# Going green: strategic evaluation of green ICT adoption in the textile industry by using bipolar fuzzy MULTIMOORA method

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**ABSTRACT – REZUMAT**

**Going green: strategic evaluation of green ICT adoption in the textile industry by using bipolar
fuzzy MULTIMOORA method**

*The widespread use of information and communication technologies in all fields has a direct impact on the way the world
is viewed. In today's competitive international business environment, companies are increasingly investing in the search
for new ideas and approaches in production. The use of information and communication technologies (ICT) is
increasingly gaining in importance, especially in the situation of a dynamic market and increasingly demanding
consumers. Today's business of contemporary organizations is not conceivable without the support of modern ICT
systems. Therefore ICT has a great influence on modern society because the ways in which information and data are
exchanged are higher than ever. Green information and communication technologies as one area that is new and in
development tend to establish a balance between these technologies and the environment. Adoption of green
information and communication technologies is not an easy task and is often related to certain limitations. Therefore, the
aim of the paper is a strategic evaluation of green ICT and their implementation in the textile industry by using
newly-developed bipolar fuzzy MULTIMOORA method. Effectiveness and efficacy of the proposed approach is
demonstrated in the conducted illustrative case study.*

*Keywords: Green ICT, ICT, textile industry, MCDM, bipolar fuzzy MULTIMOORA method*

**Adoptarea metodei ecologice: evaluarea strategică a adoptării eco-TIC în industria textilă prin utilizarea
metodei bipolare fuzzy MULTIMOORA**

*Utilizarea pe scară largă a tehnologiilor informației și comunicațiilor în toate domeniile are un impact direct asupra
modului în care lumea este privită. În mediul de afaceri internațional competitiv de astăzi, companiile investesc din ce
în ce mai mult în căutarea de noi idei și abordări în domeniul producției. Utilizarea tehnologiilor informației și
comunicațiilor (TIC) capătă din ce în ce mai multă importanță, în special în situația unei piețe dinamice și a
consumatorilor din ce în ce mai pretențioși. Afacerile de astăzi ale organizațiilor nu sunt concepute fără sprijinul
sistemelor moderne TIC. Prin urmare, TIC au o mare influență asupra societății moderne, deoarece modalitățile prin
care sunt schimbate informații și date sunt mai avansate ca niciodată. Eco-TIC, ca domeniu nou și în curs de dezvoltare,
tinde să stabilească un echilibru între aceste tehnologii și mediu. Adoptarea eco-TIC nu este o sarcină ușoară și este
adesea legată de anumite limitări. Prin urmare, scopul lucrării este o evaluare strategică a eco-TIC și implementarea
acestuia în industria textilă, utilizând metoda bipolară fuzzy MULTIMOORA, dezvoltată recent. Eficacitatea abordării
propuse este demonstrată în studiul de caz realizat.*

*Cuvinte-cheie: eco-TIC, TIC, industria textilă, MCDM, metoda bipolară fuzzy MULTIMOORA*

## INTRODUCTION

One of the biggest, oldest and most commercialized industries in the world is the textile industry. The textile industry is an important branch of the manufacturing industry and is of great importance for the economy of a country. Today, the textile industry is one of the most globalized industries. Accordingly, the prerequisite for success is the continuous monitoring of current market trends in terms of standards, raw materials and technical equipment of production [1]. The textile industry, as a very important industrial area is technically and technologically very demanding.

The opportunity for the growth of textile production can be exploited by those managers and organizations that are ready to change their business paradigms and that are open to creating changes and introducing new information and communication technologies (ICT) in production. It is emphasized that new technologies in the textile industry are developed in order to improve textile and clothing manufacturing and trade. Some of the goals which new technologies and above ICT should bring are: "1. providing response to new fashion trends; 2. ensuring the efficiency and effectiveness of mass

production through the application of ICT (computer-aided design) and 3. adaptation to increasingly sophisticated customers (selling online through web platforms, offering added value through quality or price, ensuring a long term relationship etc.)" [2].

In today's competitive business environment, companies are increasingly investing in the search for new ways and approaches in production. The use of information and communication technologies plays a vital role and is increasingly gaining in importance, especially in the situation of a dynamic market and increasingly demanding consumers. Today's business of contemporary organizations is not conceivable without the support of modern ICT systems. Therefore ICT has a great influence on modern society because the ways in which information and data are exchanged are higher than ever [3].

