Human Factors as the Main Reason of the Accident in Scaffold Use Assessment

Krzysztof J. Czarnocki, E. Czarnocka, K. Szaniawska

Abstract**—**Main goal of the research project is Scaffold Use Risk Assessment Model (SURAM) formulation, developed for the assessment of risk levels as a various construction process stages with various work trades. Finally, in 2016, the project received financing by the National Center for Research and development according to PBS3/A2/19/2015–Research Grant. The presented data, calculations and analyzes discussed in this paper were created as a result of the completion on the first and second phase of the PBS3/A2/19/2015 project. Method: One of the arms of the research project is the assessment of worker visual concentration on the sight zones as well as risky visual point inadequate observation. In this part of research, the mobile eye-tracker was used to monitor the worker observation zones. SMI Eye Tracking Glasses is a tool, which allows us to analyze in real time and place where our eyesight is concentrated on and consequently build the map of worker's eyesight concentration during a shift. While the project is still running, currently 64 construction sites have been examined, and more than 600 workers took part in the experiment including monitoring of typical parameters of the work regimen, workload, microclimate, sound vibration, etc. Full equipment can also be useful in more advanced analyses. Because of that technology we have verified not only main focus of workers eyes during work on or next to scaffolding, but we have also examined which changes in the surrounding environment during their shift influenced their concentration. In the result of this study it has been proven that only up to 45.75% of the shift time, workers' eye concentration was on one of three work-related areas. Workers seem to be distracted by noisy vehicles or people nearby. In opposite to our initial assumptions and other authors' findings, we observed that the reflective parts of the scaffoldings were not more recognized by workers in their direct workplaces. We have noticed that the red curbs were the only well recognized part on a very few scaffoldings. Surprisingly on numbers of samples, we have not recognized any significant number of concentrations on those curbs. Conclusion: We have found the eye-tracking method useful for the construction of the SURAM model in the risk perception and worker's behavior sub-modules. We also have found that the initial worker's stress and work visual conditions seem to be more predictive for assessment of the risky developing situation or an accident than other parameters relating to a work environment.

Keywords**—**Accident assessment model, eye tracking, occupational safety, scaffolding.

I. Introduction

TODAY we take occupational health into account. Therefore, we need to constantly control level of work related accidents. As research shows we still need to work on improvement occupational safety. According to Polish Central Statistical Office in Poland in 2015 there were comparatively lower amount of the accidents, according to previous decade, but still 201 fatalities. The situation did not improve in 2016, as this year we have noticed the first increase of 0.9% of fatal occupational incidents in the construction. Over 60% of these accidents were caused by human factors [1]. Meanwhile, accidents in construction in U.K. are ranked 6th out of 19 analyzed economy sectors. Other studies also support thesis of the researchers, in regarding the factors which can improve occupational health related accidents especially on construction site. The Health and Safety Executive report shows that in 2017, from total, of 137 fatal injuries of employees in U.K., 30 took place in construction. Over last five years average is even higher, 39 cases, which is placing this industry on the lead in amount of fatal accidents [2], [3]. According the Bureau of Labor Statistic 2010 report, only 0.04% construction workers did not suffer injuries at work, while 18% of total 774 accidents were fatal. More specific data show that 34% of all death accidents on construction site were caused by falling from scaffolding [4], [5].

Avoidance of work related accidents and health problems does not stand only in workers interest, nowadays many organizations and institutions are standing on the workers site, making sure that people health is well protected [6]-[8]. This leads directly to health private social protection and insurance systems. According to information above we can see that work-related accidents can take more material form. Economic dimension of occupational accidents fuels the privatization social protection and insurance systems. Economic effects caused by occupational accidents dynamically increase both direct and indirect losses. European Agency for Safety and Health at Work (EU-OSHA) in cooperation with Labor Organization have presented at the end of 2017 in their common study, the occupational injuries and illness worldwide result in the loss of 3.9% of GDP, which annually cost around 2680 billion. What is more alerting is the fact that 86% of all deaths annotations are straightly related to work induced-illnesses [9], [10].

II. Method of Research

A. Generic Assumptions

In response to the ever-increasing number of accidents in construction, on construction sites using scaffolding and the losses caused by them, a research project was initiated, as a result of which a scaffold risk assessment model to be applied in the construction process (SURAM) is to be developed. This project is financed by the National Center for Research and

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Development (NCBiR) in accordance with the grant - PBS/ A2/19/2015. The research results presented in this study are an element of this project. Main goal of this project is to develop a model for assessing the risk of construction disasters, accidents and hazardous events at workstation using building scaffolding, especially during construction work. All results that will be finally collected as a risk assessment model will be presented as a computer program, for more accessible usage.

