Car Drivers Experienced Level of Service on Rural Roads and Urban Streets

Søren Underlien Jensen
Director, senior consultant, M.Sc. planning engineer
Trafitec
2860 Søborg, Denmark
Email: suj@trafitec.dk

Kristian Skoven Pedersen
M.Sc. engineer
Road Directorate
Traffic Management Department
9220 Aalborg Øst, Denmark
Email: krsp@vd.dk

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ABSTRACT

The Danish Road Directorate sponsored a study to develop methods for quantifying car drivers experienced level of service (CLOS) on rural roads and urban streets. The results provide a measure of how well these segments accommodate car travel.

In order to determine how traffic operations, geometric conditions, and other variables affect car driver satisfaction, 262 randomly selected respondents were shown 96 video clips of rural road and urban street segments filmed from a driving passenger car. Video clips consist of high-resolution video filmed through windshield, side windows including exterior mirrors and rear window. Video clips also include a GPS based speedometer. Respondents rated video clips on a six-point scale ranging from very satisfied to very dissatisfied. This resulted in 5,514 useable ratings. 450-500 variables describe respondent answers to six background questions and the video clips i.e. roadway segment geometries, traffic operations, surroundings, weather, etc.

Car driver satisfaction models were developed using cumulative logit regression and generalized linear modeling. The developed models include 1-15 variables, which relate significantly ($p \leq 0.05$) to satisfaction ratings. These variables are average travel speed, speed limit, vertical alignment, pedestrians and parked cars per km, presence of median, edge lines, sidewalks and bicycle facilities, width of carriageway and median, drivers age, sex, type of residence and yearly mileage. Models return percentage splits of the six levels of satisfaction or average satisfaction. These splits or averages are transformed into a level of service (LOS).

Keywords: Car Driver, Experienced Level of Service, Rural Road, Urban Street

INTRODUCTION

Random utility-maximization theory is commonly used to assess travel satisfaction (McFadden, 2001). It is assumed in this theory that traveler choices that maximize utility result in satisfaction with outcomes of their choices, and satisfaction with travel is derived from observed choices such as choice of transport mode, route, etc. Another conceptualization makes distinctions between experienced utility and decision utility (Kahneman et al., 1997). Experienced utility is the satisfaction with the outcome of a choice e.g. the degree of satisfaction with a car drive on a specific road at a given time. Decision utility is the degree to which the outcome is desired when the choice is made. The theoretical reason to call this paper “Car Drivers Experienced Level of Service” is that experienced utility may reflect satisfaction with a given transport service.

Empirical research has shown that experienced utility often differs from decision utility, but may also coincide (Kahneman, 2000; Kahneman and Sugden, 2005). This means that experienced LOS may to some degree relate to mode choice, route choice, etc. Kahneman and Sugden (2005) state that the best way of measuring experienced utility probably is to measure moment-based satisfaction, and the most direct method of measuring moment-based utility is probably the experience sampling methodology. In a study using this methodology, a participant could drive with an electronic device which beeps at random times during drives, and the driver is immediately asked to respond to a question like “How satisfied are you?” and then rate his/her satisfaction on a scale. There are two problems with such a study. A safety problem due to distractions that such responses and device handling would create. Second, a study would be expensive because traffic conditions, road design, etc. have to be recorded for every satisfaction rating.

A different perhaps second-best methodology is used in the presented study as in most previous studies on experienced LOS in traffic. The methodology is: A video clip recorded from a driving car is shown to respondents and they are asked “How satisfied were you as a car driver on the shown road?” The question is then answered by rating satisfaction on a 6-point satisfaction scale. According to Kahneman and Sugden (2005) there may be problems with such a methodology especially due to the focusing illusion. If you are required to think about something like a video clip recorded from a driving car, you focus on it, and you may tend to exaggerate its relative importance. It is possible that a video survey may result in larger variations in satisfaction than car drivers experience in traffic.

Over the years, many have studied car drivers perceptions and experiences, and attempted to identify relations to road design, traffic operations, etc. However, none of the methodologies that describe CLOS has been widely accepted. CLOS is not part of the Highway Capacity Manual (HCM) (TRB, 2016). This is a problem. CLOS is important in daily communication, and understanding what makes a customer satisfied is core knowledge in any business sector. The HCM includes pedestrian experienced level of service (PLOS) and bicyclist experienced level of service (BLOS), but the resulting LOS scores of using methodologies for PLOS and BLOS are not comparable to LOS for car travel in HCM. That makes it difficult to optimize LOS across transport modes, and across road and intersection types.

