Digital Transformation and the Role of the CIO in Decision Making: A Comparison of Two Modelling Approaches

Daniela Borissova[1,2(✉)], Zornitsa Dimitrova[1], Vasil Dimitrov[1], Radoslav Yoshinov[3], and Naiden Naidenov[1]

[1] Institute of Information and Communication Technologies at the Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria
{daniela.borissova,zornitsa.dimitrova,vasil.dimitrov,naiden.naidenov}@iict.bas.bg
[2] University of Library Studies and Information Technologies, 1784 Sofia, Bulgaria
[3] Laboratory of Telematics at the Bulgarian Academy of Sciences, Sofia, Bulgaria
yoshinov@cc.bas.bg

Abstract. Digital transformation imposes to transform different business processes in order to improve their efficiency and bring organizational and operational innovations. In this regard, the role of the Chief Information Officer (CIO) becomes more important and required. It should be able to cope with different challenges related to decision-making under the lack of enough time or sometimes under uncertain conditions. To overcome such challenging situations some proper models should be used to make the right decisions. For the goal, the current article deals with the problem of group decision-making. The proposed two mathematical models are compared toward their suitability to be applied for evaluation and selection of collaborative software tools for remote working. The results show that both models based on group multi-criteria decision analysis may be used to aid the CIO in the analysis of complex problems considering different experts' opinions to make the decision-making process more transparent and objective when forming a final decision. Both models could be used not only for the selection of software tools for remote collaboration but also in cases of Internet provider selection, selection of vendor under public procurements, different software types selection, selection of conference location, etc.

Keywords: CIO · Digital transformation · Group decision-making · Mathematical models · Collaborative software tools

1 Introduction

Today the role of Chief Information Officer (CIO) is rapidly changing. This is due to not only the need for digital transformation but also due to innovation to create a more customer-centric approach is clear. CIO's dominant focus has been shown to have a direct and positive impact on corporate performance [1]. Recent research has shown that

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the responsibility of the CIO includes general and domain-specific demands to perform a digital transformation. The role of top management is essential for planning and to make significant success the CIO should provide motivated alternative decisions to cope with different challenges [2]. The CIO along with top managers should discuss the challenges and requirements toward the strategic IT innovations and select suitable and reliable IT-enabled software tools [3]. The role of CIO is to governance with multifunctional teams to combine different business aspects. To be competitive, any organization have to implement good practices and innovative IT [4]. In this way, the duties of the CIO can take on a wide range of responsibilities, which determines their important role in the organization [5]. The CIO along with chief information security officer (CISO) should make enough efforts to increase the level of network and information security. To realize reliable information security, the different methods of artificial intelligence in cyberspace could be used [6]. Special attention is needed to provide the requested cybersecurity for some critical information infrastructure [7]. The CIO with digital service team has to cope with cybersecurity policy at different levels [8].

CIO should be able to estimate the applicability of new technologies in the context of specifics hardware requirements and to determine the required short-term and long-term changes [9]. CIO should be able to propose suitable models for decision-making including group decision-making in cases of Internet provider selection, selection of vendor under public procurements, different software types selection, selection of conference location, etc. Gartner recommends evaluating the technology trends to identify the impact on people, businesses, and the IT estate [10]. Taking into account all of these and the current pandemic situation, the article aims to analyse some software tools to make possible collaboration between team members at distance. Due to the lack of sufficient time, these decisions should be well justified and based on some mathematical models. The current article aims to compare the suitability of the proposed group decision-making model for fast evaluation and selection of software tools for collaborative remote working described in [11] with a new group decision-making model based on extended simple additive weighting and combinatorial optimization.

The article is structured as follows: Sect. 2 describes the basic parameters of some widely used videoconferencing tools, learning management systems, and tools for project management; Sect. 3 contains a description of the two group decision-making modelling approaches for evaluation and selection; Sect. 4 describe the obtained numerical results and discuss the conducted comparison between two modelling approaches; while Sect. 5 summarizes the advantages and possible applications of the proposed group decision-making modelling approaches.