B. SURAMs' Research Specification

Researches are proceeding by: Lublin University of Technology, Lodz University of Technology and Wroclaw University of Technology. All Universities together finally will examine at least 120 construction sites with scaffoldings in Poland and 20 in Portugal as a control group. On each construction site there are collected data in seven fields [9], [11]:

1) Technical condition of the scaffolding (test by static-strength calculations).
2) The level of taking into account the requirements of ergonomics, safety engineering and safety regulations in shaping scaffolds.
3) Level of consideration of employee work load, ergonomics requirements, safety engineering, safety procedures and regulations during assembly, use and dismantling of scaffolds.
4) The psychophysical condition of scaffolding and workforce users working in the scaffold environment including stress psychological parameters and staff experience.
5) Influence of external factors such as noise, mechanical vibration from the ground or building, lighting, dustiness, climate conditions.
6) Influence of selected socio-economic factors, e.g.: number of investments connected with the inflow of EU founds, economic situation of the region, State Labor Inspection (PIP) inspections.
7) Other, e.g. company type, scaffolding assembler experience, etc. [10], [12].

C. Human Factor

For the purpose of the SURAM setup 800 individuals should be interviewed. During the first two years of research program over 539 individuals have been interviewed. According to Polish Central Statistical Office (GUS) Report 2016, more than 50% of occupational accidents are classified as caused by human factors [13]-[15]. That proves that concentration on human factor is relevant. To measure parameters that influence directly to human factors research tools were used:

1) Questionnaires,
2) Pulsometers,
3) Pressure gauge,
4) Eye-tracker
5) Observation
6) Interview

III. Eye-Tracker

Although the first head mounted eye-tracker was already developed in 1948, main purpose of usage of this tool was to examine eye concentration during work on the computer [16]-[19]. SMI Eye tracking tool is a modern tool to record and analyze path of visual of analyzed person. Tool is design quite comfortable, it looks like a protection glasses connected to a smartphone which is hidden in a belt [20]. Specification of this tool and its mobility can give us way more information about human factor. For SURAM research purpose eye-tracker was used on randomly selected workers on scaffolding and near to it. With average of 2 workers on all scaffoldings on which this tool could be used. The obstacle that we have met during researches was not so much workers resistance, but problems with reliability of the equipment, or calibration obstacle in environment of construction site. Nevertheless, those obstacle have been overcame, measurement was proceed from 30 to 60 minutes on each worker, that was maximum time that we could collect data without creating discomfort for investigated, same avoid misrepresented of the results. All collected data were analyzed with usage of a BeGaze software prepared by SMI to analyze eye-tracker data. SMI analyzed system gives many possibilities of presenting analyzed data. While looking at particular object or perspective we are seeing precisely a single point directly with its close surrounding area. A that moment we are convinced that we recognize all the elements clearly, but our vision is blurry. The results of eye-tracking analyses for both short and mid-long-distance areas that are observed by the employee from the workstation on the scaffold are presented on Figs. 1 and 3. More detailed image of key areas of visual concentration are displayed on Figs. 2 and 4.

This worker, whose eye-tracker analysis is presented on Figs. 1 and 3, was analyzed during one single session of working in one position on scaffolding, while moving worker did not gave us such a direct picture, especially on big scaffolding. For this purpose, person who was analyzing date was obligated to divide a picture on sectors, where we could see pattern of concentration. Each sector is representing single type of surrounding and its intensity visual focus of concentration. Multiple points can be distinguished as on Fig. 5 we can observe, that main visual concentration was on sectors that were representation of coworkers as also other people around, while Fig. 6 shows that workers' concentration was on scaffolding as well as on the surrounding. Data collected during research reveal outcomes which are shown on Figs. 5 and 6. Interestingly, in some of the cases that main concentration was beyond the area of scaffold (Fig. 6).

IV. Results

Results up to the end of 2017 year gives us alarming data 54.25% of work time people working on scaffoldings are not seeing their place of job as well as scaffolding or hey are seeing it blurry (χ^2=53.371, p=0.00001 CI=95%). Eye seeing concentration on scaffoldings is marginal, without big difference between different type of scaffoldings. Workers seems to be distracted by all factors that are happening in surrounding, like traffic, people passing by or animals. There are also used scaffolding with red curbs, which also are noticed as a blurry one.

