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Optimal selection of an electric power wheelchair using an integrated COPRAS and EDAS approach based on Entropy weighting technique

Sushil Kumar Sahoo[a*] and Bibhuti Bhusan Choudhury[a]

[a]*Department of Mechanical Engineering, Indira Gandhi Institute of Technology, Sarang, Dhenkanal, Odisha, India*

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ABSTRACT

The decision to purchase the best available electric power wheelchair (EPWC) for a person with a disability in a low-resource context is very stressful, whether it is based on financial circumstances or the availability of medical solutions. The study's objective is to assess the EPWC options available on the market, focused on a set of conflicting criteria. In this research, three multi-criteria decision-making (MCDM) approaches are used to make decisions. ENTROPY method for weightage calculation of various parameters, COPRAS and EDAS methods for evaluating and ranking alternatives are applied. Both COPRAS and EDAS are applied separately for ranking of selected wheelchair models, and to check the robustness of the applied method, sensitivity analysis on cost criterion is carried out. The result shows that for both methods, EPWC-1 is the top priority model to buy, whereas EPWC-7 is the worst model for COPRAS, and EPWC-10 is the worst model for EDAS among the ten alternatives.

1. Introduction

Disability is a social burden on persons with disabilities (PWDs), making it harder for them to perform certain day-to-day activities or communication with the world in which they live. Given the differences in cognitive, ambulatory, intellectual, mental, and sensory conditions, disabled persons are unreasonably segregated and are not fully involved in society. The UN Convention on rights of persons with Disability (UNCRPD) characterizes impairment or disability as 'including those with a disability with a long-lasting physical, psychiatric, and intelligent or sensory impairment that can impede their full and effective participation in societies equally with others when interacting with different obstacles (Assembly, 2007). According to research based on statistics, approximately 10% of global people require assistive wheelchair technology in their life to be mobile, dignified, independent, and equal, as outlined in a WHO 2011 report (World Health Organization, 2011). Based on the 2001 Census data of India, over 2.1 crore Indians are disabled in some way. The top group of the five categories of disabilities for which data had been obtained was impairment in seeing, which accounts for 48.5 percent of the total population. Others in order were ambulatory (27.9 percent), intelligence (10.3 percent), speech or voice (7.5 percent), and hearing (5.8 percent). And in total, there are 1.26 crore males and .93 crore females among the nation's disabled population, whereas the disabled population is higher in rural compared to urban areas (INDIA, 2011). So, the solution to the variety of impairment can be found in different stages such as initial patient treatments from the physician, improving the disability person's life through rehabilitation centre by providing appropriate training to recover from their respective impairment and come up with a strategy for a person with a disability to merge into working world around him/her. For PWDs, having access to these solutions and being able to use them is very important. Despite the high requirement for health care, disabled people have a difficult time finding a high-quality healthcare system. PWDs are twice as likely to discover health care providers' expertise and facilities inadequate to meet their basic needs, three times more likely to be refused care, and four times more likely to be

* Corresponding author.
E-mail address: sushilkumar00026@gmail.com (S. K. Sahoo)

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disrespected by health care providers, according to the World Report on Disability (Shakespeare, 2012). WHO defines barriers as little more than physical impediments such as factors in a person's surroundings that obstruct functionality and cause disability due to their presence or absence (Scholten et al., 2021). Aspects such as the following are included:

- An inaccessible physical environment
- There is a scarcity of appropriate assistive technology
- People's negative opinions regarding disability
- Services, systems, and regulations either do not exist or make it difficult for all persons with a health condition to participate in all aspects of life.

Out of the different type of barriers exist, this paper focuses on the selection of assistive technology-based products like electric power wheelchair (EPWC) which will break some of the barriers and help PWDs to balance their life with our progressive society. EPWCs have become a need in today's world and one of the most important conditions for a disabled person to gain self-confidence and access the good life, among others. Different companies around the world are introducing various new EPWC models with new additional features and revised technical requirements, which causes confusion among customers. It is also very difficult for buyers to choose a suitable EPWC model among a lot of models available in various markets, such as offline or online markets. There are numerous criteria that are conflicting as given in the specification of the product. This scenario can be described as a MCDM problem in general, which has caught the attention and compelled to work in this area. This research work aimed to address such perplexing situations and attempted to offer a solution.

To continue the investigation, the selection of criteria that affects the customer's interest or need to purchase is most important. First, the six most important parameters that influence EPWC selection have been identified based on specifications of a product, frequently asked questions asked by a customer on an online website, and literature data on the wheelchair. Maximum Retail Price (MRP), Weight of Wheelchair (WW), Weight-bearing Capacity (WBC), Single Charge Distance (SCD), Maximum Speed (MS), and Degree of Slope (DS) are the six major criteria used in the selection process. By interviewing with some EPWC users, it has been discovered that these are the most crucial aspects that a customer considers when choosing an EPWC. Furthermore, as shown in table 1, ten distinct EPWC models with budgets ranging from low to high were chosen from a variety of brands and have varying characteristics that can be found on various online shopping websites. The hierarchy tree depicted in figure 1 depicts the variables and variants explored in this study. Due to many EPWC models on the market, it is impossible to use all of the devices in the study. As a result of surveying online shopping websites such as www. amazon.in, www.seniority.in, and www.wheelchairindia.com, it has been determined that these 10 models are now in high demand based on review and rating of the products. It is worth noting that customer evaluations and ratings for these models are extremely positive, implying that people prefer these models over others. This study presents a real-world application of the COPRAS and EDAS techniques, as well as integrate with the ENTROPY method, to identify the best EPWCs on the market. The major goal of this study is to choose the optimal EPWC model from among these ten alternatives based on six criteria. Primarily, the ENTROPY approach is used to calculate the criteria weights, which are then integrated into the COPRAS and EDAS methods to recommend the optimal model, avoiding the influence of human factors on the weight of indicators. In this article, both COPRAS and EDAS are discussed, and rankings are compared. To ensure the model's stability, a spearman rank correlation and sensitivity analysis is performed, resulting in a complete alternative ranking of EPWC's model. This research will also benefit PWDs since they will gain a better understanding of the top EPWC models on the market and will be able to confidently choose the best one.

