Identification and impact assessment of recurring traffic bottlenecks using ANPR cameras

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Recurring traffic bottlenecks

What are recurring bottlenecks?

Bottlenecks are one of the main sources of traffic *congestion*. In particular, recurring bottlenecks are characterised by their predictability: when and where they occur, and their impact on traffic flow. Recurring bottlenecks, as opposed to congestion caused by sporadic incidents, are of special interest to traffic managers because they are associated with operational deficiencies often eligible for remediation. The identification and ranking of bottlenecks, in terms of experienced delay and variability, is therefore crucial for the prioritisation of interventions aiming to mitigate bottleneck-induced congestion [2].

Figure 1. Example of several operational elements that may cause recurring bottlenecks.

Characteristics of a bottleneck

An active bottleneck has four distinctive features: (i) congestion upstream of the bottleneck, characterised by slower speeds and longer travel times, (ii) free flow conditions downstream of the location, (iii) operation under considerable demand and (iv) existence of a specific point where traffic breakdowns and a queue starts to form upstream, in other words, a clear indication that congestion is localised rather than systemic.

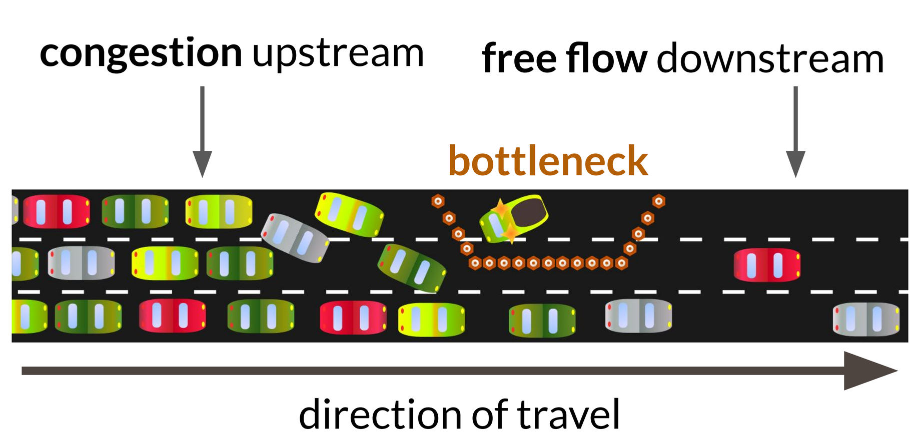

Figure 2. Conceptual schematic of a bottleneck.

Knowledge gap

Research on bottleneck identification and their impact has been done almost exclusively on *highways*. Some reasons for this are:

- Highways carry large volumes of traffic and bottlenecks can incur severe economic and social costs.
- Highways approximate idealised roads, with few entry and exit points, which makes the measurement of traffic flow easier and less costly.

Local traffic authorities. By extending the body of bottleneck research to a larger variety of road types and network topologies

This will, in turn, strengthen the proposal for funds that are put forward by local traffic authorities

Opportunity: Automatic Number Plate Recognition (ANPR) cmeras

ANPR cameras distinguish themselves from traditional traffic sensors, such as loop detectors and CCTV cameras, by their ability to identify and record the number plate of vehicles. Local traffic authorities have started to employ large groups of ANPR cameras in corridors across urban centres in order to actively monitor and report traffic conditions, particularly travel time, to drivers in real-time.

Since we can identify individual vehicles we are , with the appropriate data security and privacy measures in place,

They offer new insights into individual and aggregate travel patterns of vehicles within cities and have the potential to transform traffic monitoring and control.

Challenges: Duplicates, bad number plates, low confidence observations, invalid observations, trip identification, network graph from OpenStreetMap data, mapping cameras to edges in the network graph, shortest path assumption, calculating distances, anonymisation, ...

Bottleneck identification

Motivating example

An instance of the bottleneck identification problem is depicted in Figure 3. The A1504 Killingworthway roundabout is a well known bottleneck which slows down vehicles that travelling North (location 'A') and then Westbound (location 'C' via 'B'). The effect can be observed in Figure 4, which depicts the count (left) and mean speed (right) of vehicles driving through each segment of the corridor, on 5-minute time windows. We can clearly see that vehicles move generally slower on the first segment, particularly during the evening peak-hour, a behaviour suggestive of bottleneck activation.

Figure 3. The A1056 Killingworthway roundabout, an infamous bottleneck, and North-Westbound corridor monitored by 3 ANPR cameras.

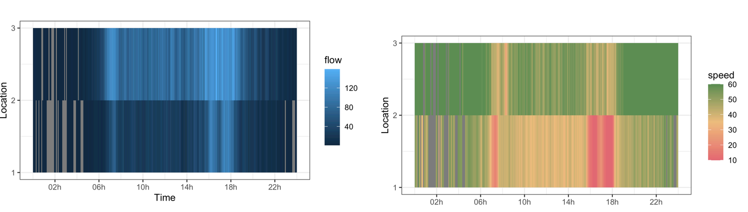

Figure 4. Speed and flow volume space-time plots for upstream camera pair (1-2) and downstream camera pair (2-3) on 5 Mar 2018.

