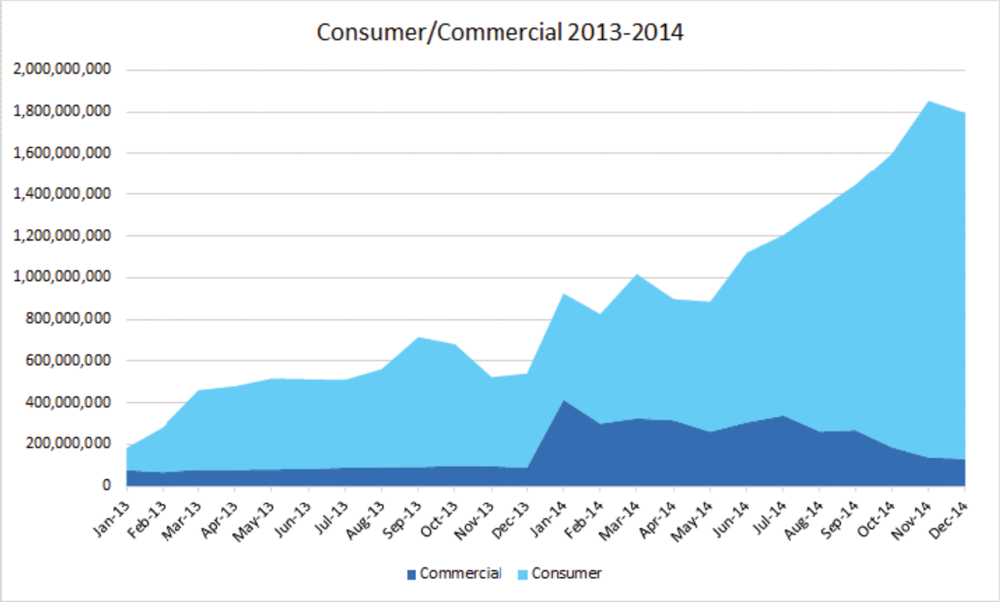

Figure 4. Composition of vehicles in the Here data 2013-2014 (MuConsult, 2016).

INRIX

In order to ascertain whether the annual development of vehicle hours of delay can be determined by combining speeds measured by INRIX and intensities measured by NDW detection points, it was first verified to what extent the speeds measured by INRIX were equal to the speeds measured by NDW (Significance 2017).

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. For each NDW detector, the corresponding INRIX subsegment is determined. Subsequently, a comparison is made between the measured NDW-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).

During this comparison, several issues with the INRIX data were discovered.

- INRIX speed changes occured approximately 3 to 7 minutes later than those of the NDW induction loops;
- INRIX speeds were strongly correlated between consecutive minutes;
- every approximately six months, INRIX segments definitions can change. As a result, only few segments have a stable length over the three year period;
- at several moments when the INRIX length changes, the underlying algorithm to derive the average speed also seems to change. This results in apparent changes in the speed levels which can be up to several kilometres per hour;
- the data structure can be irregular, indicated by blocks of missing data.

These problems were resolved by accelarating the INRIX data over a period of 5 minutes and analysing the data at a 15 minute resolution. Furthermore, strict segment selections were made to include only those for which data were available for

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all months and for which the lengths did not change substantially over the three year period. In some cases, a speed correction was applied to correct for the possible changes in the underlying algorithm. For the speed validation phase, all data for May 2014 were excluded as well due to irregularities in the data.

Speeds were validated for 4,125 locations, of which 162 locations were situated on regional roads and 22 on municipal roads and the others at national roads. Speed comparisons were made for each quarter, for each day over a three year period, resulting in almost 250 million data points. Sufficient data points were available over the whole range of possible speeds so that general conclusions can be drawn regarding the comparison of the two types of speed calculations.

