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# SIMULATION AS ERGONOMIC TOOL FOR EVALUATION OF ILLUMINATION QUALITY IN ENGINEERING

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***Keywords:*** illumination, ergonomics, engineering, Dialux
***Abstract:*** Presented article is focused on the presentation of ergonomic tool opportunities from the point of view of ergonomics which is able to quickly, reliably and appropriately evaluate the quality of illumination in the engineering. In the introduction, the article provides the overview of basic terminology from the presented issue and after that it provides the opportunity to become familiar with the software for evaluation the quality of lighting in the assembly workplace.

## 1 Introduction

Ergonomics as one of the youngest scientific discipline can be defined by International Ergonomics association (IEA) such as: "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance." Practitioners of ergonomics and ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people. Ergonomics helps harmonize things that interact with people in terms of people's needs, abilities and limitations [10].

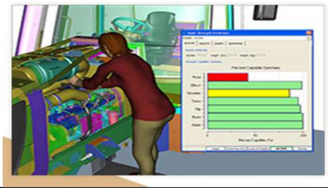
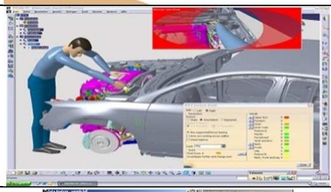
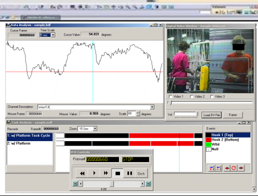
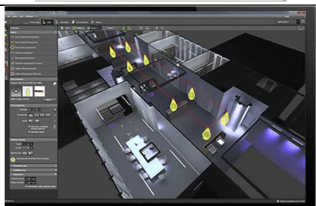
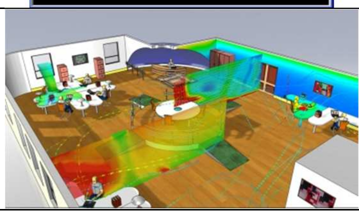

*Figure 1 Interaction of ergonomics [10]*

Domains of specialization within the discipline of ergonomics are broadly the following [10]:

- *Physical Ergonomics* **-** is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity.
- *Cognitive Ergonomics* **-** is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.
- *Organizational Ergonomics* **-** is concerned with the optimization of sociotechnical systems, including their organizational structures, policies, and processes.

All of the above mentioned types of ergonomics can be read in the interaction with civil engineering, mining industry, general engineering etc. [6]], [[9]. Multidisciplinarity of the ergonomics is guaranteed by rapid development of ergonomic simulation tools which are focused on optimization of working positions and working activities, factors of working environment, etc. Simulaaion is the imitation of the operation of a real-world process or system over time [7]], [[8]. The following table presents several examples of simulation tool which are used in the engineering.

*Table 1 The overview of the most commonly used simulation tools in engineering*

| Simulation software | Software image | Ergonomic system | Description |
|---|---|---|---|
| Tecnomatix Jack |  | human | analysis and evaluation of working positions and working activities<br>simulation of exact working motions |
| Delmia V5 Human |  | human | analysis and evaluation of burden lifting, laying and carrying<br>simulation of working activities |
| MVTA |  | human | ergonomic analysis of working activities and time motion studies<br>analysis of position and postural analysis in time |
| DIALux |  | environment – physical factor - illumination | light – technical calculations<br>calculation of indoor and exterior illumination<br>calculation of illuminance level |
| Izofonik |  | environment – physical factor - noise | one – channel and two – channel measurement of noise<br>calculation of noise level LA99 - LA01 |
| FloEFD |  | environment – physical factor - temperature | 3D simulation of heat flux and heat efficiency of buildings and working environments<br>draft temperature<br>predicted percent dissatisfied |

As stated in the previous table, one of the possible use of simulation tools is the evaluation and optimization of working environment with a focus on physical factors, namely illumination.