The role of ICT is becoming increasingly important in all aspects of life (education, work, entertainment, health, etc.). Davison [4] point out that the term is used interchangeably in order to cover the full spectrum of existing and potential ICT that are used, including computers, personal communication devices, digital video and sound systems, email, the Internet, etc. ICT is mainly related to the technologies that are used for accessing, collecting, manipulating and presenting or transmitting the information. ICT technologies may include hardware (e.g. computers and other devices); software applications; and connectivity (e.g. Internet access, local area network infrastructure, video conferencing). Exactly what is most important about ICT is the increasing convergence of computer-based, multimedia and communication technologies, as well as the rapid rate of change that characterizes technologies and their use [5, 6]. ICT is most commonly related to two main components: information technology (IT) and communication technology (CT). IT mostly involves computer hardware and software, while CT is related to Internet communication [7]. ICT is a broader concept that includes communication devices, various services, video conferencing, online learning, etc., in order to provide users with access, storage, transmission and manipulation of information [8].

Veljović et al. [9] point out that the most important components of information and communication technologies are computers. At the same time, the application and development of digital communications enabled an easy, fast, efficient and inexpensive way of exchanging information. Therefore, ICTs include a diverse set of technology tools that are used to identify and organize data and information. Murray [10] states that ICT is expanding the concept of information technology in which particularly is highlighted the role and importance of the integration of communications, telecommunications and computers, as well as the necessary software, storage and audiovisual system that gives users the ability to access, store and further manipulate information.

Today's business of contemporary organizations is not conceivable without the support of modern ICT systems. Therefore ICT has a great influence on modern society because the ways in which information and data are exchanged are higher than ever. Green information and communication technologies as one area that is new and in development tend to establish a balance between these technologies and the environment. Also, as Din et al. [11] point out, green ICT, as a concept was introduced with the aim to support the implementation of the green environment, i.e. is aimed at conserving energy as one essential domain.

There is no universal definition of green information and communication technologies. Reimsbach-Kounatze [12] emphasizes that the "green ICT is about the study and practice of using computing resources in an efficient, effective and economical way". Sarkis and Zhu [13] states that "green ICT refers more to the hardware and other infrastructure that can be better managed and designed from an environmental perspective". Andreopoulou [14] states that green ICT "are ICT tools, certain services and technologies that in combination with green practices and green behavior contribute not only to the protection of the environment but also to the enhancement of the quality of life". Radu [15] emphasizes that coherence between ICT and the environment is relatively new and that the using of environmental criteria is often referred to as green ICT.

Adoption of green information and communication technologies is not an easy task and is often related to certain limitations. The process of evaluation of green ICT can be a challenging task. However, problem of green ICT evaluation can be easily solved by using multiple-criteria decision-making methods.

Decision making is a process that is constantly happening all around us [16]. In real-world situations, decision-making is most often made on the basis of the existence of a number of criteria, which are often conflicting; therefore, for solving such problems using of multiple-criteria decision-making methods (MCDM) is an option. MCDM enables the selection of a suitable alternative from a finite set of alternatives while respecting the values of the criterion attributes, i.e. it enables decision-making in the presence of multiple, often conflicting criteria [17–22]. Ishizaka and Nemery [23] indicate the growing use of MCDM methods because these methods primarily enable better decision-making and adoption of long-term and sustainable solutions.

The extremely rapid development of the MCDM field has also caused the creation of a wide range of MCDM methods, which have been applied so far in solving different types of problems. Some of the prominent and most applied methods are: SAW, AHP, ELECTRE, PROMETHEE, ANP, VIKOR, COPRAS and so on [24–26]. Also, it is important to note that for the needs of solving more complex problems, a whole generation of new MCDM methods and approaches have been proposed, such as: MOORA, MULTIMOORA, WASPAS, SWARA, ARAS, ARCAS, PIPRECIA, MAIRCA, EDAS, CODAS and so on [27, 28].

Based on the foregoing stated, the aim of the paper is the strategic evaluation of green information and communication technologies adoption in the textile industry by using newly-developed bipolar fuzzy MULTIMOORA method. Therefore, in order to present an MCDM for the purpose of green ICT evaluation, the remainder of the paper is organized into four sections. In Section 1, a literature review is provided. Section 2 contains the presentation of the applied methodology. A case study is introduced in Section 3, which is followed by the section presenting the conclusion.

