Effect analysis of proportional indicators

Thesis book of Ph. D. dissertation

Author: **Fekete, Róbert Tamás** MSc

Development engineer

Supervisor: **Dr. habil Ábrahám, György**

Professor, doctor of MTA

Budapest University of Technology and Economics; Faculty of Mechanical; Doctorial School of Pattantyús-Ábrahám Géza; Subprogram of Analyzing, designing and fabrication of machines and instruments; Machine designing and instrumentation technology section

/ Dr. Penninger Antal, professor; Dr. Horváth Mátyás, professor emeritus; Dr. Varga László, professor /

Budapest, 2009

Impress

Author	**Fekete, Róbert Tamás MSc** *Assistant lecturer, candidate* *Development engineer*
Supervisor:	**Dr. habil Ábrahám, György** *Professor, doctor of MTA*
President of PhD committee:	**Dr. Jóri J., István** *Professor*
Comprehensive exam comm.:	**Dr. Lőrincz, Emőke** *Associate professor* **Dr. Huba, Antal** *Associate professor* **Dr. Monostori, László** *Professor*
Readers:	**Dr. Hercegfi, Károly** *Assistant professor* **Dr. Samu, Krisztián** *Assistant professor* **Dr. Melegh, Gábor** *Associate professor* **Dr. Tamás, Péter** *Associate professor* **Dr. Lipovszki, György** *Associate professor* **Dr. Wenzel, Klára** *Professor* **Dr. Aradi, Petra** *Associate professor* **Dr. Somló, János** *Professor*

1. Introduction

The main theme of my dissertation is that it is not a waste to spend time on saving people's lives or to improve their personal protection. It is worthwhile if only one life is saved as a result of the research.

Due to the interdisciplinary nature of my dissertation, the correct definition of the theme is problematic, but is a broader sense, it could be placed within the framework of transportation science. Not only is technical knowledge needed for the evaluation of the results, and to correctly interpret them, but applied psychology and cognitive knowledge as well.

I dedicate my three years of research to improving transportation safety. This seems like a huge task, but one must know that only a miniscule improvement can achieve significant results.

The foundation of my research is the test series described shortly, in which several drivers participated, and where breaking reactions were tested in different transportation conditions. The goal of the test series is to show some difference between the effects of standard and proportional stop lights – stop lights showing break intensity – have on the drivers. As results show, this is the case.

It was found that proportional indicators have beneficial effects on several transportation parameters. Most important parameters are safety, human, and transportation factors.

Proportional indicators are practical during a period, when our present state shifts into full automation. A tool is needed for this period, which provides drivers with additional information.

2. Importance of research, research history

Research history is essential, therefore I briefly describe the factors that are being improved by experts around the world. Most important parameters are safety, human, and transportation factors.

The research carried out on the transportation factor is self-explanatory. Although these needs can be speared by focusing more on safety, they play a significant role in the planning procedure of transportation.

Increasing road capacity is an actual factor, which needs to be done by focusing an safety as well. It would have a dramatic effect, if roads were planned only half as wide, but the speed of the traffic and the number of vehicles passing were proportionally the same. This goal can be achieved in many ways, but I only discuss one aspect in my dissertation. Currently there are autonomous and cooperative systems, with which the distance between vehicles can be mitigated, which increases road capacity. Such systems are the distance-keeping system and the overrun breaking system.

As I stated earlier, decreasing distance between vehicles increases road capacity, but decreasing this distance to optimal levels in itself can have beneficial effects on transportation. The vehicles get into a jam and the vehicle distance decreases with the spreading of different autonomous and cooperative assistance and safety systems. This raises the question: after settling the responsibility of assistance and safety systems, how safe will the driver feel behind the steering wheel. Is it not good to provide help for the drivers which is not dependent on autonomous systems? At this point I refer to settle the responsibilities.

The majority of road accidents are caused by not keeping the following distance between vehicles. Experts say that in case of 120Km/h speed 60 metres is the safe following distance. The German Road Safety Council advises the 2 second rule. This means, that there should be 2 seconds between two vehicles.

Maintaining safety levels while decreasing following distance is a better solution than purposefully sabotaging the speed of traffic.

It is better for the driver to reach the appropriate breaking reaction time level from the start, than to be over or under regulated. This does not only decrease the break system load, but also increases the safety and comfort level of passengers, not to mention the traffic.