From this comparison, we conclude that the average speed, as measured by INRIX, closely corresponds to the average speed as measured by NDW. Figure 5 shows the average INRIX speed for every observed NDW speed during a 15-minute period in December 2016 at any of the highway locations (i.e. national roads with a speed limit of 100 km/h or higher). This figure shows that 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), and speeds below 30 km/h rarely occur (0.04% of the time). The induction loops are known to become less accurate at very low driving speeds, which possibly explains the deviations at 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 (Significance, 2017).

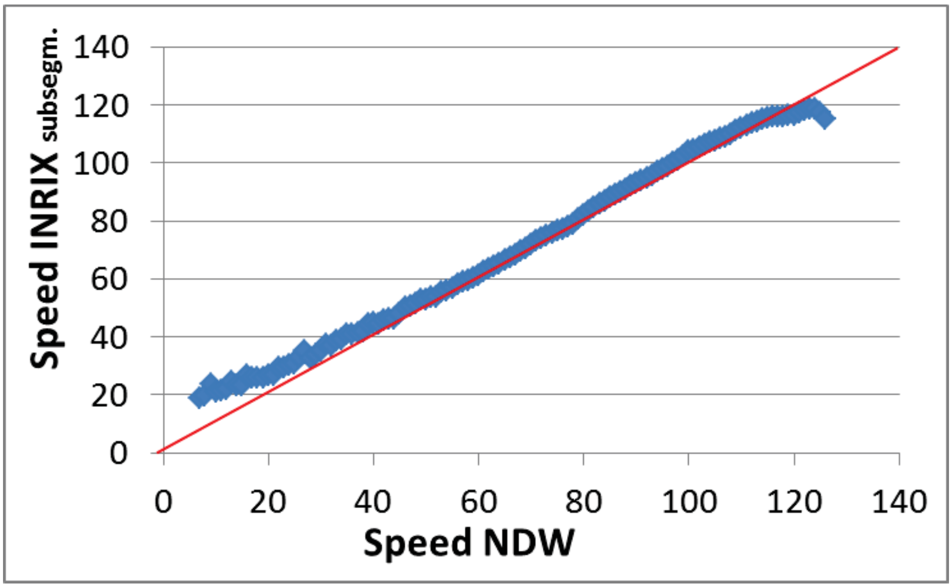

Figure 5. Relation between average INRIX speed and the measured NDW speed on 3,600 locations per 15-minutes (blue dots) on national roads with a maximum speed limit of 100 km/h in December 2016, compared with perfect correlation (red).

In the next phase, the total amount of vehicle hours of delay were determined for the whole network. For this, all INRIX subsegments (approx. 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 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.

This 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 (resp. 45, 50, 55, 60, 55, 80 and 100 km/h, respectively) are based on the average speed during off-peak hours (10:00-15:00) on roads that have the same maximum permitted speed limit (MuConsult, 2016). This makes it possible to compare changes over time (years) in an understandable and consistent way, and contributes to determining the policy measures' effects and comparing them with each other.

As can be seen from the right side of Figure 6, the development of hours of delay on national roads (Figure 6) closely corresponds to the development of hours of delay on the national roads, as calculated by Rijkswaterstaat and published in the annual Mobility Review (KiM, 2016). The difference can be attributed to a different selection of road segments to measure speeds (the INRIX selection covers the whole highway network, except some segments with varying length definitions, while the Rijkswaterstaat analysis covers the part of the network that is equipped with loop detectors, which is focussed on the regions were congestions regularly occurs).Furthermore, for the INRIX analysis, we used a general intensity profile (based on the average over a selection of segments), whereas the Rijkswaterstaat analysis used the local intensities as they are measured by the detectors.

The development of hours of delay on regional and municipal roads (left side of Figure 6) 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, and especially since September 2015. However, compared to the analysis for the highways, some additional uncertainty needs to be taken into account, since the intensity profiles, used to calculate the hours of delay, were derived from the average over a much smaller number of detection points. So, general conclusions regarding the overall development can be drawn (i.e. a 33% rise over a 2-year period), but some caution needs to be taken into account when drawing more detailed conclusions. This can be improved by determining more precise intensity profiles, i.e. by using more detection points on these type of roads.

