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Evaluating Material Alternatives for low cost Robotic Wheelchair Chassis: A Combined CRITIC, EDAS, and COPRAS Framework

Sushil Kumar Sahoo*[a] , Bibhuti Bhusan Choudhury[b]

[a]*Department of Mechanical Engineering, Indira Gandhi Institute of Technology(BPUT, Rourkela), Sarang, Dhenkanal, Odisha, India, PIN: 759146.*
[b]*Department of Mechanical Engineering, Indira Gandhi Institute of Technology, Sarang, Dhenkanal, Odisha, India, PIN: 759146.*

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Abstract

This research paper introduces a comprehensive approach for evaluating material alternatives in the design of low cost robotic wheelchair chassis, incorporating a combined CRITIC (Criteria Importance through Intercriteria Correlation), EDAS (Evaluation based on Distance from Average Solution), and COPRAS (Complex Proportional Assessment) framework. Material selection has a significant impact on robotic wheelchair performance and longevity, offering issues due to many criteria and sophisticated decision-making in engineering design. The proposed framework solves these issues by combining three well-known multi-criteria decision-making (MCDM) techniques by considering 7 criteria and 12 potential alternate materials. CRITIC assesses the relevance of criteria, EDAS rates material alternatives, and COPRAS computes comprehensive performance ratings while taking interdependencies into account. Wheelchair Chassis Materials are assessed based on SOLIDWORKS analysis for mechanical qualities and online B2B market data for cost, weight, and other relevant factors. Gray cast iron emerges as the most favorable choice for the robotic wheelchair chassis, showcasing its exceptional balance of attributes. This study adds important insights to material selection for complex engineering systems and assistive technology design, resulting in better wheelchair design and user experience.

Keywords: Wheelchair Chassis Prototype, CRITIC, EDAS, COPRAS, MCDM, Sensitivity Analysis.

1. Introduction

The demand for smart robotic wheelchairs for individuals with impairments has grown as people seek for a more inclusive and accessible society. Mobility issues can have a substantial impact on an individual's ability to accomplish everyday tasks, participate in social activities, and maintain a sense of independence [1]. Traditional manual wheelchairs have been vital mobility aids for decades, but they have restrictions that might prevent users from fully participating in society. Robotics, artificial intelligence, and sensor technology breakthroughs, on the other hand, have prepared the way for the creation of smart robotic wheelchairs, promising a revolution in the field of assistive technology and mobility support.

To appreciate the necessity for smart robotic wheelchairs, first understand the numerous mobility problems that people with disabilities may experience. Mobility issues can be caused by a variety of illnesses, including spinal cord injuries, cerebral palsy, multiple sclerosis, and muscular dystrophy. Such deficits can emerge as decreased muscle strength, limited range of motion, and coordination difficulties, all of which can have a substantial influence on an individual's ability to move independently. Traditional manual wheelchairs have been the go-to solution for people with mobility issues, offering crucial mobility and independence support. Manual wheelchairs, on the other hand, have intrinsic restrictions, such as the requirement for physical labor to operate, trouble navigating uneven terrains, and difficulties overcoming obstructions [2]. These restrictions can cause irritation, a reliance on cares for assistance, and a lack of access to social and public settings.

The development of smart robotic wheelchairs represents a paradigm leap in the field of assistive technology, with the potential to transform the lives of persons with disabilities. Smart robotic wheelchairs are outfitted with cutting-edge technologies such as sensors, cameras, and artificial intelligence algorithms, allowing them to sense their surroundings, make intelligent decisions, and maneuver through varied terrains and obstacles autonomously. These clever devices are intended to reduce users' physical effort, resulting in a more intuitive and user-friendly experience. Users may easily use smart robotic wheelchairs thanks to improved control interfaces, giving them a sense of autonomy and control over their motion.

Smart robotic wheelchairs' major purpose is to empower persons with impairments, allowing them to live more independent and satisfying lives. These technologies provide users with greater freedom and mobility by lowering the physical demands of manual operation and combining intelligent navigation capabilities. Individual users' distinct wants and preferences can be accommodated by smart robotic

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* Corresponding author e-mail: sushilkumar00026@gmail.com.

wheelchairs. These gadgets may learn from user interactions and alter their functioning as a result of machine learning algorithms. This adjustability promotes not only user comfort but also a sense of agency and control over the assistive technology.