## 2 Illumination in engineering

The illumination is possible to describe by physical quantity termed luminous intensity (E). This physical quantity describes achieved level of illumination [12]. The luminous intensity is defined as a quotient of luminous flux (ΔΦ) falling on the plane and the area (ΔS) [1]:

$$E = \frac{\Delta\Phi}{\Delta S} \quad [\text{lx}] \qquad (1)$$

, where

E – luminous intensity [lx],
ΔΦ – luminous flux [lm],
ΔS – area of fallen luminous flux [m$^2$]

The intensity of lighting is measured in Luxes (lx). The illumination of the plane gets smaller with the distance from the light source getting longer. It is also dependent on the incidence angle [3]. The plane of which the rays fall perpendicularly is illuminated the most. If the rays are parallel with the plane the illumination is zero. For the illumination by spot lighting photometric equation is in order [1]:

$$E = \frac{I}{r^2 . \cos\alpha} \quad [\text{lx}] \qquad (2)$$

, where

I – intensity [lm]
r – distance from the light source [m]
α – incidence angle of the rays

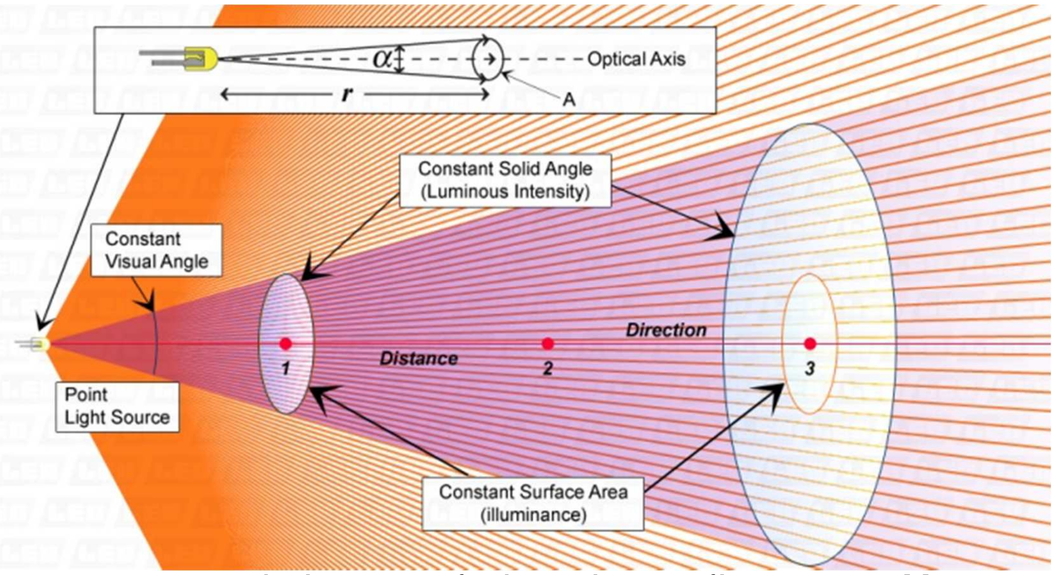



*Figure 2 Graphical presentation of mathematical equation of luminous intensity [1]*

The illumination of manufacturing buildings is secured by three basic electrical light sources: temperature sources, discharge tube sources or electroluminescent sources [2].

<u>*Temperature light sources*</u>

*Bulbs* – the least cost-effective energy light sources. They convert to light of only 3% to 8% of the incoming energy. The advantage is the low price at the expense of short-lived.

*Halogen bulbs* – they have a 15% greater light output than incandescent bulbs. Their lifetime period is longer and it is not depended on number of switching cycle.

<u>*Discharge tube sources*</u>

*Low-pressure mercury discharge tubes* – are currently the most used. It is not possible to use theirs for the exterior illumination because they unreliably ignite at a low temperature below + 7 ° C and their luminous flux decreases. The advantage of low-pressure mercury discharge tubes is high light efficiency, the low energy consumption and the long lifetime period.