Table 1
Selected EPWC models with their specifications

Models/criteria	MRP	WW	WBC	SCD	MS	DS
EPWC-1	37999₹	34kg	100kg	12km	6kmph	8degree
EPWC-2	45999₹	42kg	100kg	15km	6kmph	8degree
EPWC-3	59999₹	50kg	120kg	20km	6kmph	8degree
EPWC-4	74499₹	43kg	100kg	15km	6kmph	6degree
EPWC-5	81499₹	49kg	100kg	15km	6kmph	12degree
EPWC-6	103499₹	48kg	110kg	15km	7kmph	12degree
EPWC-7	119999₹	51kg	100kg	12km	8kmph	6degree
EPWC-8	139999₹	70kg	100kg	15km	8kmph	12degree
EPWC-9	177999₹	78kg	110kg	15km	8kmph	12degree
EPWC-10	297599₹	102kg	125kg	35km	10kmph	12degree

2. Literature Review

When an individual or organization attempts to analyze several conflicting criteria in decision-making in everyday life or in a commercial context, various selection procedures exist. This selection method is a sub-discipline of operational research within the MCDM radar. MCDM techniques come in a variety of forms such as Analytic hierarchy process (Saaty, 1980), Analytic network process (Saaty, 1996), Best worst method (Rezaei, 2015), Technique for Order of Preference by Similarity to Ideal Solution (Hwang & Yoon, 1981), VlseKriterijumska Optimizacija I Kompromisno Resenje(VIKOR) that means: Multicriteria Optimization and Compromise Solution (Opricovic & Tzeng, 2007), ELimination Et Choix Traduisant la REalité (ELECTR)(Roy, 1968), Preference ranking organization method for enrichment evaluation (Brauers, 2003), Multi-Objective Optimization based on Ratio Analysis (Zavadskas, 2007), etc. and these methods can be used in many different areas such as manufacturing industry(Nallusamy et al., 2016; Vigneshvaran & Vinodh, 2021; Jamwal et al., 2021), Logistics and Transport(Tzeng & Huang, 2012; Kumru & Kumru, 2014; Mardani et al., 2016), electronic industry(Aravind et al., 2014; Asante et al., 2019), shipping industry(Seker et al., 2017; Gavalas et al., 2021), hydrology and water management(de Castro-Pardo et al., 2021; Dey et al., 2021), telecommunication industry(Lin et al., 2010; Hussain et al., 2019), energy management(Ecer, 2021; Kannan et al., 2021) etc. But very limited research is applied to the health care industry as follows. liu et al., 2019 had implemented DANP (DEMETEL) and an adapted VIKOR method to build a DDANPMV model to examine the consumer's use of mobile health care (DEMATEL+DANP + Modified VIKOR). This technique was performed not just to help policymakers to assess alternative mobile healthcare and identify the best choice but also to recognize and enhance alternatives' performance gaps in fulfilling the customer ambitions. Lu et al., 2013 applied a hybrid DDANPV (Decision-making Multiple Criteria Decision making) method in health care system in Taiwan which includes DEMATEL, DANP (DEMATEL-based ANP), and VIKOR. Karadayi & Karsak, 2014 introduce fuzzy MCDM methods that allow both precise and linguistic information to be carried out to evaluate the output of six regions that are identified for the development of healthcare policy in Istanbul. Pintelon et al., 2021 use a hybrid MCDM framework for a health care device prototype called an endoscope Ear Nose Throat Entropy (ENT) prototype to resolve the problems of risk priority number (RPN).

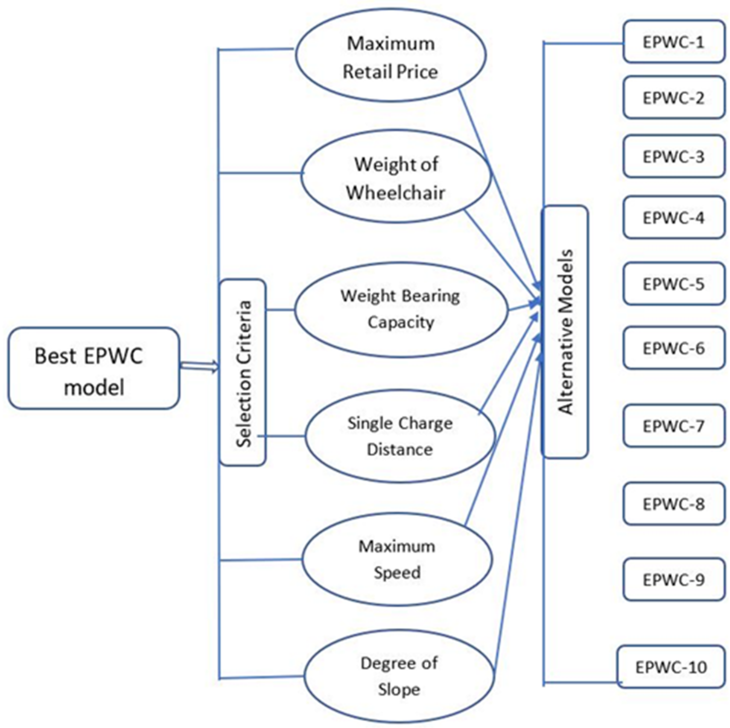

Fig. 1. A hierarchical tree of EPWC models with associated criteria

In addition to these applications, however, many researchers have taken and applied various MCDM techniques in decision-making and product selection for their daily lives. Electric Power Wheelchair is one of a kind in health care product, where no mathematical research had been carried out for best alternative selection.

