Baltic J. Modern Computing, Vol. 11 (2023), No. 2, 272-284
https://doi.org/10.22364/bjmc.2023.11.2.04

Selection of Computer-Aided Design Software Systems Using the AHP Method

Rūta SIMANAVIČIENĖ, Sonata VDOVINSKIENĖ

Vilnius Gediminas Technical University, Sauletekio Ave. 11, LT-10223 Vilnius, Lithuania

ruta.simanaviciene@vilniustech.lt.,
sonata.vdovinskiene@vilniustech.lt

ORCID 0000-0002-1614-9470, ORCID 0000-0002-4077-863X

Abstract. There is currently a wide range of computer-aided design (CAD) software systems available on the market, but there is no methodology for selecting the best-suited one for the user, considering various evaluation criteria. Taking into account the application of multi-criteria decision-making methods in software ranking and selection tasks, this paper proposes a model for the selection and suitability of CAD software systems for the preparation of a technical document, based on an expert evaluation using the AHP method. The proposed model was realised through a real situation analysis. The main advantage of the proposed model is its versatility, as it can be applied to the selection of computer-aided design software systems when the qualitative attributes are used for the evaluation of the system.

Keywords: Engineering graphics, CAD, AHP

1. Introduction

The development of information technology provides the opportunity to develop increasingly advanced computer-aided design (CAD) software systems that are not only suitable for professional use but also easy to understand and access in the study process. The variety of software programmes raises the question of how to select the right programme to meet the user requirements and what factors to consider. In the analysed sources, a universal methodology that would allow comparing various selection criteria for evaluating computer-aided design software systems has not been identified. The importance of the evaluation criteria varies according to the needs of the users: for some, the most important aspect is programme‘s accessibility, others stress its simplicity, yet others- its functionality. In the light of changes in the market, it is desirable that innovative solutions are implemented in software. It is therefore quite difficult to establish a universal methodology for evaluating automated design systems against all the desired criteria.

One of the most used groups of methods for solving choice problems is multi-criteria decision-making methods (MCDM). There are several studies that apply MCDM to the selection of computer programs. Zaidan et al. (2015) proposed a methodology for selecting the OS-EMR software package based on MCDM methods. The software was evaluated based on quantitative and qualitative attributes, i.e., the authors applied the method AHP (*Analytic Hierarchy Process*) (Saaty, 1980) in combination with the quantitative multi-criteria evaluation methods WSM (*Weighted Sum Model*) (Fishburn, 1967), WPM (Weighted Product Method) (Triantaphyllou, 2000), SAW (Simple Additive Weighting) (MacCrimmon, 1968), HAW (Hierarchical Adaptive Weighting) (Zaidan et al., 2015) and TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) method which was developed by (Hwang and Yoon , 1981). Puska et al. (2020) conducted a study to evaluate and select the best project management programme. For this purpose, the authors applied the MARCOS multi-criteria decision-making method. However, this paper did not test the consistency of the experts' judgements using expert survey data. Dorado et al. (2011) proposed the use of the analytic hierarchy process (AHP) method for the selection of computer software for Engineering Education, which was used to rank software for thermal engineering simulations. The authors used the AHP method to select the criteria, their weights and to evaluate the alternatives, based on their own experience of jointly completing the pairwise comparison matrices, but without assessing the consistency of the peer opinions. Considering the use of multi-criteria methods in software ranking and selection tasks, it can be argued that these methods are suitable for the evaluation of graphical engineering computer-aided design software systems, including both quantitative and qualitative attributes.

Technical education is one of the key factors in the evolution of humanity, covering a wide range of knowledge areas (Franc, 2016). In the preparation of future technical professionals in various fields, special attention must be paid to the teaching of engineering graphics. With the comprehensive modernisation of society and the rapid development of technology, there is an increasing influence of technology in the teaching of engineering graphics, with the greater use of computer-based three-dimensional modelling and active learning (Erro, 2022; Cabi, 2018; Klerk et al., 2019). Volumetric model visualisation not only helps to better visualise the analysed object and perform the required engineering graphics task, but also motivates the student to engage more actively in the learning process (Droessiger and Vdovinskiene, 2020).