CLOS studies indicate that traffic flow, flow of trucks, travel speed, speed variation, traffic density, lane changing, number of drive lanes, width of hard shoulders, density of entry and exit ramps, quality of road surfacing, and presence of road works influence CLOS on freeways (Chen et al., 2003; Choocarukul et al., 2004; Hohmann and Geistefeldt, 2016; Hostovsky et al., 2004; Jensen, 2017; Nakamura et al., 2000; Papadimitiou et al., 2010; Washburn, 2005; Washburn and Kirschner, 2006). Other studies indicate that CLOS is affected by travel speed, stops per mile, number and width of drive and parking lanes, median type, pedestrian and bicycle facilities, quality of road surfacing, and presence of trees and left-turn lanes on urban streets (Colman, 1994; Flannery et al., 2005a; Flannery et al., 2005b; Pécheux et al., 2004; Shafizadeh et al., 2002). Studies indicate that CLOS is affected by travel speed, speed variation, achieved/desired overtaking, flow of trucks, headways, traffic density, forward visibility (sight distances), number of lanes and travel time delay on rural roads (Kita and Kouchi, 2011; Morall and Werner, 1990; Sakai et al., 2011). Travel speed always have great impact on CLOS.

The objective of this study is to develop a rigorous methodology that systematically can describe CLOS on roadway segments. This study focuses on car drivers on rural roads and urban streets. A previous Danish study focused on freeways (Jensen, 2017). Earlier Danish studies have developed methodologies for PLOS and BLOS (Jensen, 2008; Jensen, 2013). These Danish studies enable us to compare experienced level of service on different types of road and among different road users, because the studies use similar methodology. The methodology is to set up models that describe and quantify the relationships between satisfaction ratings on one side and road design, traffic operations, surroundings, etc. on the other side. Thereby the factors that affect the experienced level of service are identified.

METHODS

The study is a stated perception (satisfaction) survey, where each roadway segment is rated on a fixed six-point satisfaction scale going from very satisfied to very dissatisfied. The methodology was to have respondents view numerous roadway segments captured on video and rate these segments with respect to how satisfied they would be driving a car under the roadway conditions shown on video.

Two basic elements in a video survey have to be addressed; duration and design of video clips. From previous studies we know that respondents want to rate a video clip after about 30-40 seconds and starts to lose interest in a video clip after about 2-3 minutes (Jensen, 2013; Washburn, 2005). In order to find the most appropriate duration and design of video clips a pilot study with a panel of respondents was undertaken (Jensen, 2014). In one test the panel rated their satisfaction as a car driver as fast as possible still feeling confident about their rating. The average view time needed to make a rating was 12-15 seconds. Fastest rating was after 3 seconds and slowest rating after 35 seconds. Overall 22 % of the fast ratings were different compared to ratings made after the end of the video clip. It was concluded that video clips with simple driving conditions should be 20 seconds or longer for respondents to rate their satisfaction reliably, while video clips with complex driving conditions should be about 30 seconds or longer.

Another test was performed in order to possibly identify The Peak-End rule (Kahneman, 2000). This rule states that the rating value of a representative moment is a simple average of the most extreme affect (Peak) experienced during the episode and the affect experienced near its end (End). For this test a few long video clips of 80-90 seconds were used. The video clips had different endings and “peaks” even though peaks were not extreme. Video clips were shown in their entire length and in bits of 20-30 seconds and the panel had to rate their satisfaction with each bit and also the entire video clips. Satisfaction ratings of the entire video clip were the same as the average of all bits of the same video clip. So peaks and ends were not more important to ratings than other parts of the video clips. Perhaps changes in road design and traffic conditions when driving are not “fast enough” for The Peak-End rule to actually materialize within 80-90 seconds. It was concluded that for video clips up to at least 90 seconds of duration, the stimuli, i.e. shown road design, traffic conditions, etc., during the entire video clip would be reflected in satisfaction ratings. In other words, variables representing peaks and the end of video clips are not stronger related to CLOS than variables representing the entire video clip.

Based on earlier studies and the pilot study we assessed that video clips should be 30-90 seconds long, but could exceptionally be 90-150 seconds long. If video clips are longer than 150 seconds there is a strong tendency to boredom/fatigue among respondents, which result in more negative ratings.

The panel in the pilot study also tested size, shape and presence of five elements in a video clip; view out of windshield, rear window, the two side windows including exterior mirrors and a speedometer. Different types of separation and frames between these elements were also tested. The panel preferred the design shown in **Figure 1**. This design provided them the opportunity to quickly perceive road design, traffic operations, etc. However, the picture in **Figure 1** suffers that the view out the rear window is not inverted, i.e. representing the view in the rearview mirror.

Different ways of recording and presenting sounds was also tested in the pilot study. Recordings of sound from two microphones located close to the driver’s ears were found to be best. Different ways of introducing a video clip was also tested. Besides a video clip number that respondents use to find the right spot to make a satisfaction rating on a scoring card, the panel found it important that the introduction informs about the type of road and the speed limit.

