Op de Amsterdamse grachten, hebben wij nu de drukte in de hand, Amsterdam ...

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Samenvatting

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In Amsterdam is het eerste real time verkeersmodel voor plezier- en beroepsvaart ontwikkeld voor de Amsterdamse grachten. In de Amsterdamse grachten neemt de laatste jaren het aantal boten voor rondvaart, goederenvervoer en pleziervaart toe, dus ook de daarbij behorende drukte en overlast. Stichting Waternet, verantwoordelijk voor het in goede banen leiden van het verkeer over water, wil de drukte van dit verkeer in kaart brengen om het efficiënt te kunnen sturen.

Er zijn op 17 strategische punten in de grachten van Amsterdam speciale sensoren opgehangen waarmee passerende boten (anoniem) worden geteld. Die sensoren meten de richting, lengte en gemiddelde snelheid van de boten die langs varen. Deze gegevens worden samen met de locatiegegevens van de gebruikers van de speciale VaarwaterApp gebruikt om ieder kwartier een drukteverwachting en actueel overzicht van de drukte op de grachten te maken met een microsimulatiemodel. Daarnaast kan met de offline-versie van het model het effect van een set aan maatregelen, zoals eenrichtingsverkeer of stremmingen, worden ingeschat en zichtbaar gemaakt.

Het model kent drie vaartuigtypes: kleine boten (bijvoorbeeld waterfietsen), middelgrote boten (bijvoorbeeld sloepen) en grote boten (bijvoorbeeld rondvaartboten). Daarnaast worden 27 dagtypes onderscheiden die variëren in soort dag (werkdag, weekenddag, evenement), weertype (slecht, normaal, mooi) en seizoen (november-maart, april-juni & september-oktober, juli-augustus).

Het model bestaat uit een dynamische HB-schatter die automatisch iedere dag om 02.00 uur 's nachts één van 27 HB-matrices update aan de hand van de historische data en de data van de afgelopen dag, een routekeuzemodel voor stremmingen, een micro-simulatiemodel waarmee het vaarverkeer over het netwerk wordt afgewikkeld voor een hele dag en een groeifactormodel waarmee ieder kwartier het model geactualiseerd wordt aan de hand van de actuele sensordata.

Het verkeersmodel is momenteel nog in ontwikkeling. Het hele vaarseizoen van 2013 worden de voorspellingen gevolgd en waar nodig verbeterd. Gestreefd wordt aar een betrouwbaarheid van 95%.

Het verkeersmodel wordt via de Grachtensite in vereenvoudigde vorm getoond (www.grachtensite.nl). Daarmee kan iedereen op de Vaarkaart van de grachtensite zelf zien hoe de verkeerssituatie op de Amsterdamse grachten is. De resultaten zijn daarnaast ook in de speciale VaarwaterApp te zien. Kleuren gegeven aan waar het druk, rustig of té druk is. Men kan dus vanaf het water de route aanpassen aan de verkeerssituatie. Die informatie wordt automatisch ieder kwartier bijgewerkt.

Dit paper presenteert het verkeersmodel voor de grachten van Amsterdam en de resultaten van het model.

1. Introduction

The network of canals in Amsterdam lie in concentric arcs of a circle that forms the basis of the urban layout, along with the radial waterways and streets. The Amsterdam canals were designated as World Heritage Site in 2010. Each year millions of tourist visit the city and most of them make a canal roundtrip. In addition, almost 10.000 citizens in Amsterdam have their own private boat for leasure activities. Frequently, noise hindrance along the canals is reported by neighbouring houses on busy days, especially late in the evening. In order to manage the busy canals in Amsterdam, Waternet (a Dutch company responsible for water management in the area of Amsterdam) wanted a tool for modelling and predicting the recreational use of boats in the centre of Amsterdam. The aim of the tool development was threefold:

- Informing the public about the current and expected future state of the canals. An indicator to describe the 'level-of-service' had to be developed as part of this;
- Off-line monitoring the usage of the Amsterdam canals;
- Obtaining a tool for off-line water management purposes, in order to being able to calculate impacts of some measures, such as one-direction boat travel, canal speed reductions of even canal closures;

TNO started the development of the model in 2012. Mid 2013 the online model was operational. In august 2013 the offline version of the model became operational. The model is a self-learning model which implies that the model quality is still improving.