2.1. Novelty Of the Present Work

According to the research findings above, no researcher has dealt with the situation of selecting an electric power wheelchair using mathematical approach, and no author has intended to solve the issue using MCDM techniques for the selection of EPWC which would help the PWDs to overcome the barrier in their life. This study compares the rankings of two different integrated approaches to EPWC selection, ENTROPY-COPRAS and ENTROPY-EDAS, and uses sensitivity analysis on cost criteria to check the robustness of the applied methods.

2.2. Identification of Selection Criteria

Finding primary selection criteria is significant before authors apply MCDM for the purchase of the best EPWCs. The first and foremost criteria is MRP to the end-users, which covers the cost of manufacturing, supply chain cost, and marketing cost, etc. Various research has been carried out with respect to cost associated with the design and development of wheelchairs. Cost as a criterion that has significant weight was selected for design consideration of prototype development smart robotic power wheelchair (Sahoo & Choudhury, 2021). A low-cost control system of assistive wheelchair is designed with raspberry-pi for elderly people that show the importance of cost (Chatterjee & Roy, 2021). Similar work has been done from the point of cost parameter to create different advanced wheelchairs implies that the role of MRP to end customers (Dahmani et al., 2020; Thomas et al., 2021). A wheelchair was designed for children to reduce their weight up to 30% to avoid bulkiness and heaviness (Suntharamurthy et al., 2015). In a recent report, researchers were modelling and manufacturing a stretcher cum wheelchair concerning lightweight material (Mohanavel et al., 2021). So, WW is taken as the second criteria for the selection of wheelchairs. The third criterion for the selection of EPWCs is the WBC of wheelchairs. Mechanical weight loading and dynamic loading on the wheelchair chassis play an important role in weight-bearing capacity of wheelchairs (Arva et al., 2009). SCD and MS of EPWCs is taken as a fourth and fifth criterion to carry out this research. The driving characteristics of powered wheelchair users were determined to see how far and fast the wheelchair moves during unequivocal community activities, and the activity levels are compared between a group of active people and a group of regular users (Cooper et al., 2002). The last criteria for the selection of wheelchairs are DS that users want to overcome during their driving scenario. The surface condition with DS was chosen for understanding the route choices for navigation was carried out for shortest possible paths (Kasemsuppakorn et al., 2015). Though the research papers on the selected criteria are very limited, the end user always focuses on the specification that is listed on the product description on the shopping websites.

3. Methodology

This section provides a brief overline on the MCDM methodologies used, such as ENTROPY, COPRAS, and EDAS. In figure 2, a flowchart model depicts the complete study in detail. The layout of this section is as follows. To begin, the criteria weights are defined by applying ENTROPY, which is followed by COPRAS based on scoring technique and EDAS based on distances from an average solution, all of which will result in a comprehensive ranking of the alternatives. And finally, to test the robustness of the applied methods, a sensitivity analysis is performed on cost criteria.

3.1. Employing Entropy Method for weight calculation

The entropy weight technique is a way of weighting that is objective in nature. It may compute the entropy weight of each variable using information entropy and then adjust the weight of each variable based on the degree of volatility of each parameter using entropy weight during specific usage.

So, the first set of calculations was carried out to determine the value of parameters using the entropy method to meet the article's goal. Shannon, the method's founder, gave the entropy method (Shannon & Weaver, 1949) as the following numerical expression:

$$S = \frac{1}{N} \sum_j x_j \ln(x_j) \tag{1}$$

where, S - entropy matrix, N - number of variable or criteria,
x_j – criteria value, j- criteria change limits (j = 1……n).

The entropy mechanism is represented in figure. 2 as a block diagram. The significance of indices is calculated in this ENTROPY method. Their value indicates which criteria are the most significant as compared to others. The indices are configured in such a way that the highest value is used to determine the significance of the best parameters. Table 1, in the introduction section displays the initial requirements and data for assessing 10 electric-power wheelchairs. So, the first step is to construct the initial decision matrix, which is shown in table 1. Then the initial normalized decision matrix is constructed using Eq. (2) and Eq. (3) as follows:

$$\bar{x}_{ij} = \frac{x_{ij}}{\max x_{ij}} \tag{2}$$

$$\bar{x}_{ij} = \frac{\min x_{ij}}{x_{ij}} \tag{3}$$

Each decision matrix element is divisible by the sum of the components in the column in which it is contained. $\bar{\boldsymbol{D}}$ matrix, as shown in table 2, was thus formed by using equation (4) to get the final normalized decision matrix as follows:

$$D_{ij} = \frac{\bar{x}_{ij}}{\sum_{i=1}^{m} \bar{x}_{ij}}, (\forall ij, i = 1\ldots\ldots m, j = 1\ldots\ldots n), \tag{4}$$

Here, D_{ij} – matrix indices, $\bar{X}_{ij}$ - criteria values

Table 2
Final Normalized decision matrix $\overline{\mathbf{D}}$ for EPWC selection

Models/Criteria	MRP	WW	WBC	SCD	MS	DS
EPWC-1	0.2113	0.1514	0.0939	0.0710	0.0845	0.0833
EPWC-2	0.1746	0.1226	0.0939	0.0888	0.0845	0.0833
EPWC-3	0.1338	0.1030	0.1127	0.1183	0.0845	0.0833
EPWC-4	0.1078	0.1197	0.0939	0.0888	0.0845	0.0625
EPWC-5	0.0985	0.1051	0.0939	0.0888	0.0845	0.1250
EPWC-6	0.0776	0.1073	0.1033	0.0888	0.0986	0.1250
EPWC-7	0.0669	0.1009	0.0939	0.0710	0.1127	0.0625
EPWC-8	0.0574	0.0735	0.0939	0.0888	0.1127	0.1250
EPWC-9	0.0451	0.0660	0.1033	0.0888	0.1127	0.1250
EPWC-10	0.0270	0.0505	0.1174	0.2071	0.1408	0.1250