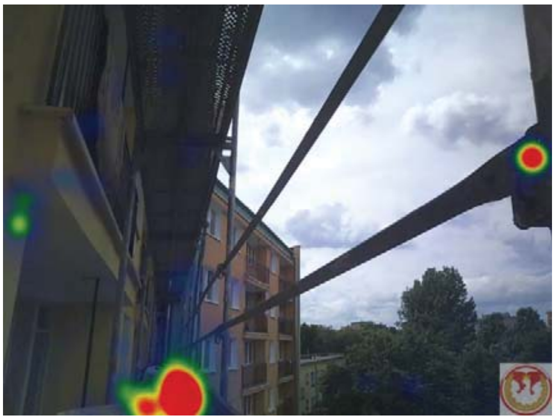

Fig. 1 Heat map scaffolding L20

Fig. 2 Focus map scaffolding L20

V. Conclusion

As we already noticed eye-tracker have shown that mainly people working on, as well as around scaffoldings aren't concentrating their eye seeing on scaffolding, without major changes between different type and colors of scaffoldings. (χ^2=3.291, p>0.05 CI=95%). Comparing that with data that 34% of all death accidents on construction site where caused by falling from heights or scaffolding, shows that we need to work on solution that can be alerting and make workers eye to focus on scaffolding especially during movement around the scaffolding. It leads us to further researches.

Meanwhile we have found implementation of eye-trackers a very useful and reliable method for the Safety System control and modelling for the occupational environment with scaffold use. This method very useful to define sources of accident (Coefficient of determination R^2>0,619 in our analysis for Relative Risk of accident RR(M) [21], which can lead us to use it, as the reliable tool for accident caused by Human Factors risk modeling at the scaffold.

