

Modelling of operator's focusing scheme along working hours: Windrowing and cultivating operations

I. Szabó, M. Hushki, Z. Bártfai, A. Lágymányosi and L. Kátai*

Szent István University, Faculty of Mechanical Engineering, Institute of Mechanics and Machinery, Páter K. street 1, HU2100 Gödöllő, Hungary

*Correspondence: katai.laszlo@gek.szie.hu

Abstract. Enhancing productivity and cost reduction are two main targets for any production operation. In the agricultural field; It is the role of researchers to come out with reliable models and make it available to be used in modern farming management organizations as well as to the rural farmers. When it comes to the Human Machine Interface it is essential to assess the system in term of the Human Centered Design aspects. This research is focusing on the developing simple models for the operator's focusing scheme as a human behaviour inside an off-road vehicle cabin based on the operator's focusing scheme measuring along working hours using proven and up to date technologies. The results of this research provide the decision makers with reliable inputs using proven methodology regarding the change of operator's focusing scheme along working hours in two agricultural operations 'windrowing and cultivating'. Both operations are requiring continuous physical involvement of the operator for checking the attached tool and steering of the vehicle in the planned track, which is directly related to the accumulated passive fatigue as a main contributor of resulted data.

Key words: off-road vehicle, operator's behaviour, eye tracking, focusing scheme, passive fatigue, precision farming.

INTRODUCTION

In continuation of the research work done by (Szabo et al., 2017) regarding Operator's behaviour measuring methodology inside off-road vehicle cabin, this research activities depend on the validated methodology to develop a model representing the change on the resulted operator's focusing scheme along working hours in windrowing and cultivating agricultural operations.

The resulted models from this research are developed to assist the decision-making activity during the planning phase (Man-power, operational procedures, ...etc.), which is usually done based on managerial assumptions in the absence of trusted models coming from research and development centres and/or academic sector. (Herdon, 2013) mentioned a very important role of the academic sector improving the development of agricultural operations by problem resolving and developing the recommendations based on the advanced analysis of data to be used in advanced farming processes easily. Therefore; the availability of such models with provide decision makers by a factual based method coming from deterministic data analysis.

Robert (2004) and Xuan (2007) showed that it is essential for the research activities to concentrate on making the necessary studies regarding the resources management to reach the precision farming concept. In this research, one of the targets is to develop dedicated models to different agricultural operations showing the impact of working hours on the accumulated mental and passive physical load. Which might be used directly by rural farming organization as an indicator of the required effort difference between different agricultural operations.

Due to the operational nature of multi-tasking off-road vehicles, operators need to spend long working hours; which increases the level of mental workload leading to human error. Li & Haslegrave (1999) introduced similar conclusion of which the vehicle design should be human oriented in order to maximize comfort and ability to perform the driving task perfectly and safely by reducing the human error possibilities'. Nowadays more and more agricultural machines are equipped with continuous measurement sensors e.g. measurement of soil resistance (Kroulik et al., 2015) to have more exact information on energy demand in order to contribute to the optimization of the production formula during performing his/her duties (i.e. the direction of windrowing based on soil properties). This means that the driver attention is split by many signals.

Operating an off-road vehicle is a complex task, requiring a concurrent execution of various cognitive, physical, sensory and psychomotor skills (Young & Regan, 2007), additionally to control attached tools to perform in-field productive tasks such as agricultural and industrial operations. Ensuring the comfortable ride is considered essential for any vehicle, as well as executing happily and safely requested operational tasks, to that end; the driver ergonomics comes to play as considered as an important parameter that can't be neglected in the design phase of the vehicle (Hsiao et al., 2005).

Tractors are companions for many agriculture workers. Well-designed human – tractor interfaces, such as well-accommodated tractor operator enclosures can enhance operations productivity, comfort and safety (Matthews, 1977; Kaminaka et al., 1985; Liljedahl et al., 1996 and Hsiao et al., 2005).

Many studies have been carried on finding preferred locations of in certain types of tractor controls (Casey & Kiso, 1990), moreover; emphasizing how critical is the placement of controls in some tractors stating that; it creates an impediment to body movement (Hsiao et al., 2005).