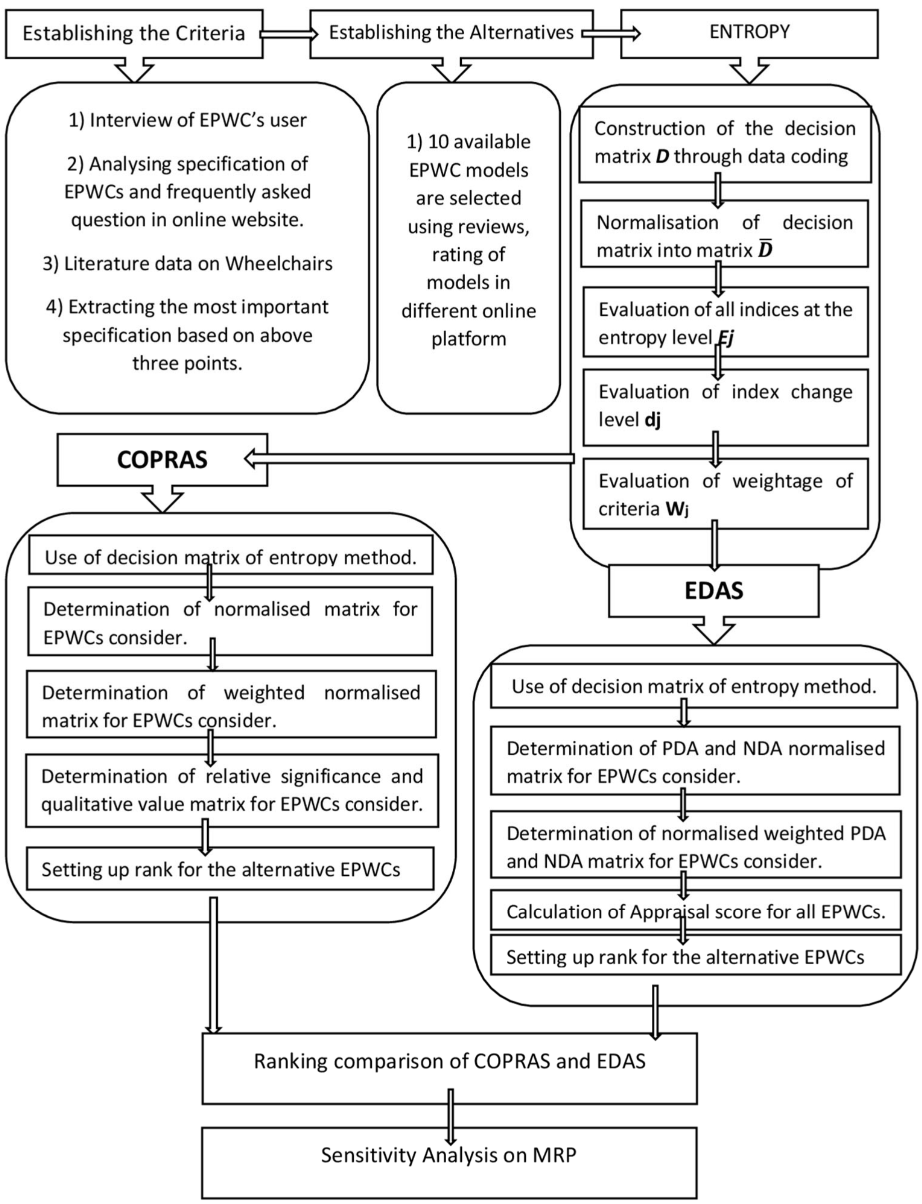

Fig. 2. Flowchart of the complete evaluation process by ENTROPY, COPRAS, and EDAS MCDM Methods

Determining the entropy level for each of the parameters Ej using Eq. (5) as follows:

$$E_j = -g \sum_{i=1}^{m} D_{ij} \ln D_{ij} \tag{5}$$

Here, $g = \frac{1}{\ln(m)}$, where m represents a number of alternatives. And entropy index varies between 1 & 0, So $0 \leq E_{ij} \leq 1, (j = 1\ldots\ldots n)$.

Calculation of the j_{th} factor d_j's variation coefficient using equation (6) as follows:

$$d_j = (1 - E_j), (j = 1\ldots\ldots n) \tag{6}$$

If all parameters are equally relevant, and there are no arbitrary or expert assessments of their values, the following Eq. (7) is used to decide their importance as follows:

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, (j = 1\ldots. n) \tag{7}$$

Table 3 displays all 3 equations are applied, and the entropy level (Ej), variation coefficient (dj), and weightage of individual criteria (Wj).

Table 3
Entropy level, j_{th} factor d_j's variation coefficient, weightage of individual criteria

Criteria	MRP	WW	WBC	SCD	MS	DS
Ej	0.9343	0.9820	0.9985	0.9746	0.9930	0.9847
dj	0.0657	0.0180	0.0015	0.0254	0.0070	0.0153
Wj	0.4944	0.1356	0.0113	0.1914	0.0525	0.1148

The priority order for considered criteria can be defined after calculating the value of the parameters as follows:
MRP>SCD>WW>DS>MS>WBC

3.2. Using the COPRAS Method to Prioritize Alternatives

To prioritise alternatives, the COPRAS approach was chosen because it outperformed other current MCDM methods in terms of ease of use, consideration of all aspects of each criterion, and differentiation of negative and positive measures (Zavadskas et al., 2007). The weighting of each of the analyzed 6 factors is the first criterion for moving further with the COPRAS approach. These weights obtained according to the ENTROPY method, as indicated in Table 3, were used to conduct the COPRAS analysis to classify the 10 EPWCs considered according to their preferred hierarchical position in following steps.

