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Effect of Using Electronic Map While Driving on Human Error Probability

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Abstract

Applications of electronic map from mobile phone have helped drivers finding travel destinations. These applications were often used by driver as guidance when he was driving. There were some factors caused traffic accident that endanger individuals. Among these factors, human error was the main factor that caused traffic accidents. This research aims analyzing the effect of using electronic maps while driving on human error probability. This research used goggle map application as secondary task on driver. Human Error Assessment and Reduction Technique (HEART) were used to analyze human error probability and its output be compared to drivers shelves report. The reports include incident and accident that have been experienced by drivers along driving while using electronic map. The value of human error probability on this condition was 0.0106 and according to driver subjective judgment, the drivers never had experienced on incidents and accidents. However sometime a driver got a warning from another driver because he inhibited the traffics. A procedure driving safely while using electronic map was designed to minimize accident and protest from others driver. This research concluded this driving activity increased human error probability very slight and it will safe if driver allow the procedure.

Keywords
Human error probability, Incident, Accident, Electronic map.

1. Background

Using electronic maps via mobile phone helps drivers in finding travel destinations. These applications were often used by drivers as guidance while driving. Driving a vehicle is a complex task that requires not only physical skills for controlling the direction and speed of a vehicle but also mental skills for sustained monitoring of integrated perceptual and cognitive inputs that allow a driver to make time-appropriate decisions. Response time of driver was significantly slower if driving task was accompanied by a concurrent auditory task like operating mobile phone (Christian, Richard and Steven, 2002).

Based on data from the World Health Organization (WHO) in 2004, there were three factors caused traffic accident that endanger individuals. First factor was human (human error), second factor was the vehicle (machine error), and third factor was the way (manufactured error). Among these three factors, human error was the main factor that caused traffic accidents. Human error is an action, a decision which is not necessary/not right which can reduce or potentially reduce effectiveness, safety, and performance of a system. The human error problem can be viewed in two ways: the person approach and the system approach. The person approach h focuses on the unsafe acts—errors and procedural violations—of people. This unsafe acts as arising primarily from aberrant mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness. The system approach is that humans are fallible and errors are to be expected, even in the best organizations. Errors are seen as consequences rather than causes (Reason, 2000).

At micro-level of transport system, the driving system is composed of the users, the transport tools and the infrastructures used for the journeys. These components operate by interacting with one another and the smooth running of the system implies that all three components have been adjusted correctly. Most safety studies have been based upon a person approach and stress the role of human error in the production of 75 to 90 per cent of accidents.

But it would be wrong to regard this error as the primary cause of accidents. A safe system approach will rather consider it as a consequence of malfunctions further upstream, so that human error is only a link in the chain of events leading up to an accident. And he is a necessary link as far the driving system is unable to function without drivers (Trace, 2007).

The driver's lack of concentration has been frequently cited as a major cause of motor vehicle accidents. The social interaction factor indicates a poor social interaction that probably interrelates with other characteristics such as low self confidence, clumsiness, and impulsivity, which makes a person susceptible to driving errors and accidents. The two factors suggested an increased effect on accidents and were strongly associated with driving errors, they are included the lack of concentration and social interaction were significant (Allahyari *et al.*, 2008).

Cognitive failure is defined as cognitively based error occurring in a simple task that people can do without any error. These events differ in nature and rate between people. The results of statistical analysis suggest that the cognitive value rate significantly contributed to any type of safety performance. The increase of the cognitive failure caused an increase in accident. Total Cognitive failure were associated with driving error rates, but not with accidents (Allahyari *et al.*, 2008).

Road traffic accidents were attributed to driver distraction caused by sources internal to vehicle. Cars now constructed to make driver saver than ever but the risk from performing secondary task within the vehicle remains significant threat to driver safety. Secondary driving tasks are not directly involved in driving and related to control infotainment, navigation, and communication function. Driving can be a complex task that demands considerable attention. Primary driving tasks include such things as steering, accelerating, braking, speed choice, lane choice, manuvering in traffic, navigation to destination, and scanning for hazards. Secondary tasks include all the other things drivers do that are not related to driving per se. These secondary tasks can distract the driver from the primary task of driving (Hedlund, 2006). All roadside billboard along the route distracted the majority of the drivers, with signs in the row and moving elements signs (video signs) causing the greater distraction. Distraction involves a diversion of attention from driving, because the driver is temporarily focused on an object, person, task, or event not related to driving, which reduces the driver's awareness, decision-making, and/or performance, leading to an increased risk of corrective actions, near-crashes or crashes (Hedlund 2005 in Sabzevari et al, 2016). The prevalence rates of potentially distracting activity in Iran was about 24.9% (Sabzevari et al, 2016), frequently observed secondary tasks were drivers talking to passengers 11.5%, followed by mobile phone use 4.0%. and reaching for an object (3.2%).