## THE COMPUTATIONAL PROCEDURE OF THE SVBFN-MULTIMOORA METHOD

Extension of the MULTIMOORA method based on Single-Valued Bipolar Fuzzy Numbers is proposed by Stanujkic et al. [29]. Brauers [30] initially proposed the well-known MOORA method, somewhat later Brauers and Zavadskas [31] have proposed MULTI-MOORA method. So far, MULTIMOORA method has been applied for solving various problems in different fields, such as: economy [31–34]; personnel selection [35–38]; supplier selection [39, 40]; information and communication technologies [41, 42], robotics [43], comminution circuit design selection [44], assessment of the energy storage technologies [45], and so on.

The computational procedure of the SVBFN-MULTIMOORA method can be expressed as follows [29]:

Step 1. Evaluation of the alternatives in relation to the selected set of criteria for each decision-maker DM. In this step evaluation could be easily performed by using the nine-point Liker scale that is proposed by Stanujkic [29].

Step 2. Determination of the importance of the evaluated criteria for each DM.

Step 3. Determination of the group decision matrix, as it is proposed in [29].

Step 4. Determination of the group weights of the criteria, as follows:

$$w_j = \sum_{k=1}^{K} w_j^k \qquad (1)$$

where $w_j$ denotes the weight of the criterion $j$, and $w_j^k$ denotes the weight of the criterion $j$ obtained from the DM $k$.

Step 5. Determination of the significance of the evaluated alternatives based on the RS approach. This step can be explained through the following sub-steeps:

Step 5.1. Determination of the impact of the benefit and cost criteria to the importance of each alternative, as follows:

$$Y_i^+ = \left(1 - \prod_{j \in \Omega_{max}}^{n} \left(1 - r_{ij}\right)^{w_j}, -\left(1 - \prod_{j \in \Omega_{max}}^{n} \left(1 - (-r_{ij})\right)^{w_j}\right)\right) \quad (2)$$

$$Y_i^- = \left(1 - \prod_{j \in \Omega_{max}}^{n} \left(1 - r_{ij}\right)^{w_j}, -\left(1 - \prod_{j \in \Omega_{max}}^{n} \left(1 - (-r_{ij})\right)^{w_j}\right)\right) \quad (3)$$

where $Y_i^+$ and $Y_i^-$ denote the importance of the alternative $i$ obtained on the basis of the benefit and cost criteria, respectively; $Y_i^+$ and $Y_i^-$ are SVBFNs. It is evident that $A_w$ operator is used to calculate the impact of the benefit and cost criteria.

Step. 5.2. Transformation of the $Y_i^+$ and $Y_i^-$ into crisp values by using the Score Function, as follows:

$$y_i^+ = s(Y_i^+) \qquad (4)$$

$$y_i^- = s(Y_i^-) \qquad (5)$$

Step 5.3. Calculation of the overall importance for each alternative, as follows:

$$y_i = y_i^+ - y_i^- \qquad (6)$$

Step 6. Determination of the significance of the evaluated alternatives based on the RP approach. This step can be explained through the following sub-steeps:

Step 6.1. Determination of the reference point (RP). The coordinates on the bipolar fuzzy reference point $r^* = \{r_1^*, r_2^*, ..., r_n^*\}$ can be determined as follows:

$$r^* = \{(<\max_i r_{ij}, \min_i r_{ij}> | j \in \Omega_{max}),$$
$$(<\min_i r_{ij}, \max_i r_{ij}> | j \in \Omega_{min})\} \qquad (7)$$

where $r_j^*$ denotes the coordinate $j$ of the reference point.

Step 6.2. Determination of the maximum distance from each alternative to all the coordinates of the reference point as follows:

$$d_{ij}^{max} = d_{max}(r_{ij}, r_j^*)w_j \qquad (8)$$

where $d_{ij}^{max}$ denotes the maximum distance of the alternative $i$ to the criterion $j$.

Step 6.3. Determination of the maximum distance of each alternative, as follows:

$$d_i^{max} = \max_j d_{ij}^{max} \qquad (9)$$

where $d_i^{max}$ denotes the maximum distance of the alternative $i$.

Step 7. Determination of the significance of the evaluated alternatives based on the FMF:

Step 7.1. Calculation of the utility obtained based on the benefit $U_i^+$ and cost $U_i^-$ criteria, for each alternative, as follows:

$$U_i^+ = \left(\prod_{j \in \Omega_{max}}^{n} \left(r_{ij}\right)^{w_j}, -\prod_{j \in \Omega_{max}}^{n} \left(-r_{ij}\right)^{w_j}\right) \quad (10)$$

$$U_i^- = \left(\prod_{j \in \Omega_{min}}^{n} \left(r_{ij}\right)^{w_j}, -\prod_{j \in \Omega_{min}}^{n} \left(-r_{ij}\right)^{w_j}\right) \quad (11)$$

where and are SVBFNs.