There are now a number of computer-aided design software systems available for the production of drawings. The choice of these depends mainly on the specifics of the drawings. Each educational establishment provides its own tasks for each subject, reflecting the chosen profession. In the case of engineering graphics, the focus of students in the construction specialities is on the drawing of the construction object, while one of the most important tasks for students in the mechanical specialities is to prepare a drawing of the assembly of the parts of a machine. Thus, for some, the most suitable programmes are those for two-dimensional drawings, while for others — those focused on volumetric models, construction drawings, etc.

Educational institutions and higher education institutions that train future engineers for various professions choose a computer-aided design software system based on a variety of criteria: the ability to perform tasks, accessibility, convenience of the tools, popularity, price, etc. The analysis of the choice of such computer systems did not reveal a method that would help in choosing the best one to meet the learning needs of engineering graphics, maximising the features of the computer systems and their accessibility.

In summary, the task of selecting computer-aided design software systems is relevant both for professional engineers and for the study process. The literature analysis has shown that evaluation of such systems is being carried out, but there is no universal evaluation methodology for it. The main objective of this paper is to propose a model for the selection and suitability of computer-aided design software systems for the preparation of a technical document, based on expert evaluation using the AHP method. To achieve this goal, a literature analysis of the evaluation of computer-aided graphic engineering software and the application of multi-criteria methods in this field was carried out; a model for the evaluation of CAD software was proposed; the proposed model was applied to a real case study of CAD software selection.

2. Aspects of software selection for teaching engineering graphics

In the era of modern technology and active integration of programming, people's mental capacities are gaining more and more weight, while at the same time, physical attributes have less and less influence on the progression of civilisation (Karimov et al., 2022). One of the most important proofs of competence for representatives of engineering professions is the mastery of computer programmes, which enables them to accurately and quickly make sense of the ideas of the projects being developed and implement them.

The use of computer software for modelling has been observed since around 1980 (Acosta-Zazueta et al, 2021). The literature on the use of CAD in teaching engineering graphics is extensive and its advantages are obvious (accuracy, scalability, representation of realistic materials, the CAD method in working drawings, fast and easy editing (Fakhry et al, 2021). *Solidworks*, *Fusion360* and *AutoCAD* are the most widely adopted according to the 2018 market results. *Onshape* is not among the top 10, although it is the first full cloud-based CAD platform. A comparison between *Solidworks* and Inventor shows that they do not differ much in terms of tool features, user environment, accessibility (Magomedov et al, 2021). There are studies identifying the applicability of individual computer programmes to specific engineering domains (Acosta-Zazueta et al, 2021). The computer-aided design software systems *Fusion 360* and *Onshape*, which are more suitable for mechanical engineering tasks, have been compared based on criteria most important for the user. The main advantage of *Fusion 360*, albeit slight, was found to be its simplicity, while *Onshape* was found to be more suitable for modelling more complex objects (Gaha et al, 2021).

The choice of programmes depends on the tasks to be solved by the programmes and on the user's abilities (Muxammadqodirovna and Khusainova, 2021). For beginners, applications with a user-friendly and simple user environment are more suitable. For example, *Sketchup*, a freely available software, is offered for creating two-dimensional elements, but it does not allow to create more complex three-dimensional elements, as, for instance, AutoCAD does (Muxammadqodirovna and Khusainova, 2021).

The fundamental basis of engineering graphics is descriptive geometry. Understanding its theoretical underpinnings is believed to help you master the principles of a technical drawing. However, this is where the difficulties of solving problems in descriptive geometry arise. To ease them, it is advisable to visualise the tasks themselves with the help of certain computer programs that have simple tools for extracting three-dimensional elements from two-dimensions (Umataliev and Qozaqova, 2021).

Mechanical engineering professionals today cannot imagine their activities without the use of cloud skills in technological documentation (Rassovytska and Striuk, 2018). Therefore, when preparing future engineers in this field, the selection of computer-aided design software systems for engineering graphics depends on the software's relationship with the cloud system. As there are quite a lot of such applications nowadays, the most attractive criteria for the user (accessibility, functionality, ability to support other application formats) help determine their selection. The selection of such systems is based on a survey in which applications are evaluated on a ten-point scale (Rassovytska and Striuk, 2018).