Using electronic map was driving secondary task that allows driving errors and encourages traffic accident. Research has established that mobile phone use and texting while driving are serious crash risks. Most recently, a review of the distracted driving research concluded that there is no conclusive evidence on whether hands-free cell phone use is less risky than hand-held use (Mayhew *et al.*, 2013). In particular, hands-free texting is not a solution for reducing young driver crashes since teen drivers already have the highest crash risk and they are the most vulnerable to distraction (Mayhew *et al.*, 2013).

Driver distraction can however be further defined as occurring due to attention being diverted by driving related tasks (e.g. sat nav) or non-driving related tasks (e.g. mobile phone use). It can also be defined as internal to the car or external to the car, and further defined by the type of attention necessary (e.g. visual, auditory, physical, cognitive). The worst performance was observed when drivers were required to regain control of driving in the automated mode, whilst distracted by the secondary task (Merat *et al.*, 2012). Secondary tasks that require visual attention and psychomotor coordination deteriorated driving performance the most, whereas tasks that required memory scanning and utilization of the auditory modality least affected driving performance (Rodrick, Bhise and Jothi, 2013). The response time of driver significantly slower if search task was accompanied by a concurrent auditory task (Christian, Richard and Steven, 2002).

In this study, researchers analyzed of the conditions faced by drivers in driving while done secondary driving task and calculated the human error probability of the driver who drove while using an electronic map. Using an electronic map was secondary driving task dominantly done by driver as impact of technology improving in transportation information system. Method of Human Error Assessment and Reduction Technique (HEART) is a technique used in the field of human reliability assessment (HRA/Human Reliability Assessment) for the purpose of evaluating the possibility of human error occurring throughout the completion of a specific task. HEART method is

based on the principle that each time the task is performed it is likely to fail and that this possibility is affected by one or more EPC (Producing Error Condition), for instance: distraction, tiredness, cramped conditions and others. The factors that have influenced on performance significanly indicated by the largest HEP.

2. Methods

2.1 Tools

Along with progress in the field of information systems, some applications of electronic map available in the mobile phone and accessible by the driver. This research used goggle map application as secondary task on driver. The applications displayed on mobile phone that have 5 inches display. Video cameras recorded activity of driving and have used reference in making the Hierarchy Task Analysis (HTA) and Fault Tree Analysis (FTA) for the driving activity.

2.2 Self report data

A self-report method was used to collect data about accident and incident that have been experienced by participants while driving using electronic map. The participants were informed about the questions and they had answered honestly. Participants also asked to explain about their experience in driving activities while using electronic map and its impact on the traffic. The self report data of accident and incident were used as the comparison against the calculation of human error probability using Heart method. Participant experience during drive using an electronic map were referenced in building standard procedure of using an electronic map while driving to keep traffic fluently. Interview to the participants have done when one driving activity reached its destination.

2.3 Participants

Participants in this research were the private motorist. All participants have drove car more than a year and already had a driving license. All participants were mature with age between 20 to 45 years old. Participants also ascertained in a healthy condition.

2.4 Research Location

Monitoring at driver was done when participants have been driving in the city, one of the major cities in Indonesia with a population of about 700 thousands individuals. Researchers sit in and went along a car that was ridden by participants and observed the driver who was driving while using an electronic map. The car was assured through the arteries road within the city with busy traffic conditions. Once completed of one trip drivers interviewed to get data of accident and incident that theirs experienced while driving using an electronic map. The cars that have used by driver were a kind of minibus and using manual transmission. The mobile phone as an electronic map display placed regularly in front of the driver. The mobile phone affixed to the dashboard neared the steering wheel, so that the driver can see electronic map display clearly with head position straight forward during driving. During the travelling the driver activities were recorded and observed.