2 Software Tools for Remote Collaboration

In the age of digitalization, the use of various technological and business solutions, allowing remote access between members, is becoming more common today. This due to the increased level of network and information security involving different tools including artificial intelligence too [12]. We identify that a minimum of three software platforms is needed to motivate persons to stay at home and to continue collaborative work. These are videoconferencing, LMS and project management. Some new trends enable the home

to become a space for entrepreneurship [13]. This involves different software tools that make possible the remote real-time collaboration between teams located in different geographical regions [14]. In the context of the remote collaboration, the current article aims to determine three essential aspects of remote collaboration namely videoconferencing, e-learning, and project management tools. These collaborative software platforms are applicable for the business companies, universities and research organizations.

2.1 Software Tools for Videoconferencing

The latest achievements in ICT make it possible to change the communication patterns by using the videoconferencing tools [15]. The usage of such tools is constantly growing in the modern digital era. The videoconferencing tools are a part of business activities that allow establishing strong relationships providing accessibility, flexibility, and clear from participants' perceptions. These tools support business-to-business commitment and suppliers and customers and speed up the innovation in SMEs [16, 17]. Among the existing platforms for videoconferencing the current article investigates a restricted number of them. The main parameters of these videoconferencing tools used during the evaluation are given in Table 1.

Table 1. Videoconferencing tools' current parameters

Parameters	Zoom	Webex	Skype	Google Hangouts	UMeetin	Lifesize
Number of participants	100	100	50	25	25	25
HD video	Yes	--	Yes	--	--	--
HD audio	Yes	--	--	--	--	--
Screen sharing	Yes	Yes	Yes	Yes	--	Yes
Group chat	Yes	--	Yes	Yes	--	Yes
Video meeting recordings	Yes	Yes	Yes	Yes	--	--
Time duration limit per meeting	40 min	40 min	Unlimited	Unlimited	30 yesmin	24 h

Among the investigated freeware tolls for videoconferencing, the most critical criteria of these tools are the number of participants and the time duration of meetings. For example, some of them provide up to 100 users like Zoom and Webex, but the Google Hangouts, UMeetin, and Lifesize accommodate no more than 25 users. There exist also major differences between the time duration of meetings among the tools given – form 30 min to 24 h. Some additional parameters such as HD video, HD audio, screen sharing, group chat, and video recording could contribute to the meetings' effectiveness. Some of these parameters are not supported in the freeware versions and this makes the selection of a proper video conferencing tool complex including different quantitative and qualitative evaluation criteria.

2.2 Learning Management System Software

The learning management systems (LMS) are applicable in the field of education and business training due to their numerous advantages [18]. The improvement of the efficiency of online courses can benefit from personalized learning supporting [19]. This involves also an integration of gamification elements in the e-learning environment too [20]. The interactive multimedia e-learning system should allow customizing to reflect different aspects of problems of learning and training [21]. The use of an appropriate system for testing the acquired knowledge and skills is also required. For generating e-tests some aspects of intelligence involving gamification elements could be used [22, 23]. In the area of business, the LMSs are related to different training courses including cybersecurity education and training [24–26]. The latest versions of LMS with mobile applications is another circumstance that contributes to students' motivation incensement. The main parameters of some free and popular LMS are shown in Table 2.