It is disadvantageous in traffic to break suddenly over a short period of time than to break slowly over a longer period of time. This benefits the speed of traffic, the safety of transportation and decreases the need for short reaction time, not to mention the creation of traffic jams.

The most important factor is the improvement of traffic safety. This can be reached in many ways: strengthening the vehicles, securing the driver, applying active and passive, intelligent safety and assistance systems, etc... There are two factors, however, which definitely decrease the risk of accidents. The first is decreasing human reaction time, and properly estimating the breaking distance.

Decreasing reaction time is very limited, but in some cases decreasing responding time might be the easier solution. Responding time includes reaction time and the idle time that test subjects purposefully insert. It is important to stress the difference between reaction time and responding time, because the introduction of a new stop lamp might increase reaction time, overall it might decrease responding time.

Due to the additional information, the reaction time will definitely increase. Therefore it is better to achieve a goal, which not only decreases reaction time but has positive effect on breaking reaction. This is the proper "guess" of the optimal breaking distance, approaching the breaking stimulus.

Guessing of the breaking distance means that the driver reaches the expected optimal breaking force when a vehicle in front of the driver breaks.

If the drivers are not aware of the degree of breaking of the vehicle in front, but only of the fact of breaking, in most cases the driver will under or over break the vehicle. In these cases a continuously dropping regulation initiates, which quickly reaches optimal values. The quantity and level of over and under regulation can severely damage the quality of reaction time. If the driver just slightly over or under breaks, the breaking reaction level will be better, the distance between vehicles can decrease, the speed of traffic can increase, the level of deconcentration can decrease, etc.

Improving the human factor is important as well. Deconcentration, mental stress, inappropriate stress level and mood of the driver can significantly decrease traffic safety. As a technical expert, I found that it is difficult to deal with these factors, but it would be a mistake not to deal with them.

It is common knowledge in psychological studies, that stress has an optimal level, which is not by all means negative. But it must be stressed that the level of stress in driving condition is closer to minimum, unlike during an oral examination or a sport sompetition.

Stress can be caused by several factors: dissatisfaction, anger, lack of information, physical stress, etc. The behaviour of the surroundings is the most important factor causing stress during driving. This can also increase the risk of accidents.

Stress and mental stress are close concepts. But they must be mentioned separately, because mental stress can be clearly indicated by HRV (Heart Rate Variability), the medial frequency component of heart rate, which is logged during tests. By measuring the time between heart beats, the actual mental stress of the driver can be measured.

Extreme stress is disadvantageous during driving, but an optimal amount of stress is needed for carrying out driving activity, since lack of stress is also disadvantageous as well (e.g. carelessness).

During driving, all mental resources are applied at once, therefore other activities are dangerous in a sense that they draw these resources to other activities.

The value of mental stress should be decreased at all times, keeping in mind the optimal level of stress. Low mental stress level makes the driver calmer, the driver can concentrate on several things at once, thus allowing him to map his surroundings better. As a conclusion, risk of accidents can be lowered.

Human dissatisfaction is a known factor in technical sciences. This not only has direct effects on driving, but is a factor which can be measured on its own. Mood and satisfaction can effect the level of stress and modifies the level of mental stress as well, and vice versa. Increased stress level can negatively effect our mood. Cause and effect mix on this area, which is not accidental, since these parameters can strengthen and weaken each other. These factors cannot and should not be separated. Man as an emotional being is also important in traffic. The extreme is the deviant behaviour of the driver. The connection, cooperation of the drivers create the traffic, and the level of security play an important role as well.

Until driving is done by humans, not only technical parameters must be considered but human and psychogenic factors as well.

3. The main idea of dissertation

In my opinion, with the introduction of proportional indicators, the safety of traffic would improve on the long term.

I tried to confirm that in case of using proportional indicators, there can be several negative factors, but on the whole and on the long term, the quality of human reaction would improve as the safety of traffic as well.

The basic idea of my dissertation is analyzing test subjects and evaluating test results with an optional measuring procedure in standard and proportional situations.

Two test series are sufficient to detect significant differences between standard and proportional indicators if there are any.