Step 1: Developing a $m \times n$ initial decision matrix as shown in Eq. (8). Here, m denotes the number of alternatives, and n denotes the number of the evaluation criteria.

$$X = [x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{8}$$

where x_{ij} denotes the performance rating of the alternative i on criterion j, and $i = 1\ldots. m, j = 1\ldots. n$. Here the initial decision matrix is shown in table 1.

Step 2: Using Eq. (9), the decision matrix is converted to a normalised matrix $[r_{ij}]_{m\times n}$ using the linear normalisation process.

$$R = [r_{ij}]_{m\times n} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{9}$$

Step 3: Using Eq. (10), the normalised matrix is converted to a weighted normalized matrix $[d_{ij}]_{m\times n}$ by multiplying the weights of the parameters by the elements of their respective columns.

$$D = [d_{ij}]_{m\times n} = r_{ij} \times w_j \tag{10}$$

Here, w_j denotes criteria weightage. The weighted normalized matrix is shown in Table 4.

Table 4
Weighted Normalized Matrix for EPWC selection

Models/Criteria	MRP	WW	WBC	SCD	MS	DS	S_{-i}	S_{+i}
EPWC-1	0.0165	0.0081	0.0011	0.0136	0.0044	0.0096	0.0246	0.0287
EPWC-2	0.0200	0.0100	0.0011	0.0170	0.0044	0.0096	0.0300	0.0320
EPWC-3	0.0260	0.0120	0.0013	0.0227	0.0044	0.0096	0.0380	0.0379
EPWC-4	0.0323	0.0103	0.0011	0.0170	0.0044	0.0072	0.0426	0.0297
EPWC-5	0.0354	0.0117	0.0011	0.0170	0.0044	0.0144	0.0471	0.0368
EPWC-6	0.0449	0.0115	0.0012	0.0170	0.0052	0.0144	0.0564	0.0377
EPWC-7	0.0521	0.0122	0.0011	0.0136	0.0059	0.0072	0.0643	0.0277
EPWC-8	0.0608	0.0167	0.0011	0.0170	0.0059	0.0144	0.0775	0.0383
EPWC-9	0.0773	0.0187	0.0012	0.0170	0.0059	0.0144	0.0959	0.0384
EPWC-10	0.1292	0.0244	0.0013	0.0396	0.0074	0.0144	0.1536	0.0627
						Sum	0.6300	0.3699

Step 4: For each and every option, the normalized weighted values of the beneficial and non-beneficial parameters are applied separately as given by Eq. (11) and Eq. (12), and also shown the calculated value in Table 4.

$$S_{+i} = \sum_{j=1}^{n} d_{+ij}, \tag{11}$$

Here, d_{+ij} denotes normalized weighted values of beneficial criterion.

$$S_{-i} = \sum_{j=1}^{n} d_{-ij}, \tag{12}$$

Here, d_{-ij} denotes normalized weighted values of non-beneficial criterion.

So, the higher the S_{+i} value results in a better alternative, and the lower the S_{-i} value results in the better alternative as S_{+i} and S_{-i} reflect the degree to which each alternative achieves its objectives. The summation of the S_{+i} and S_{-i} Values are done as expressed by Eq. (13) and Eq. (14).

$$\sum_{i=1}^{m} S_{+i} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{+ij} \tag{13}$$
$$\sum_{i=1}^{m} S_{-i} = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{-ij} \tag{14}$$

Step 5: Using Eq. (15), The relative significance (Qi) of each alternative can be found.

$$Q_i = S_{+i} + \frac{S_{-min}\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}(\frac{S_{-min}}{S_{-i}})}, S_{-min} = \min(S_{-i}) \tag{15}$$

The best option alternative, denoted by Q_{max}, is the one with the highest relative significance value (Qi) [66].
Step 6: Using Eq. (16), quantitative utility (U_i) of each alternative is calculated.

$$U_i = [\frac{Q_i}{Q_{max}}] \times 100 \tag{16}$$

Each option's utility value varies from one percent to one hundred percent. The goals of each option are determined in relation to the most ideal and effective choice. The best alternative is described as the one with the highest quantitative utility value U_i , and the ranking is done from highest to the lowest in accordance with declining U_i values.

The resultant quantitative utility vectors for each EPWC toward the suitability of their utilization for selection of an optimum electric power wheelchair are obtained using Equations (11) – (16) from the weighted normalized matrix, as shown in table 4. The priority values or relative significance (Qi) for each alternative are calculated using Eq. (15). Here, the Qi value for EPWC-1 is the maximum. Now, for each alternative, the quantitative utility values (Ui) are determined with Eq. (16). The relative significance, Quantitative utility values, and ranking of alternatives are reported in table 5.