*Compact fluorescent tubes* – are typical for household. In the industry, they are used for illumination of smaller spaces. The special types of tubes are suitable for illumination during the low external temperatures.

*In the low – pressure sodium lamp* the light arises in sodium vapour. The fluorescent lamps are among the most efficient light sources. They have very limited application in the industry. It can be installed only where it is not necessary to distinguish between colours.

*High-pressure mercury discharge tubes* – are light sources in which the major portion of the light is produced in a mercury discharge at a partial pressure in excess of 100 kPa. They are inappropriate and outdated light source.

*High-pressure sodium lamp* - are suitable for illumination of roads, public spaces and in the areas with the frequent fog. They are suitable only where there is the high visibility more important than the precise resolution.

*High-pressure halide lamp* - they have better interpretation of colour than other discharge tubes. They are used everywhere where high intensity illumination and good colour rendering.

*Xenon lamp* – are special type of lamp and they are often installed in dipped headlights cars.

Electroluminescent sources

*LED* – the light source is diode which emits the lights in the lamps. In the lamps there is usually situated the set of diodes. The advantage of LED is the long lifetime period at the expense of relatively high prices.

*OLED* – is used for illuminating of displays. This type amounts to a relatively small area of light output and low efficiency of about 50 lm / W.

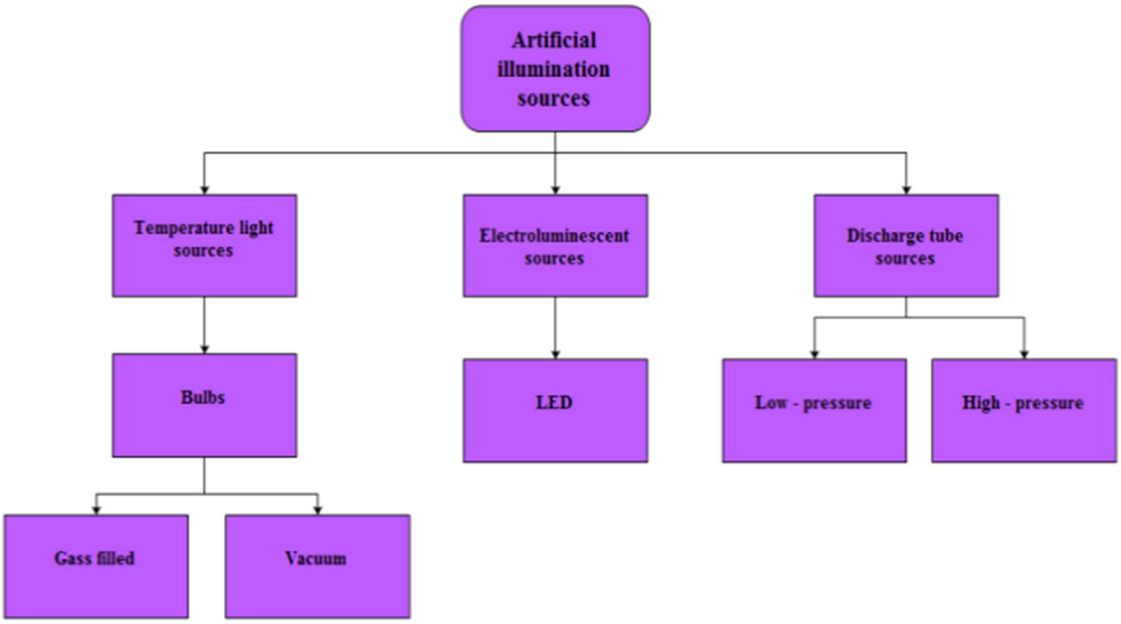



*Figure 3Categorization of light sources [12]*

## 3 Evaluation of illumination quality in the workplace using the simulation tool

The illumination quality is possible to evaluate by different simulation tool. The most frequent used software for evaluation of illumination in the industry is simulative light – technical tool Dialux evo. On the basis of simple user interface, it provides the creation of thorough suggestions of interior and exterior lighting system [11].