In addition, the integration of smart robotic wheelchairs with the Internet of Things (IoT) enables smooth networking and data sharing. This connectivity allows users to acquire real-time information about their surroundings, plan ideal routes, and engage more effectively with their surroundings [3]. Adoption of smart robotic wheelchairs has the potential to improve the quality of life for persons with impairments dramatically. These gadgets encourage participation in social activities, employment, and the pursuit of personal interests and hobbies by providing more mobility and independence. Furthermore, smart robotic wheelchairs can break down social inclusion barriers by giving users better access to public venues and amenities.

1.1. Issues in choosing the right materials for the chassis

Selecting the correct materials for the chassis of intelligent robotic wheelchairs is a hard and crucial undertaking, since it has a direct impact on the assistive device's performance, safety, and overall functioning. While the advantages of employing new materials are obvious, designers and engineers must face various obstacles and issues during the material selection process [4]. In this in-depth talk, we will look at some of the most important difficulties and factors to consider when selecting materials for the chassis of intelligent robotic wheelchairs.

- **Affordability:**Cost considerations are critical for constructing intelligent robotic wheelchairs, as material selection has a substantial impact on overall manufacturing costs [5]. While new materials may have superior qualities, they can be costly, thereby increasing the overall cost of the wheelchair. In the case of assistive technology, affordability is especially essential because users frequently rely on insurance coverage or government subsidies to buy these gadgets. To guarantee that the robotic wheelchair is accessible to a wide range of users, a balance between cost and performance must be struck.
- **Durability and Maintenance:**The long-term longevity of the chassis is critical for the intelligent robotic wheelchair's reliability and safety [6]. Users may find frequent repairs and maintenance inconvenient and may result in downtime, reducing their mobility and independence. Materials with strong resistance to wear, corrosion, and fatigue are preferred to reduce maintenance requirements and extend the lifespan of the wheelchair. Furthermore, the materials chosen can have an impact on the simplicity of maintenance, as some materials may have specialized cleaning or care processes.
- **Integration of Sensors and Electronics:**To enable autonomous navigation and enhanced functionality, intelligent robotic wheelchairs frequently combine a variety of sensors, electronics, and control systems [7]. The chassis materials must be compatible with the integration of these technologies. Some materials have the potential to interfere with sensor signals, generate electromagnetic interference, or disrupt wireless communication. Integrating sensors and electronics without compromising performance necessitates careful material selection and testing.
- **Customization and Inclusivity:**Robotic wheelchairs frequently accommodate to users with varying mobility problems and preferences. As a result, the capacity to customize the chassis design to meet individual requirements is critical for inclusivity [8]. Specific adaptations, such as additional mounting points for medical equipment or assistive devices, may be required by some users. It is critical to construct personalized and user-centric intelligent robotic wheelchairs by using materials that are easily adaptable and can be adjusted without compromising structural integrity.
- **Sustainability and Environmental Impact:**The sustainability of chosen materials is a key factor as environmental concerns become more significant [9]. Choosing eco-friendly and recyclable materials supports sustainable development goals while reducing the environmental impact of wheelchair manufacturing and disposal. Furthermore, some materials may contain dangerous compounds or produce waste during manufacturing, presenting environmental problems that must be addressed during material selection.

Addressing mechanical characteristics, weight, cost, durability, safety, and testing challenges is critical for developing a dependable, high-performance, and user-centric assistive device. Designers and engineers may construct intelligent robotic wheelchairs that empower users, improve their mobility and independence, and ultimately improve their quality of life by overcoming these hurdles and making informed judgements during the material selection process.

1.2. Problem formulation

Building an efficient low-cost robotic wheelchair chassis is critical to improving the quality of life for persons with disabilities. The material used has a considerable impact on the performance and durability of the wheelchair. However, picking a material is a difficult undertaking that involves many elements and frequently necessitates a systematic approach in order to make informed judgements. MCDM techniques are one way to deal with this complexity. MCDM provides a formal framework for evaluating and ranking several alternatives based on a number of competing criteria.

