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Rerouting behaviour of travellers under exceptional traffic conditions – an empirical analysis of route choice

Victor L. Knoop[a], Serge P. Hoogendoorn[a], Henk van Zuylen[a]

[a] *TRAIL Research School;Delft University of Technology; Stevinweg 1; 2628 CN Delft; The Netherlands*

Abstract

This paper investigates to what extent travellers change their route when faced with unexpected traffic situation. To this end, traffic data from days with serious incidents are analysed in this contribution. The flows retrieved from loop detectors on the routes past the incident and on alternative routes are compared with the same values on days without an incident. It is found that for major accidents up to 50% of the travellers deviate from their normal route if the traffic situation is different. Furthermore, more travellers take an alternative route if the delay on the original route is caused by an accident than if they are faced with the same delay on the original route without an incident. These findings are for instance important for providing route information or suggestions on alternative routes or for finding vulnerable links.

Keywords: Route choice, accidents, rerouting

1. Introduction

The traffic situation and the total traffic delay depend on the traffic supply and the traffic demand. The demand influences the delay in two ways: not only because of the changing number of travellers that queue to pass the bottleneck itself, but a long queue also can cause delays for people travelling to destinations upstream of the bottleneck. If the queue grows longer than the distance to the closest (upstream) offramp, travellers which are not passing the incident location are delayed.

In case of an evacuation, the outflow out of the hazardous area is the most important performance. It would therefore be best to never have an underutilization of the exit links of the evacuation area due to spillback. Knoop et al. [1] studied this situation and the benefits of rerouting in case of an evacuation. If evacuees choose the destination which is closest by and they choose their routes based on normal travel times, much of the evacuation capacity of the exit links is lost. In contrast, if there is control and people will change routes or destination, the evacuation will take place at a rate almost equal to the sum of the capacities of the links out of

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the evacuation area. In case people just change their routes (and not their destination) the network performs almost at maximum rate for the first part of the evacuation, until a large part of the travellers is already out of the network and the outflow links are unused caused by a lack of demand. Knoop et al. [1] therefore concluded that if travellers take other routes than their usual routes in evacuation conditions, delay caused by internal jams can be avoided.

That study used simulation and an assumed route choice. This article adds empirical results an the actual rerouting behaviour of travellers in case of exceptional conditions. We concentrate on the route choice after an accident as reference situation, rather than an evacuation for which there are no much route choice data available. However, we believe that if travellers decide to take an alternative route in case of a "ordinary" accident, they will certainly be willing to deviate from their intended route if the traffic conditions differ even more than that, like in case of an evacuation.

We analyse the routes people choose when facing an incident situation on the road. We do this by measuring traffic flows and derive the route choice change. Other studies usually use a simulator set-up or questionnaires which give the route choices made by a sample group of travellers and sometimes even give stated preferences instead of revealed preferences. There is, to the the best of our knowledge, currently no study in the literature describing the actual change in route choice due to an incident by using the data of *all* vehicles, for instance measured by traffic monitoring devices. This study fills that gap. The contribution of this paper is that we find that up to 50 % of the travellers change their route under exceptional conditions. It shows furthermore that more people change their route if there is an accident on the intended route than in case there is a queue of the same length without an accident. It even shows a hysteresis effect: the travellers' reaction is delayed compared to the traffic situation.

In the next section, previous studies discussing route choice in incident conditions are briefly described, as well as the way these studies relate to work presented in this paper. It then continues by explaining the methodology in-depth in section 3. That section also gives a description of the type of data that has been used. Section 4 describes the five incident situations which have been studied. The results, in terms of route choice, are given in section 5. That section also discusses differences found between the five incidents, and discusses the generalisability towards other events than accidents, such as evacuations. Section 6 concludes the contribution and states some ideas of future research.

2. Previous route choice studies

Many articles describe the influence of information on for instance awareness of alternative routes or the routes that are considered. Chorus et al. [2] provide an excellent overview of different studies carried out. We will refer to their article for a comprehensive overview. Here the most important are listed, which are divided into two different categories: studies describing a theoretical framework and studies presenting data on drivers' preference.

2.1. Theory

For our study, it is particularly important to which extent the travellers deviate from their intended routes when facing unexpected queues. A sensitivity analysis of this deviation percentage can be found in chapter 7 of the thesis of Li [3]. It states that for a optimal network performance, there exists an optimal percentage of travellers that adapt their route en-route. Using simulation, Li shows that the impact of the fraction of people changing routes is large.

A theoretical explanation of what the influence of route information could be is given for instance by De Palma and Picard [4]. Using a mathematical game-theoretical framework, they show possible advantages of giving route information, assuming a certain compliance rate.

2.2. *Practice*

This section describes studies which describe the personal choice (stated or revealed in practice) of travellers.