Fig. 3 Heat map scaffolding L13

Fig. 4 Focus map scaffolding L13

Fig. 5 Gridded AOIs scaffolding L12

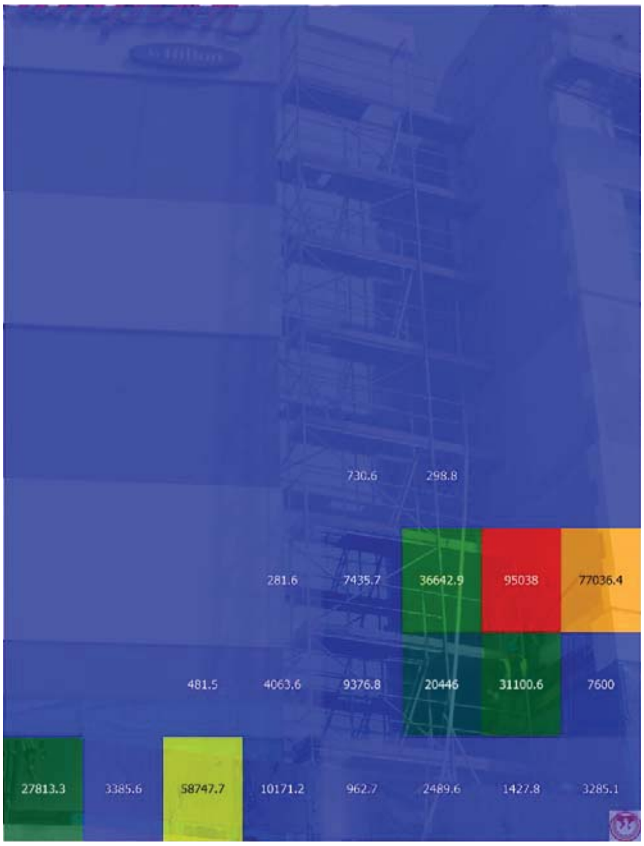

Fig. 6 Gridded AOIs scaffolding L13

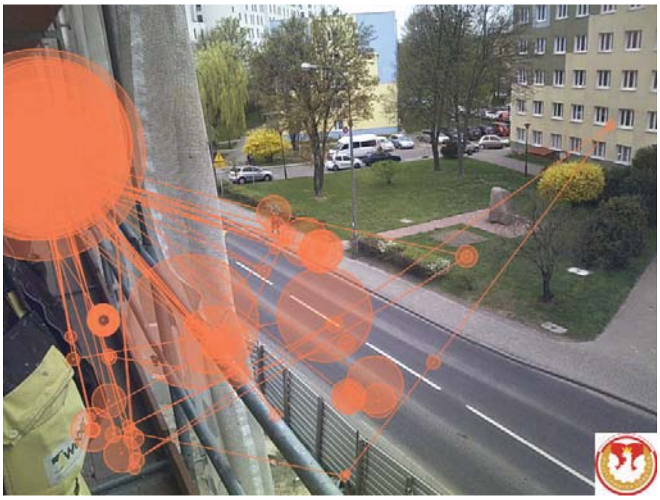

Fig. 7 Worker eye scan path scaffolding L12. (With external environment interactions during examination)

Fig. 8 Worker eye scan path scaffolding L19 (occupational activity only)