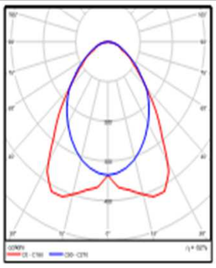
The advantage of this simulation tool is simple conception of user interface with extra speed dial right start-up splash screen, which offers access to the home menu in three sections - create a new project, edit existing project, other topics. After the chosen alternative it is possible to begin with the creation or modification of illumination system model using the main toolbar which includes options for working with modelling, supplementing and defining lighting system with a choice of lighting manufacturer's catalogues.

The newest software platform has the possibility of assigning light from various global manufacturers such as Osram, Panasonic, Philips, LG Electronics, etc. The available manufacturers for their resources regularly perform the tests and their results published in electronic form via the Internet, ensuring the timeliness and accuracy of the light sources used. They provide important data about the character of suggested illumination including the important parameters of comprehensive luminous system.

It was selected the assembly workplace (15 000 x 7 000 x 3 200) for the production of stainless banisters for the model creation. The wall thickness is 150 mm and the evaluating plane is of 0.85 meters. The following figure presents an overview of workplace for operation with the associated lighting.

In the evaluated workplaces there are six pieces of Phillips lights with the characteristics shown in the figure 5.

*Figure 4 Evaluated workplace*

| Quantity | Luminaire (Luminous emittance) | | |
|---|---|---|---|
| 6 | Philips Lighting TBH375 2xTL5-49W HFP_452<br>Luminous emittance 1<br>Fitting: 2xTL5-49W/452<br>Light output ratio: 81.83%<br>Lamp luminous flux: 7400 lm<br>Luminaire luminous flux: 6055 lm<br>Power: 108.0 W<br>Light yield: 56.1 lm/W<br>Colour temperature: 3000 K<br>Colour rendering index: 100 |  |  |

Total lamp luminous flux: 44400 lm, Total luminaire luminous flux: 36330 lm, Total Load: 648.0 W, Light yield: 56.1 lm/W

*Figure 5 Specifications of lights – output from Dialux software*

It is also 6 pieces of windows on the upper part of the end wall of the workplace (comprehensive illumination). The following figures present the disposal workplace layout and assembled model in the simulation software Dialux Evo.