In mechanical drawing, the analysis of the movement of parts in the assembly is important. The choice of CAD systems is therefore determined by the efficient and fast simulation or representation of motion. A comparison of the most popular AutoCAD and SolidWorks software on the market has been carried out by analysing the volumetric simulation and motion features and the speed of task execution (Patpatiya, 2022).

An ecological crisis has been in the centre of attention in the last decades. When creating a product, designer should consider the use of eco-friendly materials or design the product with as little material as possible without weakening it. Therefore, one of the criteria for selecting modelling software is the possibility of reworking an existing product with the simplest possible commands. In this case, it is convenient to use the computer-aided design software system CATIA (Haraga, 2013), which has an extensive library of eco-friendly materials and can easily produce realistic models.

Currently, there are many computer systems available for both two-dimensional drafting and volumetric modelling with a wide range of features, and the choice is usually driven by cost and availability, the number of users, and the ease and speed of training professionals (Łukaszewicz et al, 2018).

To be understood by the individual project participants, their product must be done properly, beyond any doubt, according to the requirements set for it. Basics rules for technical drawing are presented in national standards. They explain not only how to display a drawing so that its geometrical form is clear, but also so that dimensions and other notations do not mislead interested parties (Puodziūnienė and Narvydas, 2021). Therefore, when choosing a computer-aided design software system, it is important to pay attention to its ability to be set in accordance with ISO standards.

The literature review showed that the evaluation of computer-aided design software systems is carried out based on a number of attributes chosen by the evaluator. It has been observed that in many cases the sets of attributes chosen vary, suggesting that there is no universal evaluation methodology for the selection of CAD.

3. Methodology - CAD systems selection model

3.1. Expert evaluation

In order to select the most relevant attributes for the CAD systems assessment, a group of experts is organised to participate in the development of a set of attributes, and to rank them. One of the main requirements of expert evaluation is the compatibility of the experts' views.

The compatibility of the experts' judgements is examined calculating the concordance coefficient *W*, which is described by M. Kendall (1970):

$$W = \frac{12S}{r^2(m^3 - m)}, \quad (1)$$

here $S-$ the deviation of the sum of the attribute ranks from the overall mean of the ranks, sum of squares, r - number of experts, m - number of attributes. The value of the concordance coefficient can be determined by criterion, which is calculated by formula (Kendall, 1970):

$$\chi^2 = Wr(m-1). \quad (2)$$

Calculated χ^2 criterion value is compared with $\chi^2_{\alpha,\upsilon}$ value of distribution, in terms of significance level α (α = 0.05) and $\upsilon = m - 1$ degrees of freedom. In the case where $\chi^2 > \chi^2_{\alpha,\upsilon}$ it can be said that the concordance of experts' judgements is sufficient, in other cases — it is not sufficient (Podvezko, 2007).

In the case of sufficient agreement between experts, the significance of the attributes is calculated according to the principles set out in Beshelev and Gurvich (1974). The ranks given by the experts are written into a rank matrix. Weights of attributes $q_i, (i = \overline{1,m})$ are calculated according to the formula (Beshelev and Gurvich, 1974):

$$q_i = \frac{\sum_{k=1}^{r} \hat{c}_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{r} \hat{c}_{ik}}, \quad (3)$$

here $\hat{c}_{ik} = m + 1 - c_{ik}$, $(i = \overline{1,m}; \mathrm{k} = \overline{1,r})$, where c_{ik} is the rank of *the -i-th* attribute, as indicated by the *k-th* expert.

3.2. AHP method

For the evaluation of computer drawing programs (CAD), in relation to expert evaluation, it was chosen to use the Analytical Hierarchical Process (AHP) method, developed by T. Saaty (1980). The basis of the AHP method involves the estimation of priority weights $w_i\,(i = \overline{1,m})$ of a set of m attributes or alternatives using a square matrix of pairwise comparisons $A = [a_{ij}], (i, j = \overline{1, m})$. If the paired comparison judgment is perfectly consistent it is reciprocal, i.e., $a_{ij} = 1/a_{ji}, (i, j = \overline{1, m})$.