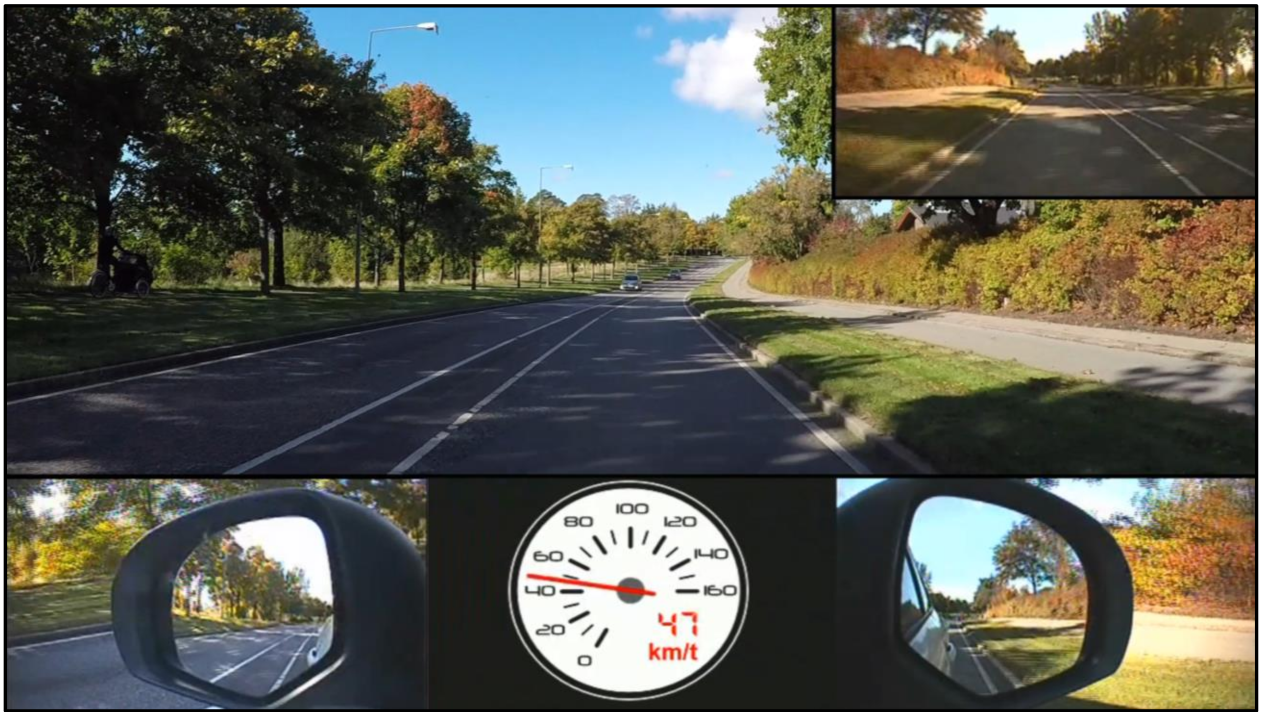

Figure 1 Preferred design of a video clip

Site selection

Based on experience with quantitative model building from previous studies it was decided that the video-based study of CLOS should include 36 freeway segments, 36 rural road segments and 36 urban street segments. A third of the roadway segments (randomly chosen) should be represented by not only one video clip but two. The extra video clip (repeater-clip) should show very different traffic conditions, i.e. the volume-to-capacity-ratio in the driven direction should be at least two categories higher or lower than in the 'original' video clip, see categories in **Table 1**. Repeater-clips were included in order to better capture satisfaction ratings for free-flow situations, and to better quantify how traffic conditions impact on satisfaction.

With a relatively small number of roadway segments, it is important to maximize the range of conditions included. Three orthogonal experimental designs were developed before site selection. The intent of the design was to ensure that the sites selected not only represented the variety of conditions drivers may encounter, but also that important quality of service factors that prior studies have found to affect CLOS were orthogonal, i.e. no relations between factors across sites. **Table 1** shows the quality of service factors chosen to set up the orthogonal experimental design for urban streets. A "buffer area" in **Table 1** may be a dividing verge, parking lane, trees, aso.

One may notice that travel speed and speed limit are not quality of service factors in the orthogonal experimental design in **Table 1** even though travel speed and speed limit are import factors related to CLOS. There are two reasons for that. First both travel speed and speed limit are often "end results" of the conditions of the street as described by the quality of service factors in **Table 1**, i.e. a given mix of the five factors in **Table 1** will often result in a narrow interval of possible travel speeds and speed limits. So if travel speed and speed limit was used as quality of service factors then most of the factors in **Table 1** should be excluded. A second reason is that it is hard to predict a travel speed, a thereby be able to video record a street from a car driving in a flow with a certain travel speed. However, when choosing the streets and the video clips to be rated by respondents, it was ensured that there was a big variation in both speed limits and travel speeds.