Table 2. Learning management systems' current parameters

Parameters	Moodle	Chamilo	ILIAS	Forma LMS
SCORM 1.2	Yes	Yes	Yes	Yes
SCORM 2004	Yes	--	Yes	Yes
xAPI	Yes	--	--	--
Mobile application	Yes	Yes	--	--
Self-hosted cloud-based	Yes	Yes	--	--
Self-hosted system	Yes	Yes	--	Yes
SaaS/cloud	--	Yes	Yes	Yes
WordPress	--	Yes	--	Yes
Google calendar	--	Yes	--	Yes

All of the examined LMSs are compatible with Linux, Mac, and Windows plat-forms and are supported by browsers like Apple Safari, Google Chrome, Internet Explorer and Mozilla Firefox. The parameters related with supported standards are SCORM 1.2/2004 and xAPI. The parameters concerning the deployment are related to a mobile application, self-hosted, cloud-based, self-hosted system, and SaaS/cloud. It should notice, that cloud natives allow a better adaptation to the new normal. The parameters WordPress and calendar are focused on the possibility to integrate additional useful applications for the learning content visualization.

2.3 Software Platform to Support Project Management

The project management (PM) software provides a flexible solution by combining different sets of tools thus helping to achieve the goals by managing project activities, time, resources, and costs. Project management practices are diverse, as the projects are, which

involve a variety of partners like business and research organizations. Therefore, the best practices should be made following the particular project characteristics and partners to improve the performance [27]. The project management tool can prioritize the processes and progress tracking that contributes to proper resource distribution [28]. The collaboration between project team members allows files and knowledge sharing thus improve better project planning. In presence of multiple alternatives, a set of baseline schedules at the project planning phase could be used to simulate different disruption types [29]. The basic parameters of a predefined set for PM are given in Table 3.

Table 3. Project management tools current parameters

Parameters	Jira	Bitrix24	Infolio	GitHub
Collaborators limit	Up to 10	Up to 12	Unlimited	Unlimited
Storage limit	2 GB	5 GB	1 GB	0.5 GB
Custom workflow	Yes	Yes	Yes	--
Timeline tracking	Yes	Yes	--	--
Calendar	Yes	Yes	Yes	--
Chat	Yes	Yes	Yes	Yes
Portfolio manage	--	Yes	--	Yes
Gantt chart	--	Yes	--	--
Version control	--	--	--	Yes

All of the presented PM alternatives could be deployed and realized as software as a service (SaaS) including a mobile application interface. Except for the storage limit, collaborators, and chat, the rest of the parameters vary – to be present or no for all investigated alternatives (Table 3).

3 Group Decision-Making Models in Determination of Software Tools for Remote Collaboration

The expanding ICT today imposes to make business decisions at different levels and to consider multiple stakeholders [30]. To consider the different stakeholders' points of view toward the mentioned above alternatives, an expert group of decision-makers is to be formed. Each DM should determine coefficients for the importance of evaluation criteria to the given set of alternatives. In some cases, combined weighed criteria [31] could be used as additional coefficients given by CIO to express DMs competence.

3.1 Group Decision-Making Model for Fast Evaluation and Selection

In such way, the mathematical model for evaluation and selection of software tools for collaborative remote working could be expressed similarly to the classic SAW and

modified SAW [32]. Instead of evaluations scores usage, the proposed mathematical model (M-1) consider the parameters of software tools as variables [11]:

$$maxA_i = \sum_{e=1}^{E} \lambda^e \sum_{j=1}^{N} w_j^e p_{ij}, i = \{1, 2, \ldots, M\} \tag{1}$$

$$\sum_{j=1}^{N} w_j^e = 1 \tag{2}$$

$$\sum_{e=1}^{E} \lambda^e = 1 \tag{3}$$

where index $i = 1, \ldots, M$ is used to represent the number of alternatives; evaluation criteria are denoted by index $j = 1, \ldots, N$; parameters performance of *i-th* alternative in respect to the *j-th* criterion is expressed by p_{ij}; the coefficients expressing the importance of *j-th* criterion regard the *e-th* expert point of view are w_j^e; and weighted coefficients λ^e are express the importance of *e-th* expert' opinion.

The weighted coefficients w_j^e express the relative importance between evaluation criteria should comply the relation (2) and additional coefficients that make difference between the importance of group members' opinions λ^e are restricted within the range of [0, 1]. The alternatives performance represents the sum of the multiplication of parameter performance taking into account the experts' opinions by the relation (1). The most appropriate suitable alternative should have maximum performance.