The weight of *i-th* attribute, or *i-th* alternative w_i is obtained by (Saaty, 1980):

$$w_i = a_{ij} / \sum_{j=1}^{m} a_{ij}, (i = \overline{1, m}). \quad (4)$$

Pairwise comparison matrices are completed in the following way: the attribute in the row is compared with the attributes in the column. If the attribute in the row is more important than the attribute in the column, an integer is entered to indicate the level of importance. If the attribute in the row is less important than the attribute in the column, the reverse number is written in the questionnaire box. The importance of the attribute is measured numerically according to the T. Saaty scale (Table 1).

Table 1. A scale of importance and its description (Saaty, 1980)

Level of importance	Definition
1	Attributes of equal importance
3	One attribute is slightly more important than another
5	One attribute is more important than another
7	One attribute is significantly more important than another
9	One attribute is incomparably more important than another
2, 4, 6, 8	Intermediate values

In order to avoid inconsistency of the pairwise matrix, each pairwise matrix has to be checked for compatibility using the eigenvalue method. The consistency index (*CI*) has been calculated for each pairwise matrix by formula (Saaty, 1980):

$$CI = \frac{\lambda_{max} - m}{m - 1}, \quad (5)$$

where *m* is the order of the pairwise comparison matrix *A*, λ_{max} – the largest eigenvalue of the pairwise matrix. Consistency ratio (*CR*) of the pairwise matrix is calculated by formula (Saaty, 1980):

$$CR = \frac{CI}{RI}. \quad (6)$$

However, if the research involves *r* experts who fill in *m* pairwise comparison matrices, then the consistency ratio for each pairwise comparison matrix will be calculated using formula (6) described by T. Saaty (1980) and adopted by authors:

$$CR_{ik} = \frac{CI_{ik}}{RI}, \qquad (i = \overline{1,m};\ k = \overline{1,r}) \qquad (7)$$

where CI_{ik} is the calculated consistency index of the matrix of *k-th* expert according to *i-th* attribute, *RI* is the average random index which values given in Table 2, according to the order of the pairwise comparison matrix.

Table 2. The values of a random consistency index (*RI*) (Adapted from Saaty, 1980)

n	3	4	5	6	7	8	9	10	11
RI	0,58	0,9	1,12	0,24	1,32	1,41	1,45	1,49	1,51

The pairwise comparison matrix will pass the consistency test, if the $CR < 0{,}1$, otherwise, the matrix *A* needs to be revised.

3.3. The proposed model

A universal model for CAD assessment and selection is proposed, which is based on expert evaluations and the AHP method. The model includes the construction of a set of attributes, the weighting of the attributes, the examination of the compatibility of the experts' judgements, and the evaluation of the alternatives under consideration. The algorithm of the proposed model is presented below (Fig. 1).

The detailed steps of the evaluations and selection the algorithm of CAD systems are the following:

The CAD evaluations and selection problem is formulated; alternatives under consideration are set $\{A_t\}, (t = 1, T)$ and a group of experts is arranged $\{E_k\}$, $(k = \overline{1,r})$. Possible alternatives are the CAD programmes to be evaluated.

1. The panel of experts puts together a possible set of evaluation attributes $\{M_i\}$ and rank them. This produces a matrix of attributes ranks for each expert $C = [c_{ik}], (i = \overline{1,m}, k = \overline{1,r})$.
2. Examining the compatibility of the experts' views. If the consistency of the experts' views is not sufficient, the criteria for selecting the experts must be reconsidered and a new group of experts must be established. If the experts' judgements are in agreement, then the weights of the attributes are calculated $q_i, (i = \overline{1,m})$ and a selection of the most dominant attributes m_1 is made.
3. Each expert receives m_1 pairwise comparison matrices to assess the alternatives under consideration against a selection of attributes.
4. The compatibility of each pairwise comparison matrix is checked by calculating a compatibility index $CR_{ik}, (i = \overline{1,m_1};\ k = \overline{1,r})$.
5. If the pairwise comparison matrix does not align, the experts are re-interviewed. If the pairwise comparison matrix align, then a final assessment of the alternatives is carried out using the AHP method.
6. By the AHP method, the alternatives are ranked and the values of the ranks, according to each expert's assessment, are tabulated to check the consistency of the experts' views on the ranking of the alternatives considered.