Step 7.2. Transformation of the and into crisp values by using the Score Function, as follows:

$$u_i^+ = s(U_i^+) \qquad (12)$$

$$u_i^- = s(U_i^-) \qquad (13)$$

Step 7.3. Determination of the overall utility for each alternative, as follows:

$$u_i = \frac{u_i^+}{u_i^-} \qquad (14)$$

In the case when evaluation is made only on the basis of benefit criteria Eq. (14) is as follows:

$$u_i = u_i^+ \qquad (15)$$

Step 8. Determination of the final ranking order of the alternatives by using theory of dominance.

## A NUMERICAL CASE STUDY

In this part of the paper, a numerical case study is considered in order to highlight the proposed methodology. As stated before, there is a tendency towards using green ICT. A textile company has decided to introduce green ICT. For this reason, a team consisted of 3 DMs was formed in order to evaluate four alternatives designated as $A_1$, $A_2$, $A_3$, $A_4$. Based on carefully literature review [49–50], a total number of 5 evaluation criteria were selected: $C_1$ – Economic and energy efficiency; $C_2$ – Eco-friendliness; $C_3$ –Technology evolution; $C_4$ – Improved systems performance and use; $C_5$ – Overall impact of green ICT on the organization.

The ratings of the evaluated alternatives in the form of SVBFNs for the three decision-makers are shown in tables 1–3.

The group decision matrix is shown in table 4.

The group weights obtained from the three DMs by applying the PIPRECIA method [48] and by using equation (1) are accounted for in table 5.

Table 1

### THE RATINGS OBTAINED FROM THE FIRST OF THE THREE DMS

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <0.80, –0.20> | <0.80, –0.10> | <0.70, –0.30> | <0.80, –0.30> | <0.50, –0.20> |
| $A_2$ | <0.40, –0.50> | <0.30, –0.30> | <0.40, –0.40> | <0.30, –0.30> | <0.20, –0.30> |
| $A_3$ | <0.50, –0.30> | <0.40, –0.30> | <0.40, 0.10> | <0.50, –0.30> | <0.60, –0.50> |
| $A_4$ | <0.90, –0.10> | <0.70, –0.10> | <0.70, 0.10> | <0.80, –0.30> | <0.70, –0.40> |

Table 2

### THE RATINGS OBTAINED FROM THE SECOND OF THE THREE DMS

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <1.00, –0.10> | <0.90, –0.20> | <0.80, –0.20> | <0.60, –0.10> | <0.70, –0.10> |
| $A_2$ | <0.60, –0.30> | <0.80, –0.40> | <0.70, –0.20> | <0.50, –0.30> | <0.60, –0.30> |
| $A_3$ | <0.70, –0.30> | <0.50, –0.30> | <0.60, –0.20> | <0.80, –0.20> | <0.50, –0.30> |
| $A_4$ | <1.00, –0.10> | <1.00, –0.10> | <0.70, –0.20> | <0.80, –0.20> | <0.80, –0.20> |

Table 3

### THE RATINGS OBTAINED FROM THE THIRD OF THE THREE DMS

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <1.00, –0.20> | <0.90, –0.20> | <0.80, –0.20> | <0.70, –0.20> | <0.60, –0.20> |
| $A_2$ | <0.50, –0.40> | <0.40, –0.20> | <0.50, –0.20> | <0.70, –0.30> | <0.50, –0.30> |
| $A_3$ | <0.40, –0.20> | <0.50, –0.20> | <0.50, –0.10> | <0.80, –0.30> | <0.60, –0.30> |
| $A_4$ | <1.00, –0.20> | <1.00, –0.10> | <0.60, –0.10> | <0.70, –0.20> | <0.60, –0.30> |

Table 4

### THE GROUP DECISION-MAKING MATRIX

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <1.00, –0.16> | <0.87, –0.16> | <0.77, –0.23> | <0.71, –0.19> | <0.60, –0.16> |
| $A_2$ | <0.50, –0.40> | <0.56, –0.29> | <0.55, –0.26> | <0.52, –0.30> | <0.45, –0.30> |
| $A_3$ | <0.55, –0.27> | <0.46, –0.27> | <0.50, –0.13> | <0.72, –027> | <0.56, –0.36> |
| $A_4$ | <1.00, –0.13> | <1.00, –0.10> | <0.67, –0.13> | <0.77, –0.23> | <0.71, –0.09> |

