Hidden Strategies of Driving Behavior at Freeways

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ABSTRACT

Traffic operations for new road layouts are often simulated using microscopic traffic simulation packages. Here, the behavior of each individual vehicle-driver combination is included. These traffic simulation packages usually simulate traffic at freeways by a combination of a car-following model and a lane change model. The car-following models have gained attention of researchers and are well calibrated against data. However, the proposed lane change models are often representations of assumed reasonable behavior, not necessarily corresponding to reality. This paper studies how lane changing actually works for a variety of drivers. Test persons are asked to take a drive in a test vehicle which is recorded on video. Afterwards, the drivers are asked to comment on their choices related to lane choice and speeds, while watching the video. The paper shows that different drivers have completely different strategies to change lanes, and that the choices to change lane are related to their speed choice. These strategies differ not only in threshold values, as is currently being modeled in most simulation packages, but there are completely different reasoning. Most remarkably, all drivers perceive their strategy as obvious behavior and expect all other drivers to drive in a similar way. However, strategies by others are found to be completely different. Potentially, this could lead to significant changes in the traffic operations. Further research should show the impact of the strategies on for instance the capacity of the road, or even the required design length of off and on ramps.

1 INTRODUCTION

In recent years, due to the growing application of microscopic simulators for the analysis of transportation systems as well as traffic control, interests in developing more reliable driving behavior models and in particular lane-changing and car-following models have increased significantly. In practice, microscopic simulation packages are being used to assess the quality of the traffic flow, as well as delays and emissions. The modeling core of the movement of vehicles on freeways is formed by a combination of two sub-models, a longitudinal and a lateral sub-model. The model for the longitudinal movement either describes the car-following behavior or considers the free speed of drivers. The lateral model describes when and how vehicles change lane. For ex-ante evaluations of traffic measures, it is important that the model predicts the driving behavior via the correct mechanisms. This holds for both longitudinal as well as lateral actions. The effect of longitudinal actions on traffic flow is obvious, but also lateral actions, i.e. lane changes, have a significant effect on traffic flow. Thus, understanding lane changing behavior is important in several application fields such as capacity analysis and safety studies. The combination of the two models will give the next position, next speed or next acceleration of the vehicle.

Current lane changing models (for an overview, see section 2) are unable to describe correctly the lane changes found in traffic. There are large discrepancies between the principles modeled and the observations, both for discretionary lane changing (*1*) and for mandatory lane changing in case of merging (*2*). This implies that current models do not properly describe the strategies. Since it is unknown what the strategies are, this paper tries to reveal the strategies that play a role in lane changing. Also, the paper investigates the effect of lane changes on speed choice. Since they are currently not modelled as such, these strategies are considered hidden (from the literature). The aim of this paper is to first investigate these strategies. In a follow-up research, the strategies can be quantified, and the percentages of drivers following these strategies can be estimated.

As far as the authors are aware, simulation packages use one specific type of model for car-following or lane-changing, although there are many models available. For car-following behavior it has been shown that different drivers drive differently (*3*). This paper will show to which extent the strategies related to lane changing behavior are also different for different drivers.

The paper investigates these strategies by a combination of revealed preference and stated preference. More specific, we let test persons make a test ride in a vehicle equipped with cameras. Afterwards, we discussed with the participants the test ride and the driver decisions, both in case the driver changed lanes as well as in case the test persons decided not to change lanes. This way, we do not only get a naturalistic driving behavior, but also insights into the motivations of drivers, which is essential for the investigation of the strategies. Where the research started as investigation to lane changes, it turned out that these were intertwined with (desired) speed choices.

The remainder of this paper is set up as follows. First, we give an overview of the most common models for car following and lane changing, as well as combined models. Then, in section 3 it is explained how the test is set up. Section 4 presents the strategies for traffic operations at the main road, whereas section 5 presents the strategies for merging. Finally, section 6 presents the conclusions.