7. In the case where the experts are in agreement, formula (3) is used for the final assessment of the alternatives. Based on the estimates obtained for the alternatives, the alternatives are ranked.

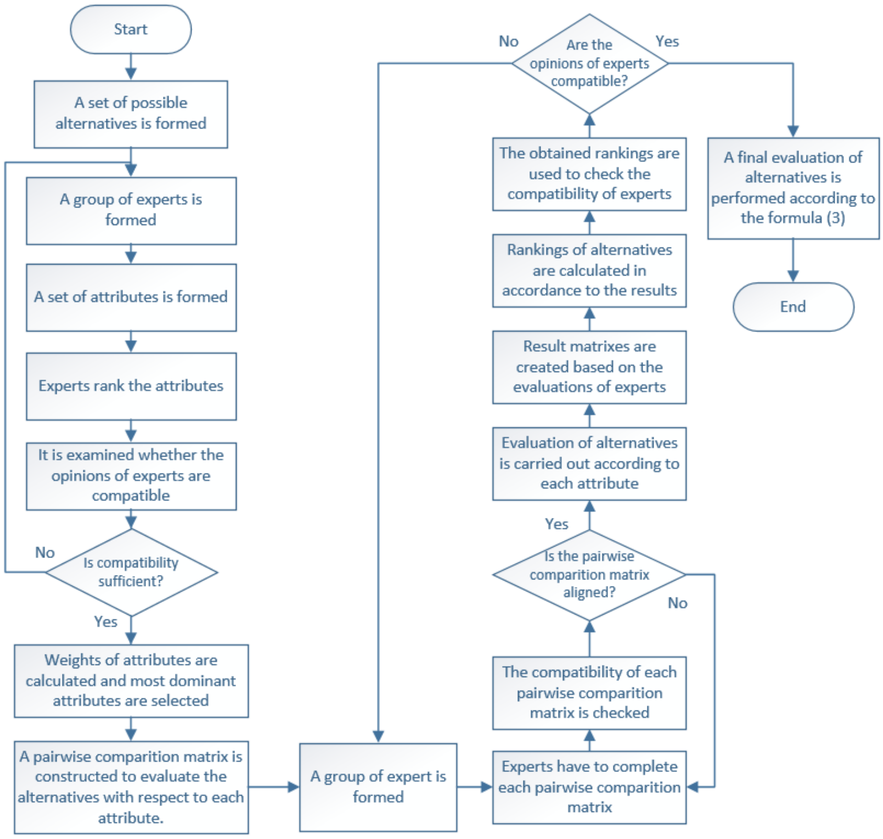

Figure 1. Algorithm for CAD system evaluation and model selection

4. Case study

To optimally select a computer-aided design software system for learning engineering graphics, it is necessary to find one that is suitable for all the factors that characterise it. This requires a method that considers the many qualitative requirements that cannot be measured on a numerical scale. The AHP method is proposed for this purpose, the essence of which is to ensure the best choice by evaluating a selection of criteria selected by experts, before assigning a weighting to each of them. The AHP (Analytical Hierarchy Process) is a decision-making method that allows the selection of the highest-ranked criteria for computer applications and the consistency of the expert judgements.

The selected experts are members of The Lithuanian Society for Engineering Graphics and Geometry (LIGGD, www.liggd.lt), an association of representatives of various educational institutions in Lithuania, who have experience in the application of computer applications in engineering graphics teaching.

The experts evaluated the most popular computer-aided design software systems currently taught in Lithuanian gymnasiums, training centres and higher education institutions:

- *AutoCAD* is a computer-aided design software system developed by Autodesk, still the market leader in automated design, used for preparing design documentation and modelling complex two- and three-dimensional structures.
- *SolidWorks*, developed by Dassault Systemes Corporation, is a parametric, automated mechanical object design package based on object orientation methodology, intended for the design of solid objects.
- *Fusion360* is a cloud-based computer-aided design software system developed by Autodesk.
- *Onshape* is one of the newer computer-aided design software systems developed by a US corporation and used exclusively online.