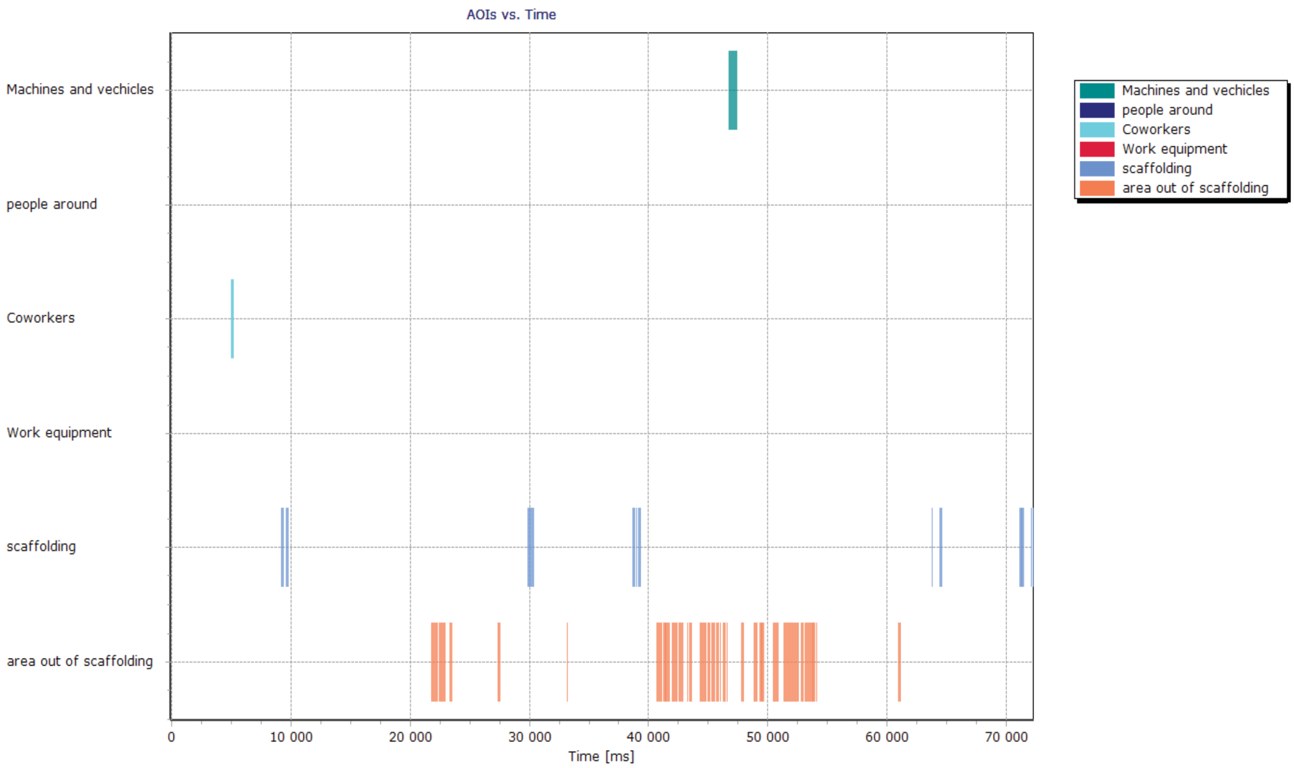

Fig. 9 AOI’s sequences chart scaffolding L13

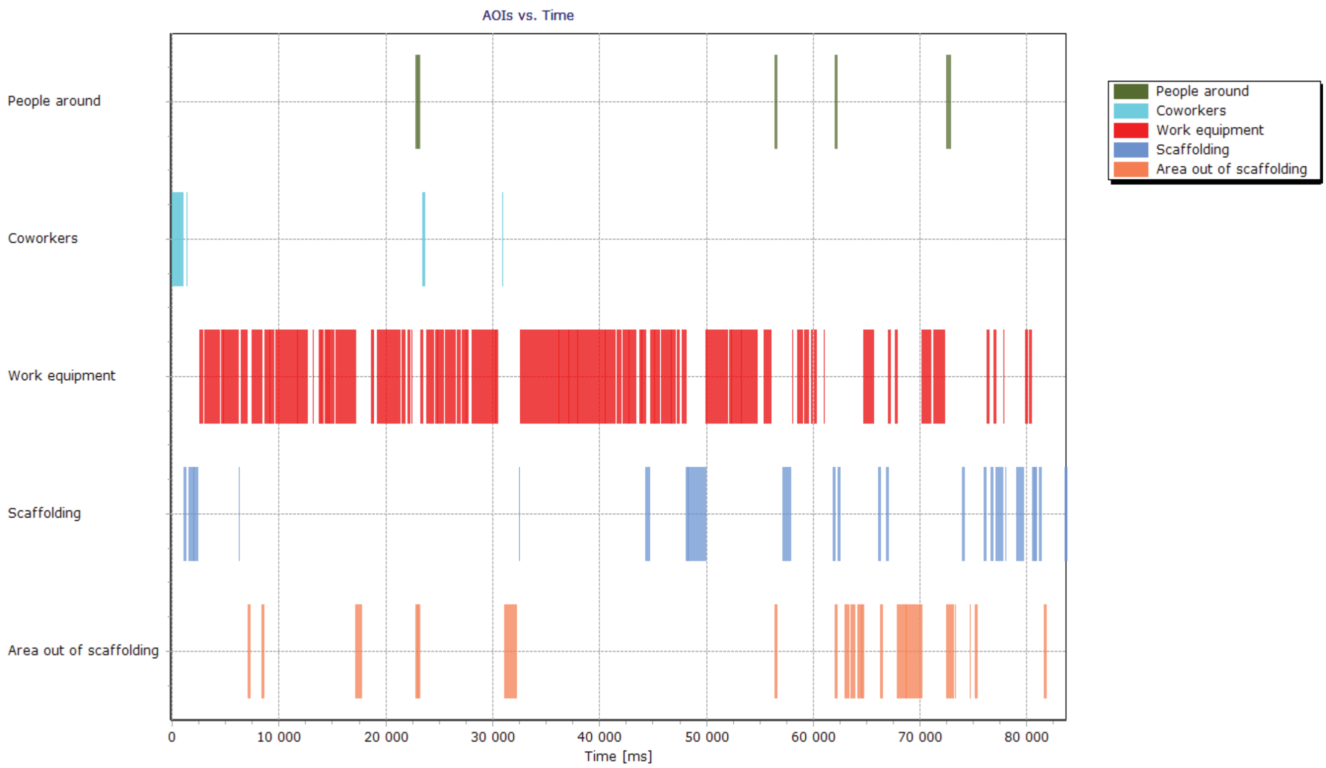