In figure 1 an overview of the online-model is presented. The offline version is a simplified version of the online model. In the remainder of this paper the functioning of the model is explained in more detail. Section 2 describes one of the most important data-sources: the sensor data. Besides sensor-data also App-data, data from a questionair, data from the canal company, timetables, weather data and data about (temporary) canal closures is included as is explained in the next sections.
Section 3 describes the model and section 4 shows the model output and quality.
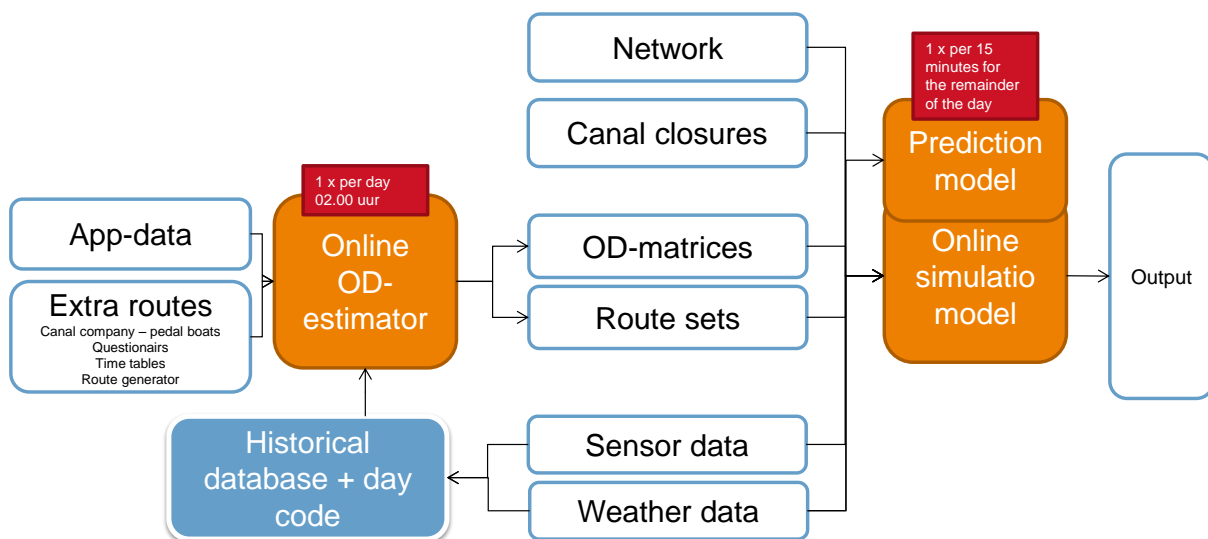

Figure 1: overview online model

2. Data-Collection

In 2012, no real-time data about boat usage was available while it was foreseen that the tool should need actual data about the number of passages at the canals. First step in the process was to physically implement a sufficient number of sensors to measure the actual boat passages in the Amsterdam canal network.

Early 2013, seventeen sensor locations were equipped with each two light barriers so the direction of travelling as well as speed and length of the boats could be derived (see Figure 2).
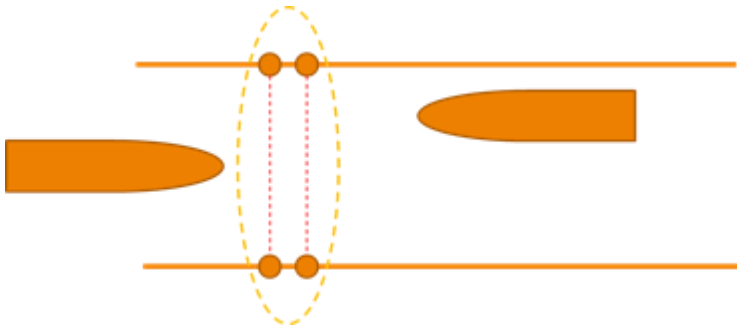

Figure 2: The setup of a sensor location.