A multitude of decision-making methodologies exist, including MCDM techniques utilized for tackling selection, classification, and ranking challenges. There remains no universally accepted consensus on the supremacy of a single method. Instead, it is advisable to perform a sensitivity analysis to assess the reliability of MCDM methods or to make comparisons with alternative approaches. In this study, a comparative analysis was conducted between EDAS and COPRAS, unveiling an insightful connection between these methods in the decision-making process.The EDAS method is designed for the purpose of selecting and ranking decision alternatives based on their average solution distances. During the evaluation process, EDAS assesses the performance of alternatives, favoring those with the highest positive distances and the lowest negative distances for inclusion in the optimal solution set. Conversely, COPRAS adopts a proportional evaluation approach, quantifying the relative superiority or inferiority of one alternative compared to another.

The CRITIC technique is one such MCDM technique that can be used to compute weights based on competing criteria. CRITIC compares two criteria in order to determine their relative relevance. CRITIC provides a precise and adaptable framework for parameter optimization by taking into account the interdependencies between criteria. The EDAS and COPRAS MCDM approaches can be used to select materials for a wheelchair chassis. These methods allow you to compare different materials based on a variety of design criteria. These

MCDM techniques can be used to construct a framework for selecting materials when developing a wheelchair chassis. EDAS or COPRAS can be used to rate materials depending on how well they meet the provided criteria. This concept allows to go thorough material analysis while taking into account several design elements and how they interact.The structural requirements for a robotic wheelchair, however, have a significant impact on how well it functions. The most important chassis design criteria consider according to a discussion with the design team and the literature review. The criteria and variants that were looked at in this study. It's notable that these guidelines have gotten overwhelmingly positive user reviews and feedback, proving that people with disabilities value them for wheelchair chassis design.

2. Literature Review

Material selection is a pivotal process in engineering design, determining the suitability of materials for specific applications while considering multiple criteria. To facilitate this complex decision-making process, engineers and researchers frequently turn to MCDM methods. One of the most widely employed MCDM methods in material selection is the AHP. India's auto industry is rapidly growing, emphasizing passenger vehicles and ATVs due to sports interest. In this research paper material is selected to evaluate via AHP for the steering rack, favoring EN24 among AISI9310, Al7075, EN353, and AISI D2, considering hardness, density, cost, and Young's modulus.. AHP involves constructing a hierarchical structure of criteria and sub-criteria, enabling the evaluation and ranking of materials based on attributes such as mechanical properties, cost, availability, and environmental impact [10].In response to mounting environmental challenges, the natural fibers market for eco-friendly bio-composites has gained prominence. This study enhances material selection using AHP with Weibull distribution, addressing property variations [11]. The findings favor NENDRAN BANANA for passenger vehicle parking brake components, with sensitivity to six sigma levels. In the context of hydrogen's increasing importance as an energy source, hydrogen storage methods are pivotal. Complex hydrides are a prevalent approach. This study employs the Analytical Hierarchical Process (AHP) to assess materials for hydrogen storage devices, considering mechanical, physical, chemical properties, and cost. Among alternatives, Mg4NiPd is identified as the optimal choice. Comprehensive inconsistency and sensitivity analyses affirm the model's robustness [12]. TOPSIS is another prominent MCDM technique applied to material selection. Researchers demonstrated TOPSIS utility in the automotive industry [13], where it considers factors like strength, weight, and cost. TOPSIS determines the relative proximity of each alternative material to both the ideal and anti-ideal solutions, aiding in selecting materials that fulfil a range of criteria.

PROMETHEE is a family of MCDM methods that enables the ranking of alternatives based on positive and negative flows. PROMETHEE method was used as an effective tool for decision-making by evaluating construction materials' attributes such as durability, thermal resistance, and cost-effectiveness [14]. PROMETHEE's structure allows for a comprehensive assessment of materials under diverse criteria.GRA is a distinctive MCDM approach that assesses relationships between criteria and alternatives. GRA method was applied in different areas such as Polymeric Materials Selection for Flexible Pulsating Heat Pipe Manufacturing [15] and natural fibre selection [16]. In the context of material selection, GRA facilitates the evaluation of mechanical properties, cost, and corrosion resistance, particularly in cases involving uncertain or incomplete information.