2 LITERATURE REVIEW

For traffic operations in multi-lane traffic facilities, lane changing is essential. Lane changes are causing disruptions (e.g., (*4*)) and might influence the capacity of the road by leaving voids (e.g., (*5*)). Despite its great importance, lane changing has not been studied nearly as extensively as longitudinal acceleration and deceleration behavior. This could be due to insufficiency of reliable data (e.g. cross-sectional data from detectors, (*6*)). However, in recent years, interest in the development of lane changing models and their implementation in traffic simulators has increased drastically. In most lane changing models, the lane changes are classified based on the reason for which the lane changes are performed (e.g. mandatory, discretionary or voluntary). Mandatory lane changes occur when a driver must change lane to follow a path or reach his/her destination. Discretionary lane changes occur when a driver changes lane to improve his driving condition (e.g. for higher speed). In most lane changing models (e.g. (*7*); Laval and Daganzo (*5*)) discretionary lane changes only look at speed as an incentive to change lane. After Gipps (*8*) introduced his model, many lane change models distinguish between mandatory and discretionary lane changes. It should be noted that classifying the lane changing in MLC and DLC may lead to a rigid behavior structure which does not consider the trade-offs between these two. Toledo et al. (2003) developed a model that integrates MLC and DLC in a single utility framework (*9*).

2.1 Discretionary lane changes

The basic requirements for discretionary lane changing are as follows: (1) a driver cannot drive with its intended speed in its current lane; (2) the speed in the adjacent lane is preferred over the speed in the current lane; (3) there should be a gap, large enough, in the adjacent lane. These requirements can be found in (*8*). This has been formalised, for instance by the MOBIL (*7*) lane change model. The fundamental idea behind MOBIL is to include both the appeal of a given lane (i.e., its utility) and the risk associated with lane changes in terms of accelerations. That model compares each time step the utilities – defined as accelerations – of the vehicles involved in a lane change. For each time step, the model calculates the weighted sum of accelerations of himself and the other drivers. If this exceeds a threshold value, the lane change is performed. To calculate the expected accelerations a car-following model is applied (e.g. IDM).

None of these models provide a full explanation for the phenomena seen in practise where it is for instance observed that the number of lane changes to a certain lane increases if that lane has a higher density (*1*).

2.2 Mandatory lane changes

In mandatory lane change models or merging models, often gap acceptance models are used (10). Also these models are not able to describe the observed gap choices in merging (*2*). Other attempts have been made, for instance by modeling gap choice behavior. In these studies, no questions were asked regarding the incentives of the drivers. This might help to describe the right choice.

Empirically, it is shown that for merging traffic, drivers may apply small decelerations and accept smaller time headways (e.g., (*2*)) than for discretionary lane changes. This phenomena is called relaxation. Also, vehicle speeds are synchronised such that a driver adapts its speed to the speed of the neighboring lane. This is modeled in the LMRS (*11*), a lane changing model which

includes relaxation and synchronisation. The LMRS is integrated with an adapted version of IDM. Generally, this model may be employed with any car-following model which calculates the vehicle acceleration. It basically accounts for the fact that drivers sometimes merge into gaps which are too small, and then create a larger gap. Toledo et al. (*12*) introduced a model which integrates the various decisions, such as acceleration, lane changing and gap acceptance. MOBIL provides a lane change using the possible acceleration in the current lane and after a lane change. The integrated model by Toledo et al. (*12*) does the opposite, by taking the lane change decision as leading and determining the acceleration. LMRS accounts for accelerations related to a lane change, both for the lane changer and the presumptive follower.

Thus, although models exist, no literature is known which microscopically measures or validates the longitudinal actions following from lateral actions.

2.3 Empirical study methods

For earlier work, the authors have used inductive loop detector data to find the lane changes, even on a microscopic scale (*1*). This gives a very large number of observations, but not real insights in the motivations behind these lane changes. Video recordings from the helicopter (*2*), showing the movements of the vehicles in the area, give more information on the drivers actions, but also miss the motivations.