3.2 Group Decision-Making Model for Evaluation and Simultaneous Selection of Several Software Tools for Remote Collaboration

The second modelling approach relies also on the SAW, but utility function includes an additional two types of coefficients. First of them represents binary integer variables for selection of the best alternative/s as an aggregated group decision, while the second type of coefficients expresses the importance of the expert' opinions. Taking into account these considerations, the selection of 3 collaborative software types could be done by the following group decision-making model with combinatorial optimization formulation (M-2) as follows:

$$max\left(\sum_{i}^{M} x_i \left(\sum_{e=1}^{E} \lambda^e A_i^e\right) + \sum_{s}^{S} y_s \left(\sum_{e=1}^{E} \lambda^e A_s^e\right) + \sum_{t}^{T} z_t \left(\sum_{e=1}^{E} \lambda^e A_t^e\right)\right) \tag{4}$$

subject to

$$\forall i = 1, 2, \ldots, M : (\forall e = 1, 2, \ldots, E : A_i^e = \sum_{j}^{N} w_j^e a_{i,j}^e) \tag{5}$$

$$\forall s = 1, 2, \ldots, S : (\forall e = 1, 2, \ldots, E : A_s^e = \sum_{p}^{P} w_p^e a_{s,p}^e) \tag{6}$$

$$\forall t = 1, 2, \ldots, T : (\forall e = 1, 2, \ldots, E : A_t^e = \sum_{q}^{Q} w_q^e a_{t,q}^e) \tag{7}$$

$$\sum_{i=1}^{M} x_i = 1, x_i \in \{0, 1\} \tag{8}$$

$$\sum_{s=1}^{S} y_s = 1, y_s \in \{0, 1\} \tag{9}$$

$$\sum_{t=1}^{T} z_t = 1, z_t \in \{0, 1\} \tag{10}$$

$$\sum_{j=1}^{N} w_j^e = 1 \tag{11}$$

$$\sum_{p=1}^{P} w_p^e = 1 \tag{12}$$

$$\sum_{q=1}^{Q} w_q^e = 1 \tag{13}$$

$$\sum_{e=1}^{E} \lambda^e = 1 \tag{14}$$

where A_i^e express the aggregated assessment of the *i*-th alternative against all criteria considering the point of view of the *e*-th expert, and respectively for the next two selection types A_s^e and A_t^e, while $a_{i,j}^e$ denotes the evaluation score from *e-th* expert for *i-th* alternative toward *j-th* criterion and the evaluation scores for the rest next two selection types are respectively $a_{s,p}^e$ and $a_{t,q}^e$. The relations (8)–(10) guarantee the only one selection from each software type and are based on three types of binary integer variables for each software type. The weighted coefficients representing the importance of criteria for different groups of selection are expressed by the equalities (11)–(13). The last Eq. (14) shows that the sum of weighted coefficients for experts' opinions importance should be exactly equal to 1.

The advantage of this modelling approach is the fact that the optimal group decision about the selected alternative for all three types of collaborative tools is determining as a single run of the optimization task. This is due to the used binary integer variables x_i, y_s, z_t, that make the formulated model a combinatorial one.

4 Numerical Application

The inputs from Table 1, Table 2, and Table 3 are used to compare the applicability of the proposed two group decision-making models when selecting software tools for collaboration remotely. These software tools are evaluated by a formed group that involves CIO (E-1), IT (E-2), and an expert from a digital service team (E-3). Evaluation of the VCT, LMS, and PM is done by using of same evaluation criteria for both models, and by using the same weighted coefficients that express the relative importance between criteria for the alternatives evaluation.

4.1 Evaluation of Collaborative Software Tools by Group of Experts

To get a group decision, each expert should determine corresponding weighted coefficients that express the relative importance between evaluation criteria (parameters) of videoconferencing tools. These weighted coefficients are given in the first 3 rows of Table 4, while the rest rows contain the evaluation scores for each alternative toward evaluation criteria.

