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Abstract to Conference 2nd Symposium of the
European Association for Research in Transportation.

How Driving Style affect Bus & Metro Passengers' Assessments of Comfort

Abstract

Ride quality is part of the total comfort experience for any passenger. It can be seen as the result of the infrastructure, vehicle characteristics as well as how the driver handles the vehicle, i.e. the driving style. Poor ride quality generally leads to low attractiveness and more specifically to travellers being less comfortable and rested. At worst it can cause difficulty to keep balance and lead to falls. As a passenger you may be unable use travel time to read (Sundström, 2006) and some of us even become motion sick.

Literature shows that interest has been focused on dynamics of vehicles and road/rail to vehicle interaction. To some extent, the road and rail quality as well as the vehicle suspension systems are main components for influencing the ride quality. But, for example the authors (Kottenhoff et al. 2005, 2007) has studied the willingness to pay for increased ride comfort levels by means of better track maintenance for long distance train services. Studies have also been made on effects of "eco driving" (Wåhlberg, 2006). However, little or no research has been focusing on how the driver's input or control of the vehicle affects the passengers' experience of the ride.

The following project aims to raise the awareness of the relationship between drivers' driving style and gained ride quality, including motion sickness. Comparisons are made between ride comfort in bus and metro services and how

ride quality can differ between different driving styles. A concrete goal is to provide a basis for driver training and new driver support.

An array of complementary methods have been applied, beginning with analysing traffic operator statistics of comfort complaints, via on board interviews and field measurements with accelerometers in regular bus and metro services, ending with an experimental design exposing test subjects to field like situations.
The interviews with bus and metro travellers showed that driving styles including heavy stop jerks and/or uneven speed irritates passengers the most. In parallel to these interviews, measurements of acceleration profiles and jerks were made in real bus- and metro-services. Then, in the autumn 2009, experiments were conducted with test subjects that evaluated different driving styles with regard to their assessment of comfort. Visual analogue scales without intermediate grading were used in conjunction to binary questions like: Is this comfort level good enough?
The results showed that heavy braking, harsh cornering, strong jerks, and uneven speed all affected passengers' assessment. In fact, all the tested factors gave rise to statistically significant decreases of the perceived comfort level.

Two types of models were finally made; a linear regression model and a logit model. The latter was used for the binary yes/no answers. The main model based on correlation and regression analysis was developed for further quantitative analysis of a travel with public transport. A critical step was to design indicators with dual purposes, to represent a physical motion as well as providing an explanation to the passengers' assessment.
The four indicators produced, essentially reveal the sensitivity for; 1) longitudinal acceleration and braking, 2) longitudinal jerks, 3) cornering forces, and 4) uneven speed, so-called "Throttle Pumping".
The regression model for the comfort level in relation to the indicators can be expressed in simplified form as:

$$CI = k + b1 \bullet X_{rms} + b2 \bullet J_{ind} + b3 \bullet Y_{rms} + b4 \bullet P_{ind}$$ where

CI	*Comfort Index*, higher values are worse
k	Regression constant
X_{rms}	The rms average for longitudinal accelerations in the measurement time period
J_{ind}	Jerk indicator designed for optimum fit between test subjects' assessments and cornering accelerations
Y_{rms}	The rms average for latitudinal accelerations in the measurement time period

P_{ind}	"Pump" indicator designed for optimum fit between test subjects' assessments and cornering accelerations
b1-b4	Estimated sensitivities for output of the various indicators

Two of the indicators are more complicated constructs; the jerk indicator and the indicator for uneven speed, the "Pump" indicator. Both require filtering in the time domain and regarding level thresholds. For example, jerks that affect passengers' comfort perception, are not correctly described by a simple derivation of the longitudinal acceleration signal.

The indicators have been used to assess the hundreds of runs previously recorded, with accelerometers in buses and metros in real traffic. By plotting each indicator a graphical display reveals how big discomfort the real traffic situation causes and also what type of discomfort.