When we are talking about automation, it is a general aim to improve comfort and safety (Sheridan, 1992; Endsley, 1996; Fukunaga et al., 1997; Scheduling et al., 1999; Shen & Neyens, 2017; Zewdie & Kic, 2017), additionally, it is stated that, in the automated driving condition, driver responses to the safety critical events were slower, especially when engaged in a non-driving task. At the same time in their paper – dealing with driver visual attention (Louw & Merat, 2017) reached a conclusion shows that the drivers understanding of the automated system increases as time progressed, and that scenarios which encourage driver gaze towards the road centre are more likely to increase situation awareness during high levels of automation'.

Generating dependable and deterministic data representing human behaviours inside the workplace using validated method will be beneficial for enhancing current cabin designs as well as the future cabin designs.

Driving is not only a physical task but also visual and mental tasks. The eyes of a driver are indispensable in performing visual tasks such as scanning the road and monitoring in-vehicle devices. Mental tasks are important during driving, and include

such factors as understanding vehicle dynamics, making situation-dependent decisions, and judging time/space relationships (Kramer, 1990; De Waard, 1996; Brookhuis & De Waard, 2010 and Marquart et al., 2015) were examined the eye-related measures of drivers' mental workload. The mental workload could be defined as the relation between demands resulted from various tasks to be performed on the operator and his ability to fulfil; with satisfactory; these demands. While (Sporrong et al., 1998) described the mentioned demands as multidimensional, as it involves tasks, operator and system demands together with other factors. Additionally; many studies showed that; the need for well fitted architectural space to the operator's dimensions is considered crucial. The mental workload level is found to be increasing with the time passing.

For the purpose of this research, we focus on passive fatigue. This type of fatigue is characterized by being the indirect product of the human driver's exertion of a set of tasks whose demands are low, monotonous or repetitive (Saxby et al., 2013). These rules out any sort of physical fatigue or mental active fatigue.

(Gonçalves & Bengler, 2015) conducted a study i claims that Highly Automated Driving (HAD) will be commercially available in a near future, yet human factors issues like the influence of driver state can have a critical impact in the success of this driving paradigm for in road and field safety. It is very likely that Driver State Monitoring Systems (DSMS) will play a bigger role than they have played so far.

MATERIAL AND METHODS

Tobii equipment and software packages

Tobii Pro Glasses 2 is a wearable eye tracker with a wireless live view function for insights in any real-world environment. The ultra-lightweight, user-centric design encourages natural viewing behaviour and ease of use. The system captures data at 50 or 100 Hz. Pro Glasses 2 shows exactly what a person is looking at in real time while moving around in any real-world environment, giving researchers deep and objective insights into human behaviour. Complete unobtrusiveness and Tobii's proprietary 3D eye model technology combine to ensure researchers capture the most natural viewing behaviour and supreme data quality. Quick calibration and system-guided procedures reduce time in the field and make it easy for anyone to start using the system with very little training.

The Real-World Mapping tool integrates into the Pro Glasses Analyzer, streamlining the coding process and dramatically reducing the analysis time. It aggregates and maps data from eye tracking videos to snapshots, allowing immediate visualization of the quantified data or extracting statistics. The powerful post-analysis and visualization tools provide a full spectrum of qualitative and quantitative gaze data analysis and visualizations provides for log events, define areas of interest (AOIs) during the selected time of interest (TOI) from the total recording time, calculate statistics, create heat maps, and export data for further analysis in other software.

MATLAB curve fitting toolbox

The Curve Fitting Toolbox is used to provide the Model of the change on operator's focusing scheme along working hours for the samples collected from windrowing agricultural operation and will be used at later stages to create the models from the samples of the two agricultural operations (windrowing and cultivating).

Implementation steps

The experiment is to be conducted on 3 phases (Fig. 1):

Phase 1: in which the consistency and similarity of the used work field and timing of operations will be ensured. Which applies as well for the experimental execution procedure. Operators are tasked to conduct the same operational procedures along trials. A calibration process for the Tobii glasses 2 is conducted via its dedicated software Tobii glasses controller software. Each operator profile is stored in the software, the software and the equipment have the capability to keep on each operator's profile stored containing the name of the operator and the calibration records, and no recalibration is required to start the next experiment or to restart the recording during the same experiment in case of interruptions.

Phase 2: in which the execution of the experimental trials and data gathering are conducted. The operator is requested to wear special Eye-tracking Tobii glasses 2 providing the operators vision area and defining the point of focusing. Connected to the central station, the recording time is synchronized for all resulted video records.