Table 3. Weights and ranks for the attributes

Attributes	Weight	Rank
X1 – availability of computer software	0,104	1
X2 – user friendliness	0,102	2
X3 – availability of teaching materials	0,059	9
X4 – sketch creation and editing	0,061	8
X5 – selecting line widths	0,073	6
X6 – dimensioning	0,074	5
X7 – creating and editing a volumetric model	0,082	3
X8 – getting projections from a model	0,077	4
X9 – presentation of the cut line	0,046	12
X10 – drawing a half-section	0,046	13
X11 – selecting or drawing threads	0,034	15,5
X12 – support for other formats	0,066	7
X1 3– writing text	0,034	15,5
X14 – cloud support	0,047	11
X15 – rendering of realistic materials	0,050	10
X16 – uploading and editing images	0,046	14

First, we include four objects in the set of alternatives, i.e., the four computer graphics applications described above. The second step is to create a set of attributes against which the alternatives will be assessed. The panel of 7 experts selected 16 key attributes, considering the tasks contained in the learning modules and the availability of the applications. The experts ranked these attributes, giving the most important one a rank of 1 and the least important one– a rank of 16. Using the resulting rank values, the experts' views on the importance of the attributes were initially checked for consistency. Result was $\chi^2 = 74{,}2805$, significantly higher than $\chi^2_{0{,}05{,}15} = 24{,}9958$, and therefore the consistency of the experts' judgements is considered sufficient ($\alpha = 0{,}05$).

Based on the data in Table 3, the 6 most dominant attributes were selected and their weights were recalculated according to the original weight values (Table 4).

Table 4. Attributes selected for the study and their weights

Attributes	New weights
X1 – availability of computer software	0,202
X2 – user friendliness	0,199
X5 – selecting line widths	0,143
X6 – dimensioning	0,144
X7 – creating and editing a volumetric model	0,161
X8 – getting projections from a model	0,151

Each expert had to fill in 6 pairwise comparison matrices for all 6 attributes. For example, the pairwise comparison matrix (Table 5) below shows one of the experts' relative evaluations of the applications on one of the selected criteria X1 – availability of computer software.

Table 5. Pairwise comparison matrix completed by the first expert

According to X_1	AUTOCAD	SOLIDWORKS	FUSION360	ONSHAPE
AUTOCAD	1	3	1	1/3
SOLIDWORKS	1/3	1	1/3	1/3
FUSION 360	1	3	1	1/3
ONSHAPE	3	3	3	1

The steps of the model must be followed to assess the consistency of each pairwise comparison matrix in the calculation of the *CR* according to (3). For the matrix presented, the following is obtained:

$$CR_{11} = \frac{CI_{11}}{RI} = \frac{0{,}053}{0{,}9} = 0{,}059 < 0{,}1. \quad (8)$$

The pairwise comparison matrix in question is consistent because $CR_{11} < 0{,}1$.

The aim of the study was to ensure that all pairwise comparison matrices were aligned. In case of incompatibility, the experts were re-interviewed and the resulting matrix was again checked for compatibility. Once all the experts and all the matrices were compatible, the weights and ranks of the alternatives considered were calculated for each attribute separately. The resulting values were used to construct the decision matrix (Table 6). For example, the decision matrix below is based on the results of the first expert's evaluation.

Table 6. Decision matrix based on the results of the first expert assessment

Alternative	X1	X2	X5	X6	X7	X8	Priorities	Rank
AUTOCAD	0,210	0,099	0,558	0,578	0,090	0,082	**0,252**	**2**
SOLIDWORKS	0,098	0,210	0,263	0,295	0,201	0,449	**0,242**	**3**
FUSION360	0,210	0,345	0,122	0,079	0,354	0,235	**0,232**	**4**
ONSHAPE	0,481	0,345	0,057	0,048	0,354	0,235	**0,273**	**1**

Column *Priorities* shows the estimates of the alternatives obtained by applying formula (4), based on which the alternatives are ranked. *Onshape* has the highest priority value and is therefore ranked 1. The worst-ranked alternative is *Fusion360*.