4. Main objectives

Main objectives of my research are the following:

- To prove that there is a traceable difference between standard and proportional stop lamps.
- To develop a new measuring procedure for comparing drivers and stop lamps.
- To develop a human-machine-environment model (HME–model) to predict the behaviour of drivers.
- To develop a new coefficient (coefficient of speed variation reaction) for objective comparing.
- To point out that the measuring procedure is good only if we schedule an optimal studying phase. Single testing may be insufficient.
- To do an effect analysis for a speed indicator reflector, which indicates the speed of a vehicle for neighbouring cars and helps drivers to avoid crashes.

5. Verification method of thesis

In the course of my research, the main goal was the comparison. I did not develop a new procedure with which we can carry out accurate measuring procedure with meticulous care and with fairly big reproducibility. This would have exceeded the available time. My goal was to procreate a new procedure which can detect the difference between different stop lamps in case of big number of subject.

Verification method of thesis consequently is the evaluation of a fairly big test.

I confirmed the first thesis by procreation and probation of the measuring procedure and measuring station. Furthermore, I do this with evaluation of measuring results.

I confirmed the second thesis by procreation of braking quality coefficient, and by evaluation of results of test series.

I confirmed the third and the fourth thesis by evaluation of test series and by processing of results of these test serious.

I confirmed the fifth thesis by evaluation of course of test series.

6. Probable results

In point of probable results naturally I can not show any prognostication, because the technician developments means nothing if the developed instrument would not get into the traffic.

For this we have to mobilize fairly big force, and we have to retrace the present form of the traffic. Actually the bigger car maker company should join with themselves and should work together for a nicer future.

If I would not be able to add to improving of safety of traffic, I would like to try to remind everybody of opportunity of proportional stop lamps and their benevolent effects.

7. Effect analysis

Different measuring procedures and principles draw the conclusion according to which the proper measurement results can only be obtained by employing several measurement methods, which decreases the risk of obtaining inaccurate results.

In my dissertation, I show how I reached my conclusions. Keeping this in mind, I call the attention to the fact that my research is not a psychological or neurological study, but an effect analysis, in which I study the total effect of standard and proportional stop lamps. I do not think that my measurement methods and the measurement station perfectly reflect realistic procedures, but I am sure that if there is significant difference between different types of stop lamps, I can measure it.

During preparation of the test series, I accepted measurement values, which could not be reproduced due to the insufficient reproducibility of human values.

A pedal simulator was used for measurement, with high resolution, where the detector's time sensitivity is important.

I found that an EKG device is sufficient to measure human parameters, which records heart rate intervals for further evaluation.

The measurement of skin resistance is limited by resolution on low reliability, and is in-all difficult to interpret.

I used only simple and effective devices for measurement, which can be easily installed on the test subjects.

I also considered using a camera. This would probably yield extreme and non-representative results, since other detectors would already modify human factors.

8. Measured quantities

We would like to create a procedure to compare proportional and standard stop lamps, and possibly, show difference between them. This was my intention with the measuring station. I created a measurement location, which is useful for testing drivers. I created two measurement series, and I used the measurement station in a simplified version in the second series. As results clearly show, I found no difference between the two measurement stations, therefore I consider the two stations similar.

The emphasis is on comparison. The goal was not to create a perfect measurement station to get absolute results. The goal was on comparison. My research aim was to study the effect of proportional indicators, which is the difference between standard and proportional indicators, since the effect of the introduction of the proportional indicators is shown compared with the current situation. It must be mentioned that the measurement procedure can be applied to the ranking of other types of indicators.

9. Interactive tester (LOLITA – Long term Overall Light and Indicator Tester and Analyzer)

The interactive tester is minimal designed and minimal mean needed software. The software developing require one semester in itself. This application is good for analyzing behaviour of test subjects really and it can change the primary condition from reactions of test subject like a feedback channel.

After the construction of this application, I established the evaluation software, which is good for evaluating and analyzing diagrams. This application is integrated to the main (LOLITA) program. This evaluation programs helped me to evaluating the innumerable braking characteristic (about twenty thousand).

The simulation software does not play pre-recorded videos but play simulation themes with predefined primary parameters. This is the reason of the forfeiture of homogeneity.

Therefore, the software plays interactive simulation themes whit defined primary parameter for test subjects. After that it record the responses of test subjects and evaluate these braking characteristics.

This interactive tester plays just night driving, because in this way the number of factor and measuring time are decreasing.

10. The full experiment, test subjects

The full experiment series, after two years successive approximation, planning and test running was staged in two semesters.