TABLE 1 Quality of service factors and related categories in orthogonal design of the selection of urban street segments

Quality of service factors	Categories	Number of urban street segments
Volume-to-capacity in the driven direction	0.00-0.25 0.25-0.50 0.50-0.75 0.75-	9 9 9 9
Total width of drive lanes	Less than 7.1 m 7.1-10.0 m More than 10.0 m	12 12 12
Sidestreets and driveways per km	0-10 11-25 26 or more	12 12 12
Elements in the sides of the street	Sidewalks Sidewalks and cycle tracks/lanes Sidewalks, cycle tracks/lanes and "buffer areas"	15 12 9
Presence of median or speed reducing measures	No median or speed reducing measure With median With speed reducing measures	20 8 8

All 108 roadway segments are located in Denmark and described in detail by Jensen (2018). A roadway segment had to fulfill a number of other things than just the quality of service factors described in **Table 1**. The recording car may not encounter a yield line, stop line, formal pedestrian crossing, level crossing (rail), etc., where the car may have to brake or stop on the segment. The roadway segment should have a good surface and marking quality. No road works must take place on the video recorded segment. Video clips should not start before the car had accelerated away from e.g. an intersection, and should end before decelerating towards e.g. a roundabout. The video clip should end at least 100 m before a yield or stop line on a rural road, and at least 40 m before a yield or stop line on urban streets. Also, a 10 and a 5 seconds rule apply stating that the video clip should start at least 10 seconds before a lane change or major change in cross section, and should end at least 5 seconds after a lane change and major cross section change. The reason for these rules is that respondents do not understand these changes unless they have time to experience a state before and after.

Video production

Video recordings were made in two periods from November 2014 to September 2015 and from October 2017 to March 2018. Recordings were done in daylight hours, with no precipitation and no snow on the ground. Video recordings were made from a passenger car using a GoPro camera for the view out of the windshield and a VBOX system with synchronized cameras through side and rear windows and GPS based speedometer. If possible, the car travelled 0-5 km/h below the speed limit, in the right-hand lane, in center of the drive lane, and with a time distance of 2 seconds or more to a vehicle in front and in the same drive lane. Turn signals were always used when performing lane changes. There was no radio, music, talk or fiddling with stuffs inside the recording car. All recordings that had aggressive or unusual behavior were deselected e.g. near-crashes, extreme speeds, wrecked vehicles, hunks, barking dogs, sirens, etc. Each roadway segment was filmed 3-12 times. Selected video clips were edited into about 60 minutes long video films using Adobe Premiere Elements. There were 8 different video films. Video clips were 30-140 seconds long, however only 30-70 seconds long for rural roads and urban streets. Two freeway video clips were longer than 90 seconds. On average a video clip for rural roads and urban streets was 37.5 seconds long.

Data collection

Fixed conditions were measured in the field and using aerial photos and road databases. Data on fixed conditions include e.g. cross section, alignment, road surfacing, planting within road area, markings, types of separation, signs and regulation, road lighting and barriers and other equipment, exits, entries, side roads and driveways, speed reducing measures, bus stops, medians, turn lanes, visible landscape and buildings within 100 meters from road, etc.

A synchronized stationary camera placed on the last half of the roadway segment recorded traffic in both directions during recording of video clips and with known position of the recording car. Traffic in the driven direction was counted per lane in length categories and 10 seconds intervals for one minute with the recording car in the middle. Traffic in the opposite direction seen on the video clip was counted per lane in length categories and 10 seconds intervals for at least two minutes. Video clips and stationary camera were used to estimate motor vehicle speed in the opposite direction.

Data from the video clips include information about e.g. weather, sunlight, speed of the recording car every second, passed road users in opposite and same direction respectively including over takings, passed parked vehicles, passed yielding road users, and estimated speed of other motor vehicles in the driven direction.

Respondents, video shows and questionnaire

A total of 2,956 randomly selected citizens 18 years of age or older from four urban areas in Denmark were invited to participate. 268 participated in a total of 16 video shows, but satisfaction ratings from six respondents were discarded due to unreliable answers. Videos were shown in local ballrooms using professional video projectors on 3.5 x 2.0 m screens and sets of stereo loudspeakers. Between 6 and 43 participated in the individual video shows.

Before the video show the respondent got a questionnaire where all answers and ratings should be given. At the start of the video show, six background questions about age, sex, type of residence, type of driver license, years with driver license, yearly driver mileage were asked. After a brief, neutral welcome presentation and a short neutral instruction to satisfaction rating, the respondent should rate two learner video clips, and could after that ask questions about how to rate. The learner video clips were shown in order to avoid beginner problems. The ratings of learner video clips are not included as observations when developing models for experienced level of service. After the learner video clips, the video show included 20 video clips to be rated, then a 10 minutes break, then another 20 video clips to be rated. The video clips were shown in a random order, and this random order was then turned in backward order in another video show in order to avoid respondent fatigue bias. Afte each video clip there was a short question: "How satisfied were you as a car driver on the shown road?" – and respondents had 10 seconds to rate their satisfaction. An overview of satisfaction ratings is given in **Table 2**.