Table 5
The Relative Significance and Quantitative Utility Values of Each Alternative

Models	Relative Significance (Qi)	Quantitative Utility (Ui)	Ui in 100%	Rank
EPWC-1	0.1516	1.0000	100%	1
EPWC-2	0.1329	0.8769	88%	2
EPWC-3	0.1176	0.7757	78%	3
EPWC-4	0.1007	0.6642	66%	5
EPWC-5	0.1011	0.6670	67%	4
EPWC-6	0.0914	0.6026	60%	6
EPWC-7	0.0748	0.4936	49%	9
EPWC-8	0.0774	0.5104	51%	8
EPWC-9	0.0700	0.4616	46%	10
EPWC-10	0.0824	0.5436	54%	7

3.3. Using the EDAS Method to Prioritize Alternatives

To prioritise alternatives, EDAS approach was chosen as a newly proposed method by Ghorabaee (Keshavarz et al., 2015). The EDAS method's fundamental concepts are that it uses two distance scales, the Positive Distance from Average (PDA) and the Negative Distance from Average (NDA), and that it evaluates alternatives based on the higher values of the PDA and lower values of the NDA. The EDAS method's computational procedure for a decision-making problem with m parameters and n alternatives can be summarised in seven steps as follows:

Step 1: Developing a $m \times n$ initial decision matrix as shown in Eq. (18). Here, m denotes the number of alternatives, and n indicates the number of the evaluation criteria.

$$X = [x_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{17}$$

where x_{ij} denotes the performance rating of the alternative i on criterion j, and $i = 1\ldots.. m, j = 1\ldots.. n$. Here the initial decision matrix is shown in Table 1.

Step 2: Using Eq. (19), calculate the criteria-wise average solutions (AV_j) as follows:

$$AV_j = \frac{\sum_{i=1}^{m} x_{ij}}{n} \tag{18}$$

Here, n denotes number of criteria.

Step 3: Using Eq. (19) and Eq. (20), calculate positive distance from average (PDA_{ij}) and negative distance from average (NDA_{ij}) respectively, according to the type of criteria, i.e., benefit criteria (B) or cost criteria (C), as follows:

$$PDA_{ij} = \begin{cases} \dfrac{\max(0, (x_{ij} - AV_j)}{AV_j} & ; j \in B \\ \dfrac{\max(0, (AV_j - x_{ij}))}{AV_j} & ; j \in C \end{cases} \tag{19}$$

$$NDA_{ij} = \begin{cases} \dfrac{\max(0, (AV_j - x_{ij})}{AV_j} & ; j \in B \\ \dfrac{\max(0, (x_{ij} - AV_j))}{AV_j} & ; j \in C \end{cases} \tag{20}$$

Step 4: Using Eq. (21) and Eq. (22), determine the weighted sum of PDA (WP_i) by taking the sum of multiplication of weight vector (w_j) with PDA_{ij} and a weighted sum of NDA (WN_i) by taking the sum of multiplication of weight vector with NDA_{ij} for all the alternatives as shown in Table 6, and Table 7.

$$WP_i = \sum_{j=1}^{n} w_j \, PDA_{ij} \tag{21}$$

$$WN_i = \sum_{j=1}^{n} w_j \, NDA_{ij} \tag{22}$$

Table 6
Weighted PDA for EPWC selection

Models/Criteria	MRP	WW	WBC	SCD	MS	DS
EPWC-1	0.3295	0.0543	0.0000	0.0000	0.0000	0.0000
EPWC-2	0.2948	0.0352	0.0000	0.0000	0.0000	0.0000
EPWC-3	0.2340	0.0160	0.0014	0.0351	0.0000	0.0000
EPWC-4	0.1711	0.0328	0.0000	0.0000	0.0000	0.0000
EPWC-5	0.1407	0.0184	0.0000	0.0000	0.0000	0.0287
EPWC-6	0.0452	0.0208	0.0004	0.0000	0.0000	0.0287
EPWC-7	0.0000	0.0136	0.0000	0.0000	0.0067	0.0000
EPWC-8	0.0000	0.0000	0.0000	0.0000	0.0067	0.0287
EPWC-9	0.0000	0.0000	0.0004	0.0000	0.0067	0.0287
EPWC-10	0.0000	0.0000	0.0020	0.2050	0.0214	0.0287

Table 7
Weighted NDA for EPWC selection

Models/Criteria	MRP	WW	WBC	SCD	MS	DS
EPWC-1	0.0000	0.0000	0.0007	0.0555	0.0081	0.0191
EPWC-2	0.0000	0.0000	0.0007	0.0215	0.0081	0.0191
EPWC-3	0.0000	0.0000	0.0000	0.0000	0.0081	0.0191
EPWC-4	0.0000	0.0000	0.0007	0.0215	0.0081	0.0431
EPWC-5	0.0000	0.0000	0.0007	0.0215	0.0081	0.0000
EPWC-6	0.0000	0.0000	0.0000	0.0215	0.0007	0.0000
EPWC-7	0.0264	0.0000	0.0007	0.0555	0.0000	0.0431
EPWC-8	0.1132	0.0318	0.0007	0.0215	0.0000	0.0000
EPWC-9	0.2782	0.0509	0.0000	0.0215	0.0000	0.0000
EPWC-10	0.7973	0.1083	0.0000	0.0000	0.0000	0.0000

Step 5: Using Eq. (23) and Eq. (24), determine the normalized values of $\mathrm{WP_i}$ and $\mathrm{WN_i}$ for all alternatives, as follows:

$$\mathrm{NWP_i} = \frac{\mathrm{WP_i}}{\max_i(\mathrm{WP_i})} \tag{23}$$

$$\mathrm{NWN_i} = 1 - \frac{\mathrm{WN_i}}{\max_i(\mathrm{WN_i})} \tag{24}$$

where, $\mathrm{NWP_i}$ and $\mathrm{NWN_i}$ denote the normalized weighted sum of the PDA and NDA, respectively.