Table 4. Weighted coefficients for the evaluation criteria and scores for the alternatives of videoconferencing tools from a group of 3 experts

Experts & alternatives	Number of participants	HD video	HD audio	Screen sharing	Group chat	Video meeting recordings	Time duration limit per meeting
	w_1	w_2	w_3	w_4	w_5	w_6	w_7
E-1	0.2	0.08	0.07	0.13	0.05	0.15	0.32
E-2	0.1	0.13	0.18	0.15	0.07	0.15	0.22
E-3	0.13	0.1	0.2	0.19	0.1	0.08	0.2
A-1	0.78	0.91	0.93	0.98	0.79	0.69	0.19
A-2	0.65	0.12	0.15	0.92	0.21	0.70	0.08
A-3	0.50	0.89	0.12	0.95	0.81	0.66	0.97
A-4	0.25	0.11	0.19	0.90	0.73	0.62	0.94
A-5	0.25	0.09	0.07	0.02	0.31	0.11	0.06
A-6	0.25	0.05	0.10	0.89	0.84	0.13	0.81

For the first modelling approach (1)–(3) the normalizing is within the range between 0 and 1, where 1 means present of a feature and 0 in the opposite situation [11]. The supported maximum participants' number is chosen to be equal to 1 and the same is valid for the videoconferencing time duration expressed by "unlimited". The other existing values are normalized proportionally.

The weighted coefficients for the relative importance between criteria determined from group members' along with evaluation scores for the alternatives in respect to the evaluations criteria about the LMS are shown in Table 5.

Table 5. Weighted coefficients for the criteria and evaluation scores for the LMS alternatives from a group of 3 experts

Experts & alternatives	Supported specifications					Deployment			
	SCORM 1.2	SCORM 2004	xAPI	Mobile application	Self-hosted cloud-based	Self-hosted system	SaaS/cloud	Word-press	Google Calendar
	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9
E-1	0.08	0.15	0.16	0.12	0.09	0.13	0.07	0.10	0.10
E-2	0.07	0.13	0.17	0.11	0.08	0.20	0.10	0.08	0.06
E-3	0.07	0.10	0.05	0.10	0.13	0.15	0.10	0.10	0.20
A-1	0.88	0.94	0.94	0.86	0.95	0.92	0.15	0.72	0.13
A-2	0.84	0.17	0.27	0.90	0.88	0.90	0.92	0.89	0.92
A-3	0.91	0.79	0.25	0.42	0.25	0.21	0.88	0.15	0.09
A-4	0.92	0.88	0.23	0.18	0.31	0.88	0.91	0.75	0.69

For the first modelling approach (1)–(3), the normalizing is simple and uses 0 for absence and 1 for the presence of the corresponding LMS feature.

The determined from the experts weighted coefficients for the relative importance between criteria along with evaluation scores for the alternatives concerning the criteria for the PM are shown in Table 6.

Table 6. Weighted coefficients for the evaluation criteria and scores for the alternative of PM tools from a group of 3 experts

Experts & alternatives	Collaborators limit	Storage limit	Custom workflow	Timeline tracking	Calendar	Chat	Portfolio manage	Gantt chart	Version control
	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9
E-1	0.09	0.1	0.05	0.18	0.19	0.05	0.1	0.11	0.13
E-2	0.18	0.09	0.07	0.07	0.07	0.1	0.02	0.13	0.27
E-3	0.12	0.1	0.17	0.14	0.17	0.06	0.02	0.11	0.11
A-1	0.1	0.4	0.83	0.93	0.79	0.76	0.2	0.14	0.25
A-2	0.12	0.9	0.92	0.88	0.84	0.86	0.93	0.98	0.12
A-3	0.95	0.2	0.87	0.23	0.91	0.72	0.17	0.11	0.19
A-4	0.98	0.1	0.12	0.21	0.11	0.92	0.88	0.09	0.99

For the first modelling approach (1)–(3), the normalization is also within the range between 0 and 1 and express the presence or not of parameters except the parameters for the collaborators limit and storage limit. The unlimited of collaborators limit is considered equal to 1, while the maximum storage limit (5 GB) takes the value of 1, and the rest are proportionally calculated.