2.2.1. *Stated preference*

Koo and Yim [5] study the behaviour of individual travellers in practice and analyse how they adapt their behaviour to traffic information. The study is restricted to 1052 participants that have filled out a questionnaire on their behaviour and it is limited to one specific type of incidents, namely the larger incidents giving a delay of more than 30 minutes, but not completely blocking the motorway. They find that even if travellers are informed about the traffic situation, 70% of them still keep stick to their original plan of departure time and route choice. A similar methodology with a questionnaire is applied by Jou et al. [6]. Amongst others, they conclude that while the travel times are within a certain band width, the travellers do not change their routes.

Some studies describe how people choose their route and how Advanced Traveller Information Services (ATIS) influences them using a simulated route choice environment, [7, 8]. Bogers et al. [8] discuss how people weight the influence of on-line information compared to their previous experiences. The authors conclude that people learn from bad experiences and that travellers only rely on correct information. That is, as soon as they find out that the information is incorrect, their reaction is not always in line with the provided information.

2.2.2. *Revealed preference*

Muller et al. [9] discuss the type of data that can be used to measure traffic data in congested network. One of the examples shown is how loop detector data can show what alternative route people take when an incident has happened, which the type of information which is needed for the analyses in the current paper.

Kraan et al. [10] show the influence of Variable Message Signs showing the queue length. They find that "each additional kilometer queue length displayed leads to a reduction of the proportion of drivers that select that route between 0.8 and 1.6 percent." These are percentages of the total flow which possibly consist of travellers which have a destination upstream of the point where the two alternative routes come together. Therefore, the fraction of travellers changing their route might be larger then this 0.8% to 1.6% percent, conclude the authors. Their findings are based on the (stochastic) change of recurrent congestion. They do not study the route choice changes in incident situations in particular. Whether queues caused by incidents have a different effect will be studied in this contribution.

The study presented here is inspired by findings of Kraaijeveld [11] who uses detector data and an incident database. He analyses five cases, in which he finds one case in which travellers deviate significantly. His conclusion is that, for the specific situation considered, a serious incident makes around 7% of the drivers deviate, whereas in the other cases the disruption was too small to cause a change. The final conclusion is based on one observation on one day, and the statistical variations in the normal route choice are not given.

This contribution also studies revealed preference in real-life, like Kraan [10] and Kraaijeveld [11]. Rather than Kraan, we study the situations with an incident. We use a similar methodology,

Table 1: The alternative routes

Alternative	I	II	III
Exit at	A	C1	C2
Extra free flow time	9 min	2 min	4 min
Extra distance	6 km	5 km	7 km
Distance on non-motorway	4 km	7 km	3 km

but a larger set of incidents. Furthermore, we choose another location where is it possible to analyse the flows in more detail.

3. Methodology and data selection

This section discusses how the route choice change is determined and how the incidents are selected that are used in this study.

3.1. Possible alternative routes

The motorway A13, east of the town of Delft in the Netherlands (figure 1a), is the main corridor for traffic with an origin in The Hague or more north to Rotterdam and other destinations more south. We consider the network of the A13 motorway and its alternative (highway) routes. In the study we will focus on traffic from “O” to “D” or vice versa. To get from “O ”to “D”, one has to pass the motorway junction indicated with a “B” in figure 1a. The quickest route between these motorway junctions next to the letters “O” and “B” in figure 1a is along the A13. This trip is 24 kilometers long and would take 17 minutes in free flow.

In a database of incidents we looked for incidents on the A13 near Delft. This location is particularly interesting because it provides two alternative routes that can be followed, depending on incident severity and incident location.

The remainder of this section describes the alternative routes. There are two routes, one with a large overlap with the old route and one with a small overlap. Some properties can be found in table 1. Alternative route I is described for traffic from “O” to “D”, whereas the alternative routes II and III are described for traffic from “D” to “O”. This is because for the considered accidents (see section 4), these turn out to be the relevant directions for these routes. However, they can be driven in both directions.

Route I is a good alternative for travellers if the main delay takes place on the motorway between Delft and The Hague (“Den Haag” on figure 1a). It uses an alternative motorway, the A4 motorway at the west side of Delft (route I). Traffic can return to the original route by a connecting highway just south of Delft. This is a short detour of 6 km. Coming from the north, the A4 motorway entrance is convenient, namely continue on the A4. In fact, to turn to the A13, one has to take the exit. The location of this junction is indicated by an “A” in figure 1a.

For larger queues there is a detour completely avoiding the A13 between Delft and The Hague. This is only possibile for people wanting to go from Rotterdam or origins more south towards destinations which are as north as The Hague or more north (see figure 1a), or the other direction. However, traffic does not pass towns in between, such as for instance Delft and is therefore unsuitable for traffic with these destinations. The alternative route is here described for traffic coming from the south at the eastern part of the ring road around Rotterdam. When reaching the northern branch of the ring road of Rotterdam (at the point marked with a "B" in the map), traffic can divide from the original route, the A20 westbound towards the A13, and take the A20 eastbound and then travel westbound on the A12 instead. It is not possible to turn directly from the A20 to the A12 westbound at the motorway intersection. Therefore, traffic has to cross on a non-motorway to the A12, which is possible at "C1" (route II in table 1) or "C2" (route III). The route turning at C2 is the quicker of the two, but has a larger detour compared to the main route (7 km) including 3 kilometers on non-motorways.