TABLE 2 Satisfaction ratings of roadway segments

Nominal and ordinal scale	Number of responses (percent in brackets of column total)							
	Freeways		Rural roads		Urban streets		Total	
1 Very satisfied	2,041	(41%)	858	(30 %)	459	(16 %)	3,358	(34 %)
2 Moderately satisfied	1,550	(32 %)	916	(30 %)	797	(27 %)	3,263	(30 %)
3 A little satisfied	643	(13 %)	473	(19 %)	568	(19 %)	1,684	(15 %)
4 A little dissatisfied	384	(8 %)	284	(12 %)	430	(15 %)	1,098	(10 %)
5 Moderately dissatisfied	219	(4 %)	174	(7 %)	344	(15 %)	737	(7 %)
6 Very dissatisfied	105	(2 %)	52	(2 %)	159	(8 %)	316	(3 %)
Total	4,942	(100 %)	2,757	(100 %)	2,757	(100 %)	10,456	(100 %)
Average (nominal)	2.09		2.33		2.96		2.38	
Average, best roadway segment	1.31		1.37		1.47		1.31	
Average, worst roadway segment	4.42		4.17		4.77		4.77	

Table 2 shows that respondents are most satisfied with the shown freeway segments and most dissatisfied with the shown urban street segments. A total of 10,456 satisfaction ratings were used to model car drivers experienced level of service, of these 2,757 ratings of rural road segments and 2,757 ratings of urban street segment. A video clip from a rural road or urban street was on average rated by 57 respondents. This is a reasonable number of respondents, because the nominal average of ratings often become stabile after about 50 ratings.

Model development

Car driver satisfaction models were developed using the software SAS version 9.4. PROC GENMOD was used to set up generalized linear models (GLM). GLM models use average ratings for each roadway segment on the nominal scale. PROC LOGISTIC was used to set up cumulative logit models (CLM). CLM models use response ratings on the ordinal scale.

The CLM is a rather simple logit model. It is only the intercept a that varies in the utility function: $logit(p) = a + bx_1 + cx_2 \ldots$, meaning that when modeling a 6-point satisfaction scale, the intercept a have five different values for the first five shares of satisfaction responses. The predicted six shares of level of satisfaction may be calculated on the basis of the utility function in the following manner:

$$SHARE_{\text{very satisfied}} = 1 - 1/(1 + \exp(logit(p)_{\text{very satisfied}}))$$

$$SHARE_{\text{moderately satisfied}} = 1 - SHARE_{\text{very satisfied}} - 1/(1 + \exp(logit(p)_{\text{moderately satisfied}}))$$

…

$$SHARE_{\text{very dissatisfied}} = 1 - SHARE_{\text{very satisfied}} - SHARE_{\text{moderately satisfied}} - SHARE_{\text{a little satisfied}} - SHARE_{\text{a little dissatisfied}} - SHARE_{\text{moderately dissatisfied}}$$

From a mathematical point of view, it is more correct to use the logit model rather than the linear model, because the mathematical "Euclidean" distance between two levels of satisfaction is unknown and not nesessarily the same, as assumed in the linear model.

Determining the key independent variables that influence respondents (car drivers) satisfaction was the primary objective of the model development. The approach was to use CLM stepwise regression to determine all main effects, search for significant square and interaction terms, and eliminate spurious variables and variables not significant at a $p \leq 0.05$ level. Optimization technique was Fisher's scoring. Increasing the number of variables had to result in a reasonable reduction in Akaike Information Criterion (AIC). After the development of CLM models, the same variables were then used in GLM models except for variables describing respondents (background questions).

Three sets of CLM models were developed. One set consists of 3 models for rural road segments with an increasing number of variables. Another set consists of 4 models for urban street segments, and the third set consists of 5 models for both rural road and urban street segments. After developing these models, 2 GLM models for rural road segments, 3 GLM models for urban street segments and 4 GLM models for rural road and urban street segments were developed. In the next section, **Results**, only two recommended models are shown, and these are a simple CLM model and a more complex CLM model for both rural road and urban street segments.

RESULTS

Analyses of satisfaction ratings together with roadway segment design, traffic, surroundings, etc. and the work with model development clearly show that car drivers experienced satisfaction on urban streets and rural roads can be put on formula. The variable that has the strongest relation to satisfaction is *average travel speed* for motor vehicles *in driven direction* (that the recording car have travelled) on the roadway segment. This variable explains more of the variation in satisfaction ratings than all other significant variables put together. The travel speed in the opposite direction has no relation to satisfaction. In cases where information about streets and roads is limited, it is recommended to use a simple model for both urban street and rural road segments, where the only variables are average travel speed and speed limit for calculating car drivers experienced satisfaction, see *CLM 1 urban and rural* in **Figure 2**.