Fig. 10 AOI’s sequences chart scaffolding L12

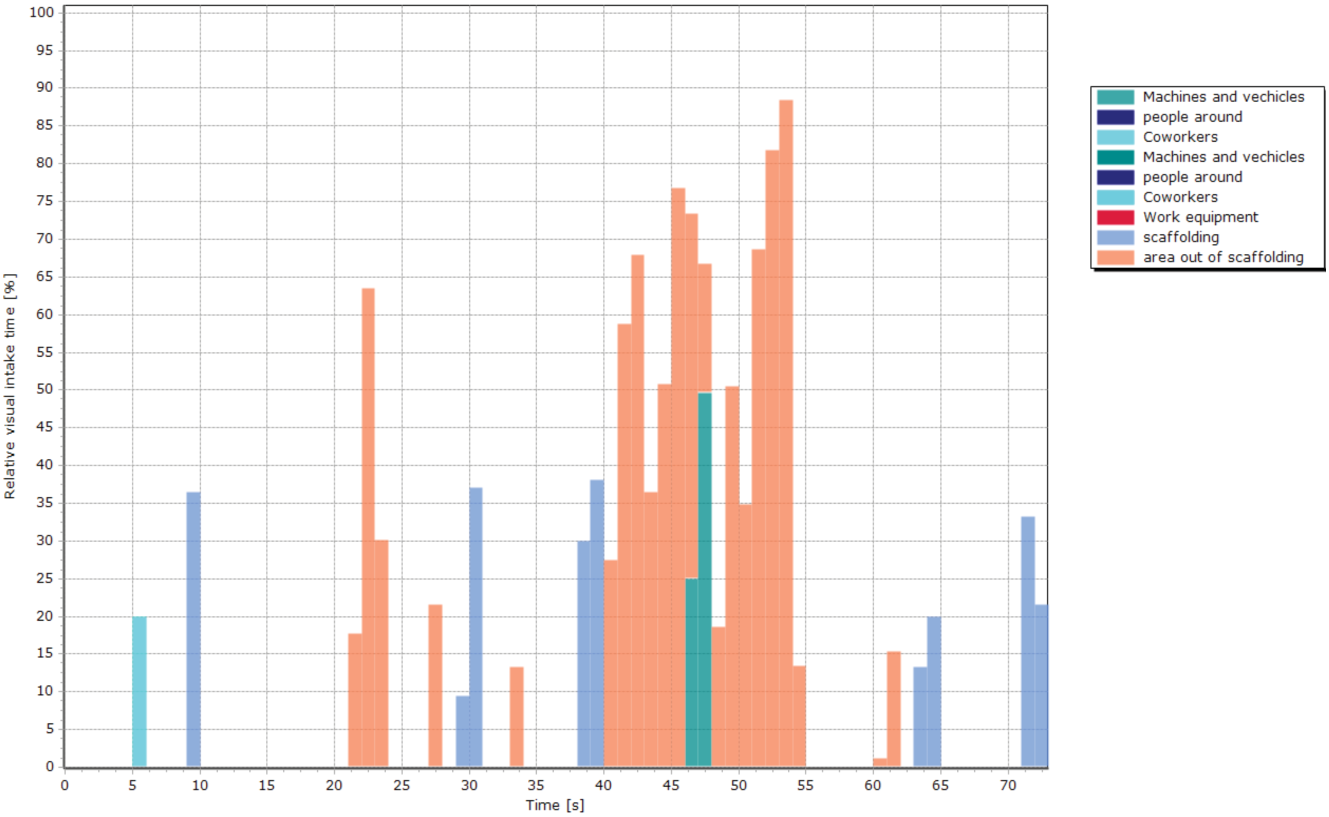

Fig. 10 Binning chart scaffolding L13

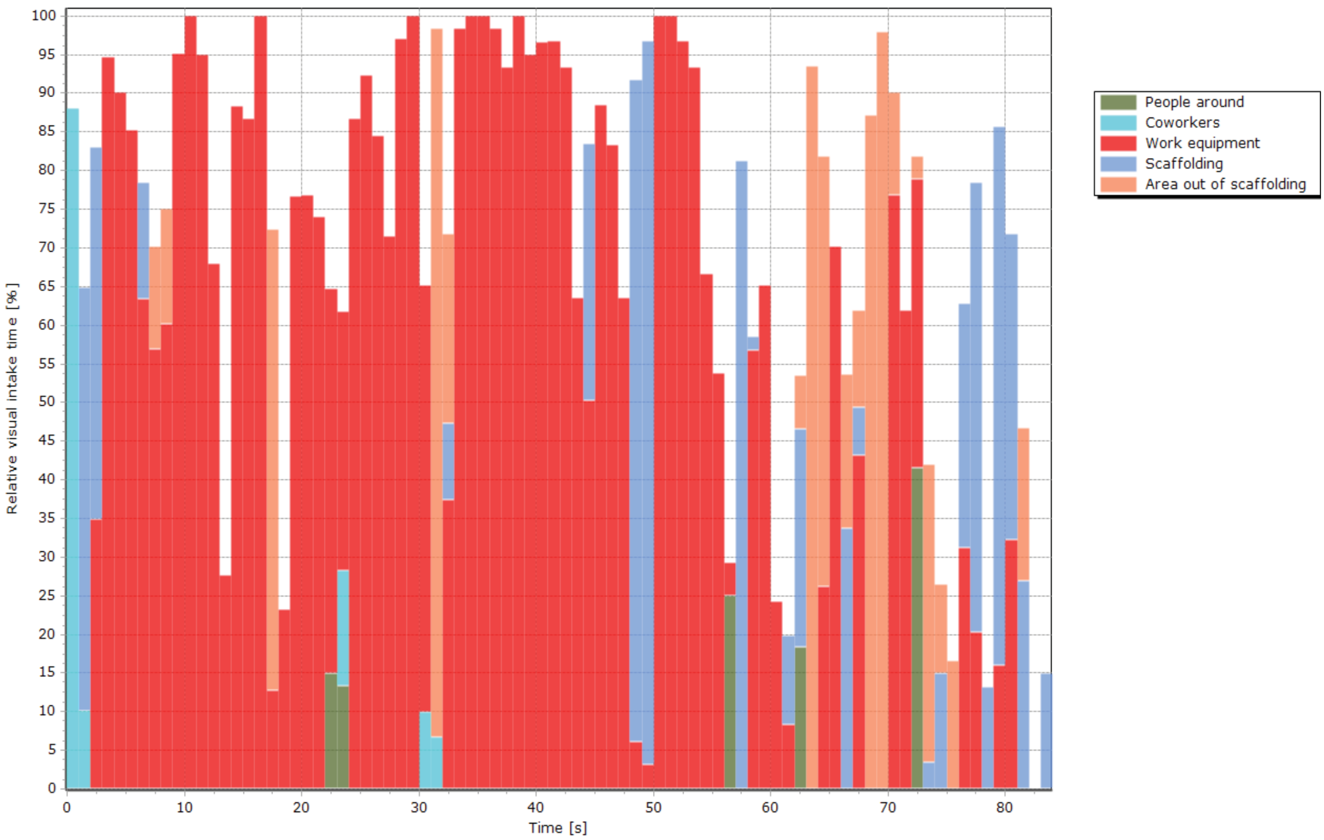