For merging, interview techniques have been applied (*13*) which reveal valueable information. Later, the same authors test drivers in an instrumented vehicle (*14*). Since both the interview and the set-up of natural driving in an instrumented vehicle is promising, we combine these. However, in their study, the drivers were made aware of their actions by commenting in real time on their behavior. In our study we explore the strategies underlying the actions by discussing the actions afterwards in the interviews. Another difference with the aforementioned studies is that the scope of our study is wider, also including lane choices on freeways and not only merges. This way, we aim to get an overview of the strategies drivers follow when driving on multi-lane freeways.

3 DATA COLLECTION METHOD

In order to get a good overview of the incentives of drivers to change lanes, we combine a test drive followed by an interview and a discussion of the decision process. In the test drive, the drivers show their normal driving style (naturalistic driving) and the normal way of making decisions (revealed preference). This is similar to previous work, for instance Kondyli and Elefteriadou (*14*), except that we do not ask the participants to comment on their decisions during the driving. Instead, afterwards, these decisions are being discussed based on the videos recorded during the test drive. The drivers are also being asked what they would have done in different situations if that is relevant (stated preference). This section first describes the test drive, then discusses the interview. Section 3.3 presents the details on the test persons, and section 3.4 shows how the video data is processed afterwards.

3.1 Test drive

The 2013 Toyota Prius of the Department of Transport and Planning, Delft University of Technology (TU Delft), is used as test-car for the participants. The vehicle is equipped with two high

FIGURE 1 The view of the rear facing camera

(a) Opened peak hour lane

(b) Closed peak hour lane

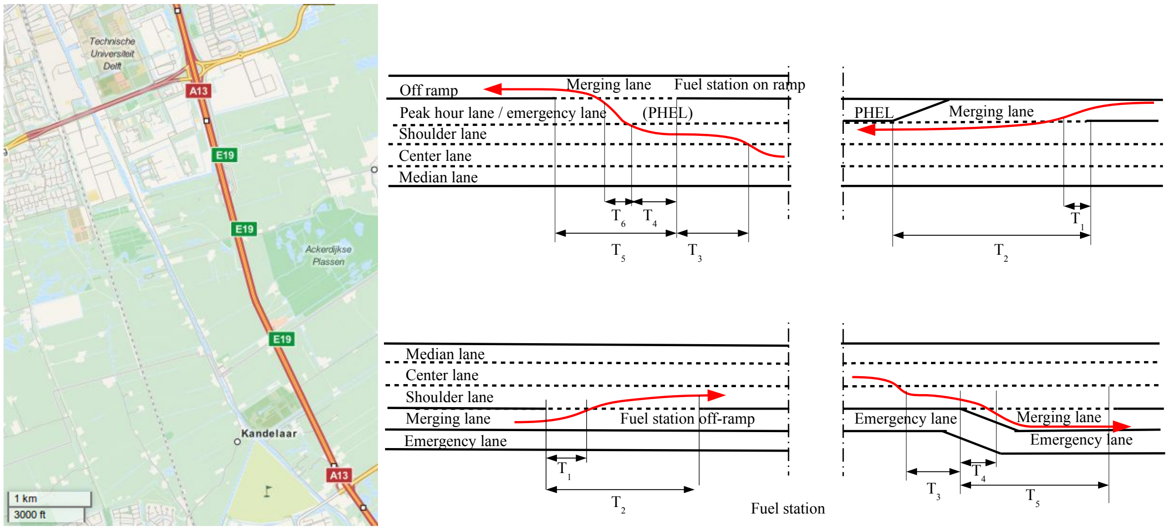
FIGURE 2 The signaling for the peak hour lane

resolution wide angle video cameras, monitoring the front and rear view of the car at a 25 Hz frequency. The cameras are installed at the left side of the windshield and rear window of the car . For a screen shot of the rear view, see figure 1; the front view can be seen in figure 2. In the image a synchronised time is shown, such that the front and back images can be matched. In the front image, the speed of the head up display was being recorded in the image, see the green digits in figure 2.