4.2 Comparison Between Group Decision-Making Approaches

The obtained results for the selected combination of VCT, LMS, and PM by using both approaches along with the coefficients for the experts' opinions importance under three scenarios are shown in Table 7.

Table 7. Group decision for the selected combination of VCT, LMS, and PM under three scenarios for the importance of experts' opinions

	E-1	E-2	E-3	Model M-1			Model M-2		
				VCT	LMS	PM	VCT	LMS	PM
Case-1	0.33	0.33	0.34	A-3	A-2	A-2	A-3	A-1	A-2
Case-2	0.20	0.35	0.45	A-1	A-2	A-2	A-1	A-2	A-2
Case-3	0.50	0.40	0.10	A-3	A-1	A-2	A-3	A-1	A-2

The Case-1 represents the scenario where experts' opinions are with equal importance; the Case-2 illustrate scenario with the most important opinion of the expert E-3, followed by E-2 and E-1, while Case-3 emphasises on the opinion of the expert E-1 closely followed by E-2 and then E-3.

The empirical comparison of the results when using model M-1 and M-2 under the same coefficients for the criteria importance w_j^e, along with the evaluation of the parameters for VCT, LMS, and PM from Table 4, Table 5, and Table 6 are graphically illustrated in Fig. 1.

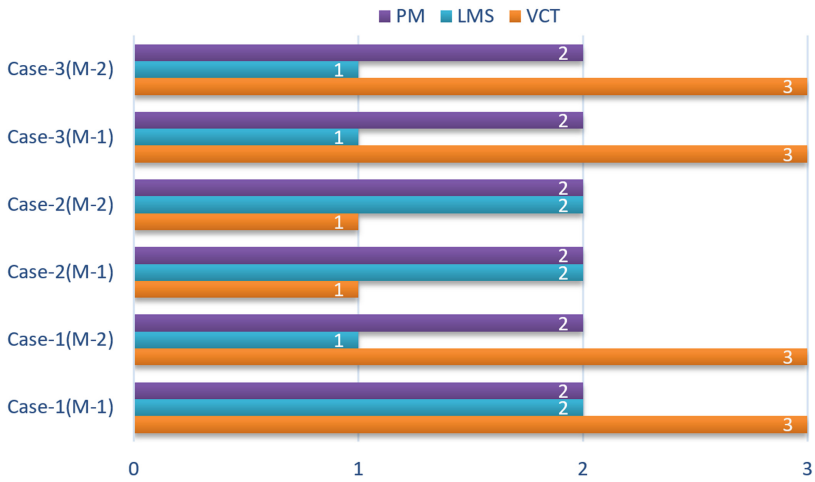

Fig. 1. Comparison of the results from two group decision-making models

When all experts take part with equal importance (Case-1) to form the final group decision, the selection of VCT is the same for both mathematical models. In Case-1

the selection of PM determines also identical results and decisions from both models recommend selecting the alternative A-2 (Bitrix24). Determination of the most suitable LMS via two models shows different solutions for Case-1 (Fig. 1). The usage of model M-1 that is suitable for fast evaluation by group decision-making determine as preferable alternative A-2 (Chamilo) for LMS. In contrast to model M-1, the M-2 model is a more precisely formulated group decision-making model for evaluation and selection via combinatorial optimization. The obtained solution using model M-2 for Case-1 determines as the most preferable selection alternative A-1 (Moodle) for LMS. This difference is due to the more informed evaluations based not only on the presence or not of the functional features but including the evaluation score for their particular alternative's performance versus given criteria.