According to the experiment execution procedure, several areas of interest will be added to matrix storing the representing scheme [M], each element in the matrix will store the accumulated time of operators' glances (gaze) to that area of interest [AM].

Phase 3: in which data analysis and discussion are conducted. The video records are studied and analysed by the research team to decide and document all none beneficial periods that includes abnormal behaviours or reactions to a random external inducer of the operators describing the reason of period exclusion.

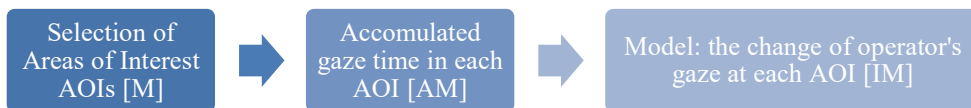


Figure 1. Generating the Change of Operator's focusing scheme along working hours.

Thereafter, the resulted data from the used eye-tracking glasses technology after exclusion procedure is represented in the matrix [AM].

Elements of [AM] are integrated at selected periods of working hours (i.e. at the end of each working hour or based on the nature of the operation) to produce the matrix [IM]_k, where k is the selected period number from 1 to K times.

Along working hours, the change of [IM] with increment of k with increment of 1 will be placed on a graph showing the change of the operator's focusing scheme. Which is the target behaviour studied for each operator along several experimental trials.

Research methodology

To the purpose of this research, the followed methodology is summarized in process map showed in (Fig. 2).

The operator is mandated to wear Tobii glasses and to go through the calibration process whenever a new recording is started. The glasses are connected wirelessly to the windows tablet which is running the Tobii controller software to register the recording information, monitor the real-time view of the operator, conduct the calibration process and to stop, pause and start the recording process.

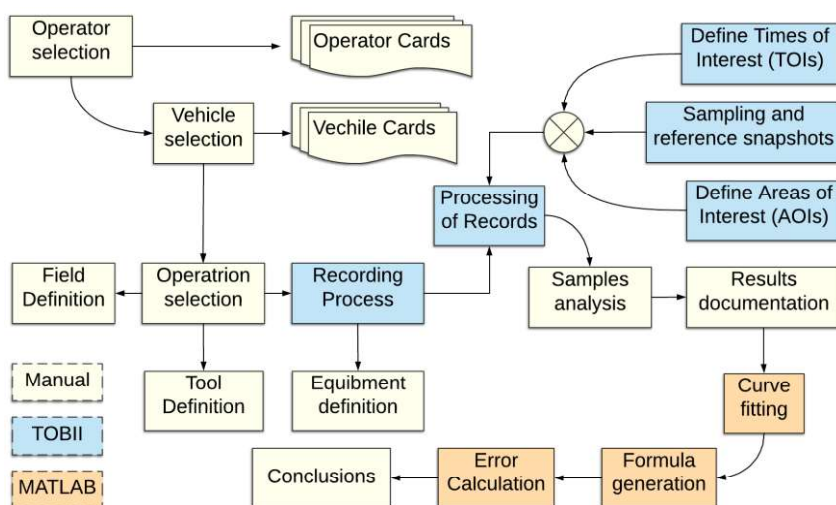


Figure 2. Methodology process map.

Thereafter, the collected video recordings are transferred to the PC which is running the Tobii pro lab software to be analysed using the real-time mapping and available filtering packages to obtain the accumulated times.

Windrowing operation

Windrowing agricultural operation is selected to be the studied operation in this research to produce the model of the change on operator's focusing scheme along working hours. After hay cutting in the agricultural field, windrowing operations are conducted to sort hay into lines in the field. The operation is conducted by specific tools attached to tractors generating hay lines to prepare for the hay baling operation. To the purpose of this research, the used attached tool to the CLAAS tractor (Model: ARES 567 ATZ) is CLAAS LINER 450T (Fig. 3).



Figure 3. CLAAS LINER 450T used for windrowing.

Cultivating operation

The operation is loosening and breaking up of the soil. The soil is cultivated using an attached cultivator (Fig. 4) to destroy weeds and promote growth by increasing soil aeration and water infiltration. Soil being prepared for the planting of a crop is cultivated.

CASE tractor (Model: CASE 7210) (Fig. 5) is selected to the purpose of accommodating the experimental trials. This model has a covered cabin for the operator, which is helpful to control some of experimental conditions (i.e. temperature and humidity inside the cabin) keeping on the consistency of those parameters and conditions.