The full list of test subjects was scaled on three stages, so three groups were exfoliated. One of group is the group of drivers without experience. Other is the group of driver with experience with about maximum two years experience), and finally the third group is the group of professional drivers (with minimum ten years experience).

All of groups had nine persons, who came to measure one time in a week. (Figure 1.). The full measuring series had three groups with nine persons.

Together there were fifty-four test subjects in the full experiment series. Tests go for twelve weeks (through two semesters). This means six hundred forty eight measurements, which were just four hundred seventy eight measurements because of absences.

Time of testing was about three days, seven hours and forty minutes. The complete interactive test consists about twenty thousand braking reaction diagrams. This means that we had to evaluate about twenty-five diagrams per day.

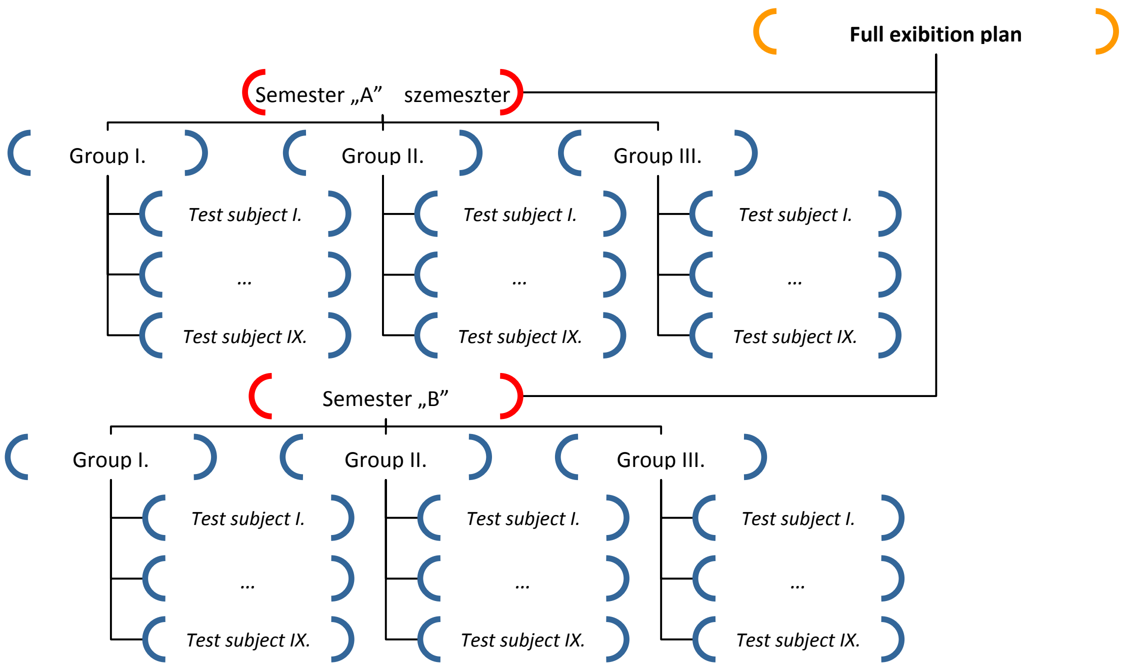

Figure 1. – *Full experiment schema*

11. New scientific results

11.1. First thesis about the new measuring procedure

This thesis contains the developed environment, interface, software and used tools, so the full measuring procedure.

The developed measurement procedure and test station for validating and comparing indicators and test subjects is capable of efficient recording, processing and objective analyzing of reaction time, heart rate variability, vehicular parameters, human parameters and braking reaction characteristics.

[7][8][10][13][14][17][20][22]

With this measuring procedure, you can compare and rate drivers. This procedure is good for defining reaction time, heart rate variability (with an EKG sensor), vehicular and human parameters with LOLITA (Long Term Overall Lamp and Indicator Tester and Analyzer) measuring systems.

11.2. Second thesis about HQC (Human reaction Quality Coefficient)

In my second thesis, I would like to present the HQC rate, which was a measure by me. This is the braking quality coefficient, which is the origin of comparing drivers and indicators.

In case of traffic situations where speed modification is required, the validation and comparison of human reactions are more practically carried out by a procedure where we combine all the relevant criteria into one single variable (HQC – Human reaction Quality Coefficient). This way one can get a more objective and comparable coefficient.