Smaller disruptions will not make people change their route towards route II or III. These routes are namely more congestion prone than alternative I in peak hours, which means there is an extra risk on delays. Furthermore, the point at which travellers need to take that route decision is further upstream, which means that they will take route II or III only if the traffic conditions on the originally intended route are really bad. For smaller disruptions route I is a sensible alternative.

Both at the northbound decision point (for accident 1 and 2, "A" in figure 1a) and at the southbound decision point (accidents 3 to 5, "B" on figure 1a) a variable message sign (VMS) is present which could suggest an alternative route. It was not possible to find the messages shown at the VMS, which might include a route advice, which are at best based on instantaneous travel times are communicated.

3.2. Data selection

For this study we use incident data from December 2007 to September 2008. The database of incidents mentions the location of the incident, the moment it happens, as well as the time the emergency vehicles leave the incident location. From the database we select incidents on the A13 motorway if there are wrecks or emergency workers at the roadway on working days and if there is a significant queue. The last requirement means that most of the considered incidents are within the peak period.

All motorways within the study area are equipped with double loop detectors every 500 meters. To analyse the route choice, flow data obtained from these double loops is used. At the detectors, speeds and counts are recorded and then aggregated over one minute. These one-minute data are stored and can be accessed for each detector individually.

Unfortunately, it was impossible to track back if route advice messages were given to the drivers by Variable Message Signs or radio broadcasted traffic information. On the radio messages in the Netherlands usually the reason of the delay is given, so it is likely that travellers are informed in case the road is completely closed.

3.3. Indicators for route choice change

To find the amount of traffic that reacts on these flows, several indicators are computed which are introduced in this section. The first step to get insight in the route choice process is computing the split fractions (i.e., the quotient of the flow to the main direction and the total flow) at the decision points. By using split fractions rather than flows, we remove the effect of fluctuating demand. Also, if the congestion spills back onto the link where the decision has to be made, the flow on that particular link is reduced and traffic to both directions is hindered. Only for a few minutes there will be a queue on some lanes of a multilane motorway. Although there can be temporarily an effect that one lane to the alternative route is not congested. This situation, however, will not exist very long since congestion grow further upstream and block drivers in both directions. This means that traffic in both directions is equally influenced and the split fraction remains the same.

Mathematically, the split fractions can be expressed as follows:

$$S = \frac{q_{\text{main}}}{q_{\text{total}}} \tag{1}$$

in which q_{main} is the flow to the normal route (fastest in non-incident conditions) and q_{total} is the flow to the junction, i.e. the sum of the flow of the alternative route and the normal route. S is the split fraction as function of time, which will be calculated for the day of the accident and for several reference days. We now compare the split fractions for the incident day with the other days, both at the same time of the day. Thus, we have one value for the split fraction at the accident day, and one for each of the reference days. Using a t-test it is tested whether S on the accident day differs significantly from the values in the reference days. This is repeated for each time interval and this will show in in which time interval S differs.

This split fraction qualitatively show weather people change their routes. However, the difference of the two split fractions will not tell which fraction of the travellers actually take another route. We will assume that the change in split fraction comes only from people that in normal conditions would travel to the main direction. The amount of people changing routes is $S^{\text{normal}} - S^{\text{acc}}$ in which S^{normal} is the split fraction in normal, non-incident, conditions, and S^{acc} is the split fraction during the accident. This can be devided by the number of people travelling towards the incident in normal conditions (the only ones who might consider taking an alterative route) Then, the amount of people rerouting relative to the number who might reroute can now be expressed by:

$$R = \frac{S^{\text{normal}} - S^{\text{acc}}}{S^{\text{normal}}} = 1 - \frac{S^{\text{acc}}}{S^{\text{normal}}} \tag{2}$$

The changes in route choice will be analysed in combination with differences in instantaneous queue length and instantaneous travel time between the main route and the alternative routes. To this end, loop detector is collected. For routes II and III, the queue length and the travel times can be constructed. Only a part of route I is equipped with loop detectors, so the speeds are unknown. However, from experience it is known that the part of route I which is not equipped with detectors is usually not very congested.

The road is split up into sections in such a way that the detectors are exactly halfway each section with a length of approximately 500 meters each. It is assumed that the average speed is constant over the section and that that speed equals the average speed on the detector. A section is assumed to be congested if the average speed is below 70 km/h. This threshold speed is chosen for all roads since it marks the speed where traffic changes from smoothly flowing to a traffic state where drivers need to be active in their driving. There are more accelerations and decelerations, and for cars with a manual gearbox it is required to change gears.