Figure 4. Cultivating attached tool.



Figure 5. CASE 7210 with attached cultivating tool.

Sampling

To measure the operator's focusing on the AOI during the experimental samples of execution times 11 recording samples are used in windrowing operation and (25) recording samples are used in cultivating operation. Each recording sample (X) represents 600 seconds of the real-time recording of the operator's gaze during the windrowing operation.

Due to the differences between the planned and actual recoding time, each sample is normalized to represent the 600 seconds of recording with a factor (N) not exceeding the 17% of the planned recording time. However, collected snap times on the attached tool is multiplied by the Normalization factor (N) according to the formula:

$$\begin{aligned} \text{Normalized snap time of (X) sample} &= \\ &= \text{Normalization factor (N)} \cdot \text{Actual snap time of (X) sample.} \end{aligned} \quad (1)$$

Selection of Areas of interest

To the purpose of this research, the selected area of interest are the attached tools; which require continuous monitoring and checking by turning back; to keep focusing on the passive fatigue of the operator. Reference snapshots are taken for the item in the area of interest form videos recorded by the Tobii Glasses 2 equipment (Fig. 6).



Figure 6. Reference snapshots (windrowing and cultivating tools).

Selection of operator

One operator is selected to wear the eye-tracking equipment. Operator's details are listed in the (Fig. 7). The operator is mandated to spend several minutes inside the selected vehicle cabin during conducting the windrowing operation.



Grebely Csaba	
Age	22 years
Height	184 cm
Weight	78 kg
Experience	5 years

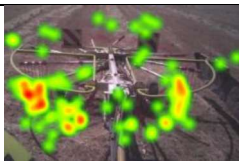
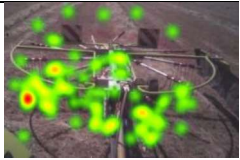



Figure 7. Operator's card.

RESULTS AND DISCUSSION

Measurements and analysis results

After accomplishing the analysis process, the resulted data was exported by Tobii pro lab analyser software to MS Excel sheet. The samples were normalized in accordance to the mentioned normalization formula.

Table 1. Sample Experiment results of windrowing operation

Sample Reference	X value	Tool Snap time (Sec)	N Factor	Time (Normalized) (Sec)	Generated Heat map
10	3	15.17	1.00	15.17	
12	5	15.38	0.83	12.82	
15	8	12	0.86	10.29	
17	3	7.92	1.00	7.92	
18	4	48.72	1.00	48.72	

(Table 1) presents sample of exported results for the windrowing operation and cultivating operation, where:

- The sample reference in the original video (column 1); which represents the reference of a certain sample inside the used analyser software (Tobii Pro Lab).
- The sample serial number (X) (column 2); which will represent the X-Axis on the resulted curve.
- The tool snap times in (X) sample (column 3); which will represent the accumulated time of operator's gaze inside the AOI on the Y-Axis on the resulted curve.
- The normalization factor (N) for the sample (X) (column 4).
- The Normalized tool snap times ($X*N$) (column 5).
- The generated heat map for the sample (X) (column 6); which is a graphical representation for the operator's gaze distribution and accumulated time over the reference image along the sample recording time.

Modelling results

The curve fitting operation is conducted using the MATLAB Curve Fitting Toolbox™, the resulted curves (Fig. 8) for the windrowing and cultivating operations were processed selecting the Linear model (Poly 2) which generates a polynomial equation with the second degree and using Bi-square robust method.

Where

X-Axis represents the samples serial number (1 unit = 600 working seconds);

Y-Axis represents the OFS (Accumulated gaze time on the AOI in seconds)