CLM 1 urban and rural (AIC = 16,587, AvgRes = 0.33)

$$logit(p) = a^{\times\times} \cdot \begin{bmatrix} vs = -12.7338 \\ ms = -11.1528 \\ ls = -10.1485 \\ ld = -9.1439 \\ md = -7.6095 \end{bmatrix} + 6.7127 \cdot \log(Avgspeed^{\times\times}) - 0.1154 \cdot Spund^{\times\times} + 6.2198 \cdot Pct^{\times\times}$$

CLM 4 urban and rural (AIC=16,276, AvgRes = 0.27)

$$logit(p) = a^{\times\times} \cdot \begin{bmatrix} vs = -13.2800 \\ ms = -11.6369 \\ ls = -10.5759 \\ ld = -9.5268 \\ md = -7.9821 \end{bmatrix} + 6.7625 \cdot \log(Avgspeed^{\times\times}) - 0.1100 \cdot Spund^{\times\times} + 6.8123 \cdot Pct^{\times\times} - 0.0493 \cdot \sqrt{Pedkm^{\times}}$$

$$-0.00327 \cdot Parkkm^{\times\times} - 0.0782 \cdot \sqrt{Hilliness^{\times\times}} + 0.6997 \cdot \log(Waywidth^{\times\times}) + 0.1671 \cdot Swalkwidth^{\times\times} - 0.0568 \cdot Mwidth^{\times}$$

$$+Median^{\times\times} \cdot \begin{bmatrix} yes = 0.1967 \\ no = 0.0000 \end{bmatrix} + Edgeline^{\times\times} \cdot \begin{bmatrix} none = 0.0000 \\ narrow = 0.2959 \\ wide = 0.4488 \\ dotted = -0.7832 \end{bmatrix} + Bikefac^{\times} \cdot \begin{bmatrix} none = 0.0000 \\ lane = -0.2007 \\ track = 0.2766 \\ tbuf = 0.1096 \end{bmatrix}$$

where logit(p) = utility function of CLM,
a = intercept parameter (vs = very satisfied, ms = moderately satisfied, ls = a little satisfied, ld = a little dissatisfied, md = moderately dissatisfied),
Avgspeed = average travel speed (km/h) in driven direction,
Spund = speed limit minus Avgspeed (km/h),
Pct = 1 – (Avgspeed/speed limit),
Pedkm = number of pedestrians on roadway per km,
Parkkm = number of parked cars on roadway per km,
Hilliness = running sum of change in altitude (meters) of roadway per km,
Waywidth = width of carriageway (meters) on roadside in driven direction including drive lanes, hard sholders and cycle lane,
Swalkwidth = width of sidewalk (meters) on roadside in driven direction,
Medwidth = width of median (meters),
Median = presence of median,
Edgeline = presence of edgeline, narrow = 10-15 cm, wide = 20-30 cm, dotted = 30 cm dotted, and
Bikefac = type of bicycle facility on roadside in driven direction, lane = marked cycle lane, track = curbed cycle track, tbuf = cycle track with buffer to drive lane.

$^{\times\times}$ is a p-value of <0.001, $^{\times}$ is a p-value of <0.05.

Figure 2 Recommended CLM models for car drivers experienced level of satisfaction on urban streets and rural roads. Based on ratings of 96 video clips. AIC is Akaike Information Criterion. AvgRes is average residual of nominal satisfaction average.

On rural roads and urban streets, it is predominantly the travel speed in driven direction that influences car drivers satisfaction. The driver become more and more dissatised as the speed slows down. Analyses show that it does not matter why the speed slows down e.g. due to dense traffic, sharp curves or speed humps. The car driver has the same level of satisfaction driving 30 km/h in dense traffic as driving 30 km/h on a bumpy street or curvy road.

Car drivers expect to be able to drive faster on a rural road compared to an urban street, and expect to drive faster as the speed limit goes up. Analyses and the models in **Figure 2** show clearly that satisfaction depends on speed limit. The car driver actually has to drive faster on a road with a high speed limit in order to reach the same good level of satisfaction as on a road with a lower speed limit.

A larger share of car drivers on rural roads become very dissatisfied at low travel speeds than on urban streets (and on freeways) at the same low travel speeds. This might be because low travel speeds are more uncommon on rural roads than on urban streets and freeways. Poor traffic operating conditions on rural roads perhaps deserve larger political focus. About other road conditions one may say based on the model *CLM 4 urban and rural* in **Figure 2**:

- More pedestrians along or crossing the road make car drivers less satisfied.
- Wider sidewalks make car drivers more satisfied.
- More on-street parked cars make car drivers less satisfied.
- Steeper and hillier roads make car drivers less satisfied.
- Wider carriageways make car drivers more satisfied.
- Narrow medians make car drivers more satisfied (very wide medians tend to have trees, which make car drivers less satisfied).
- Narrow edge lines are more satisfiying for car drivers than no edge lines. Wider edge lines make car drivers even more satisfied, however, wide dotted edge lines marked on "2-1 roads", make car drivers less satisfied than no edge lines.
- Car drivers are more satisfied, when the road has bicycle facilities.