Fig. 11 Binning chart scaffolding L12

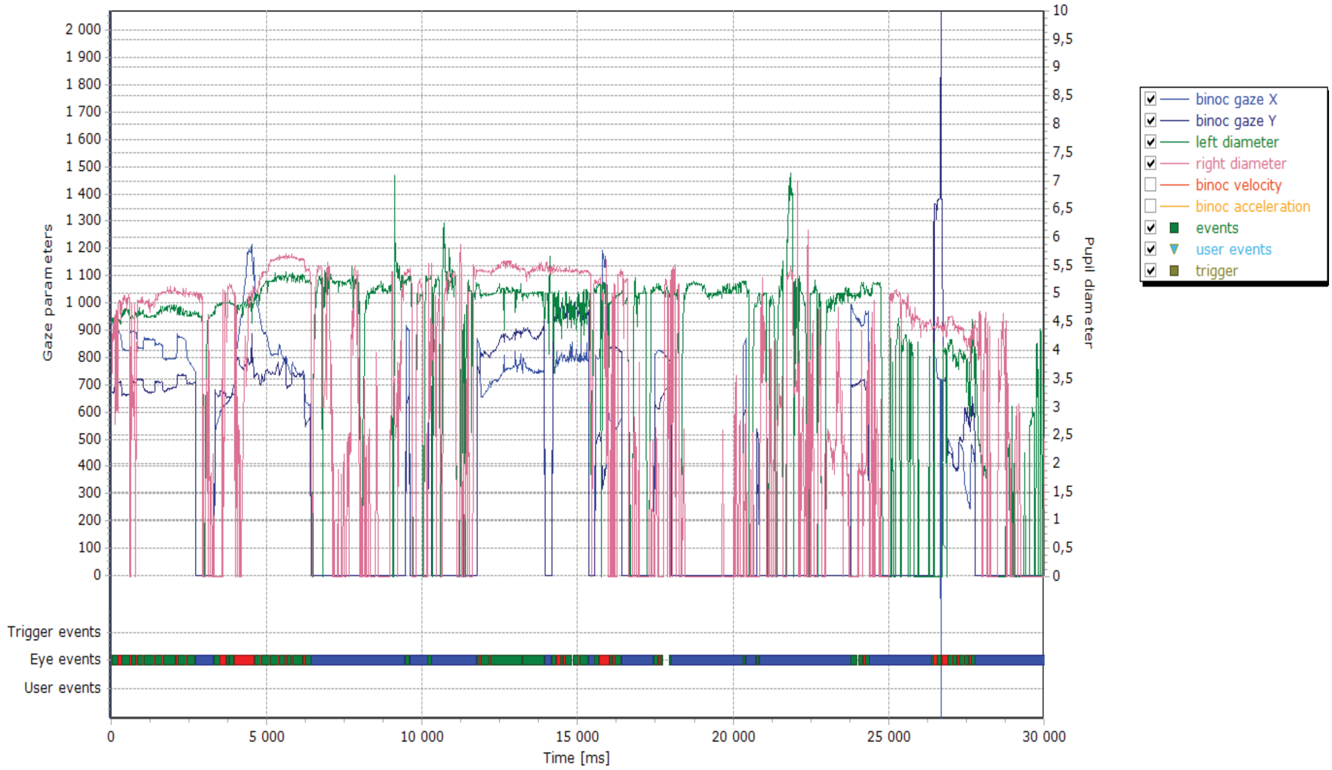

Fig. 12 Detail aye movement analyze graph scaffolding L13