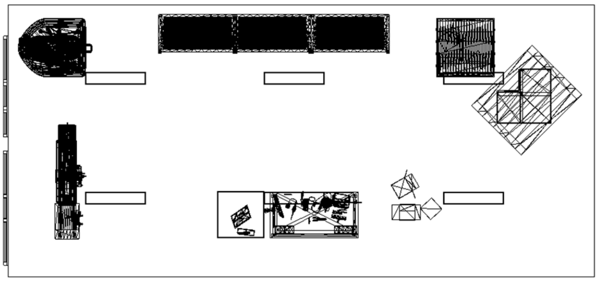


*Figure 6 Workplace layout*

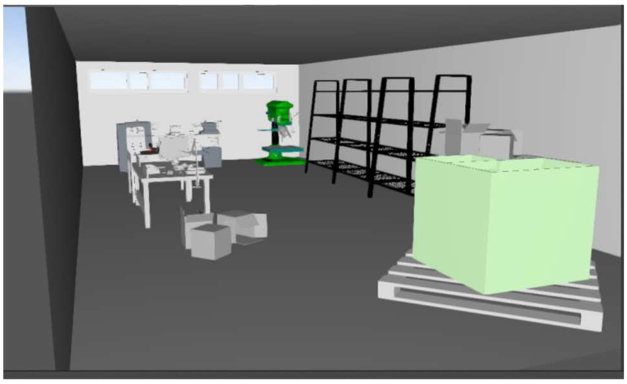
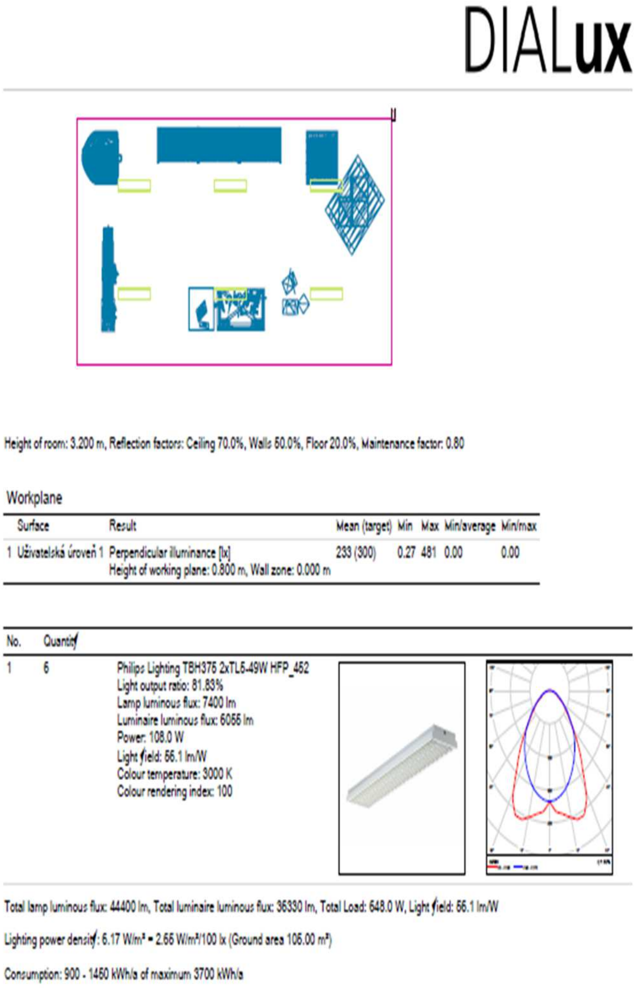


*Figure 7 Model of workplace – Dialux evo*

The target of model creation and realization of illumination simulation is getting the light – technical data which is possible to improve or optimize by modification of model or modification of illumination. After the achievement of necessary data, it is possible to interpret the results obtained in graphical and tabular form. From the graphical interpretation of results it is possible to state that the actual illumination of working environment is not suitable. This statement is confirmed by numerical results which are presented in the figure under the text.

*Figure 8 Isophote course 2D (left) a 3D (right)*




Height of room: 3.200 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

| | Surface | Result | Mean (target) | Min | Max | Min/average | Min/max |
|---|---|---|---|---|---|---|---|
| 1 | Uživatelská úroveň 1 | Perpendicular illuminance [lx]<br>Height of working plane: 0.800 m, Wall zone: 0.000 m | 233 (300) | 0.27 | 481 | 0.00 | 0.00 |

| No. | Quantity | |
|---|---|---|
| 1 | 6 | Philips Lighting TBH375 2xTL5-49W HFP_452<br>Light output ratio: 81.83%<br>Lamp luminous flux: 7400 lm<br>Luminaire luminous flux: 6056 lm<br>Power: 108.0 W<br>Light yield: 56.1 lm/W<br>Colour temperature: 3000 K<br>Colour rendering index: 100 |

Total lamp luminous flux: 44400 lm, Total luminaire luminous flux: 36330 lm, Total Load: 648.0 W, Light yield: 56.1 lm/W

Lighting power density: 6.17 W/m² = 2.66 W/m²/100 lx (Ground area 105.00 m²)

Consumption: 900 - 1450 kWh/a of maximum 3700 kWh/a

*Figure 9 Numerical evaluation of illumination quality*

The results of the simulation confirm that the maximum value reached workplace lighting is 482 lux, which is far from sufficient. Therefore, it is necessary to make amendments and additions to the lighting holes, supplementing or replacing lamps. After implementation of optimization is required to perform the simulation again and compare the results obtained.