By summing the lengths of the congested sections, the (instantaneous) queue length is constructed. We will compare the queue length to the fraction of travellers that take another route. We choose for the instantaneous queue length, rather than the travel time that will be experienced by the travellers since this is the information that is given to the road users by VMS signs, or radio broadcast. We also construct the instantaneous travel times based on the section distances and average speeds measured by the detectors, since this is the best information that VMS signs might give.

There are many factors influencing the route choice. One of them is the weather which can influence the number of trips for specific origins and destinations. The number of trips can also depend on the day of the week. Obviously, a different number of trips on several OD-pairs can influence the split fractions. Therefore, as reference for the split fractions, we use the split fractions on the same day of the week on days with comparable weather conditions.

The route choice are first analysed as function of time. A t-test is used to test differences in split fraction at the same time between the day with an accident and comparable days. However, this will not reveal whether people change their route due to an incident directly or due to the queues caused by the accident. We also analyse this. We compare the route choice for similar queue lengths on days with an accident and without. If for the same queue length difference (or travel time difference) the route choices differ, travellers do not only react on the congestion, but also on the occurrence of the accident itself. To analyse this, we will make a scatter plot of the split fraction and the queue length. Similarly, a scatter plot of the split fraction and the instantaneous travel time will show whether people react only on travel time differences or also on the fact that an accident has occurred.

All measured data is one-minute aggregated data which fluctuates much. In order to see a trend in the graphical representations, we smoothed the data using a moving average filter. In particular, the filter replaces each data point with a weighted average of which the weight factor depends on the distance to the considered time step. Data which is collected at times which differ more than 15 minutes from the considered time is not considered at all and therefore get a weight factor of 0.

4. Incident description

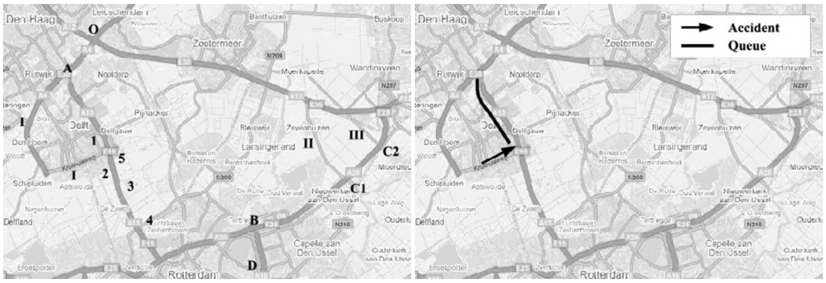
This section describes five incidents which meet the criteria posed in section 3. Table 2 in the conclusions section shows the results of the study, but also shows an overview of the main characteristics of the accidents.

The first incident is a car accident which took place at Monday 23 June 2008 at 13h15 and lasted until 16h45, blocking one lane of the A13 southbound during the afternoon peak hour. It was a clear day, so as comparison we use 9, 16 and 30 June 2008, all Mondays with clear weather. The accident caused extra congestion during the peak hour on the A13 southbound. The resulting traffic conditions are depicted in figure 1b.

The second incident is similar to the first incident. At Friday 22 August 2008 a car crashed at around 16.50 hours during the afternoon peak hour. The location of the incident is marked with a 2 on the map in figure 1a. Also in this case, traffic at the A13 southbound was delayed during the afternoon peak hour. The resulting traffic conditions are shown in figure 1c. The traffic conditions on this rainy Friday are compared with other Fridays with similar amounts of rain.

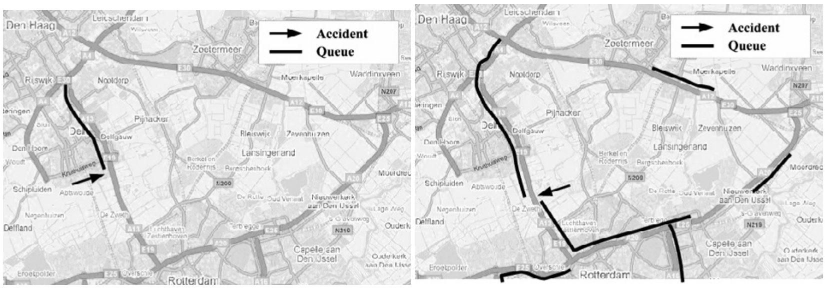
The length of the jams does not exceed several kilometers in either of the two incident cases. Since the road is not completely blocked, we expect people not to take detour II or III (as explained in section 3.1). For both these incidents we therefore consider the amount of traffic taking alternative route I.