The final stage of the study is devoted to checking the consistency of the experts'. This is done using the rank values obtained from the evaluations of the alternatives based on each expert's evaluation data. A table of ranks is given below (Table 7).

Table 7. Ranking of alternatives by experts

Rank	Alternative	E1	E2	E3	E4	E5	E6	E7
3	AUTOCAD	2	2	4	3	4	1	4
2	SOLIDWORKS	3	1	1	2	2	3	2
4	FUSION360	4	3,5	3	4	3	4	3
1	ONSHAPE	1	3,5	2	1	1	2	1

Using the resulting rank values, the consistency of the experts' views on the evaluation of the alternatives is checked. Retrieved $\chi^2 = 8{,}8714$ is significantly higher than $\chi^2_{0{,}05{,}3} = 7{,}815$, and therefore the consistency of the expert judgements is considered sufficient ($\alpha = 0{,}05$).

For the final evaluation of the alternatives, formula (3) is applied, the results of which are shown in (Fig. 2).

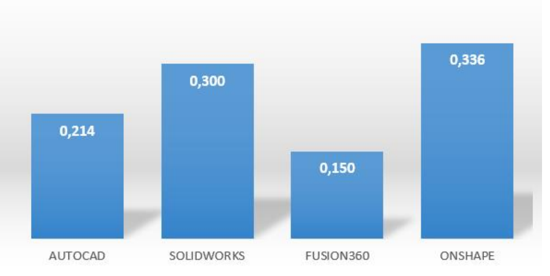

Figure 2. Priorities of alternatives

The proposed model found that *Onshape* was the best alternative, followed by *SolidWorks* in second place, *AutoCad* in third place and *Fusion360* in fourth place.

5. Conclusions

As the literature review found, there is no methodology for the evaluation and selection of computer-aided design software systems. This paper proposes a universal methodology for evaluating and selecting the suitability of a computer-aided design software system. The literature review found that the main attributes for such systems are qualitative, and therefore it is necessary to perform expert evaluation and apply a multicriteria decision making method suitable for qualitative attributes when developing the evaluation model. For this purpose, the AHP method was chosen.

Using the proposed evaluation model, four computer-aided design (CAD) systems - *AutoCad*, *Onshape*, *SolidWorks* and *Fusion360* – were evaluated. The results of the evaluation showed that *Onshape* was the dominant software in the assessment by the expert group.

The proposed evaluation model can be applied to the evaluation of a wide range of computer applications, as experts in the field are selected for the evaluation process. The model provides for an examination of the consistency of the experts' views. Qualitative attributes can be used to evaluate the alternatives.

References

Acosta-Zazueta, G., Alcaide-Marzal, J., Diego-Más J. A. (2021). Generative design software and different approaches, *Proceedings of DARCH 2021 1st International Conference on Architecture & Design,* 101–108.

Beshelev, S. D., Gurvich, F. G. (1974). *Mathematical and statistical methods of expert assessments* (Russian), Statistika, Moscow.

Cabi, E. (2018). The Impact of the Flipped Classroom Model on Students' Academic Achievement, *International Review of Research in Open and Distributed Learning* **19**(3), 202−221.

Dorado, R., Gómez-Moreno, A., Torres-Jiménez, E., López-Alba, E. (2014). An AHP application to select software for engineering education, *Computer Applications in Engineering Education* **22**(2), 200–208.

Droessiger, G., Vdovinskienė, S. (2020). Factors for increasing motivation to theory class attendance among students of technology studies, *Integration of Education* **24**(1), 50–61.

Erro, A. M., Menéndez-Pidal, S. N., Díaz-Obregón, C. R., Suz, A. A. (2022). A framework for visual literacy competences in engineering education, Journal of Visual Literacy 44(2), 132−152.

Fakhry, M., Kamel, I., Abdelaal, A. (2021). CAD using preference compared to hand drafting in architectural working drawings coursework, *Ain Shams Engineering Journal* **12** (2021), 3331–3338.