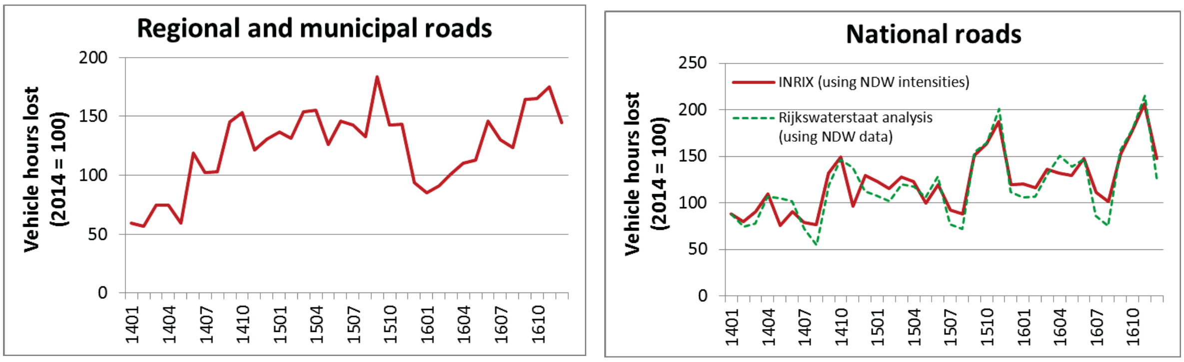

Figure 6. Development of hours of delay on roads per month 2014-2016 of INRIX/NDW and on national roads of RWS (2014 = 100).

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Speeds and hours of delay on highways were also studied for peak hours and off-peak hours separately (Figure 7). With INRIX data, generally a higher speed is measured, which is related to the (previously discussed) problems that the INRIX-data encounter at higher speeds. The agreement between the two data sets for the hours of delay (bottom half of Figure 7) is much better. Although the differences vary with each month, no trend seemingly emerges in which the differences become increasingly larger or smaller. This 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).