The driving tests took place at the A13 freeway stretch between Delft and Rotterdam on May 26, 2014, see figure 3a. The trip involves in total 11 km of freeway driving on multi-lane freeways. The selected freeway is equipped with dual loop detectors at 500 m intervals. The complete round trip, starting at the TU Delft campus was 14 km and took about 25 minutes on average.

The freeway in southbound direction has 3 driving lanes available. The northbound stretch contains 3 regular driving lanes, as well as an emergency lane at the right of the driving lanes, which is being opened in peak hours with high demand. Figure 3 shows the names of the lanes. Note that Dutch driving regulations indicate that drivers should keep right unless overtaking. On the overhead gantries a red cross or a green arrow indicates whether the lane is being opened or closed. Besides, a sign at the side of the road indicates the opening of the lanes, see figure 2. The road markings do not change.

The speed limit for the stretch is 100 km/h for passenger cars; during the tests (9.45 to 16.00



(a) map

(b) Lane layout for both directions, including names. Top figure is northbound, the lower figure is southbound. The road stetch is longer in between the open areas in the middle. Figure is not to scale.

FIGURE 3 Layout of the road

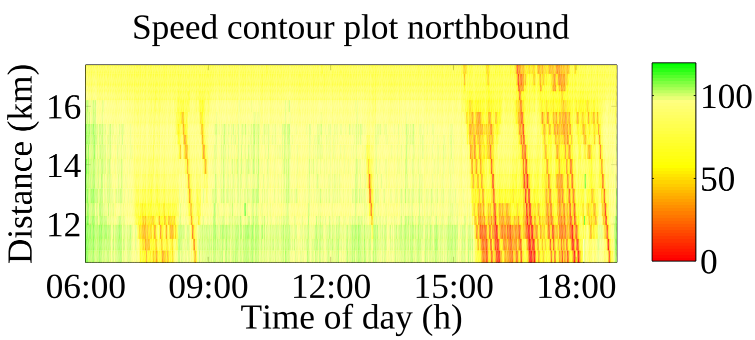


FIGURE 4 Speed contour plot of the northbound traffic

hours), the road was in free flow conditions. From the loop detector data we can get the average traffic conditions, which are shown in a speed contour plot (figure 4). Heavy good vehicles (HGV) have a speed of 80 km/h, while Dutch HGVs are physically limited to 89 km/h. There are no speed checks on the stretch. Usually, the speedometers indicate a speed which is several km/h higher than the real speed. For automated tickets (speed cameras), a 3% correction is deducted from the measured speed. Fines are only issued at corrected speeds of 104 km/h and higher. Police patrol officers are usually less strict, and will only fine speeds which are more than typically 15 km/h over the speed limit. The average speed on the road is 90 km/h, including trucks.

Between the entry point and the exit point of the road there are no other connections. There are entries and exits to the fuel station, though. The merging lane of the southbound on-ramp changes into a merging lane for the traffic to the fuel station (total length: 560 m). Downstream of the fuel station, there is a 300 m merging lane parallel to the right lane. In the northbound direction there is a fuel station at the same position. Upstream of the fuel station, there is a merging lane

(right of the peak hour lane) of 300 m length. Downstream of the fuel station, the merging lane for traffic from the fuel station is the same as the merging lane for the traffic towards exit Delft. The total length of this weaving lane is 560 m.

Having a short test-drive might be considered to some extent a disadvantage, but on the other hand, it can be advantageous for the drivers to recall all situations during the test and may help them to comment on the rationale behind their actions. Moreover, in the stretch are two merges, and, except for a fuel station, there are no disruptive on-ramps in between. On average in the Netherlands, there are on-ramps every 4-5 km (*15*). Three or more lane freeways are mostly found in the more densely populated western part, where the density of the on-ramps is even higher. The total test took approximately 1 hour per person: 10 minutes instructions, 25 minutes drive and 25 minutes discussion and interview.