These other conditions may improve or worsen the experienced level of satisfaction by up to two steps, e.g. going from a majority of moderately satisfied car drivers to a majority of a little dissatisfied car drivers or from moderately satisfied to very satisfied. On urban streets it is predominantly factors like number of pedestrians and parked cars, and sidewalks and bicycle facilities that may change car drivers' level of satisfaction. On rural roads it is often the factors hilliness, carriageway width, edge lines and bicycle facilities that alter the level of satisfaction.

Four of the variables describing respondents (background questions) were statical significant but are not part of the recommended models, because they increase the average nominal residual i.e. degrade the models predictive capabilities. However, based on these correlations one may state that female drivers are more satisfied than male drivers. Older drivers are more satisfied than younger drivers. Drivers living in terraced houses are more satisfied than those living in flats. Drivers driving 1,000-9,999 km a year are less satisfied than those not driving at all.

Experienced level of service criteria and results

The definition of CLOS is based on the split of the response levels of satisfaction. To remain consistent with the Highway Capacity Manual (TRB, 2016), six CLOS designations, A through F, were defined as follows. A "democratic" definition is used, meaning that if 50 percent or more are very satisfied then LOS is designated A. LOS is designated B if 50 percent or more are very or moderately satisfied and less than 50 percent are very satisfied. And so forth, ending up with a LOS F if 50 percent or more are very dissatisfied, see **Table 3**.

TABLE 3 Definition of car drivers experienced level of service on urban streets and rural roads

Definition of CLOS on urban street and rural road segments			Nominal average of satisfaction
LOS	Satisfaction	Respondents satisfaction rating	
A	Very satisfied	At least 50 % are very satisfied	< 1.77
B	Moderately satisfied	≥ 50 % are moderately or very satisfied	≥ 1.77 and < 2.75
C	A little satisfied	≥ 50 % are a little or more satisfied	≥ 2.75 and < 3.50
D	A little dissatisfied	≥ 50 % are a little dissatisfied or more satisfied	≥ 3.50 and < 4.27
E	Moderately dissatisfied	≥ 50 % are moderately dissatisfied or more satisfied	≥ 4.27 and < 5.22
F	Very dissatisfied	At least 50 % are very dissatisfied	≥ 5.22

Having these definitions makes it much easier to grasp car driver satisfaction and to present the models relationships. **Figure 3** presents the relations between CLOS, average speed and speed limit. The figure shows as a rule of thumb that the experienced level of service on rural roads and urban streets deteriorates by one level, when the average travel speed is reduced by 10-20 km/h.