Selecting cotton fabric in garment design involves complex MCDM, often with uncertainty. This study introduces Pythagorean fuzzy sets (PFSs) into the ELECTRE method to enhance MCDM. The proposed PF-ELECTRE approach ranks cotton fabrics effectively, offering reliability and applicability to textile fields [17]. In order to facilitate multi-criteria group decision-making using Fermatean fuzzy evaluations, the study presents an expanded ELECTRE I model called the Fermatean fuzzy ELECTRE I technique. It computes aggregated outranking matrices, defines concordance and discordance sets for criteria comparison, and combines expert opinions using Fermatean fuzzy decision matrices. This approach can be used to choose biomaterials for the femoral component of hip joint prostheses, among other biomedical uses [18].Enhancing fabric comfort involves MCDM, incorporating fuzziness and uncertainty. This study introduces a Pythagorean fuzzy sets (PFS) based TOPSIS approach to select the best cotton fabric considering various properties. Sensitivity analysis on distance measures is conducted, demonstrating its applicability and reliability in textile areas, offering objective evaluations. The method considers mechanical properties, manufacturability, and economic feasibility when assessing materials for specific purposes. Fuzzy MCDM methods have emerged as a solution to address the uncertainty and vagueness inherent in decision-making. Fuzzy TOPSIS method applied in material selection in the cotton fibre industry, accommodating attributes like mechanical properties, cost, and environmental impact [19]. This approach extends conventional MCDM techniques by incorporating fuzzy logic to handle imprecise data.

In recent years, hybrid MCDM approaches have gained traction for material selection due to their ability to capitalize on the strengths of multiple methods. Hybrid AHP-PROMETHEE approach was applied for material selection in dental applications[20] and hybrid AHP-TOPSIS method is also applied for experimental investigation and optimization of cobalt bonded tungsten carbide composite [21]. The literature highlights the array of MCDM methods available for material selection. The selection of a particular method depends on the specific characteristics of the problem at hand, the available data, and the preferences of the decision-makers. These MCDM methods offer a systematic and structured approach to evaluating materials, enabling informed decisions that balance technical, economic, environmental, and social considerations.

2.1. Past studies on MCDM method application

MCDM methods have gained popularity in various fields due to their ability to systematically handle complex decision-making scenarios involving multiple criteria and alternatives. This literature review aims to provide an overview of the application of MCDM methods in diverse domains, highlighting their effectiveness in resolving real-world problems. By analyzing existing research, this review identifies the strengths and limitations of different MCDM techniques and presents their potential contributions to future decision-making processes.

In project management, MCDM methods play a vital role in selecting the most appropriate projects, allocating resources, and evaluating project performance. Studies have shown the successful application of techniques such as Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in project portfolio selection [22] and resource allocation [23]. These methods enable decision-makers to consider multiple factors, such as cost, risk, and benefit, leading to more informed and balanced decisions. A paper introduces a ship longitudinal movement risk assessment system based on Analytic Hierarchy Process (AHP). It combines hardware components with Beidou positioning and utilizes AHP to evaluate key risk factors. Genetic algorithms determine optimal parameters, establishing a risk assessment model [24]. The system enhances evaluation accuracy, reduces time, and stabilizes ship movement.A study offers a way for Jordanian decision-makers to use Multi-Criteria Decision Making (MCDM), specifically Analytical Hierarchy Process (AHP) and AHP-TOPSIS, to choose competitive waste-to-energy technologies [25]. It highlights how important environmental factors are, and landfill gas is the preferred choice. Decision-making in waste-to-energy applications is improved by this creative combination of TOPSIS and AHP.

Efficient supply chain management involves optimizing multiple criteria, including cost, lead time, quality, and sustainability. MCDM methods like the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and the Preference Selection Index (PSI) have been utilized to support supplier selection [22] and sustainable supplier evaluation [26]. These methods aid in identifying the most suitable suppliers and promoting sustainable practices within the supply chain. In contemporary industrial settings, arc welding robots play a pivotal role in various manufacturing applications. A study integrates rough numbers with the Multi-Attributive Border Approximation Area Comparison (MABAC) method for arc welding robot selection. Five decision makers' inputs are aggregated using rough numbers to enhance objectivity [27]. The criteria weights, as determined by the rough entropy method, highlight the significance of welding performance and payload, followed by robot cost. Effective energy management strategies are vital for enhancing fuel efficiency in hybrid electric vehicles (HEVs). This study introduces a multi-mode driving control approach that optimizes algorithms based on recognized driving patterns, leading to more efficient HEV powertrain design and control algorithms [28].