Step 6: Using Eq. (25), calculate the appraisal score (AS_i) for all alternatives as follows:

$$\mathrm{AS_i} = \frac{(\mathrm{NWP_i}+\mathrm{NWN_i})}{2} \tag{25}$$

Table 8
Appraisal score and corresponding Rank

Models	NWPi	NWNi	ASi	RANK
EPWC-1	1.0000	0.9079	0.9539	1
EPWC-2	0.8597	0.9454	0.9025	2
EPWC-3	0.7467	0.9699	0.8583	3
EPWC-4	0.5311	0.9190	0.7250	5
EPWC-5	0.4893	0.9665	0.7279	4
EPWC-6	0.2477	0.9754	0.6116	6
EPWC-7	0.0528	0.8612	0.4570	7
EPWC-8	0.0921	0.8153	0.4537	8
EPWC-9	0.0931	0.6128	0.3530	9
EPWC-10	0.6699	0.0000	0.3349	10

Step 7: Alternative are ranked from best to worst alternative based on decreasing appraisal score. Among the alternatives, the one with the highest ASi value is the best choice. The values of NPWi, NWNi, appraisal score, and associated rank produced using the entropy based EDAS technique are shown in Table 8.

4. Results and Discussions

All the electric power wheelchair models are compared to one another using the COPRAS and EDAS methods. The quantitative utility values in the case of COPRAS and appraisal score for the EDAS method are determined for all the alternative models. In the following section, the consequence results from both techniques are explained in detail. EPWC-1 has the maximum quantitative utility value of 100%, followed by EPWC-2 (88%) and EPWC-3 (78%), indicating that EPWC-1 is the most appropriate electric power wheelchair among the selected wheelchairs, and it also explains the ranking of all the electric power wheelchairs based on the quantitative utility values that are declining. Furthermore, the order on the preference of EPWCs for EPWCs users as follows:

- EPWC-1> EPWC-2> EPWC-3> EPWC-5>EPWC-4>EPWC-6>EPWC-9>EPWC-8>EPWC-10>EPWC-7 based on ENTROPY-COPRAS technique.
- EPWC-1> EPWC-2> EPWC-3> EPWC-5>EPWC-4>EPWC-6>EPWC-7>EPWC-8>EPWC-9>EPWC-10 based on ENTROPY-EDAS technique.

For both approaches, the end findings and model ranking are approximately or nearly the same. EPWC-1 is the best model for both processes, while EPWC-7 is the worst for copras and EPWC-10 is the worst for EDAS. Moreover, the first six rank and rank eight models are identical in both the mcdm technique, though the end-order alternatives are ranked slightly differently. Fig 3 graphically depicts the ranking comparison.

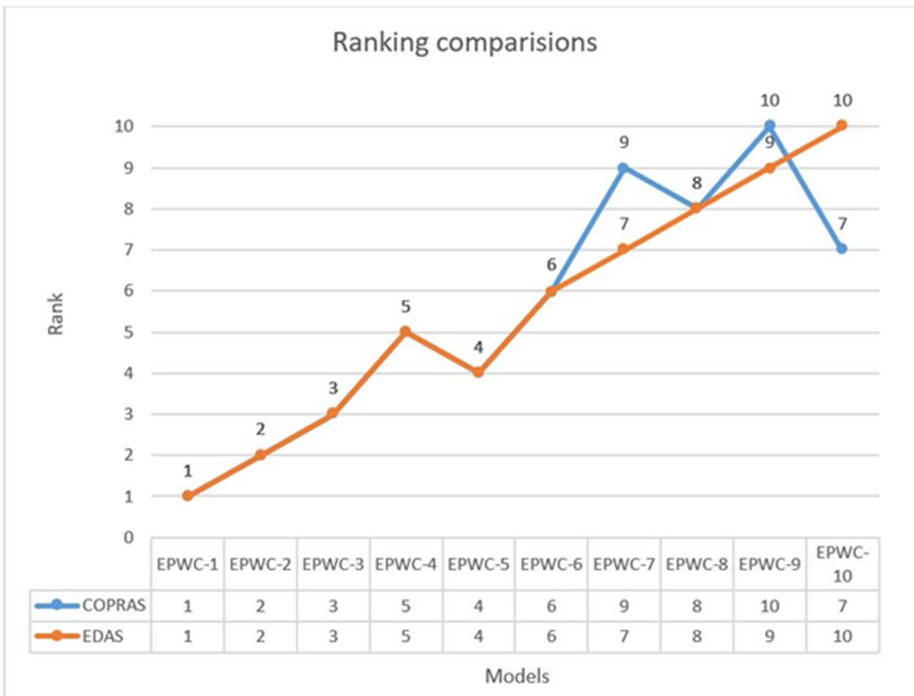

Fig.3. Ranking Comparisons of the electric power wheelchair models by COPRAS and EDAS

4.1. Comparative Analysis

The results of this study are compared to show how consistent the performance rankings of the alternatives are. The degree of connotation ranks generated by different combination procedures is determined using the Spearman rank correlation coefficient in this study. Equation (26) is used to determine the Spearman's rank correlation coefficient (SRCC).

$$R_{scc} = 1 - \frac{6 \times \sum R_d^2}{N_a \times (N_a^2 - 1)} \quad (26)$$

where N_a signifies the number of EPWC alternatives and R_d represents the difference in rank of ENTROPY-COPRAS and ENTROPY- EDAS. R_{scc} value is between 1 and -1. In general, a faultless correlation is recognized when the calculated value of R is closest to 1, that is, from 0.8-1.0. The R_{scc} value after using Eq. (26) and the data from Table 13 is 0.9151, which is extremely near to 1. As a result, it demonstrates the consistency of the performance rating. As a result, the methodology utilized in this study is equivalent efficient in determining the best EPWC selection strategy.

4.2. Sensitivity Analysis

Six distinct parameters determining the selection of electric power wheelchairs for use by people with disabilities are investigated in this study. Even though there are numerous criteria to consider when making a decision, in the real world, buyer preference for EPWCs is heavily influenced by cost-related factors, as evidenced by the ENTROPY calculation of this study, which shows that the weight coefficient of MRP is 0.4944, the highest value among the selected parameters, as shown in Table 3. Cost-related factors, in this case, MRP of EPWCs, rank relatively high when it comes to the most significant influence of a specific attribute on the obtained favourable scale of outcomes.