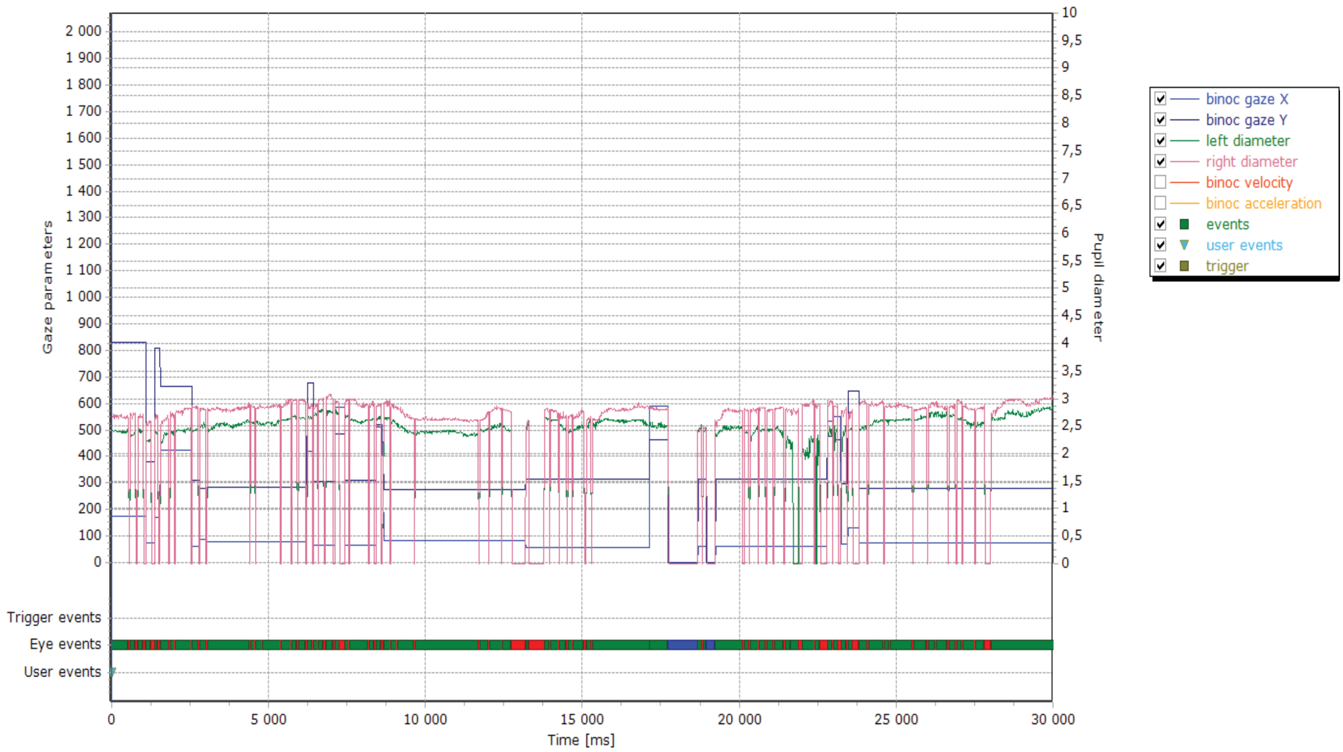

Fig. 13 Detail aye movement analyze graph scaffolding L11

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