Accidents 3 to 5 cause a larger disruption of the traffic flow for traffic and happen in the northbound direction. The third incident takes place at 12 December 2007 at the A13 in northbound direction. At the accident location, indicated with a 3 on the map in figure 1a, two out of the three lanes are closed in the morning peak from 6.25 am to 8.05 am. This resulted in long queues: 5 km on the A13 and then a spillback queue on the A20 westbound of more than 7.5 km, which means that it spills back further than the motorway junction indicated with a “B” in figure 1a. The resulting traffic jams are depicted in figure 1d. The weather was clear at 12 December 2007,



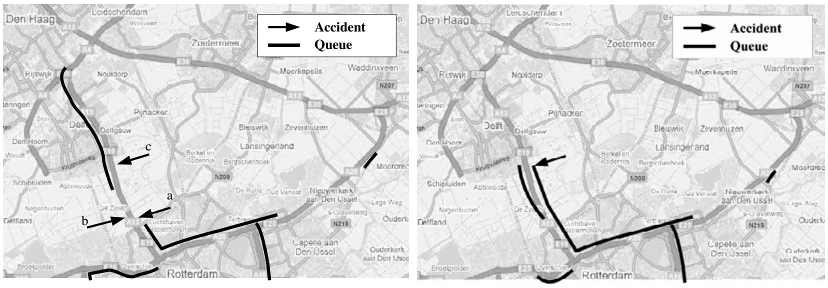
(a) The case study area with the incident locations (numbers) and points for route decisions (letters)

(b) 23 June 2008 at 16.00 hours (accident 1)



(c) 22 August 2008 at 15.45 hours (accident 2)

(d) 12 December 2007 at 7.30 hours (accident 3)



(e) 22 February 2008 at 7.30 hours (accident 4) – accident b and c happened later in the morning peak

(f) 22 September 2008 at 13.30 hours (accident 5)

Figure 1: The studied area and the traffic situations in each of the incident cases

the temperature was a few degrees Celsius and there was no precipitation. The Wednesdays between 19 December and Wednesday 2 January were not considered to give good reference on the normal traffic state because many people in the Netherlands might take off around Christmas and New Year. Therefore, other days in November and January are taken as reference (not in early December because the weather was different).

At the fourth day we consider, Friday 22 February 2008, an incident happened at the beginning of the morning peak hour at around 6.30 hours in the northbound direction at the location indicated with a 4 in figure 1a. Later a second incident happened in the southbound direction at about the same position. When the accident was removed at around 8.45 hours in the morning, a new accident happened in the northbound direction at the position indicated with a 5 in figure 1a. In spite of both accidents, the road was never completely closed; however, the northbound traffic was seriously hindered by the congestion. The traffic situation at 7.30 hours in the morning is shown in figure 1e. The weather at 22 February 2008 was cloudy with some rain and therefore also cloudy and rainy Fridays are used as reference.

The fifth situation we analyse is an incident happening at the A13 in northbound direction (see “5” in figure 1a). In the tail of the queue, a second, larger, incident took place. To have enough safety during the emergency work, the police closed down the road completely. The results are long queues in northbound direction, spilling back on the A20 and even on the A16, as depicted in figure 1f. The incident took place at Monday 22 September 2008. As reference we take other sunny Mondays in September and October.

For case 3 to 5, the traffic volume taking detour I is not analysed, since the main delay takes place south of the part for which route I provides an alternative (see section 3.1). Therefore, we only analyse the use of the alternative routes II and III during this incident for travellers coming from the south (“D” in figure 1a).

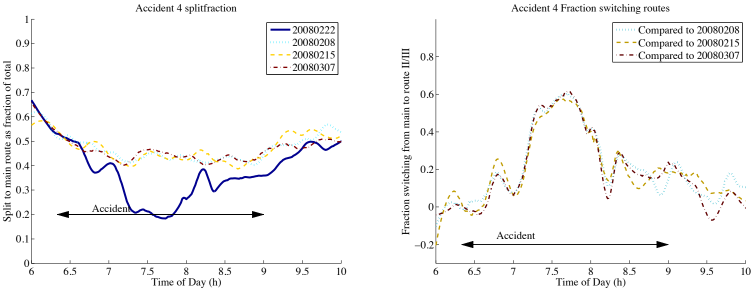
For accident 4 and 5, the larger accidents, historical news messages could be found traced on a Dutch website (nu.nl). In both cases it was stated that traffic had been advised to take the alternative route II or III. That route advice could lead to an increased part of the travellers taking an alternative route.

5. Observed route choice changes

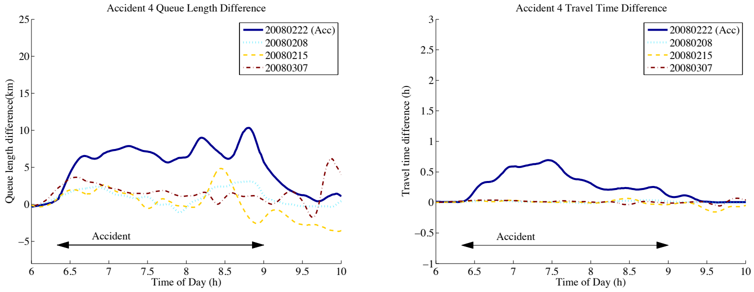
This section presents the actual change in route choice which come out of the data analysis. For one accident (accident 4) all results are presented in section 5.1. After analysing these results for all accidents, we found a distinction between the drivers’ behaviour after minor accidents and major accidents. Therefore, these are described separately in sections 5.2 and 5.3 respectively. Section 5.4 discusses the differences and the generalisability of the outcomes.