HQC – Human reaction Quality Coefficient is calculable with the following formula:

$$\left[\begin{bmatrix} \Delta\overline{x} \\ \Delta\overline{v} \\ \Delta\overline{a} \\ No_B \\ T_R \\ AV_a \\ AV_d \\ \left(M_{\ldots ms}+M_{\ldots mk}\right) \\ \left(E_{\ldots es}+E_{\ldots ek}\right) \end{bmatrix} + \begin{bmatrix} -\frac{53}{46} \\ -\frac{12}{11} \\ -\frac{9}{8} \\ -1 \\ -1 \\ -\frac{5}{4} \\ 0 \\ -1 \\ 0 \end{bmatrix}\right]^T \times \begin{bmatrix} -\frac{5}{46} \\ -\frac{15}{11} \\ -\frac{13}{8} \\ -\frac{16}{8} \\ -\frac{16}{5} \\ -\frac{6}{8} \\ 1 \\ -\frac{9}{10} \\ \frac{9}{10} \end{bmatrix} = HQC_x$$

where $\Delta\overline{x}$ ***is the mean value of distance,*** $\Delta\overline{v}$ ***is the mean value of speed difference,*** $\Delta\overline{a}$ ***is the mean value of acceleration difference,*** No_B ***is the number of accidents,*** T_R ***is the reaction time,*** AV_a ***is the variability of acceleration values,*** AV_d ***is the variability of distance values, "M" is the mean values of estimated value of mental effort and finally "E" is the mean value of the estimated satisfaction.***

[20][22]

You can count the HQC value with the presented algorithm. Huge advantage of usage is its compactness.

While the mean of its value is between around 0.45 and 0.60 in standard cases, this value in proportional cases is between 0.45 and 0.85.

The HQC value includes several ingredients with weight factors. Accordingly, the goal of measuring is variable by change of weight coefficients.

11.3. Third thesis about the effect of proportional indicators

This thesis shows a lot of advantage of usage of proportional indicators. This thesis does not include the social consequences of usage.

With the application of the proportional indicators, after certain learning time and keeping a given safety level, the probability of selecting the optimal braking and acceleration level increases as well as the satisfaction of the drivers, consequently decreasing the false human reactions. This fact also decreases the oscillation of the braking or the acceleration levels, its standard deviation, the tracking distance, oscillation of the vehicles' distances, its standard deviation and the amount of mental effort.

The value of HQC is significantly larger in case of proportional indicators.

[7][8][10][13][14][17][20][22]

I confirmed the safety level with the run of number of accident. This number in case of proportional indicators sometimes is higher than the number of accident with standard stop lamps, but this difference on short term is the most significant and longer term shows an advance beyond the simple conversation.

The correlation coefficient is about -1 between the number of false human reaction and the choice of optimal braking level.

The right reaction means that the test subject approximately hit the rate of braking level of ahead vehicle and reacts accordingly.

The satisfaction of test subjects is measured by asking. The total satisfaction is the mean of opinion of test subject and the test leader.

In the long run, we can declare that proportional indicators cause less mental effort.

Optimal indicator of oscillation of braking and acceleration levels is the variability of braking and acceleration. You can see in the graphs that in case of proportional indicators this value is fairly lower from the fourth week on.

The standard deviations of variability of braking or acceleration show how the different test subjects use the pedals in similar situations. According to the result of measuring, the test subjects react fairly similarly. Consequently, the insecurity is picking up.

On the variability of distance values, there is a very similar situation as well as the variability of acceleration and braking level and their standard deviations.

The optimal indicator of following distance is the mean of distances, which we would like to reduce.

11.4. Fourth thesis about variation of reaction times

In my fourth thesis, I would like to show a principal part of this test series. This is the variation of reaction time.

Namely with proportional indicators, notwithstanding excess information the reaction time does not extend, moreover on longer term it decreases.

The comparison of human reaction times induced by braking or acceleration stimulus, with or without proportional indicators does not exhibit significant difference in case short adaptation period (<10 practices). However after longer (>10 practices) adaptation period the difference of reaction times and its standard deviation decreased significantly by the proportional indicators. [20][22]

Therefore, the main idea of this thesis is the proportional indicators have a favourable influence on human reaction times on the long term. The reaction time is decreasing with both of the indicators but with proportional indicators, this effect is bigger, so the decrease is minor.