Boat passages measured by the sensors are sent to a server and stored in a database. The delay between the sensor observation and storage in the database is about 15 minutes.

3. The model

For the on-line prediction tool it was a prerequisite that an updated prediction must be determined at each 15 minute interval. The calculation time of a new prediction should therefore also be less than 15 minutes. The modelling technique chosen was micro simulation in order to realistically model overtaking behavior and speed reductions at turns. This section describes the network, boat types, traffic demand modelling and calibration, progression model and prediction model.

3.1 Network
In figure 3 the applied network for the simulation model is shown. Each black dot represents a node and also represents a potential origin or destination.

Figure 3: The network definition. Line width proportional to the width of the canals.

3.2 Boat types

The model distinguishes three boat types:

- pedal boats and other small boats (length < 4 m)
- Pleasure boats (4-12 m)
- Tourist boats and other large boats (>12 m)

The boat types have their own characteristics (e.g. speed, width). Calibration of the traffic demand and routes depend on the boat type.

3.3 Routes

The routes of boat trips in the network were initially derived using app-data from the VaarwaterApp from the summer of 2012. The app-data contained the gps-locations of users that were equipped with the app and communicated their positions to the server. This data was map-matched to the network so the routes could be derived. In the future, it is foreseen to collect the data again using an update of the App. The data will then be used daily in the calibration process.

Besides app-data, some routes were manually added to get a better representation and coverage of the canals in the network. For the tourist boat routes from the timetables of the companies exploiting these boats were added. For the pedal boats routes specified by the Canal company were added and for the pleasure boats routes specified by users of the canals via a questionnaire were added.

Finally, additional routes were generated with a monte-carlo based route generator. These extra routes were needed to make a sufficiently large route-set also for the cases in which canal closures are modelled.

3.4 Traffic demand and calibration

Traffic demand is an essential input in the simulation model. It was decided to use 27 matrices using a classification by day type, weather type and season:

- Day type: weekday , weekend day or special event. Derive from calendar;
- Weather type: bad, normal, good. Derive from on-line weather sources;
- Season: winter period, fall/spring period, summer period.

The database with boat observations was enriched with data of this classification so it is possible to generate historical data of counts for a specific day-weather-season combination for a specific count site.

Each day around midnight, the calibration of the matrix is carried out with a dynamic matrix estimation tool (DyMaEs) earlier developed for road traffic. Historical sensor count data is compared with the previous initial matrix (based on a questionnaire, route-frequencies of app-data, and time tables) together with the predefined route set. The iterative calculation process results into an updated matrix which is used in the simulation model. The calibration process will be more reliable as the database grows. In figure 4 an example departure profile per hour is shown for one of the matrices.
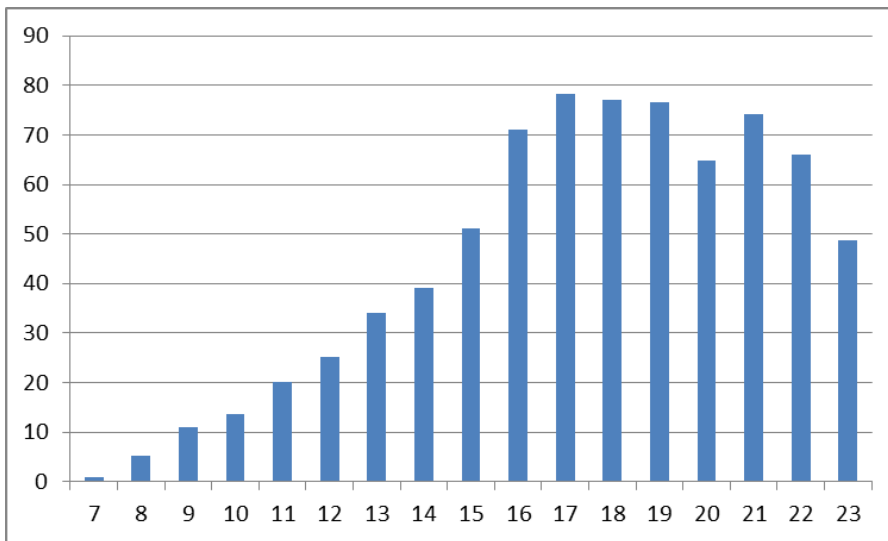

Figure 4: Example departure profile for a day classification derived from historical data.