5.1. Analysis outcomes

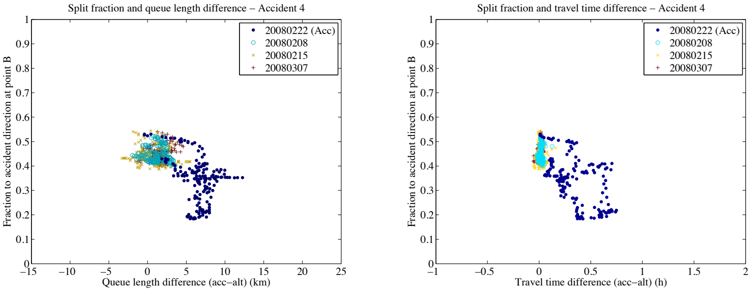
For all five accidents the same analysis is carried out. Figure 2 shows the result for accident 4, which is taken as example to explain the analysis. Note that a full description of the results is presented in chapter 5 of the thesis of Knoop [12]. Figure 2a shows the split fraction S (equation 1). For accident 1 and 2, the split fraction at point A is analysed. For accidents 3 to 5, the traffic to alternative routes II and III is considered and therefore the decision at point B is analysed. Figure 2b shows the fraction of traffic that takes another route R (equation 2). The expample also clarifies the difference between the two measures. Instead of approximately 50% of the traffic, only 20% of the traffic heads towards the incident. That means that 60% of the original 50%



(a) Split fraction (b) Fraction changing towards route II/III



(c) Queue Length Difference (d) Queue Length Difference



(e) Split fraction compared to queue length (f) Split fraction compared to travel time

Figure 2: The resulting route choice for accident 4

(being 30 base points) changes its route. Therefore, the line in figure 2b raises to around 60%. This is considered the most interesting measure and will be shown for all other accidents as well.

Figure 2c and d show the queue length difference and the travel time difference respectively as function of the time of the day. The patterns seen here are typical: a queue forms after the accident happens, builds up, then decreases and finally dissolves.

Figure 2e and f plot the split fraction versus the difference in queue length and travel time respectively. These figures show how sensitive travellers are in their route choice. It shows weather they react differently on the same queue length (travel time) differences in case there is an accident an in normal situations.

5.2. Minor incidents

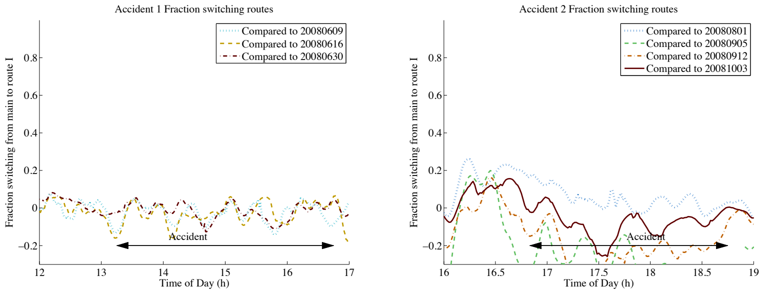
Minor incidents are accident 1 and 2. The lines in figure 3a and b show that that the split fraction at the day of the incident does not differ compared to the route choice on other the other days: the fraction of travellers changing route is close to zero. A t-test shows that there is indeed no difference.

In accident 1 and 2, more or less the same phenomena are observed. Although there is an incident, the delays are minor compared to the normal congestion: for some of the reference days, the congestion is even (much) more. The normal congestion, however, is is caused downstream, on the Rotterdam ring road. At the days of an accident, the congestion already starts a bit more upstream and then there is a part free flow driving, south of the point where alternative route I joins the main route. The first part of the queue could be avoided by taking route I. For both cases it holds that in total, it would be several minutes shorter to change routes. However, no changes in route choice are observed.