## Conclusions

Simulation is a key technology of industrial engineering from the various reasons - increasing the complexity of issues that need to be addressed today, but also by computer programs to simulate descended from "sterile" data centres to design offices and production workshops. [4],[5] One of these problems is the provision of well-being in the workplace in terms of ergonomics, evaluation burden and physical factors of the working environment. The subject of this article was to introduce the possibility of simulation tools in terms of ergonomics, which can quickly reliably and adequately assess the quality of lighting in the workplace. On the basis of results, the individual user can evaluate the status of work and propose adequate solutions to the finish. Then, the optimized solution is again carrying out simulation and they are discussed the achieved results. In conclusion, the proper selection and effective use of simulation tools requires many experts and knowledge by means of which subsequently formed the correct simulation models. The benefits of simulation tools (ergonomic planning, management etc.) if used correctly they provide an added value to the company.

## References

[1] AHRAM,T., JANG, R.: *Advances in Physical Ergonomics and Human Factors: Part I*, AHFE Conference, p. 402, 2014.

[2] FLIMEL, M.: New approaches to obtrusive light evaluation inside the interiors, *Journal of Light & Visual Environment*, Vol. 31, No. 3, p. 141-145, 2007.

[3] LINDSEY, J. L.: *Applied Illumination Engineering*, The Fairmont Press, Inc., p. 516, 1997.

[4] PETRIK, M.: Optimization of non-production processes, *Acta Simulatio*, Vol. 1, No. 2, p. 19-22, 2015.

[5] REINER,R., ČEP, R., SADÍLEK, M.: *Simulace držáků a nástrojů pro stroj EMCO PC Mill 155 při využití CAD/CAM systému EdgeCAM*. ERIN 2009 Sborník přednášek, Proceding of Papers, Vysoká škola báňská-Technická univerzita Ostrava, p. 1-8, 2009. (Original in Czech)

[6] TRÁVNÍČEK, P., VÍTĚZ, T., JUNGA, P.: *Modelování šíření kontaminantu v akviféru při havarijním úniku*, Aprochem, p. 275-281, 2012. (Original in Czech)

[7] STRAKA, M. TREBUNA, P. ROSOVA, A. MALINDZAKOVA, M. MAKYSOVA, H.: Simulation of the process for production of plastics films as a way to increase the competitiveness of the company, *Przemysł Chemiczny*, Vol. 95, No. 1, p. 37-41, 2016.

[8] STRAKA, M., ŽATKOVIČ, E.: *Modelovanie a simulácia - teória, výskum a vývoj*, Výskumné aktivity v doprave, staviteľstve a príbuzných odboroch: vedecko-odborný seminár, Herľany, 21.-22.01.2014. – Košice, SSL, p. 1-4, 2014. (Original in Slovak)

[9] ZAJAC, J., BERAXA, P., MICHALIK, P., BOTKO, F.,POLLÁK, M.: Simulation of Weld Elbows Hot Forming Process, *International Journal of Modeling and Optimization*, Vol. 6, No. 2, p. 77-80, 2016.

[10] International Ergonomincs Association: Definition and Domains of Ergonomics, [Online], Available: http://www.iea.cc/whats/index.html [16 Jan. 2017], 2017.

[11] Lighting design software DIALux. [Online], Available: https://www.dial.de/en/dialux/, 2017.

[12] Slovenská inovačná a energetická agentúra: Osvetlenie v priemysle, [Online], Available: https://www.siea.sk/materials/files/poradenstvo/publikacie/letaky/osvetlenie_v_priemysle/SIEA_osvetlenievpriemysle.pdf, 2013. (Original in Slovak)

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