11.5. Fifth thesis about effect of driving experience and learning phase

In my fifth thesis, I would like to show how the performance of test subjects depends on experience.

The effects of the proportional indicators – described in thesis number three – are significantly larger in case of inexperienced drivers, after an adequate perceptual, cognitive and manual learning phase. In case of experienced drivers, the application of proportional indicators, without adequate learning phase, has a negative influence on the quality of reaction in braking and acceleration

situation depending of the HQC value. However, the difference between experienced and inexperienced drivers is cancelling out after a longer learning phase.

During the learning phase, the rate of the performance change is well estimated by the following polynomial:

- ***For experienced drivers:***

  $y = 0{,}000266 \cdot x^3 - 0{,}01039 \cdot x^2 + 0{,}13378 \cdot x + 0{,}26771$

- ***For moderately experienced drivers:***

  $y = 0{,}029841 \cdot x + 0{,}51503$

- ***For inexperienced drivers:***

  $y = 0{,}002634 \cdot x^2 + 0{,}008089 \cdot x + 0{,}41925$

where y is the HQC value and x is the time parameter. [20][22]

This thesis declares that the test subjects, who do not have a huge experience in driving, can exploit the advantages of proportional indicators. Namely, the test subjects with less driving experience have bigger HQC values than the test subjects with huge experience.

Additionally, this thesis declares that after optimal learning phase, when drivers exfoliate in perceptual, cognitive and manual skills, performances of test subjects are far better.

Accordingly, the drivers with huge experience in reality do not make bigger mistakes than the drivers with less experience; just they notice advantages of proportional indicators later.

Additionally in the graphs, you can see clearly that the HQC values converge to themselves, and they are depending on learning phase and experience level. Performances of all types of experience level converge to the same HQC value.

Previous improving trends are approachable with tertiary (in case of drivers who have much experience), linear (in case of drivers who have less experience) and quadratic polynomials.

12. Further results

Results of experiment series presented that the driving style and the driving experience influence the quality of reactions. Moderate drivers without experience have the best HQC values, while moderate drivers with much experience have the worse HQC values. [20][22]

Results of experiment series presented that the number of accidents correlates with the HQC value. [20][22]

There is a noticeable HQC value difference between morning, evening and midday measuring. This different exceeds the 30 percent. The maximum of HQC values are in the morning and evening, while the minimum of HQC values are at about midday. [20][22]

The tiredness feeling significantly influences the HQC value. While driver who is relaxed has better HQC values, driver who is tired has lower values. [20][22]

The temperature feeling significantly influences the HQC value. While driver who is cold has better HQC values, driver who is hot has lower values. [20][22]

The hunger significantly influences the HQC value. While driver who feel hollow has better HQC values, driver who is bellyful has lower values. [20][22]

The subjective stress feeling significantly influences the HQC value. While driver who is peaceful has better HQC values, driver who is absorbed has lower values. [20][22]

The mental effort significantly influences the HQC value (based on medium frequency component of hart rate variability). While driver who has low HRV value at the same time has high mental effort, driver who has high HRV value at the same time has low mental effort. Accordingly, high mental effort means worse HQC value, and lower mental effort means better HQC value. [20][22]

For simulation of traffic situations where speed modification is required, I developed and identificated a new human-machine-environment model that is well declares the real running and good for detection of difference between standard and proportional stop lamps. The controlled variable of this model is objective distances of vehicles. By means of calculated transfer functions with this model, you can forecast the human reactions, vehicular positions, velocities and accelerations. [18]

With proportional reflector which indicate the velocity of vehicles, in speed-critical traffic situations (overtaking, changing traffic lane, wheeling), the standard deviation of reaction distances decrease (consequently the doubtfulness of derivers decrease also), in addition the subjective stress feeling of drivers decrease and the satisfaction of drivers increase. [20][22]

13. The most important results of dissertation

In my opinion, the most important result of this dissertation is the pointing out the different between standard and proportional indicators. Namely, these differences are confirmed with simulations and real tests.

During my research I originated a new coefficient (HQC – Human reaction Quality Coefficient), which is applicable for objective comparing several test subjects and indicators.