Fishburn, P. C. (1967). Additive Utilities with Incomplete Product Set: Applications to Priorities and Assignments. *Journal of the Operations Research Society of America*. doi:10.1287/opre.15.3.537.

Franc, M. (2016). The Dimensions of Creativity in Technical Education, *Integration of Education* **20**(2), 245–253.

Gaha, R., Nicolet, P., Bricogne, M., Eynard, B. (2021). Teaching Experiments for Engineering Education Based on Cloud Cad Software, *Proceedings of the International Conference on Engineering Design (ICED21)*, 2951–2960.
Haraga, G. (2013). Modeling Eco-Friendly Products in CAD Systems, *Transactions on hydrotechnics* **58**(72), 45–48.
Karimov, B. Yu., Muxsiddinov, J. R., Ergashev, I. X. (2022). Prospects for studying 3d modelling programs in mechanical engineering. *Asia Pacific Journal of Marketing & Management Review* **11**(6), 64–65.
Kendall, M. (1970). *Rank correlation methods*, Griffin, London.
de Klerk, R., Duarte, A. M., Medeiros, D. P., Duarte, J. P., Jorge, J., Lopes, D. S. (2019). Usability Studies on Building Early Stage Architectural Models in Virtual Reality, *Automation in Construction* **103**(2019**)**, 104–116.
Łukaszewicz, A., Skorulski, G., Szczebiot, R. (2018). Main aspects of training in the field of computer aided techniques (CAx) in mechanical engineering, *Engineering for rural development*, 865–870.
MacCrimmon, K. R. (1968). *Decision making among multiple-attribute alternatives: a survey and consolidated approach.* Rand Corporation, Santa Monica California.
Magomedov, A., Bagov, A. M., Elmurzaev, A. A. (2021). Comparative analysis of CAD software packages for engineering design, *IOP Conf. Series: Materials Science and Engineering* **1155**(2021), doi:10.1088/1757-899X/1155/1/012083
Muxammadqodirovna, Y., Khusainova, Z. (2021). Improvement of 3d graphics technologies in computer modeling studies, *American Journal of Interdisciplinary Research and Development* **5**(2022), 310–312.
Patpatiya, P. (2022). A Comparative Motion Study of Mated Gears on AutoCAD and SOLIDWORKS, *Advances in Augmented Reality and Virtual Reality. Studies in Computational Intelligence* **998**, 57–72.
Podvezko, V. (2007). Determining the level of agreement of expert estimates, *International Journal of Management and Decision Making* **8**(5–6), 586–600.
Puodziuniene, N., Narvydas, E. (2021). Standards for Transition from 2D Drawing to Model Based Definition in Mechanical Engineering, *Mechanika* **27**(4), 351−354.
Puska, A., Stojanović, I., Maksimović, A., Osmanović, N. (2020). Evaluation software of project management used measurement of alternatives and ranking according to compromise solution (MARCOS) method, *Operational Research in Engineering Sciences: Theory and Applications* **3**(1), 89–102.
Rassovytska, M., Striuk, A. (2018). Mechanical Engineers' Training in Using Cloud and Mobile Services in Professional Activity, *CEUR Workshop Proceedings* **1844**(2017), 348–359.
Saaty, T. L. (1980). *The Analytic Hierarchy Process*, M. GrawHill, New York.
Triantaphyllou, E. (2000). *Multi-Criteria Decision Making: A Comparative Study.* Dordrecht, The Netherlands: Kluwer Academic Publishers. p. 320.
Umataliev, M. A., Qozaqova M. S. (2021). Methods of Using Graphic Programs in the Lessons of Descriptive Geometry. *International Journal of Discoveries and Innovations in Applied Sciences* (1)6, 149–152.
Zaidan, A. A., Zaidan, B. B., Hussain, M., Haiqi, A., Kiah, M. M., Abdulnabi, M. (2015). Multi-Criteria Analysis for OS-EMR Software Selection Problem: A Comparative Study, *Decision Support Systems* **78**, 15–27.

Received January 28, 2023, revised April 11, 2023, accepted May 15, 2023