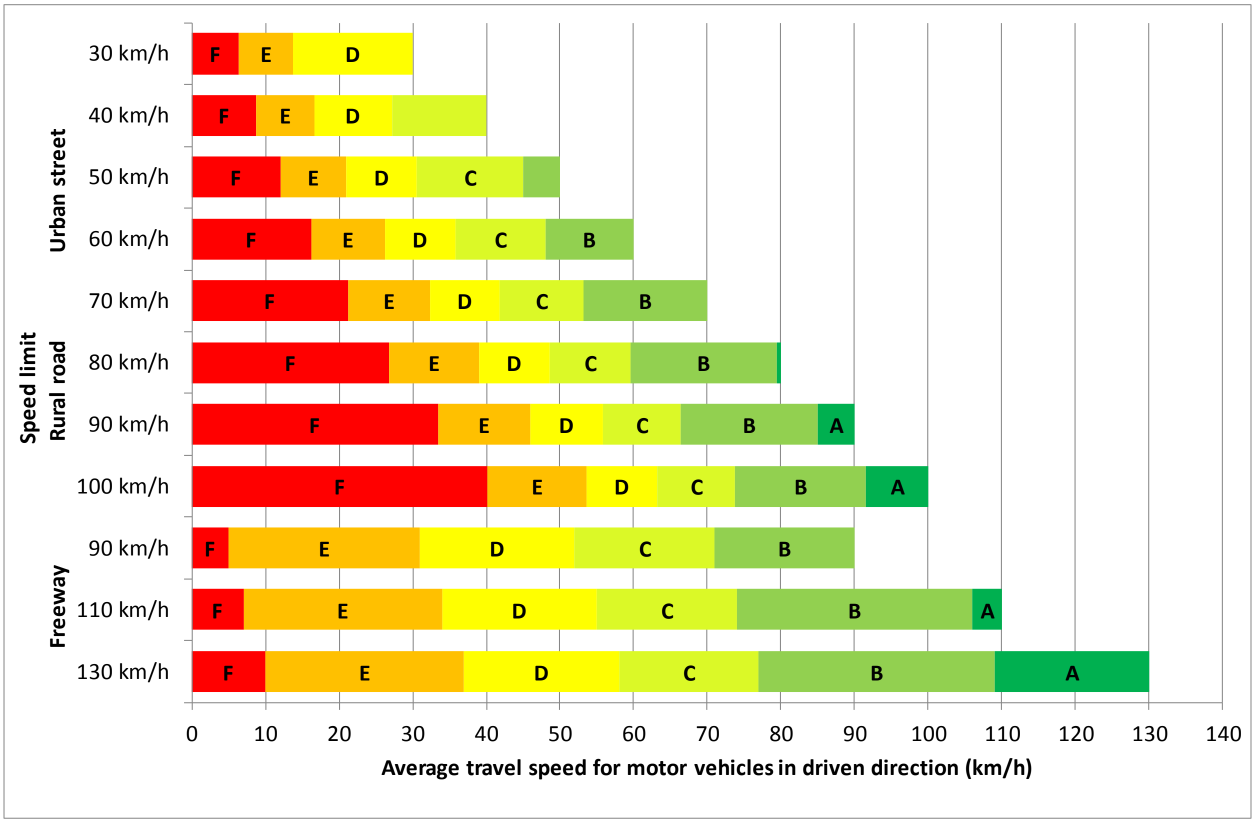

Figure 3 CLOS relations to average travel speed and speed limit on rural road and urban street segments based on model CLM 1 urban and rural, and CLOS on freeways based on Jensen (2017)

In urban areas, it is rather rare that car drivers are very satisfied (LOS A), because traffic often operates at low travel speeds. At *Quiet streets* with a 30 km/h speed limit almost all car drivers are dissatisfied (LOS D, E or F). Many vulnerable road users and parked cars may complicate driving a car and worsen CLOS. Along some urban streets it is important for car drivers to have facilities for cyclists, pedestrians and off-street parking. Good planning of the urban street network in terms of travel speed for cars (proper speed management) and the design of especially urban arterials are important for CLOS.

Travel speeds below 20-40 km/h on rural roads make car drivers very dissatisfied (LOS F). On rural road segments it is often sharp horizontal curves, agricultural vehicles, reductions in the number of drive lanes, and long queues up to roundabouts and intersections that reduce travel speeds. It is seldom that slow travel speeds occur solely due to high traffic flows on rural road segments. The width of the rural road and marking of center line and edge lines are also important to CLOS, and on some rural roads with relatively many slow road users like cyclists, pedestrians and agricultural vehicles it will also improve CLOS to build facilities for these slow road users.

Spreadsheet and application

A user-friendly spreadsheet has been developed due to the considerable number of calculations that needs to be undertaken to estimate CLOS. This spreadsheet includes the two models shown in **Figure 2** and four other recommended models. As a minimum the average travel speed and the speed limit or zone (rural or urban) needs to be entered in order for CLOS to be estimated. Since average travel speed very often is known due to the considerable amount of GPS based travel speed data, and since e.g. road administrations by law in the European Union must have digital data on speed limit for every road, it should be easy to find relevant data for road networks. One may also enter data about the design of the roadway segment and number of pedestrians and parked cars to get more precise CLOS estimations.

CLOS could be used for different applications. Road administrations or politicians could set CLOS goals/targets for specified road networks. Models and spreadsheet could be used to identify streets and roads with a poor experienced level of service. CLOS could be used when planning new roads and making larger reconstructions of existing roads. CLOS could be used as a tool in different types of communication to road users e.g. in radio, on the internet, in apps, through navigation systems, etc.

UPDATES

Trafitec completed a new study of car drivers experienced level of service at non-signalized and signalized intersections (Jensen, 2020). Based on 2,800 satisfaction ratings of 70 video clips it is found that CLOS at intersections heavily depends on waiting time but also depends on type of intersection, manouvre, and type of give-way marking/signage or type of signals.

CONCLUSIONS

Overall models show that car drivers experienced level of service on urban street and rural road segments heavily depend on average travel speed of motor vehicles in driven direction and the speed limit. Travel speed is much stronger related to CLOS than traffic flow or traffic density. However, car drivers typically go from being satisfied to being dissatisfied when a traffic breakdown occur. But travel speeds are much more often low on urban streets and rural roads due to other conditions than high traffic flows. CLOS also depends on the number of pedestrians and parked cars on the roadway segment, and on hilliness, width of sidewalks, carriageways and medians, type of edge lines and presence of bicycle facilities and medians.

The car driver satisfaction models and the subsequent LOS designations provide traffic planners and others capability to rate urban streets and rural roads with respect to road user satisfaction. Models can rate existing urban streets and rural roads in real-time and retrospective, and provide road users, navigation systems and road administrations with valuable information to choices before and during journeys and to optimize budgets for roadway improvements. Models may also be used in the process of designing new roads or redesigning existing roads.

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