The cameras are installed such that they are not hindering the view of the participants; especially the backwards looking camera is hardly visible. The drivers are informed that they participate in a test where their driving behavior is analysed and will be discussed after the driving. However, no further details are provided on beforehand on which driving behavior will be discussed. The drivers are instructed to drive as they normally would. The route has been programmed in the in-car satellite navigation system.

3.2 Interviews

After the test drive drivers were being asked on their experience. The first question was to which extent their driving behavior was the same as their normal driving behavior, and then specific points in their trip were being discussed. We questioned lane changes, possible lane changes which did not take place (why) and speed changes in particular in relation to the lane changes.

The interview was a mix of asking prepared questions and asking open questions related to what happened on the road. The basic questions consisted of three different groups of questions. In the first part, some background questions are asked such as age, profession, years of holding a driving license, annual driving in kilometers, accident records on motorway and the reasons and self speed-wise rating. The second part contained some general driving behavior questions which are not expected to be responded specifically according to the test-drive experience. The participant is asked about the frequency of his/her lane changes in a stretch of 10 km of motorway, the reasons for accelerating or decelerating on a freeway, main situations for deciding to change lanes, considerations during a lane changing action (including merging) and the fraction of lane changes for reaching the destination or improving the driving conditions. The third group of questions were answered according to the test-drive experience of the test-person. The videos recorded during their test-drive (i.e. the rear and the front view) were shown to the participants.

3.3 Test persons

Ten test persons were recruited using oral communication and using digital media (e.g. Facebook, Twitter). A 15 euro gift card was awarded to each of the drivers at the end of the test. The recruitment hence has a direct link to the university, which is being reflected in the test persons' characteristics.

In total 8 male and 2 female drivers took part in the test. The average age is 28 years. The annual mileage varies from 30 to 12,000 km annually. The median annual mileage is 4,000

km/year. One driver indicated that she drove this stretch on a daily basis, but most drivers indicated that they were familiar with the stretch (it is close to the university). Two drivers were unfamiliar with the particular road stretch. Most test persons had finished higher education or were in the process of getting a degree. Seven test drivers passed their driving test in the Netherlands 2 in Spain, and 1 in Iran. All hold a driving license which is valid in the Netherlands.

As mentioned, a large part of the test persons were students (Master degree, or post-master, PhD students), or administrative staff related to the university. One person was also a part time professional private driver, for which he had received additional training. Clearly, this is not a representative sample for all drivers. Moreover, the number of drivers is too small to draw conclusions on the whole. However, it does give a good starting point for the identification of strategies.

3.4 Data analysis

In addition to the interviews, the videos have been watched by the authors to analyze the behavior for performing the mandatory lane changes, i.e. the lane change from the merging lane into the main lanes of the freeway as well as the merging from the main lane into the merging lane at the off ramp.

For both lane changes, the speed at the moment of the merge has been studied using the video and the in-view head-up display. Moreover, it has been studied at what location drivers changed lane. This has been done by analyzing the time they change lanes compared to the time they take to drive the distance of the complete merging lane. We convert this to a distance without taking the speed differences into account. This assumption does not hold, because speeds generally increase when merging onto the main road and decrease when merging out of the main road. The error is zero at exactly the beginning or end of the merging lane (because those moments are known exact). Calculations show that for changing speed profiles the error never exceeds 10 m or 3% of the length of the merging lane. Therefore, this measure is still considered to be relatively accurate.

For the off-ramp, it is also indicated how long before the start of the off ramp drivers are in the right lane, and what is the speed at the end of the off-ramp. Because speed is not constant but will be generally increasing, this will give a bias. The measure is accurate for the beginning and end of the merging lane, but in between the estimation of the merging location will be further upstream than the real location. This error can be quantified. An example calculation with a speed profile increasing from 75 to 95 km/h over 90% of the distance of the merging lane shows that the error in position is in the worst case 10m, which is at a speed of 30 m/s 1/3 of a second. Note that we read the time in seconds, so the error due to speed changes can be neglected.