5.3. Major incidents

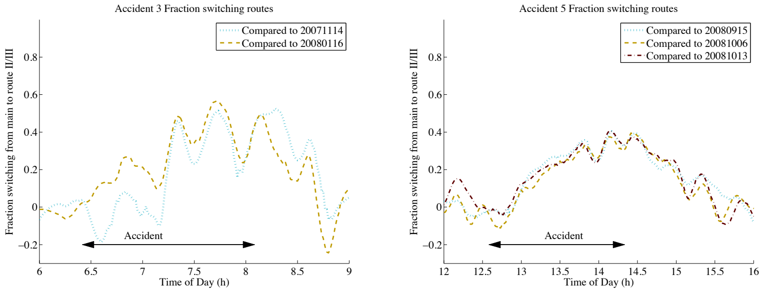
For accident 3 to 5, we analyse the split faction at point B, indicating how much traffic will deviate to routes II and III. For accident 3 the split fraction changes considerably, as shown in figure 3c. This shows that between 7h30 and 8h45 the traffic arriving at the motorway junction takes an alternative route. A t-test shows that the difference is statistically significant (p-value < 0.01) between 7h25 and 8h10. The figure shows that up to 30% changes their route. The instantaneous travel time for the alternative route is over 30 minutes shorter. Although the extra flow to the alternative route causes congestion of several kilometers on route II/III, this is not as bad as the extra congestion on the normal route. In fact, a larger fraction of travellers take an alternative if the queue length is considered as explanatory factor, which could indicate that the accident itself, rather than the queue length causes the rerouting. However, the resulting route choice is line with normal behaviour if travel time differences between the two routes are considered to be the explanatory factor.

Accident 4 shows traffic situation similar to accident 3. The split fraction to the original route reduces strongly as can be seen in figure 2a. The fraction of people switching routes, computed by equation 2, is shown in figure 2b. This percentage increases up to values above 50%. The queue length on the main route is up to 12 kilometers in length, whereas the queue length on the alternative route never exceeds several kilometers; the queue length difference is plotted in figure 2c. Alternative route III is up to 45 minutes shorter, whereas in normal conditions they have the same travel time (figure 2d). Figure 2e shows that there are longer queue lengths at the normal route and less travellers taking the normal route.



(a) Accident 1, alternative route I

(b) Accident 2, alternative route I



(c) Accident 3, alternative route II/III

(d) Accident 5, alternative route II/III

Figure 3: Fraction changing route, *R*

Figure 2 shows that the travellers will not deviate immediately after the incident has happened. Also, they will not change back to the original route once the incident has been cleared. This delayed reaction causes a hysteresis loop in figure 2f.

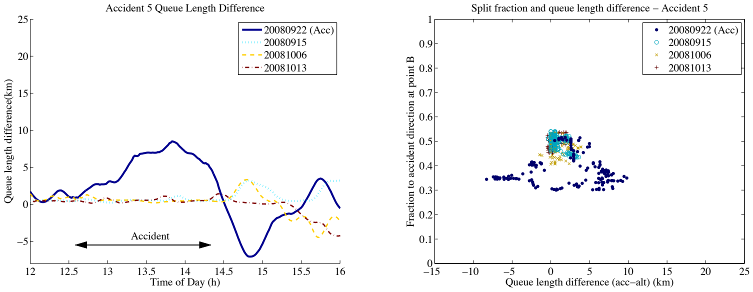
For accident 5 the split fraction differs considerably, as depicted in figure 3d. From the travellers normally taking the A13, 40% takes another route. This fraction is less then for accident 4, although the main road now is blocked. From 13.00 hours to 15.00 hours there is a significantly higher fraction of travellers turning towards the route II and II, although the incident itself has been cleared at 14.20h hours.

The extra volume to the A20 east is around 1000 vehicles per hour. This extra volume is supported at the motorway, but not at the underlying roads at the connection points C1 and C2 (see figure 1a and 1f). Therefore, extra congestion sets in on the motorway just upstream of C1, the off ramp to the road connecting both motorways of the alternative route. This extra congestion is around 7 kilometers. This can be an explanation why the fraction of travellers choosing another route is lower than at accident 4. It is furthermore interesting to note (see figure 4a) that at the end of the incident, the queue on the main route decreases rapidly, whereas the queue on the alternative route takes longer to solve since it also includes a secondary road with a low capacity. Therefore, shortly after the incident has been cleared, the congestion on the alternative route is longer than on the main route. The travel time differences fluctuate similarly. During the incident the alternative route is up to 30 minutes quicker. However, after the incident has been cleared, the travel time on the alternative route is around 15 minutes longer than on the main route. An explanation for the fact that the alternative route is more congested than the main route where the incident took place could be that people still did not get an update of the travel advice to take an alternative route.

Figure 4b shows clearly that the incident is an extra incentive for drivers to take an alternative route. For the same queue length difference or travel time difference, a larger percentage than normal takes an alternative route. The queue length then reduces quickly. In the diagram this means that first there is a queue length difference (points moving to the right), then the travellers change their route choice (points moving down). Then, the queue length difference reduces (points moving left), but the travellers do not adapt their route choice again and they will not switch back to a normal route choice. Hence, the points stay low in the diagram. This hysteresis causes a clockwise movement in the figure. The reaction of drivers to change back to the original route is made later, once the queue on the alternative route is longer than on the route with the accident. This means that first the points in figure 4b move further left and then they move up again. Then the traffic normalises and the traffic conditions return where they started, and the circle is closed.