Table 5

| Criteria | $w_j^1$ | $w_j^2$ | $w_j^3$ | $w_j$ |
|---|---|---|---|---|
| $C_1$ | 0.24 | 0.23 | 0.27 | 0.25 |
| $C_2$ | 0.19 | 0.25 | 0.20 | 0.21 |
| $C_3$ | 0.21 | 0.23 | 0.20 | 0.21 |
| $C_4$ | 0.18 | 0.18 | 0.17 | 0.18 |
| $C_5$ | 0.18 | 0.12 | 0.15 | 0.15 |
| Total | | | | 1.00 |

THE GROUP CRITERIA WEIGHTS

Based on the ratings from table 4 and the weights from table 5, the overall significance, the maximum distance to the RS and the overall utility are calculated for each alternative in the next step. The overall significances accounted for in table 6, are calculated by applying equations (2)–(6).

Thereafter, the RP is determined by using equation (7). The maximum distances to the RP accounted for in table 7 are determined by using equation (8) and equation (9).

The overall utility shown in table 8 is calculated by applying equations (10)–(14).

Taking into consideration ranking orders shown in tables 6, 7 and 8, the most appropriate alternative is determined by the theory of dominance, as is shown in figure 1.

As can be seen from figure 1, the alternative denoted as $A_4$ is the most appropriate in the terms of evaluated criteria.

Additionally, to verify the reliability of the proposed approach and to confirm ranking orders obtained by using the SVBFN-MULTIMOORA method, a sensitivity analysis was conducted with the comparison of the ranking results obtained by using of SVBFN-MULTIMOORA method with 2 well-known and

proven MCDM methods (TOPSIS and SAW). The obtained results of the conducted sensitivity analysis are shown in figure 2 and table 9.

It can also be concluded from table 9 that the small inconsistency in the ranking orders of the considered alternatives obtained by applying the TOPSIS
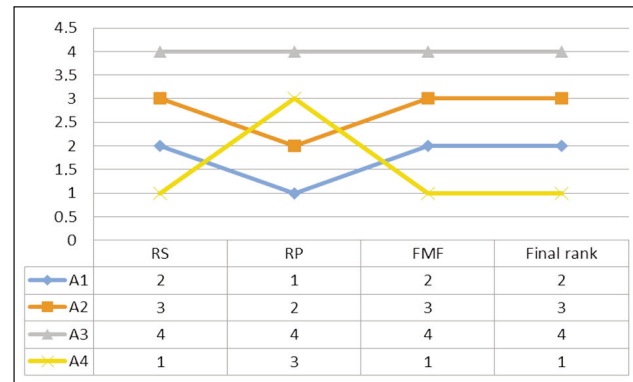


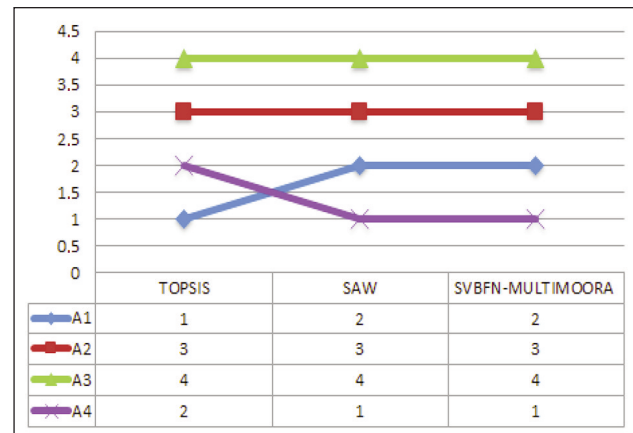Fig. 1. The final ranking order of the considered alternatives by using theory of dominance