I developed a new tester system (LOLITA – Long term Overall Lamp and Indicator Tester and Analyzer), which is applicable for simulation of traffic situations and for recording, processing and evaluation of reactions and measuring data.

I specified a new adaptive / proportional reflector, which can indicate the speed of vehicles with its LEDs, and with it can grade up the safety of traffic, because it gives surplus information to drivers. This instrument has been already tested by me.

I specified a new human-machine-environment model, which is applicable for measuring the differences between standard and proportional indicators. I accorded the parameters, noises and transfer function of this model.

Method of certification was unequivocally the measuring and human testing.

Finally, I would like to summarize effects of proportional indicators on humans:

The reaction times in proportional situations did not have a significant difference in short term, but after an adequate learning time they were significantly lower.

In case of using proportional indicators, drivers can decide the correct reaction lots better. The number of over controlling and under controlling is lower also.

With proportional indicators, the value of doubtfulness of drivers decreases also. Namely in the same situations drivers react fairly the same.

The mental effort, with proportional indicators, is lower than with standard stop lamps in front of expected happens.

While drivers without experience get acclimatized the useful of surplus information, professional drivers can do this just lather.

14. Further research

The first and the most important development are improving the quality of measuring environment. This means expressive material expenditure but we should try to reach this with less material expenditure.

Other development direction is the really testing. It will be very interesting if we will be able to see the effect of this proportional stop lamp on the latent rush hours.

In other experiment we should examine the space arrange of proportional indicators as a function of reaction time. I planning put the visual angle, colour and size factor into this experiment.

We should examine the interruption of non-watched information or else the effect of subconscious on driving performance. This topic deals with the lateralization when the two cerebral hemispheres tolerate other measure the levels of awareness.

15. Application of results of researches

I hope that results of my research will be underhanded and applicable by the biggest carmaker companies to improve the safety of roads.

The developed measuring procedure (with HQC value) is applicable for comparison and validation of several test subjects and indicators.

With this application, you can discover size of differences between standard and proportional indicators. In this way, the introduction of a new product is not such risky.

However without exact declaration of appropriation, this measuring procedure and measurement station were applicable for driver validation and pre-screening, and in addition it is good for selection and classification drivers also.

This procedure is applicable for prediction also, if the prediction factor in choice from independent factors of procedure.

16. Publications for thesis

[7] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Development of a measurement station and a procedure for measuring differences between standard and proportional stop lamps*. Periodica Politechnica Transportation Engineering, HU ISSN 0303-7800 (Budapest, HU. várható megjelenése: 2009), angol nyelvű lektorált cikk

[8] **Fekete Róbert Tamás, Dr. Ábrahám György**: *A fékezés intenzitását kijelző féklámpák emberre gyakorolt hatásainak mérése.* Műszaki Szemle Vol. 38, No. 15, p. 106-109., ISSN 1454-0746 (Kolozsvár, RO. 2007), magyar nyelvű lektorált cikk

[10] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Proporcionális féklámpa, a vezetőre gyakorolt hatás vizsgálata*. MM Műszaki Magazin 2007 Vol. 4, No. 1, p. 50-54., ISSN 1417-0132 (Budapest, HU. 2007), magyar nyelvű cikk

[13] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Színes jelzőfények alkalmazása a járművek mozgásállapotának kommunikációjára.* Kolorisztika szimpózium 2007 Vol. 31, No. 1, p. 1-11., HU ISSN 1788-3717, ISBN 978-963-9319-66-0 (Eger, HU. 2007), magyar nyelvű publikáció

[14] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Komplementáris fényjelzések hatásvizsgálatának méréstechnikája.* A jövő járműve, Vol. 1, No. 1-2, p. 42-45., ISSN 1788-2699 (Budapest, HU. 2007), magyar nyelvű lektorált cikk

[17] **Fekete Róbert Tamás**: *Procedure for measuring differences between standard and proportional stop lamps*. OWD 2007 Conference Vol. 1, No. 23, p. 133-138., ISBN 83-922242-2-1 (Wisla, PL. 2007), angol nyelvű konferencia kiadvány

[20] **Fekete Róbert Tamás, Dr. Ábrahám György**: *A proporcionális féklámpák hosszú távú hatásai.* A jövő járműve, Vol. 1, No. 2-3, p. 56-60., ISSN 1788-2699 (Budapest, HU. 2008), magyar nyelvű lektorált cikk