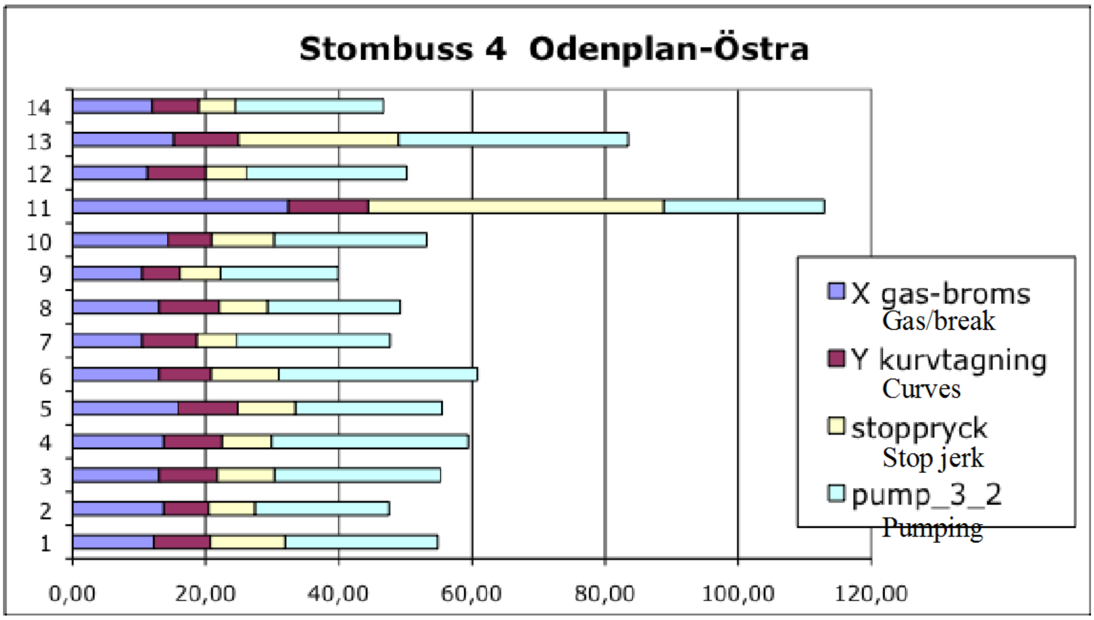

Diagram showing estimated ride comfort - dis-comfort levels in 14 different runs with different drivers and driving styles on Stockholm trunk line 4. The dis-comfort levels are split into four indicators: X) longitudinal acceleration, Y) Cornering forces, Stoppryck), longitudinal stop-jerks and Pump) uneven speed.

First, the registrations show that ride comfort generally is somewhat higher in the Stockholm metro than in buses. Secondly, it appears there are great differences between drivers, but that most are intermediate, with regard to comfort levels. The diagram above illustrates this. Most of the ride comfort levels in the diagram actually lie on the boundary of unapproved according to the scale developed by this project. Thirdly, it appears that about 10% of the drivers differ with considerable uncomfortable driving. Fourth, there are a few drivers who drive a lot better than average drivers. Their favourable driving style actually indicates a potential for increased ride comfort among all drivers.

So, what impact has the drivers for improving the comfort of public transport? The third and fourth conclusion shows potential for improved ride comfort in public transport through the drivers' involvement. The knowledge and quantitative variables that the project has derived can be used for programming of electronic driving support systems. These systems should be used as tools for driver training and as well as in regular passengers services.

What remains is to design and try out different driving tools that make use of the developed indicators. Further tests should also be performed to validate the usefulness and correctness of the acceleration based indicators for passengers' comfort assessments. The results can also be used to better align the various tools of eco-driving to also indicate comfort levels and warn the driver for un-comfortable driving.

Literature excerpt (mentioned in the abstract):

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