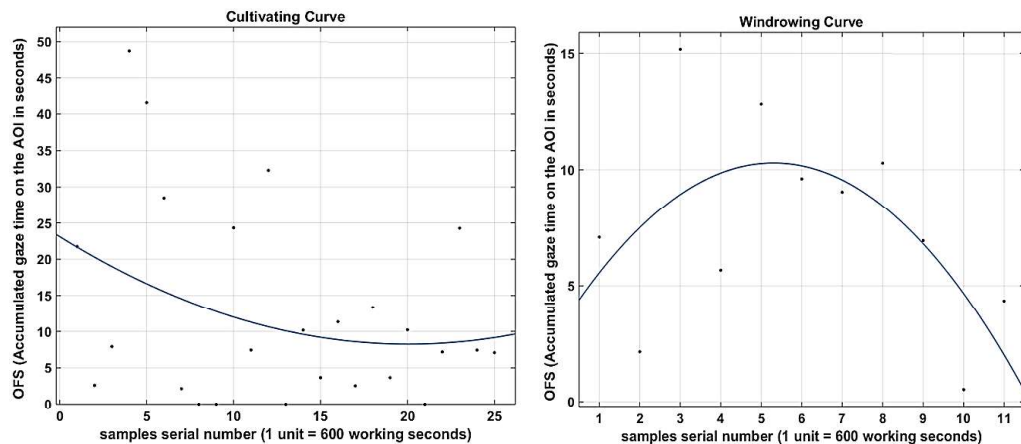


Figure 8. Curve fitting of results.

The resulted models and the goodness of fit is shown in (Table 2), which gave the final equation:

Table 2. Resulted models and the goodness of fit

Windrowing operation model	Cultivating operation model
Linear model Poly2: $f(x) = p1 * x^2 + p2 * x + p3$	Linear model Poly2: $f(x) = p1 * x^2 + p2 * x + p3$
Coefficients (with 95% confidence bounds): p1 = -2.809 p2 = -1.176 p3 = 10.17	Coefficients (with 95% confidence bounds): p1 = 1.999 p2 = -3.831 p3 = 10.1
Goodness of fit: SSE: 142.5 R-square: 0.2598 Adjusted R-square: 0.07474 RMSE: 4.221	Goodness of fit: SSE: 4083 R-square: 0.0713 Adjusted R-square: -0.01312 RMSE: 13.62

Discussion

The results showed accurate and dependable data of the operator's gaze on selected area of interest. The used equipment and supporting software packages easily defined the time in which the operator paid his attention to the attached windrowing and cultivating tools during working time in operations.

The selection criteria considered the common nature of agricultural operations, the AOI, the use of vehicles, the use of same operational conditions regarding the covered cabin and the use of same operator. Which all contributes to accomplish unified inputs keeping on the realistic implementation behaviour of the operator.

The nature of the selected agricultural operations includes the routine tasks; in which the operator needs to be involved is adding on the mental load due to monitoring of the vehicle track and the accumulated physical fatigue due to checking and monitoring the attached tool.

The resulted models are developed to be used as a simple tool predicting the behaviour of an operator inside the off-road vehicle cabins based on deterministic data analysis. The contribution of the implemented models is expected to assist the decision-making process regarding many aspects (i.e. scheduling of breaking times, working hours and payment estimation). Which make it necessary not to exclude the uncertainties expected to be faced during the real-time implementation of the model. Taking into consideration keeping on the simplicity of the model and not excluding of uncertainties, the resulted models are showing low R² Number. However; the resulted models are for the two agricultural operations are found to be the first attempt to modelling the change on operator's focusing scheme along working hours, which is subjected to be improved on a continual base.

CONCLUSIONS

The resulted models showed a notable decrement behaviour in operator's focusing scheme along working hours, which is correlated to the passive fatigue and mental load accumulated along working hours due to the operator contribution to monitor and control the attached back tool on a continual base.

The availability of such models provides the decision makers with dependable and deterministic data to decide on which operation requires more contribution by operators

in order to support the developed precision farming concept by dissemination of the resulted modelling results into a simple and reliable way to the rural farming areas.

The resulted models are subjected for further development in the term of the modelling quality. However, it is still usable to provide an indication for comparing different agricultural operations.