Activation model

We design our approach based on the model for freeway bottlenecks specified in [1]. Let $C = \{s_j\}_{j=1}^{n}$ denote a road corridor monitored by a series of ANPR cameras placed along its path, where s_j designates the jth segment (camera-pair) of the corridor. The sensors generate observations of traffic speed and flow, represented by $v(s_j, t)$ and $q(s_j, t)$ respectively, at each segment j and time interval t. We are interested in whether the segments of C are operating under localised congestion, particularly under the effect of a bottleneck. Let $A(s_j, t)$ be a binary variable which indicates the presence of an active bottleneck in segment j during time period t. We specify $A = 1$ if the following inequalities are met:

$$v(s_j, t) < \theta \cdot v_f(s_j) \quad (1)$$

$$\frac{v(s_{j+1}, t)}{v(s_j, t)} > \frac{v_f(s_{j+1})}{v_f(s_j)} + \phi \quad (2)$$

$$q(s_j, t) > q_m(s_j) \quad (3)$$

where $v_f(s_j)$ denotes the segment expected value of free flow speed; $q_m(s_j)$ indicates the typical-day median flow; θ is the upstream congestion factor; and ϕ is the factor that determines a substantial downstream speed gain.

Criterion 1 represents the presence of congestion upstream of the bottleneck; expression 2 symbolises improved traffic flow downstream, operating in or close to free flow; and condition 3 suggests user demand is within medium to high levels. We can not determine, however, the exact location of the bottleneck and where traffic breakdown (we may be possibly able to infer it in some cases).

Identification results

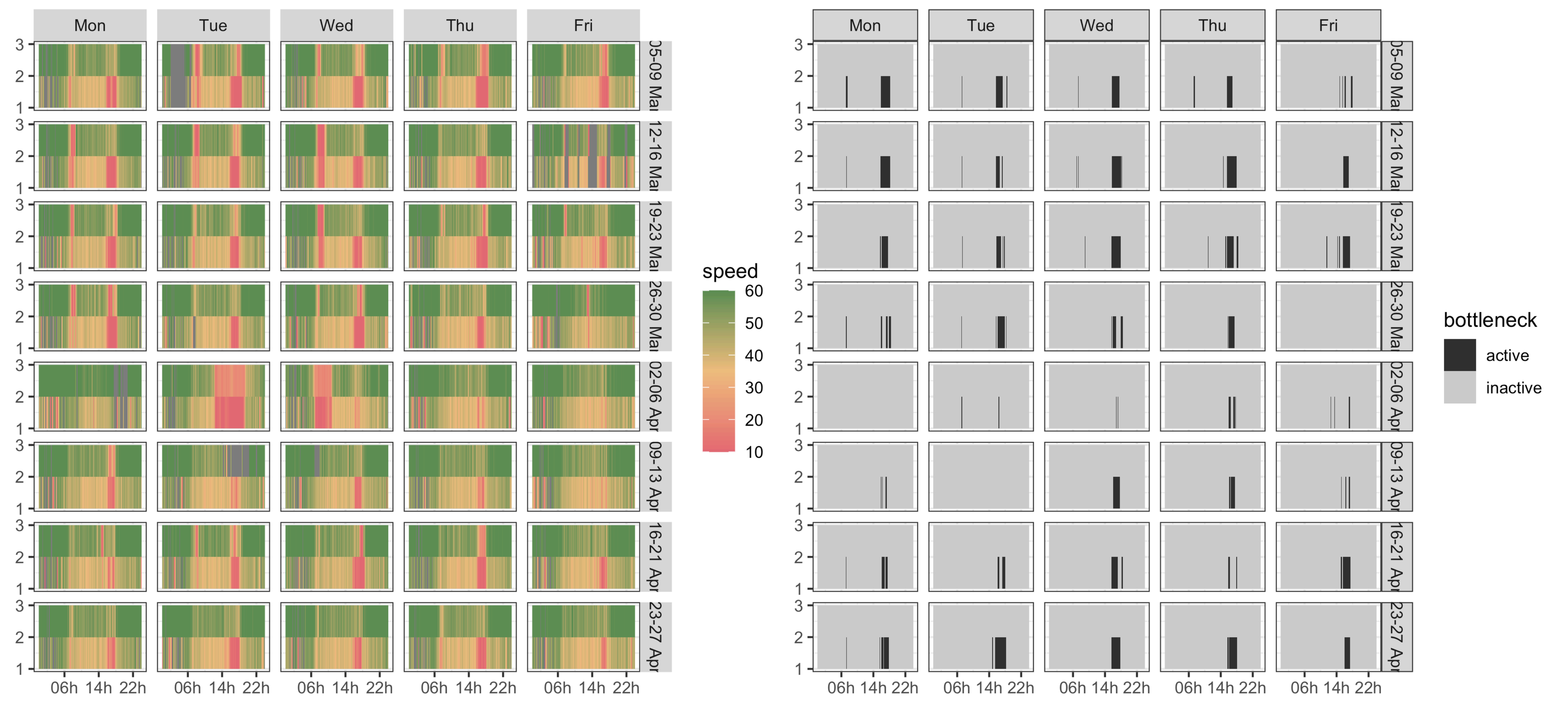

Figure 5. Speed and bottleneck activation space-time plots for every weekday during a 8-week period in 2018.

Scaling bottleneck identification to the whole network

The corridor labelling problem

Since to, In order to run our identification algorithm across the whole network

The corridor labelling

- A flow graph is by itself not sufficient to

References

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Systematic identification of freeway bottlenecks.
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