3.5 Traffic propagation

The simulation model assigns individual boat trips from origins to destinations from the current time up to midnight. At midnight, the simulation settings are updated (new day, new day type, weather type, possibly new season). Because the traffic demand (od-matrix) is specified per hour the boat generation is made stochastic to distribute the departure within an hour. Each second in the simulation horizon the positions of all boats in the network are calculated. For each boat the route is known and thus the new position in the network may be determined when the speed is calculated. The following rules are used to update the position (in order of priority):

- Traveling at desired speed when there is no hindrance in front (predecessor, overtaking boats) or other restrictions;

- Reducing speed to speed limit or speed restriction due to infrastructural limitations (bridges, canal width, turns);
- Boat-following behaviour (deceleration) when predecessor is nearby and travels at speed below own desired speed. Helly's car-following model is used (Helly, 1959);
- Evaluate overtaking possibility, in case overtaking is possible no speed reduction is needed.

After a boat has reached its destination or exited a link, statistics are collected. After a simulation run of one day, the results are archived and to the web interface with the results from the simulation. As explained before this is done every 15 minutes. Each simulation starts at the current timestamp and the simulation is carried out for the remainder of the day.

3.6. Prediction model
The prediction model updates the traffic demand (od-matrix) which was selected at midnight using the actual data of last hour that is stored in the database. The prediction model runs at the same frequency as the simulation model. Each 15 minutes the most recent count data is read from the database. Then for each count site a comparison is made between:
- Actual (hourly) count data;
- Historical (hourly) count data;
- Expected (hourly) count according to traffic demand matrix;

Ideally, all three values are available and equal. However, due to day-to-day differences the actual counts will mostly be different from the historical data or expected counts. Also, sometimes a sensor is malfunctioning and does not provide actual data.

In order to get a better fit, the traffic demand matrix used in the simulation will be adapted to match the actual count data using a growth factor approach. For all origin-destinations with a route via (multiple) sensor locations a weighted growth factor is calculated and applied. The next simulation run will use the most recently updated od-matrix as input.

4. Results
The simulation model generates as output link statistics such as number of boats on the link, entering the link, leaving the link for each 5-minute interval over the simulated time horizon. This section describes the level-of service indicator used and shown in the web-interface, as well as the validation of the results of the prediction model.

4.1 Level-of-service
One of the aims of the project was to inform the public about the level of service (LoS) on the canals. Therefore, a traffic density based LoS-indicator was chosen: the number of boats per square meter on a canal as input. This indicator takes account of the presence of the different boat types (and their dimensions) and the dimensions of the canal. It was found that visualisation of this indicator best shows the level of service on a scale of five: quiet, normal, a bit busy, busy, and very busy. An example of this indicator is shown in figure 5 for an afternoon snapshot.