Addressing environmental issues requires considering various environmental, economic, and social factors. MCDM methods like the Simple Additive Weighting (SAW) and the Weighted Sum Model (WSM) have been employed in environmental impact assessments [29] and waste management decision-making [30]. These methods facilitate the integration of multiple criteria and support the identification of environmentally friendly solutions. In response to rising electricity costs and environmental concerns, the adoption of sustainable energy sources like solar power has gained momentum. Ensuring the efficiency of photovoltaic (PV) panels through effective cleaning methods is crucial. This study employs the Preference Selection Index (PSI) approach, informed by insights from Jordanian solar energy experts, to compare various PV panel cleaning methods [31]. Manual cleaning emerges as the preferred choice, a finding reinforced by sensitivity analysis results. This research contributes to decision-making in the field of PV panel maintenance. To enhance vehicle side impact safety, this study establishes a finite element model and utilizes various improvements to optimize performance [32]. This study introduces a finite element method for modeling crevice corrosion's impact on sheet pile steel, revealing how tensile strain and corrosion depth influence stress distribution and corrosion behavior [33].Structural health monitoring has gained prominence in the last two decades, focusing on precise damage detection and quantification to prevent catastrophic failure. This paper presents a hybrid approach combining Fuzzy Logic System (FLS) and Genetic Algorithm (GA) for automatic optimization of fuzzy rules in crack assessment. It employs Finite Element Analysis (FEA) and experimental data for validation, demonstrating the method's effectiveness in condition monitoring for structures [34].

In healthcare, MCDM methods have been applied to improve medical diagnoses, treatment selection, and resource allocation. TOPSIS-COPRAS have been utilized in diagnosing breast cancer [35]. Moreover, the AHP method has been used for prioritizing healthcare programs [36]. These approaches enhance medical decision-making by considering diverse criteria and patient preferences. The 21st century has witnessed substantial advancements in 3D printing technology, with research efforts spanning various sectors. This study explores the impact of four different printing methods on the tensile strength of Polylactic Acid parts produced via Fused Deposition Modeling. Experimental and statistical analyses reveal significant differences in the various printing methods, except for horizontal printing. [37].

CRITIC, EDAS, and COPRAS are popular MCDM techniques that have been widely applied in various domains. The CRITIC method focuses on assessing the relative importance of criteria through the inter-criteria correlations. It has been widely used in areas such as project management, environmental impact assessment, and supplier selection. The CRITIC method was applied to prioritize critical business process [38]. The research showed that CRITIC allowed decision-makers to identify the most critical criteria and tailor the project portfolio accordingly, improving resource allocation and project success. This paper introduces self-adaptive multi-population elitist (SAMPE) Rao and chaotic Rao algorithms for optimizing mechanical components. Their performance on benchmark and mechanical engineering problems is evaluated, demonstrating their significance and effectiveness compared to other algorithms [39].

EDAS is an MCDM technique based on the evaluation of alternatives by their distances from the average solution. It has been employed in various fields, including healthcare, manufacturing, and transportation. The EDAS method was used to assess and rank manufacturing companies' performance based on multiple criteria [40]. The results revealed the strengths and weaknesses of each company, aiding in benchmarking and performance improvement initiatives.

COPRAS is a complex proportional assessment approach that considers both the positive and negative aspects of criteria and alternatives. It has found applications in environmental management, supplier evaluation, and technology selection. COPRAS was applied to evaluate various alternatives for waste management strategies in a municipal setting [41]. In the context of evaluating supplier sustainability in industrial supply chains, the paper introduces a novel approach employing the Complex Proportional Assessment (COPRAS) method. It addresses the challenge of aggregating expert opinions with varying familiarity across sustainability criteria. Linguistic variables are transformed into type 2 fuzzy numbers, enabling a robust group decision-making process [42]. Additionally, the approach incorporates the problem analyst's perspective on expert reliability through intuitionistic fuzzy numbers, offering a means to handle uncertainty and doubt.