Fig. 2. Results of the sensitivity analysis

Table 6

THE OVERALL SIGNIFICANCES OF THE CONSIDERED ALTERNATIVES

| Alternatives | $Y_i^+$ | $Y_i^-$ | $y_i^+$ | $y_i^-$ | $y_i$ | Rank |
|---|---|---|---|---|---|---|
| $A_1$ | <1.00, −0.13> | <0.33, −0.07> | 0.94 | 0.63 | 0.30 | 2 |
| $A_2$ | <0.40, −0.23> | <0.22, −0.12> | 0.59 | 0.55 | 0.04 | 3 |
| $A_3$ | <0.38, −0.16> | <0.33, −0.13> | 0.61 | 0.60 | 0.01 | 4 |
| $A_4$ | <1.00, −0.08> | <0.39, −0.10> | 0.96 | 0.64 | 0.31 | 1 |

Table 7

THE RATINGS OF THE ALTERNATIVES OBTAINED BASED ON THE RP APPROACH

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $d_i$ | Rank |
|---|---|---|---|---|---|---|---|
| $A_1$ | 0.12 | 0.13 | 0.01 | 0.09 | 0.08 | 0.01 | 1 |
| $A_2$ | 0.25 | 0.22 | 0.11 | 0.06 | 0.07 | 0.06 | 2 |
| $A_3$ | 0.29 | 0.28 | 0.20 | 0.14 | 0.16 | 0.14 | 4 |
| $A_4$ | 0.13 | 0.10 | 0.11 | 0.15 | 0.19 | 0.10 | 3 |

Table 8

| Alternatives | $U_i^+$ | $U_i^-$ | $u_i^+$ | $u_i^-$ | $u_i$ | | Rank | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| THE OVERALL UTILITY OF THE CONSIDERED ALTERNATIVES | | | | | | | | |
| $A_1$ | <0.92, –0.32> | | <0.86, –0.53> | | 0.80 | 0.67 | 1.20 | 2 |
| $A_2$ | <0.66, –0.46> | | <0.77, –0.65> | | 0.60 | 0.56 | 1.07 | 3 |
| $A_3$ | <0.63, –0.35> | | <0.86, –0.65> | | 0.64 | 0.60 | 1.06 | 4 |
| $A_4$ | <0.92, –0.24> | | <0.90, –0.61> | | 0.84 | 0.64 | 1.30 | 1 |

Table 9

THE FINAL RANKING ORDERS OBTAINED BY USING THE TOPSIS AND THE SAW METHODS

| Alternatives | TOPSIS | | SAW | |
|---|---|---|---|---|
| | $C_i$ | Rank | $S_i$ | Rank |
| $A_1$ | 0.527 | 1 | 0.646 | 2 |
| $A_2$ | 0.498 | 3 | 0.538 | 3 |
| $A_3$ | 0.488 | 4 | 0.531 | 4 |
| $A_4$ | 0.526 | 2 | 0.672 | 1 |

method is caused by a very small difference in $C_i$ values of alternatives $A_1$ and $A_4$ that are 0.527 and 0.526. Any slight change in the weight of the criteria or the ratings of the alternative probably would lead to the same ranking order of alternatives.

## CONCLUSION

Information and communication technologies play a significant role in the processing of information and their transformation into knowledge, which is a basic condition for creating an information society. As stated before, green ICT as an area that is new and in development is directed towards establishing a balance between these technologies and the environment. Adoption of such technologies is a very complex and challenging task. In this paper, the application of bipolar fuzzy MULTIMOORA method is proposed for the evaluation of green ICT adoption in the textile industry. During the evaluation process, a total of three decision-makers (domain experts) were involved, who evaluated four alternatives. For the purpose of evaluation of alternatives, a total number of five criteria were used. When it comes to the determination of criteria, PIPRECA method was used, because of its simplicity and ease of use, especially when collecting attitudes from the experts who are not close with the MCDM methods. The final ranking of the alternatives was determined by applying the newly-developed bipolar fuzzy MULTIMOORA method. Alternative denoted as $A_4$ is the best in terms of evaluated criteria. Although the proposed method is relatively new, the same was an excellent choice for the given purpose. The proposed integrated approach that is based on the PIPRECIA and bipolar fuzzy MULTIMOORA method has proved to be easy, effective and applicable for the evaluation of green ICT adoption in the textile company.

Additionally, with the purpose of verification of the proposed approach, sensitivity analysis is conducted. The obtained results have confirmed adequacy and the applicability of the proposed approach. Also, the proposed MCDM approach could be used in other areas as well. As a direction for future research, the proposed model could be easily modified with additional criteria or sub-criteria, if needed. Besides, other methods for weights determination can be used as well, such as the fuzzy PIPRECIA method, the fuzzy AHP method, and the Plithogenic-CRITIC method.

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