The boundary of 'very busy', the red color, is in this example set to 4.5% which means that about 4.5% of the water surface in the canal is occupied by boats.
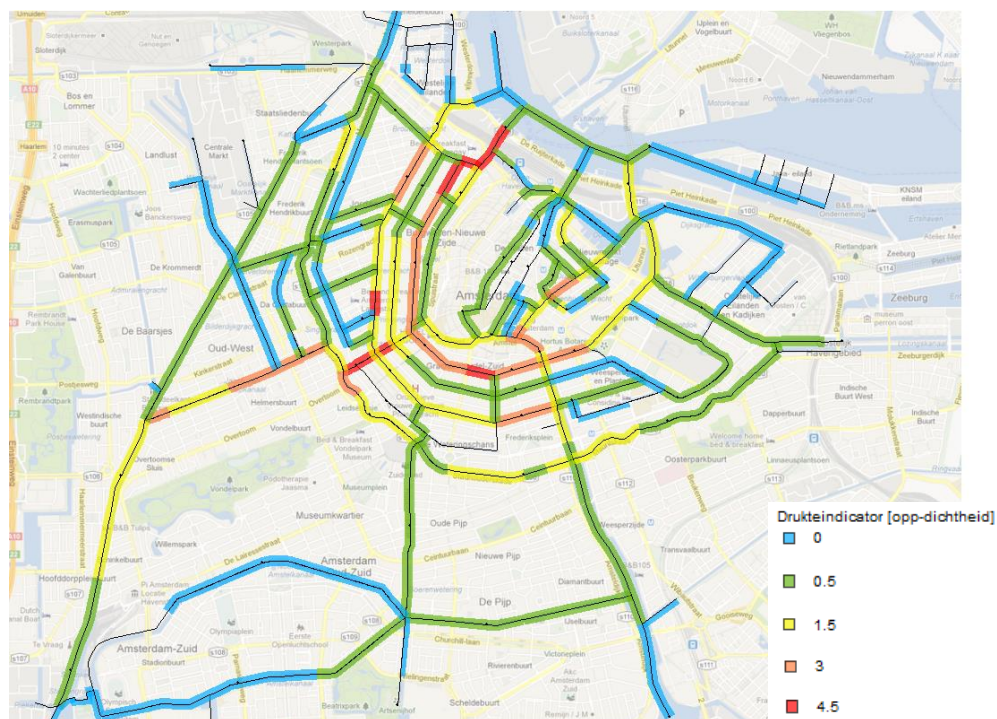

Figure 5: Modeling result: example showing actual predicted traffic densities at the canals (2013-07-20, afternoon average)

The simulation results are directly sent to a web page (www.grachtensite.nl). The web page is updated each time a new result is received (each 15 minutes). An example is shown in figure 6. On the web page also additional information about canals and bridges can be found.
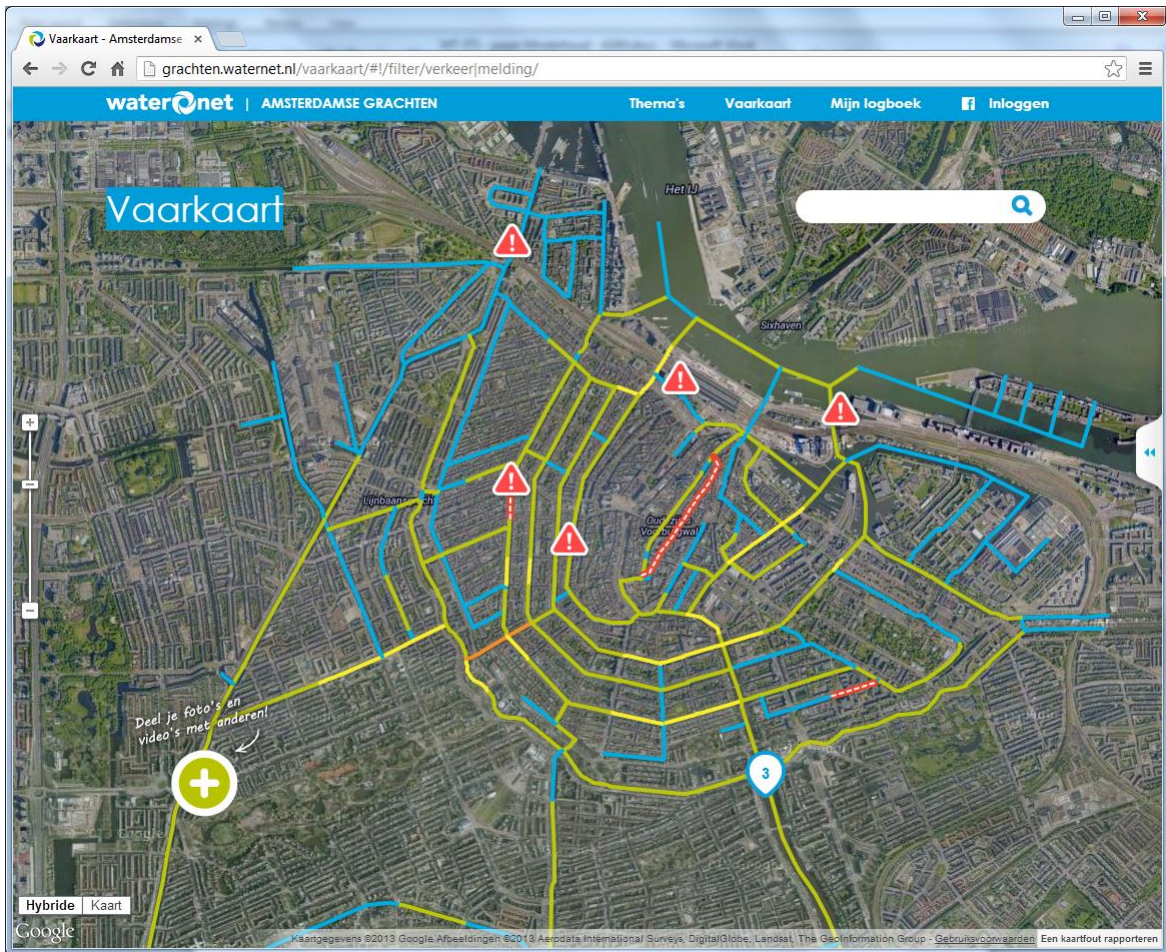
Figure 6: Modeling result: example showing actual predicted traffic densities at the canals in the web page (2013-07-23, noon)