5.4. Discussion: similarities, differences and generalisability

Table 2 summarises the results. It shows a clear difference in route choice between accidents 1 and 2 at one hand and accidents 3 to 5 at the other hand. In the first two cases the queue is shorter, but still the alternative route is shorter than the original, congested route. The nature of accidents 3 to 5 is different. Those accidents reduce the capacity considerably; for accident 5 the road is even blocked completely. This means that the traffic is moving very slowly over more than 10 km. One of the reasons for traffic to deviate from their intended route could therefore be the length of the queue they are facing. If it is long, then the travellers will change their route, but when the queue is not longer than several kilometers, they will not change routes even if the alternative route has become slightly quicker than the original.



(a) Difference in queue length over time

(b) Split fraction and difference in queue length

Figure 4: The drivers' reaction in accident 5

Table 2: The incidents used in this study

Nr.	Direction	Date	From	To	Complete blocking	Extra delay	Percentage changing route
1	South	23 Jun 2008	13h15	16h45	no	Minor	0
2	South	22 Aug 2008	16h50	18h45	no	Minor	0
3	North	12 Dec 2007	6h25	8h05	no	Major	30%
4	North	22 Feb 2008	6h20	9h00	no	Major	>50%
5	North	22 Sep 2008	12h35	14h20	yes	Major	40%

For accident 5 a hysteresis loop is seen (figure 4b) and explained in section 5.3. The same hysteresis loop is seen for accident 4 (figure 2e) and also at accident 3. A reason why the lines are not smooth is that travel updates come at discrete intervals in time (radio messages for instance). We suppose that travellers start taking an alternative route once it becomes clear there is a serious accident, and then are risk-averse in their route choice. This reasoning is in line with the fact that drivers do not change their routes when there is just a minor incident. This risk-averse route choice behaviour is for instance also shown in Bogers et al [13]. A route passed an accident location has a less certain travel time than an alternative route, because it is unclear what is the capacity at the accident location. Even once the queue *length* is known, the delay can still be varying.

A similar reasoning can be followed for evacuations. As long as traffic is not very congested, people will travel their normal route, since that is familiar to them. However, once heavy congestion sets in, travelers will understand that the situation is considerably different and they will reroute to a route that is shorter, or more reliable as long as they succeed of getting out of the affected area in time.

This reasoning might be different if very accurate predictions of the traffic situation – in terms of travel time – are given to the drivers, and if this information is perceived to be correct. In that case, they might trust that information and take the advised route.

6. Conclusions and future work

The research shows how travellers change their route if the intended route is blocked due to an incident. Hereto, the actual route choice behaviour is studied for five incident cases. It is found that the severity of the capacity reduction incident and therefore the severity of the delays play an important role in the decision to deviate from the intended route. A considerable percentage of the travellers will take an alternative route when faced exceptional conditions on their intended route, even causing congestion on the alternative route. It is likely that in large calamities, like an evacuation, this fraction will be at least the fraction of rerouting traffic during a large incident.

The percentage found changing their routes could be more than 50%. Knoop et al showed earlier [1] the consequence of this finding. It means that that the internal congestion due to spillback of traffic jams, or even grid lock effects, play a minor role during evacuation.

The study presented here showed a rerouting percentage of 50%, even though it is not yet the last possibility to get off the motorway. This means that traffic which is assumed to take the original route still has possibilities to avoid the queues by taking another alternative route. Also, traffic having a destination before (i.e. upstream of) the bottleneck is now included in the volume of traffic that might consider to change their route. Both these effects mean that the fraction that changes its route during an incident as found in this study is a lower bound for this value. If it were possible to track the individual vehicles over two different routes, there would have been no need to make the assumption that all traffic needs to pass the bottleneck. This could be achieved for instance by data from licence plate cameras or track vehicles by GSM signal. One would expect that in that case the fraction of deviating traffic is even higher than the values found here. This could be an interesting approach for the future, but that requires a different type of data which was not (yet) widely available at the time of this research.

It is also found that travellers actually avoid a route passing an incident location. The split fractions towards the normal route is lower in case of an incident compared to a situation with the same travel time difference but without an incident. Finally, it is shown that travellers have a delayed reaction on the traffic situation.

This delayed reaction can be due to the delayed information on which they react. It would be therefore be interesting to analyze the amount of information that is given to the drivers. For instance, Dynamic Route Information Panels could be used to provide information. In addition, nowadays, more and more information about the traffic state is presented in-car using a navigation device with Traffic Message Channnel (TMC) options or – in the Netherlands – a "Live Traffic" function which gives information on the traffic speeds in the network based on the speeds of other cars equipped with the same navigation devices. In this study it was impossible to track back which information was communicated to the drivers, and at which moment. This would be a valuable addition for future research. Moreover, it would be interesting to see how the values of traffic adapting their route change over time as the penetration rate of dynamic navigation systems increases. These new techniques could in the future also be used to analyse the route choice during evacuations.

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