2.5 Data Processing

Observation against drivers who use electronic maps was analyzed using the method of Heart to get the value of Human Error Probability (HEP). Five steps of Heart method include 1. Generic Task Unreliability: Classify the task in terms of its generic human unreliability into one of the 8 generic HEART task types; 2. Producing Error Condition & Multiplier: Identify relevant error producing conditions (EPCs) to the scenario/task under analysis which may negatively influence performance and obtain the corresponding multiplier; 3. Assessed Proportion of Effect: Estimate the impact of each EPC on every task based on judgment; 4. Assessed Effect: Calculate the impact for each assessed EPC according to this formula, Assessed effect = ((1 − Multiplier) * Assessed Proportion of Effect) + 1; 5. Human Error Probability (HEP): Calculate overall probability of failure of task based on the formula, HEP = Nominal human unreliability × Assessed impact1 x Assessed impact2 x ....
Selves reports by participants about accident and incident that they have experienced along driving while using electronic map were used as compariton as calculation of HEP. Selves reports about traffic condition and reaction

from others driver to the participant along they drove while using electronic map was used as reference in designing model of driving while using electronic map safely.

3. Result and Analyze

Data observation at driver who driving when using electronic map was analyzed using Human Task Analysis (HTA), Fault Tree Analysis (FTA), and Human Error Probability (HEP). This research also designed a model of driving safely while using electronic map based on experienced and observed along this research.

3.1 Human Task Analysis (HTA)

Human task for driving activity while using electronic map have separeted into two steps, they are car set up before driven and human activity when driving car. Next was the HTA for the task.

a. Car set up
Car set up included activity of prepared for electronic map and the car. Preparation of electronic map included activity of search destination location and make route from original location to destination using e-map. After e-map set up, driver positioned handphone in front of him. Its position can on dashboard or on steering wheel. After that driver had prepare car before be driven, its included activities of start engine, put on seat belt, and set gear, and than followed by removing handbrake. Set gear included activity of put clutch pedal down and move gear stick. Figure 1 described Human Task Analyze of car set up.