[22] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Proporcionális féklámpák hatásvizsgálata.* A jövő járműve, Vol. 1, No. 1-2, p. 41-44., ISSN 1788-2699 (Budapest, HU. 2008), magyar nyelvű lektorált cikk

17. Further publications

[1] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Way to the "intelligent" vehicles.* ISSE 2006 29th IEEE International Spring Seminar on Elektronics Technology, Nano Technologies for Electronics Packaging, Vol. 1, No. 29, p. 68-69., ISBN 3-934142-23-0 (Dresden, D. 2006), angol nyelvű konferencia kiadvány

[2] **Fekete Róbert Tamás, Dr. Ábrahám György:** *Járművek fényjelekkel történő kooperatív irányítása.* A jövő járműve, Vol. 1, No. 1-2, p. 68-70., ISSN 1788-2699 (Budapest, HU. 2006), magyar nyelvű lektorált cikk

[3] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Járművek fényjelekkel történő kooperatív irányítása.* BME EJJT I. Tudományos konferencia No. 5/2 (Budapest, HU. 2006), magyar nyelvű konferencia előadás

[4] **Fekete Róbert Tamás**: *Light sign based cooperative control of vehicles*. OWD 2006 Conference Vol. 22, No. 22, p. 137-140., ISBN 83-922242-1-3 (Wisla, PL. 2006), angol nyelvű konferencia kiadvány

[5] **Fekete Róbert Tamás**: *A vezetőt támogató segéd-, és biztonsági rendszerek fejlődése*. Magyar Elektronika Vol. 23, No. 11, p. 24-26., HU ISSN 0236-6134 (Budapest, HU. 2006), magyar nyelvű lektorált cikk

[6] **Fekete Róbert Tamás**: *Mit kell tudni a haszongépjárművek fényjelzéseiről?* Általános rendelkezések DDD Magazin Vol. 1, No. 2, p. 52-53., HU ISSN 1788-3717 (Budapest, HU. 2006), magyar nyelvű lektorált cikk

[9] **Fekete Róbert Tamás, Dr. Ábrahám György**: *A fékezés intenzitását kijelző féklámpák emberre gyakorolt hatásainak mérése*. OGÉT 2007, XV. Nemzetközi Gépészeti Konferencia, No. 15. (Kolozsvár, RO. 2007), magyar nyelvű konferencia előadás

[11] **Fekete Róbert Tamás**: *Autonóm és kooperatív járműirányítási rendszerek.* DDD Magazin Vol. 2, No. 1, p. 54-56., HU ISSN 1788-3717 (Budapest, HU. 2007), magyar nyelvű lektorált cikk

[12] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Színes jelzőfények alkalmazása a járművek mozgásállapotának kommunikációjára.* Kolorisztika szimpózium 2007 No. 31/2 (Eger, HU. 2007), magyar nyelvű konferencia előadás

[15] **Fekete Róbert Tamás**: *Mit kell tudni a haszongépjárművek fényjelzéseiről?* Fényszórók. DDD Magazin Vol. 2, No. 1, p. 52-53., HU ISSN 1788-3717 (Budapest, HU. 2007), magyar nyelvű lektorált cikk

[16] **Fekete Róbert Tamás**: *Mozgásállapot-kijelző féklámpák.* DDD Magazin Vol. 2, No. 4, p. 54-55., HU ISSN 1788-3717 (Budapest, HU. 2007), magyar ny. lektorált cikk

[18] **Fekete Róbert Tamás, Dr. Ábrahám György**: *Integrated human-machine-environment system model of proportional stop lamps in braking situations*. Periodica Politechnica Transportation Engineering, HU ISSN 0303-7800 (Budapest, HU. várható megjelenése: 2009), angol nyelvű lektorált cikk

[19] **Dr. Ábrahám György, Fekete Róbert Tamás**: *Szabadalmi leírás: Berendezés járművek mozgásállapotának fényjelek útján történő külső kijelzésére.* Budapest, 4-16p. (HU, 2007)

[21] **Fekete Róbert Tamás, Antal Ákos**: *Jármű karosszériaelemek kvázi-interferometrikus alakvizsgálata.* A jövő járműve, Vol. 1, No. 3-4, p. 44-47., ISSN 1788-2699 (Budapest, HU. 2008), magyar nyelvű lektorált cikk