REFERENCES

- Brookhuis, K. & De Waard, D. 2010. Monitoring drivers' mental workload in driving simulators using physiological measures. *Accident Analysis and Prevention* **42**, 898–903.
- Casey, S.M. & Kiso, J.L. 1990. The acceptability of control locations and related features in agricultural tractor cabs. In: *Proceedings of the Human Factors Society 34th annual meeting* (Santa Monica, CA: Human Factors Society), pp. 743–747.
- De Waard, D. 1996. The measurement of drivers' mental workload. *Doctoral thesis*, University of Groningen, Haren, Netherlands, pp. 97–107.
- Endsley, M.R. 1996. Automation and situation awareness. *Automation and Human Performance: Theory and Applications*, CRC Press. 163–181.
- Fukunaga, A., Rabideau, G., Chien, S. & Yan, D. 1997. Towards an application framework for automated planning and scheduling. Aerospace conference. In *Proceedings IEEE*, pp. 411–427.
- Gonçalves, J. & Bengler, K. 2015. Driver State Monitoring Systems– Transferable knowledge manual driving to HAD, *AHFE*, pp. 3011–3016.
- Herdon, M. 2013. Aggroinformatics. University of Debrecen, 5–20. ISBN: 978-963-473-671-4
- Hsiao, H., Whitestone, J., Bradtmiller, B., Whisler, R., Zwiener, J., Lafferty, C., Kau, T.Y. & Gross, M. 2005. Anthropometric criteria for design of tractor cabs and protection frames. *Ergonomics* **48**, 323–353.
- Kaminaka, M.S. 1985. Research needs in the American agricultural equipment industry. *Applied Ergonomics* **16**(3), 217–220.
- Kramer, A. 1990. Physiological metrics of mental workload: A review of recent progress. In D. Damos, (Ed.). 2015. *Multiple-task Performance*. London, Taylor & Francis, pp.279–328.
- Kroulik, M., Chyba, J. & Brant, V. 2015. Measurement of tensile force at the fundamental tillage using tractor's built-in sensor and external sensor connected between machines and their comparison. *Agronomy Research* **13**(1), 95–100.
- Liljedahl, J.B., Turnquist, P.K., Amith, D.W. & Hoki, M. 1996. *Tractors and Their Power Units*. St. Joseph, MI: American Society of Agricultural Engineers, pp. 226–231.
- Li, G. & Haslegrave, C.M. 1999. Seated work postures for manual, visual and combined tasks. *Ergonomics* **42**(8). Taylor and Francis. 1060–1086.
- Louw, T. & Merat, N. 2017. Are you in the loop? Using gaze dispersion to understand driver visual attention during vehicle automation. *Transportation Research Part C* **76**, 35–50.
- Marquart, G., Cabral, C. & Winter, J. 2015: Review of eye-related measures of drivers' mental workload. *Procedia Manufacturing* **3**, 2854–2861.
- Matthews, J. 1977. The ergonomics of tractors. *ARC Research Review* **3**, 59–65.
- Robert, P. 2004. Agricultural Systems Management: Optimizing Efficiency and Performance. Taylor & Francis. 2004, 3–12. ISBN 0-203-02183-5
- Saxby, D.J., Matthews, G., Warm, J.S., Hitchcock, E.M. & Neubauer, C. 2013. Active and passive fatigue in simulated driving: discriminating styles of workload regulation and their safety impacts. *J. Exp. Psychol. Appl.* **19**(4), 287–300.
- Scheding, S., Dissanayake, G., Nebot, E.M. & Durrant-Whyte, H. 1999. An experiment in autonomous navigation of an underground mining vehicle. *IEEE Transactions on Robotics and Automation* **15**(1), 85–95.

- Shen, S. & Neyens, D.M. 2017. Assessing drivers' response during automated driver support system failures with non-driving tasks. *Journal of Safety Research* **61**, 149–155.
- Sheridan, T.B. 1992. Telerobotics, automation, and human supervisory control. MIT Press, pp. 1–10.
- Sporrong, H., Palmerud, G., Ka defors, R. & Herberts, P. 1998. The effect of light manual precision work on shoulder muscles-an EMG analysis. *Journal of Electromyography and Kinesiology* **8**, 177–184.
- Szabó, I., Hushki, M., Bártfai, Z. & Kátai, L. 2017. Operator's behaviour measuring methodology inside off-road vehicle cabin, operator's focusing scheme. *Agronomy Research* **15**(5), 2172–2182.
- Xuan, Z. 2007. Artificial Intelligence and Integrated Intelligent Information Systems: Emerging Technologies and Applications. Idea Group Inc (IGI), 1–75. ISBN 1-59904-249-5.
- Young, K. & Regan, M. 2007. Driver distraction: A review of the literature. In: I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter & J.D. Irwin (Eds.). *Distracted driving*. Sydney, NSW: Australasian College of Road Safety, pp. 379–405.
- Zewdie, R. & Kic, P. 2017. Substantial factors influencing drivers' comfort in transportation. *Agronomy Research* **15**(5), 2236–2246.