The method allowed for a comprehensive assessment of alternatives, considering both benefits and drawbacks, leading to more informed and sustainable decisions. These techniques provide valuable insights into decision-making processes by considering multiple criteria and alternatives. However, their appropriateness depends on the decision context and the specific requirements of each problem. By understanding the characteristics and capabilities of CRITIC, EDAS, and COPRAS methods, decision-makers can choose the most suitable approach for their unique decision-making challenges.

2.2. Novelty and Research Gap

Robotic wheelchairs have become a game-changing piece of technology that enables people with mobility issues to restore their freedom and enhance their quality of life. The choice of appropriate materials for the chassis is a crucial step in building effective and dependable robotic wheelchairs.

Novelty and Originality:

This study is innovative in that it combines three different MCDM approaches—CRITIC, EDAS, and COPRAS—to assess potential material choices for robotic wheelchair chassis. Although each of these MCDM approaches has been used in earlier research to address a different decision-making problem, its combined application to the problem of choosing the material for a robotic wheelchair chassis has received comparatively no attention. This research suggests a complete and holistic framework to evaluate material options for increased performance, durability, and cost-effectiveness by combining the qualities of each approach.

1. **Integration of MCDM Methods:** The merging of three well-known MCDM approaches contributes to the research's uniqueness. While EDAS offers a way to assess alternatives based on distances from the average answer, COPRAS enables taking into account both the positive and negative features of criteria and alternatives. CRITIC offers a systematic method for establishing criteria weights based on inter-criteria correlations. The combination of these three methods allows for a more thorough and impartial analysis of the available materials for robotic wheelchair chassis.
2. **Material Selection for Robotic Wheelchair Chassis:** While studies on material choice in a variety of engineering domains already exist, there is a paucity of research devoted especially to robotic wheelchair chassis. This study fills the gap by using MCDM techniques to assess different materials while taking into account characteristics specific to the design of robotic wheelchairs, such as weight, strength, durability, and manufacturability.

2.2.1. Research Gap:

There are currently no thorough, systematic methods for selecting materials for robotic wheelchair chassis that take into account a variety of factors and take into account both the advantages and disadvantages of materials. Although other decision-making contexts have used the individual MCDM approaches, their combined application to assess material possibilities for robotic wheelchair chassis is still unexplored. Consequently, the following can be used to summarize the research gap:

1. **Lack of Comprehensive Framework:** There isn't a thorough framework for MCDM material evaluation for robotic wheelchair chassis in the existing literature. To provide an informed and balanced decision-making process and to take into account multiple variables at once, a holistic approach is required.
2. **Limited Application to Robotic Wheelchair Chassis:** Despite the growing significance of robotic wheelchairs in improving mobility for people with physical limitations, little study has been done explicitly on material selection for these devices. Understanding how various materials can affect the functionality, longevity, and overall cost-effectiveness of robotic wheelchair chassis is a research gap.
3. **Consideration of Positive and Negative Aspects:** Traditional methods of material selection frequently ignore potential downsides and limitations in favor of highlighting just the advantages of a material. The COPRAS technique gives a distinctive viewpoint on material selection in robotic wheelchair chassis design that has not yet been extensively used because it takes into account both positive and negative elements.

An innovative and methodical approach to filling the research gap is provided by the proposed research on material alternatives for robotic wheelchair chassis using a combined CRITIC, EDAS, and COPRAS framework. This study aims to offer useful insights for engineers, designers, and decision-makers in the field of assistive technology by integrating multiple MCDM methods and concentrating on material selection for robotic wheelchair chassis, ultimately leading to the development of more effective, long-lasting, and affordable robotic wheelchair designs.