In Case-2 and Case-3, where the experts' opinions are considered with different importance in the final group decision, both models show that identical results. Considering the experts' importance expressed by Case-2, the selected alternative for VCT is A-1 (Zoom), for LMS the decision is to select alternative A-2 (Chamilo) and for PM alternative A-2 (Bitrix24). In Case-3, which represents another combination of experts' opinion importance, the selection of collaboration software tools is as follows: for VCT to be chosen alternative A-3 (Skype), for LMS – alternative A-1 (Moodle), and for PM – alternative A-2 (Bitrix24).

The empirical comparison of the results from the described two different group decision-making modelling approaches shows their applicability for the selection of collaborative tools for remote working. The first modelling approach (1)–(3) based on the parameters of software tools used as variables and expressed by 0 or 1 if the functional features are present or not is suitable for fast group decision-making. The advantages of this model are the possibility to consider not only the coefficients for relative importance between evaluation criteria (software parameters) but also to take into account the weighted coefficients used to differentiate the experts' opinion importance. The second modelling approach (4)–(14) requires more attention to evaluate in respect to some scale to get the corresponding score that expresses the performance of the alternatives toward given criteria. The advantage of this modelling approach is the fact that the optimal selection of the interesting combination of software item is obtained as a single run of the optimization task. This is due to the used binary integer variables that make a possible selection of a single representative item from different software tools.

Despite the difference between describe approaches both of them could be successfully applied for group decision-making. This is proved by the obtained numerical results illustrated in Fig. 1 where the decision for selection of VCT, LMS and PM are identical in Case-2 and Case-3, while Case-1 differs in the selection only in MLS. Depending on the selected strategy that is the core of each of the models, it is possible to use one of them on different stages to determine reasonable group decision-making. It should be pointed out some essential elements of both models namely the number and qualification of the experts, and their opinions' importance when aggregating the final group decision. All this is possible only with the active role of the CIO in organizing the decision-making process. That is why the CIO plays an important role in the organization, especially in providing a variety of effective solutions that contribute to the satisfaction of managers

and employees. On the other hand, this will provide the necessary market flexibility and lead to better economic sustainability.

After selection the needed software tools for collaborative remote working it is needed to determine their way of deployment (self-hosted, cloud-based, SaaS, etc.) and access. For this purpose, it should carefully to consider available access points and configuration of the existing wireless network to avoid additional expenses and from another hand to don't increase the radio frequency pollution from these devices that have a negative effect on the human body.

5 Conclusions

The role of CIO become more important due to the ongoing digital transformation and is extremely needed considering by the current pandemic situation and the requirements to work at the home office. To make possible such remote collaboration, the proper software tools are to be selected. In a similar situation, the CIO should be able to provide proper mathematical models to make reasonable decisions. For such purposes, the current article deals with an empirical comparison between two modelling approaches for group decision-making. First of them aims to make fast evaluation and selection based on the availability or not of parameters of the items (software tools) from which the selection should be done. The second modelling approach includes also evaluation expressed by corresponding score (from given scale) and require the formulation of more complex optimization task, and is more time consuming compared to the first modelling approach.

The conducted numerical experiments demonstrated that both of described approaches could be applied for the purposes of CIO for selection of different software tools. In both mathematical models, the opinions of the experts that form a group could take part with different importance. This feature is important when forming the final group decision, where different experts' points of view toward evaluation criteria importance could be integrated with different weights. The advantage of the second model is the possibility for simultaneous selection of several software tools.

The proposed two mathematical models could be used for other similar problems. For example, the problems of evaluation and selection of IT hardware or infrastructure equipment. The CIO should determine a proper group of experts qualified in the area of IT equipment. This will give a more transparent solution to the executive managers about the particular selection, where the final decision will be based on different experts' opinions. In such a way, it is possible to achieve better economic sustainability.

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