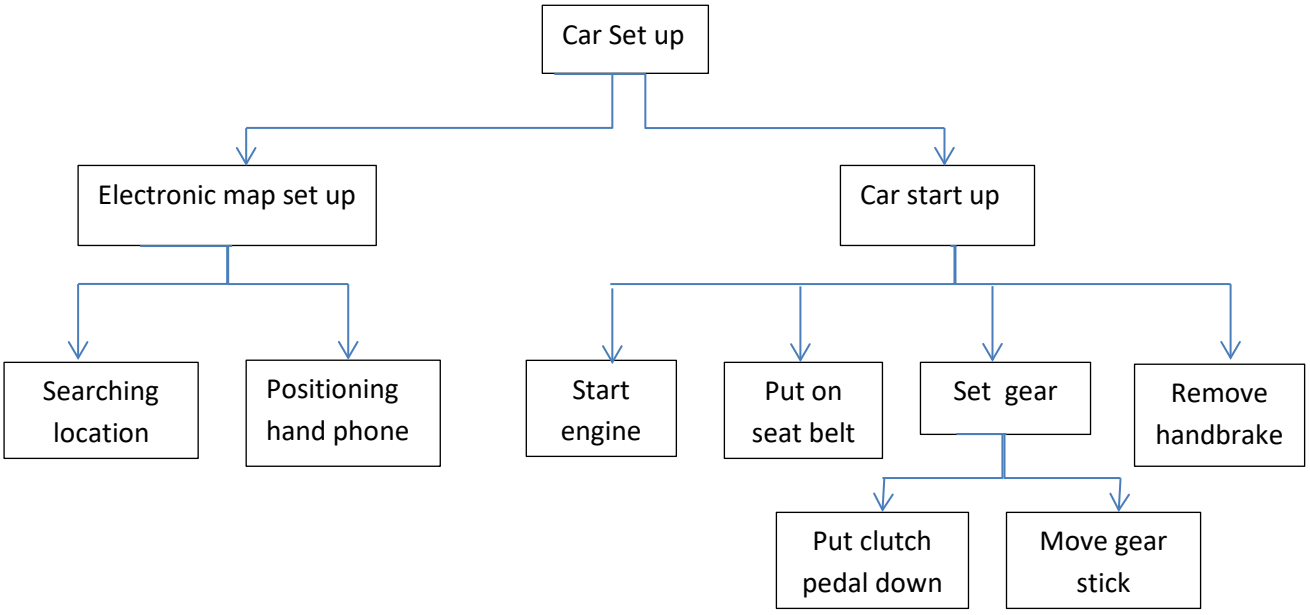

Figure 1. HTA for car set up

b. Driving car
Activity of driving car included driving car while follow map. When driving car, driver had watchful traffic at the same time controled accelerate and brake. Driver should attend e-map while concentred surrounding. Figure 2 described Human Task Analyze for driving car.

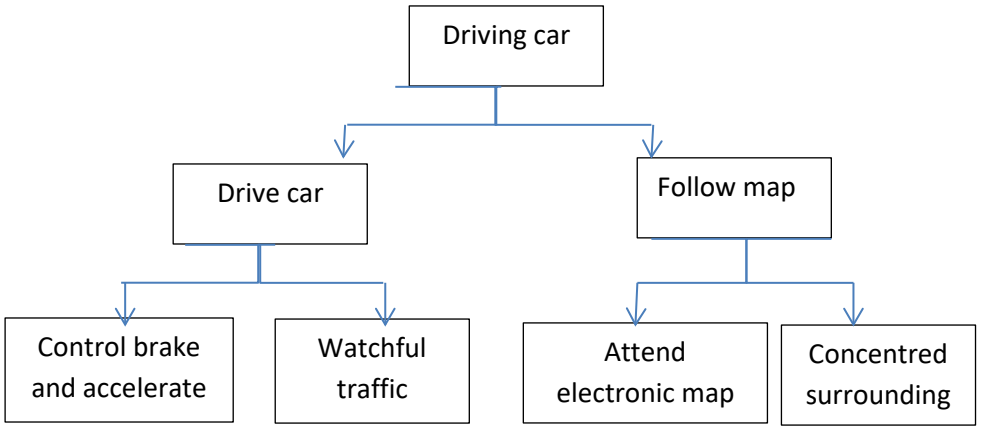

Figure 2. HTA for driving car

3.2 Fault Three Analyzing (FTA) of Driving Accident when using electronic map

Fault three analysis described the fault that might happened when someone drive a car and caused accident. Driving accident when using electronic map happened if driver failure watchful traffic and done secondary driving task. Meanwhile secondary driving task included attended electronic map or searched address surrounding. There were three faults that caused driving accident when using electronic map, they were driver attend electronic map or search address surrounding and followed by failure watchful traffic. Schema of these three faults figured on Figure 3 Fault Three Analysis.