4.2 Quality of the prediction model

One of the key elements of the tool is the prediction model. Although the classification of historical traffic demand into 27 categories is a first step in a good prediction of expected traffic demand for a given day, fine-tuning on day-to-day base is needed. One of the methods to validate the functioning of the prediction model is comparing the expected counts with the actual counts and with the results of the updated/predicted counts after applying the growth factors.

In figure 7 the count site sensor data (aggregated for all boat types) at four randomly chosen count sites in two directions are shown in blue. The expected counts -derived from the od-matrix used for that day as input- is shown in red. Although both lines are quite close some differences are clearly visible. Especially at the end of the simulation (21-24 hour) the red line is much higher than the blue line. The growth factor approach used in the prediction model corrects this misbehaviour partially, as can be seen in the green line.
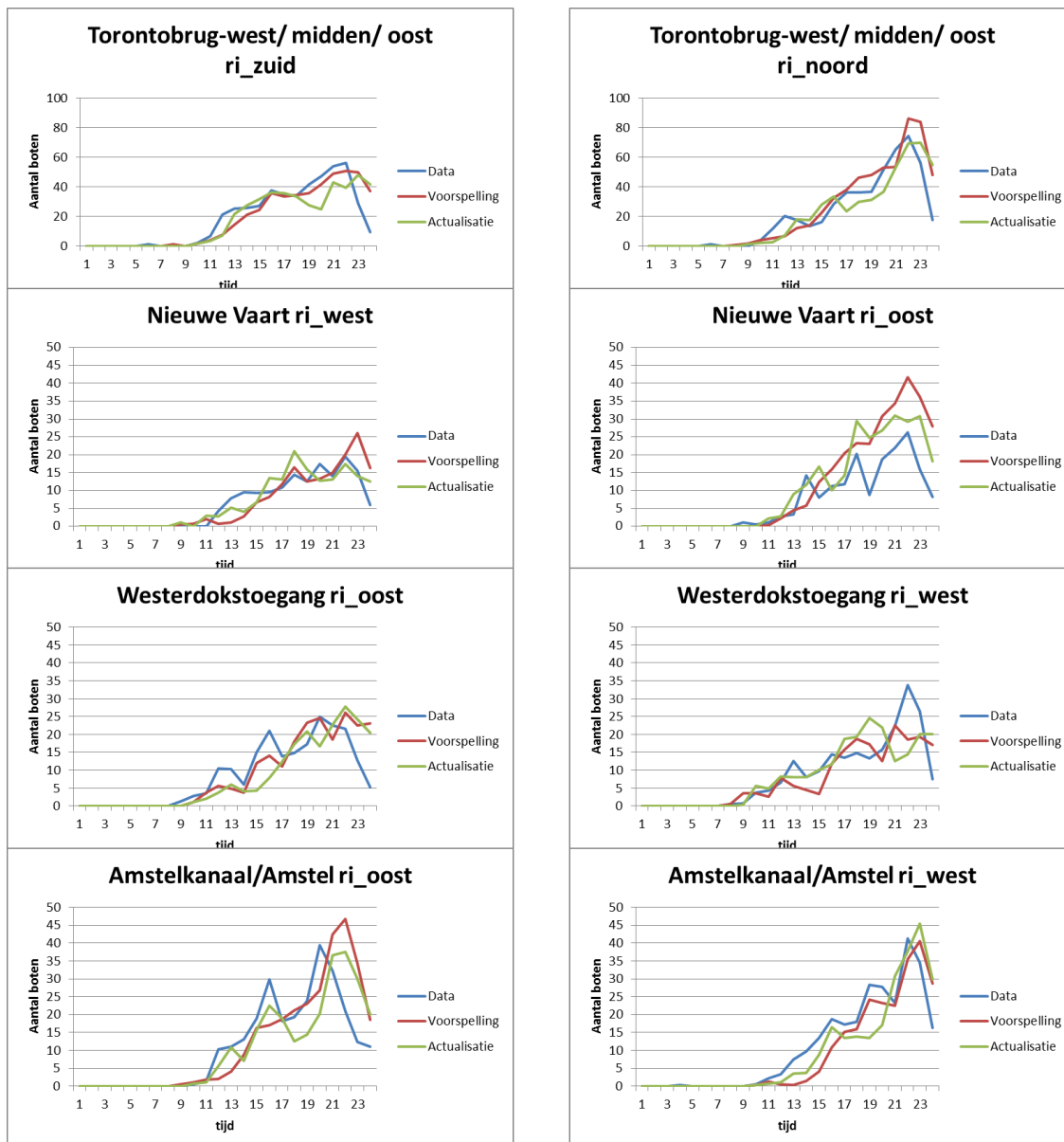
Figure 7: Example fit showing actual count data [blue] expected count using historical data as incorporated in the od-matrix [red] and on-line prediction [green] (2013-07-22)