4 STRATEGIES: OPERATIONS AT THE FREEWAY

The interviews revealed four completely different strategies. This variety of strategies is not described in literature. Most remarkable was that all drivers considered that all drivers would have the same driving strategy as the driving strategy they showed themselves, whereas the strategies of others are in fact completely different. Most drivers have one or two general strategies, which is shown in table 1. In this section we present the four strategies: speed leading, speed leading with overtaking, traffic leading and overtaking. Moreover, we will comment on the use of the peak hour lane.

TABLE 1 The different strategies applied by the drivers

ID	Speed leading	Speed leading with overtaking	Lane Leading	Traffic Leading
1	•		•	
2	•			
3		•		
4	•		•	•
5	•			•
6			•	
7		•		
8	•			
9	•		•	
10			•	

4.1 Speed leading

This strategy of drivers is that they choose a desired speed and try to keep that speed. Although the car is equipped with an adaptive cruise control, none of the drivers used this. The strategy is that drivers adapt the lanes such that they can drive their desired speed. Most of the drivers adapted this strategy. The desired speed that drivers showed in free flow conditions differed between around 90 km/h to well over 120 km/h (see also the other strategies).

4.2 Speed leading with overtaking

Another strategy is to choose a speed and stay at the rightmost lane which is possible with that speed. When the speed in that lane decreases, i.e. when there is a driver with a lower speed limiting the continuation of that speed, this driver will change lanes. Contrary to the driver applying the "speed leading" strategy, this class of driver applying this strategy will consider this as overtaking and increase the speed while being in the other more left lane. The motivation for this increase in speed is that "this way, the overtaking maneuver takes less time". This driver seems to take the progress of other drivers more into account. However, note that none of the drivers commented explicitly on the driver following him. All comments were made generally, and no specific cars or possible tail gating were mentioned. This might be due to the limited sample, since this is a well known irritation for the Dutch drivers, being the top irritation of drivers (*16*).

4.3 Lane leading

Most drivers have an idea of their perceived driving speed. Some consider themselves the faster drivers, other the slower. The strategy based on this ranking is that drivers choose a lane based on their perceived relative driving speed. On a strategic level perhaps the speed is leading to determine which lane would match the current "urgency" of the driver. For tactical decisions to change lanes, this is fixed. So at a tactical level, the decision is made such that the speed (almost) completely follows the others in the same lane.

For instance, one of the test persons commented he always choose the center lane, and adapted his speed accordingly. For a 100 km/h speed limit in uncongested conditions he accepts speeds between 85 and 120 km/h (seen in video and explored in interview). He would not change

lanes. He considered changing speeds as less tiresome than changing lanes. Note that this strategy implies an offence of the Keep Right Unless Overtaking rule in case there is not much other traffic, for instance in the right lane.

4.4 Traffic leading

Several drivers indicated that they followed the speed of other drivers on the road. It is very important to note that this does not at all mean that all drivers who claim so, drive similarly. We will discuss two extremes of this strategy here. First, there was a driver who had little experience on the Dutch roads ("around 30 km", gained over one year living in the Netherlands), but much experience in Asian countries. In the interview he told he was unaware of the speed limit, and adapted his speed to the other vehicles. The practical consequence for this driver in the driving experiment is that he took the center lane and chose a speed between 75 and 90 km/h. That was approximately the speed of the HGVs at the right lane, and he overtook not a single passenger car. It was also much lower than the normal speed in that lane at around 95-100 km/h. However, the vehicles behind him – queuing – drove the same speed.

The other extreme was a driver who was a professional private driver. He commented that he would "go with the flow". For him, that meant taking the speed of the fastest vehicles on the road – except perhaps for the most extreme and aggressive (high acceleration and deceleration) drivers. His motivation was that he wanted to be quick because the boss would usually be in a hurry, but he should still drive in such a way that the boss could work in the car. In the interview, the driver indicated that his free speed could be *lower* than the speed he shows with traffic. Namely, his speed would go up if there are faster vehicles around. This is similar to a finding by Tracz and Gaca (*17*), which find that speeds go up if the density increases. This driver would be most in the left lane, because that is the overtaking lane, but he still changes to the center lane if there are possibilities. On this two aspects (the increased desired speed with more traffic and the lane changes), this strategy differs from the previous strategy. Note that in this strategy, speed choice and desired lane changes cannot be separated from a behavioral point of view.