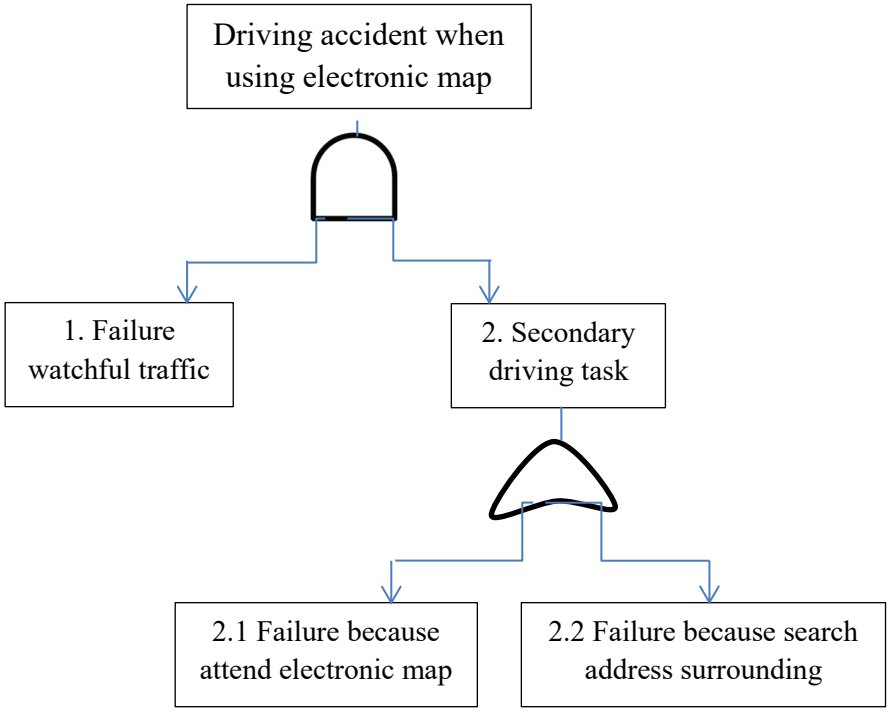

Figure 3. FTA on driving accident while using electronic map

3.3 Analyzing Human Error Probability (HEP)

Analyzing Human Error Probability (HEP) used the Heart method. The Heart technique was developed by Williams (1986) and is based on human performance literature. The human factors analyst must undertake five steps in order to estimate the probability of failure for a specific task.

1. Generic Task Unreliability. Classify the task in terms of its generic human unreliability into one of the 8 generic Heart task types. There are eight generic task types based on Heart method. Generic Task for the activity of 'failure watchful traffic' was E, this task characterized routine, highly practiced, rapid task involving relatively low level of skill. The Generic Task Unreliabelity for this task proposed Nominal Human Unreliability 0.02. The nominal have 5^{th} until 95^{th} percentiles of boundaries. Generic Task for the activity of 'failure because attend electronic map' was F, this activity was restored or shifted task to original or new state following procedures with some checking. The Generic Task Unreliability for this task proposed Nominal Human Unreliability 0.016. And Generic Task for the activity of 'failure because search address surrounding' was E, this task characterized routine, highly practiced, rapid task involving relatively low level of skill. The Generic Task Unreliability for this task proposed Nominal Human Unreliability 0.09.

2. Error Producing Condition & Multiplier. Identify relevant error producing conditions (EPCs) to the scenario/task under analysis which may negatively influence performance and obtain the corresponding multiplier. This step output was maximum predicted nominal amount by which unreliability may increase (Multiplier), based on Table 3 Heart method,
There were three EPC for task 1:

1. Shortage of time available for error detection & correction
2. A means of suppressing or overriding information or features
3. Task pacing caused by the intervention of others

There were three EPC for task 2.1:

1. A mismatch between an operator's model of the world vs. Designer
2. Channel capacity overload
3. Shortage of time available for error detection & correction

And there were four EPC for task 2.2:

1. Shortage of time available for error detection & correction
2. A means of suppressing or overriding information or features
3. A mismatch between an operator's model of the world vs. Designer
4. No clear direct and timely confirmation of an intended action from the portion of the system over which control is to be exerted

3. Assessed Proportion of Effect. Estimate the impact of each EPC on every task based on expert judgment. Assessed proportion of effect based on researcher judgment with range 0 until 1. Study literature on many researches that used Heart method and discussion with driver were referenced in assessing.

4. Assessed Effect. Calculate the 'assessed impact' for each EPC according to the formula:
Assessed effect = ((Multiplier −1)*Assessed Proportion of Effect)+1

5. Human Error Probability (HEP). Calculate overall probability of failure of task based on the formula:
HEP = Nominal human unreliability × Assessed impact1 × Assessed impact2 x .....
Table 1 was steps for calculating Human Error Probability (HEP) in driving while using electronic map.

Tabel 1. Failure in Driving

	Task	Generic Task Type	Nominal Human Unreliability	EPCs	Multipli-er	Assessed Proportion of Effect	Assessed Effect
1	Failure watchful traffic	E	0.02	Shortage of time available for error detection & correction	11	0.01	1.1

				A means of suppressing or overriding information or features	9	0.05	1.4
				Task pacing caused by the intervention of others	1.06	0.2	1.12
2.1	Failure because attend electronic map	F	0.16	A mismatch between an operator's model of the world vs. Designer	8	0.05	1.35
				Channel capacity overload	6	0.3	2.5
				Shortage of time available for error detection & correction	11	0.01	1.1
.2.2	Failure becaused search address sorounding	E	0.09	Shortage of time available for error detection & correction	11	0.01	1.1
				A means of suppressing or overriding information or features	9	0.02	1.16
				A mismatch between an operator's model of the world vs. Designer	8	0.05	1.35
				No clear direct and timely confirmation of an intended action from the portion of the system over which control is to be exerted	3	0.3	1.6