4.3 Network quality indicator

The quality of the model is also expressed by a quality indicator. As network wide quality indicator the percentage of time that the difference between the model results and the data is less than 10 boats per hour is chosen. The quality indicator is computed for all sensors that are active and correctly functioning over all the hours of the day.

The model results are shown in figure 8 for the period 18th June – 12th September. The figure shows that the quality of the model is slowly increasing and approaches the 95% which is the preferred model quality. It must be taken into account that that there are 27 scenario's for which the model has to learn from the data. This process starts when a scenario first occurs in practice. So at the first day of a new scenario the model performs worse than at the second, third, fourth day etc. There are still some scenario's for which

the model is not trained at all, because of the simple fact that these scenario's did not yet occur (e.g. winter scenario's). During 2013 the model results are being monitored and the quality of the model will be improved further.
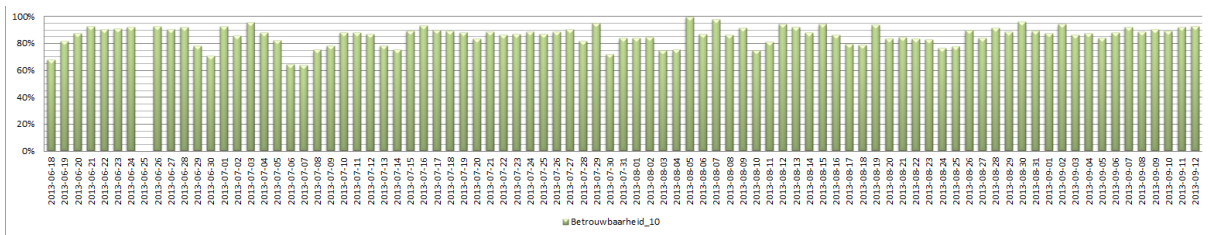

Figure 8: Model quality indicator

References

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http://grachten.waternet.nl/