The Sensitivity Analysis technique is frequently cited by researchers (Bhattacharya et al., 2004; Bhattacharya et al., 2005) as a reasonable methodology for testing the effectiveness of obtained outcomes by varying price factors. For each of the wheelchairs studied for the proposed study, just one cost-based criterion, particularly "MRP of EPWCs," was used in the selection process. The sensitivity analysis is the sturdy way of demonstrating the uncertainties by changing the judgment of the decision-maker and presenting afterward the effects of the various options. The value of β in this study is between 0 and 1, with an increase of 0.1. Based on published literature, a mathematical method is assumed to integrate the potential criteria with classification orders encountered in the analysis of ENTROPY-COPRAS and ENTROPY-EDAS. The mathematical Eq. (27) and (28) have been transformed into a simple coding in MATLAB to create the graphs between selective index value and objective factor decision weight as shown in Fig. (4) and (5). The principal equations of the framework stated are:

$$\mathrm{SIV_i} = [(\beta \times \mathrm{SFMi}) + (1 - \beta) \times \mathrm{OFMi}] \tag{27}$$

$$\mathrm{OFMi} = \frac{1}{[\mathrm{OFCi} \sum_{i=1}^{n} \mathrm{OFCi}^{-1}]} \tag{28}$$

where SIV represents selective index value, β is objective factor decision weight, SFM is subjective factor measure, OFM is objective factor measure, OFC is objective factor measure, and n is the number of alternatives of EPWC. OFCs are the MRP for each wheelchair, as mentioned in table 1. OFMs are constructed to create a non-dimensional quantity of cost elements from each EPWC, as shown in Eq. (28). Tables 5 and 8 show the SFM values of each EPWC for every factor, which are based on ENTROPY-COPRAS relative significance vector values and ENTROPY-EDAS normalized appraisal vector values by EPWC candidates. The Sensitivity Analysis resultant graph is shown in Fig. 4 and Fig. 5.

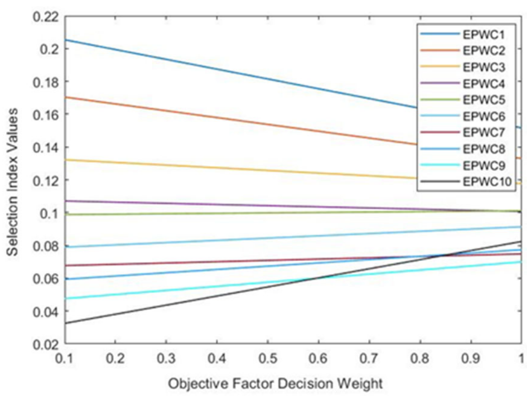

Fig. 4. ENTROPY-COPRAS-based sensitivity analysis graph

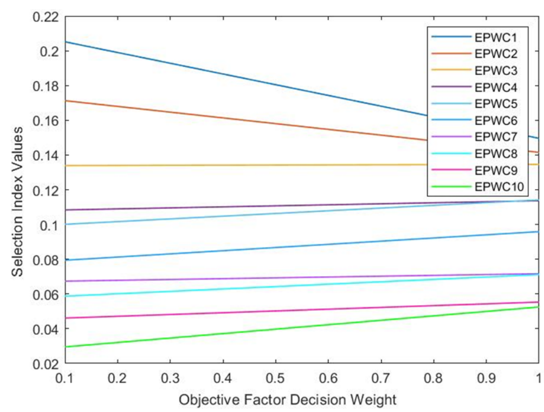

Fig. 5. ENTROPY-EDAS-based sensitivity analysis graph

Variation of the value of " β " or the objective factor decision weight in Eq. (27) in a 0–1 range with an increased value of 0.1 yields this graph of sensitivity analysis. When the value of "β" changes, the corresponding SIVi values for the cost of EPWCs change as well. The "β" values show how the research findings from the ENTROPY-COPRAS and ENTROPY-EDAS methods change due to variations in cost-related parameters, inevitably demonstrating the robustness of the study findings. The instantaneous values of "β" could link to the influence of cost-related dimension in the screening process over other parameters, a lower value which would represent a higher predominance for electric wheelchairs with the corresponding lower SFM value.

5. Conclusions

This research has concluded that of the 10 EPWC models available on the e-market, the EPWC-1 is the highest, followed by the EPWC-2 and EPWC-3 in second and third place, respectively. If someone wants to purchase an electric power wheelchair, they can opt for EPWC-1, and if this product is not available in the market due to shortage, then he/she can opt for EPWC-2 or EPWC-3. Since there are so many other choices on the market, the last rank of EPWC- 9 under the ENTROPY-COPRAS method and EPWC-10 under the ENTROPY-EDAS method should be avoided.

5.1. Limitations

The criteria for the following study were chosen based on data collected from an online website, related literature data, and mathematical calculations.This research does not ensure that there are no other models on the market that are better than

EPWC-1; it only implies that EPWC-1 is the best option among all these ten models, as well as the final ranking could modify when more electric-power wheelchair models are taken into consideration in addition to all these. However, there are additional subjective parameters that can be considered in addition to these, such as power tilt function, sit-to-stand operation, wheelchair stopping distance, and time to reach maximum speed to obtain more precise and reliable outcomes.

5.2. Future work

Implementing the same problem can be studied using multiple MCDM techniques like TOPSIS, CODAS, VIKOR, PROMETHEE, ARAS, MOORA methodology, etc., and the results can be compared with these outcomes. And also, other weighing tools such as AHP, BWM, Entropy and CRITIC may also be accepted for determination of parameters weights. The ENTROPY-COPRAS and ENTROPY-EDAS methodologies are not just for these kinds of applications but can also be used for the selection of other electronic devices and household appliances for disabled persons.

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