Human Error Probability (HEP) for each of task based on above table were :
1. HEP on failure watchful traffic (task 1) = 0.02 x 1.1 x 1.4 x 1.12 = 0.0345
2. HEP on failure because attend electronic map (task 2.1) = 0.16 x 1.35 x 2.5 x 1.1 = 0.0594
3. HEP on failure because search address surounding (task 2.2) = 0.09 x 1.1 x 1.16 x 1.35 x 1.6 = 0,2480, so

HEP on failure because of secondary task (task 2) =
= HEP on task 2.1 + HEP on task 2.2
= 0,00594 + 0,2480
= 0,3075

Total HEP = HEP failure because of secondary task x HEP failure watchful traffic
= 0,0345 x 0,3075
= 0,0106

Human error probability of driving while using electronic map was 1.06%, this value was seen from driver side who use electronic map, but if we analyze from other drivers its impact will be difference.

3.4 Probability of Accident on Driving while Use Electronic Map Subjectively.

A questionnaire distributed to the drivers who had experience driving when using the electronic map. As many as 35 questionnaires disseminated to car drivers. They gave respond subjectively based on their experiences using an electronic map when driving.

Next were respondent characteristics: Age of respondent from 20 until 46 years old; Gender was male and female; Driving experience more than 2 years; 100% respondent have driving lycence; Experienced of using electronic map while driving more than six months. Next was respond on questions in the questionnair: 100% respondent answered never had experience of accident as long as driving when using the electronic map; 100% respondent answered never had experience in incident as long as driving when using the electronic map; Losses suffered due to accidents have not happened.

But although 100% respondent answered never had an accident or incident when driving using electronic map, reality in field this activities often create other riders distracted and honked for several reasons: 1. Because the driver have drove slower than the average speed of other vehicles so it can inhibit the traffic on the road. 2. Because the drivers were not in the lane that determined so it can inhibit the other drivers, 3. Because drivers often turned abruptly without giving turn signal early, and 4. Because the driver switched lanes suddenly without giving turn signal early. So although the activity of driving using electronic map almost never cause an accident but it can inhibit the rate of speed of other vehicles and almost gave wretched condition to another drivers.

3.5 Procedure of driving safety while using electronic map

Probability of accident and incident in driving while using electronic map almost have value of zero. But for the other drivers, a driver who used the electronic map can impede their vehicles and complicate them. Next procedure was designed for drivers who use electronic map while driving so they can drive safely and not inhibit the traffic.

I. Set up electronic map before turn on the car:
1. Search your destination before turn on the car
2. Set voice of map application can hear
3. Fix electronic map display (mobile phone) straight forward or on visual angel of the driver. You could fix it on dashboard or steering wheel.
4. Learn the route before you start
5. Sure you remember some turning, building, or place along the line to destination.
6. Sure position of your destination, in the right or left.
7. Remember the distance up to destination.

II. Driving along the road:
1. You know the distance to turnings.

2. You know the distance to get destination.
3. Find some place or building that appeared on the map before get your destination.
4. Don't forget turn on indicators when turning or changing lanes.
5. Be aware your surroundings
6. One km before turning sure you have been on the right lane.
7. One km before your destination sure you have been in edge line according the position of your destination.
8. Observe your speed, One km before your destination drive slowly.

This procedure was a detail operation procedure for driving safety while using electronic map. Some global strategy how to low risk of mobile phone use while driving have formulated by (Oviedo-trespalacios *et al.*, 2017), include: (*i*) re-engineer mobile phone tasks to avoid sub-tasks that require visual demands project information onto the vehicle windscreen in line with the driver's forward line of sight), (*ii*) restructure enforcement strategies to overcome behavioural adaptations such as keeping the mobile phone low and searching for police (e.g. technologies to support automated enforcement through the detection of radio frequencies), and (*iii*) educational campaigns could be designed to prevent visual interfaces while driving.

4. Conclusions

Probability of human errors that cause accidents or Human Error Probability (HEP) on the drivers using electronic map while driving is very small, just 1.06%. The drivers have not experiencing on the condition almost wretched or accidents while driving using an electronic map. But for the other drivers, using the electronic map can impede their vehicles and gave wretched conditions. A standar procedure was designed to keep activity of using electronic map as secondary driving task didn't impede the traffic.

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