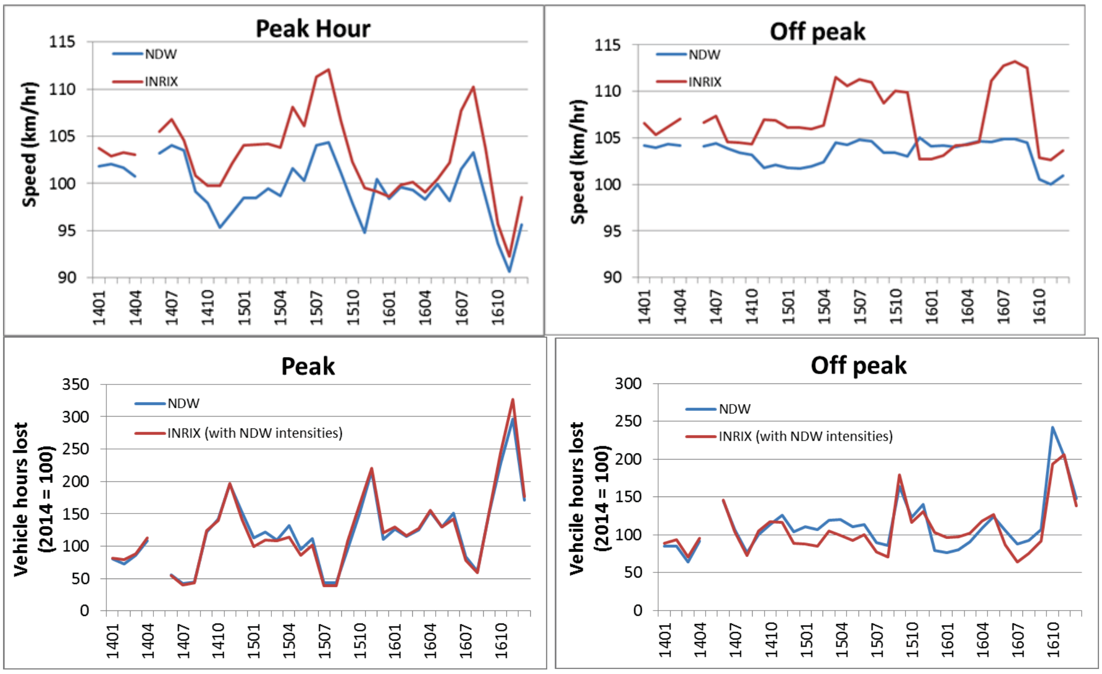

Figure 7. Development of driving speed (km/h) and hours of delay on the national roads per month 2014-2016, as based on INRIX/NDW at peak (7:00-9:00; 16:00-18:00) and rest of day.

For the above-stated reasons, and owing to minor differences between both developments, the combination of INRIX and NDW is regarded 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 and if the intensity profiles for regional and municipal roads are determined using a larger number of detection points.

6. FLOATING CAR DATA 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, and concluded that in general a reasonable level of agreement existed between the GSM data and data from road side 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 data obtained via INRIX, with data from road side 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.

6.1 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 this has primarily been provided for specific detailed research on a project basis. Little is known about the 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 for determining smaller-scale applications, such as determining traffic flow distributions at a urban road network intersection and at a junction on the national roads (whereby it is possible to make comparisons with visual observations), for 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 lanes. Pilots should then examine the usability.

RWS examined whether Vodafone GSM data could be used to improve the O-D matrix (RWS et al., 2017). 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 with GSM data 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.

6.2 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 consideration 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).

7. CONCLUSIONS

In recent years floating car data have become available for policy research, as a by-product of traffic information. They can serve three functions in policy research: identify bottlenecks in traffic flows, monitoring trends, and policy evaluation. Various indicators are used for these functions: travel times, hours of delay, unreliability of travel time and robustness.

1. Identifying bottlenecks in traffic flows.

- Due to spatial detailing, and because an approximate speed is sufficient, mobile data is suitable for identifying bottlenecks in traffic flows on the national, regional and local road network (more than is possible with fixed data, which cannot achieve such intricacy).
- The fact that mobile data does not provide adequate information about the size of the traffic stream, means that the number of vehicles involved in these bottlenecks cannot be identified. Mobile data alone are therefore unsuitable for determining travel time loss and bottlenecks, because this requires two indicators: driving speed and traffic volume.
- With a view toward the comparability of various studies, the preference is for measurement of delay with fixed reference speeds.

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 cannot be used 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; therefore, this should be checked first. Owing to changes in the composition of the population of vehicles over time, mobile data cannot necessarily determine changes in travel times. To date, there are no mobile data studies verifying that this problem is completely under control.
- Mobile data cannot currently be used to determine traffic volumes. 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.

At present, mobile data are not readily usable for ex-ante and ex-post policy evaluations. Mobile data seem to be very promising, but analyses done using Here, INRIX and Vodafone data reveal that these data contain many discrepancies, rendering it unusable for ex-ante and ex-post policy evaluation. This might improve over time if the suppliers' mobile data improve and users gain more experience in determining the strengths and weaknesses of these data.

Future developments

The question is whether mobile data's current disadvantages – such as inconsistencies between years – are structural or solvable? In future not only data on more vehicles might become available, but the clarity might also be improved.

Mobile data is currently made available through the use of "secret" algorithms. Consequently, there are no insights into how the data are calculated from the original sources, which 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 and/or composition of their mobile data. Moreover, as recognizing patterns in the available data improves, the information available from the data pertaining to total traffic volume will also improve over time. Nevertheless, 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.

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