4.5 Use of the peak hour lane

Two test drives were carried out with the peak hour lane opened. Not all drivers were familiar with the peak hour lane. One driver merged at the end of the driving lane, and did not see the signs of the opened peak hour lane until he merged into one of the remaining lanes. Another participant performed an overtaking maneuver. Afterwards, he decided not to change back onto the peak hour lane because of the uninterrupted marking at the right hand side. That means that the drivers, especially the drivers which are not familiar with the peak hour lanes, are not using it, and will not comply to the Keep Right Unless Overtaking rule. Moreover, this might be a reason why the lane is underutilized.

5 STRATEGIES: MERGING

In this test drive, there were mandatory lane changes at the on ramps and off-ramps. Twice, the drivers needed to merge from the freeway into the main road, and twice they needed to exit. This section describes the decisions related to those maneuvers.

5.1 Use of the on ramp and merging lane

We also asked all drivers about the process of gap selection for merging. All drivers said they started with the process of speed selection and gap selection “as early as possible”. However, there where large differences in the moment when drivers actively started considering traffic conditions.

Some drivers started analyzing the traffic as soon as they could see the traffic. For most drivers that meant they would actively been involved in the merging process around 150 m upstream of the start of the merging lane. Some drivers were already considering the speed of the traffic much more upstream, when they could not yet see the gaps next to them, but mainly the speed of the flow. One driver did not realize he had to merge into the stream until the merging lane ended, and he had to use the emergency lane to merge onto the driving lanes.

The gap selection was for most drivers an easy task because the merging was done at higher speeds. That meant that after speeding up to approximately their desired speed, or the speed of traffic, the number of suitable gaps reduced mostly to one.

Table 2 shows the details of the merging actions for all drivers as well as the median values, indicated by Md. The median speed of merging is 89 km/h in the southbound direction and 86 km/h in the northbound direction. This difference – although not significant –may be due to the layout and geometric characteristics of the on-ramp. In the southbound direction the on-ramp is long and open, whereas in the northbound direction it is curved with road works.

The sample size is too small to perform statistically relevant tests. For larger samples, it would be interesting to check whether there is a correlation between the merge location and the driver, i.e. do the same drivers always merge early. Also relations between speed and merging location would be interesting.

5.2 Use of the off ramp

Table 2 shows the details of the use of the off ramp. The table shows how long the drivers are in the right lane before they reach the start of the exit lane. This differs for the southbound and northbound direction, with median values of 52 and 15 seconds respectively, equalling approximately 3000 m and 500 m. Perhaps the minimum value is more appropriate to indicate when drivers do not want to change any more (it is a so-called censored observation, where all values can be observed which are larger than the minimum). That also shows differences, with 38 seconds in the southbound direction and 9 seconds in the northbound direction. This difference might be due to the road geometry. In the southbound direction, the exit is after a corner and therefore not visible from a long distance, and drivers might take extra care. For the southbound direction, all commented that they could have gone later, but in order to be sure, they wanted to be in the right lane already before. On average drivers preferred to be in the right lane approximately 1 km before the 300 m long merging lane started. Some drivers commented that they were already in the right lane at or before that point and because of a HGV in front of them, they could not see whether there were other opportunities to take over these HGVs and change back to the shoulder lane. So, they decided to stay in the right lane. For one driver, at 3000 m before the start of the merging lane, the distance was too short to be in another lane than the right lane.

Note that for the northbound direction, the off ramp is located right of the peak hour lane. If that is not in use, the drivers have to cross that lane as well. The time they take to cross that lane is also indicated in table 2

TABLE 2 Empirical data on the mandatory lane changes

	Merging								Diverging										
	Southbound				Northbound				Southbound					Northbound					
Id	Speed at merge (km/h)	Time on merging lane, T_1 (s)	Total time to pass merging area, T_2 (s)	Percentage (%)	Speed at merge (km/h)	Time on merging lane T_1 (s)	Total time to pass merging area T_2 (s)	Percentage (%)	Speed at merge (km/h)	Time at right lane before merging lane T_3 (s)	Time on right lane next to merging lane T_4 (s)	Total time to pass merging area T_5 (s)	Percentage (%)	Speed at merge (km/h)	Time at right lane before merging lane T_3 (s)	Time on right lane next to merging lane T_4 (s)	Time on closed peak hour lane to cross to merging T_6 (s)	Total time to pass merging area T_5 (s)	Percentage (%)
1	96	5	21	24	84	5	14	36	96	38	4	11	36	99	42	5	-	24	21
2	84	1	24	4	81	8	16	50	80	51	5	11	45	89	10	9	-	27	33
3	87	2	22	9	99	4	11	36	80	97	4	12	33	102	9	4	4	17	24
4	77	29	27	107	86	12	15	80	81	34	6	12	50	85	15	5	4	23	22
5	97	5	23	22	85	6	15	40	83	53	4	12	33	99	80	6	4	20	30
6	91	2	28	7	95	5	14	36	92	43	5	11	45	110	14	4	3	15	27
7	87	3	23	13	91	3	15	20	85	69	6	12	50	95	18	4	3	18	22
8	110	2	20	10	94	3	13	23	77	41	5	12	42	99	13	6	4	16	38
9	85	3	30	10	82	3	15	20	74	184	4	13	31	93	14	6	-	26	23
10	94	4	22	18	85	3	15	20	71	175	4	13	31	99	57	12	-	25	48
Md	89	3	23	12	86	5	15	36	81	52	5	12	39	99	15	6	4	21	25

Most drivers slowed down on the merging lane. The speed at the shoulder lane is usually lower than in the other driving lanes, so this way drivers prepare for the lower speed. One driver *increased* his speed on the deceleration lane. He commented that he likes to speed up and tries to overtake at least one other car.

6 CONCLUSIONS

This study revealed strategies which are relevant to implement in driving simulation packages. Generally there are different classes of drivers, which can not only characterized by a different parameter set in the same driver models. We found distinct strategies regarding speed and lane choice. Especially the relation between speed and lanes is currently not in most models. We found that there is not a single desired speed, but this changes with the lane and with traffic conditions.

These findings are relevant for the modelling of multi-lane traffic control, and especially if control measures are being applied. A lane change ban might hence influence the desired speed, or strict speed check might influence the lane change behavior, but possibly in a completely different

way than if predicted by the regular software packages, where longitudinal and lateral behavior are disconnected.

Whereas these strategies are being revealed now, the next research steps are to find which fraction of driver uses which strategy (e.g,, 30% of the drivers have a lane leading strategy). Afterwards, the different elements of the driving strategy needs quantification (e.g., the lowest speed for which drivers in the lane leading strategy do not change lane is stochastic with normal distribution of 90 km/h and at standard deviation of 5 km/h).

One strategy can be implemented in a driving simulation package right away, which is the “do not miss exit” strategy. This is already present in several packages. This study showed that drivers are hesitant to overtake from 1500 m before the start of the merging lane and like to be in the right lane from at least 500 meters upstream of the start of the ramp, but for some ramps that might be considerably more.

There is limited number of test drivers that drove with an opened peak hour lane. Lane flow distribution plots show that the lane is under utilized. The test drives showed that drivers are not aware of the opened lane, do not know that the solid line can be crossed. Finally, the drivers do not notice the opened peak hour lane on the merging lane in time so they change towards the main line. The road authority could hence improve the use of the peak hour lane by improving communication on its usage.

The results of these strategies on an aggregated level are unknown. Only if implemented in a traffic simulation program one can find the effects.

Potentially, this might have an effect of how new roads are being designed. However, all these strategies are found for the current road design. Another road layout might lead to other driving strategies.

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