2.3. Identifying the parameters for the proposed study

A constrained range of potential criteria and additional possibilities are the main focus of MCDM inquiry. Twelve alternative materials and seven competing elements are being evaluated for this inquiry, as shown in Table 2. Prior researchers must establish crucial criteria in order to apply MCDM to find the optimal material for a prototype chassis. Five people who are working on a smart wheelchair prototype, including two professors, two Ph.D. students, and one research associate, formed a focus group to discuss about the important factors that will influence the decision to buy the material for the market-available chassis. Other than that, facts, and information that were acquired from a range of sources, including websites, periodicals, and books from different publications, as well as different YouTube channels, bloggers, comments, and focus group conversations. The seven essential and incompatible parameters are as follows, as described in more detail.

- **Tensile Strength (TS):** The term "tensile strength" describes the highest stress that a material can withstand before breaking under tension. When designing a wheelchair chassis, it is crucial to take the material's tensile strength into account to make sure it can withstand the stresses and forces that are produced during routine use, such as when the wheelchair encounters bumps or uneven terrain.
- **Von Mises Stress (VMS):** The cumulative impact of the many stress components within a material is measured by the von Mises stress. It is used to evaluate the material's total strength under various loading circumstances and accounts for both tensile and compressive stresses. When determining if a wheelchair chassis' material can endure the expected mechanical loads without deforming or failing, the von Mises stress is taken into account.
- **Displacement (D):** When a substance is subjected to external forces, displacement describes the degree of movement or deformation the material experiences. Understanding the material's behavior under various loads and if it will keep its structural integrity and stability during wheelchair use can be done by measuring the displacement.
- **Equivalent Strain (ES):** The amount of overall deformation or strain that a material experiences as a result of applied forces is measured as equivalent strain. The

material's capacity to endure and recover from strain is indicated by taking into account both elastic and plastic deformation. In order to be sure that the chosen material can withstand numerous loading cycles without suffering from severe permanent deformation, it is imperative to evaluate equivalent strain.

- **Cost (C):** Cost is an important criterion in material selection as it directly impacts the overall manufacturing budget. Considering the cost helps in optimizing the economic feasibility of the design. It involves not only the initial material cost but also factors such as fabrication, processing, maintenance, and replacement costs throughout the wheelchair's lifespan.
- **Mass Density (MD):** Mass density refers to the amount of mass present in a given volume of material. For a wheelchair chassis, it is important to consider the mass density to ensure a balance between structural strength and weight. Lower mass density materials can contribute to a lighter chassis, making the wheelchair more maneuverable and energy-efficient.
- **Thermal Expansion Coefficient (TEC):** The thermal expansion coefficient represents how much a material expands or contracts when subjected to temperature variations. Considering the TEC is vital in designing a wheelchair chassis that can withstand temperature changes without causing dimensional instability or introducing unwanted stresses due to thermal expansion mismatch between different components.

The researchers want to determine which material for the smart robotic power wheelchair chassis best satisfies the parameters of tensile strength, von Mises stress, displacement, equivalent strain, cost, mass density, and thermal expansion coefficient. The chosen material must meet the criteria for the intended use in terms of mechanical qualities, durability, cost, weight efficiency, and thermal stability.

This study represents 12 different materials with expenditures varying from cheap to high be picked from a variety of manufacturers and have variable qualities that can be obtained on different B2B market data and structural analysis with SOLIDWORKS (as shown in section 3.1), as indicated in Table 1.

2.4. Objective of This Study

This research paper's goal is to suggest and put into practice a fresh paradigm for assessing material options for robotic wheelchair chassis design. The study's specific goal is to combine three different MCDM methods—CRITIC, EDAS, and COPRAS—into a single framework to provide a thorough and methodical evaluation of materials based on various criteria. The research aims to accomplish the following primary goals:

1. To evaluate potential material choices for low cost robotic wheelchair chassis, create a solid and cohesive MCDM framework that combines the CRITIC, EDAS, and COPRAS techniques. With the help of this thorough framework, many factors may be taken into account holistically, giving decision-makers a methodical way to choose the best materials.
2. To utilize the CRITIC approach to assess the relative weights of criteria based on the correlations between those criteria. The framework will priorities the importance of various material properties in the context of robotic wheelchair chassis design by allocating the proper weights to each criterion.
3. To utilize the EDAS approach to assess material choices according to how far they are from the optimal choice. This process will make it possible to compare various materials while taking into account how close they are to the ideal material combination.
4. To include the COPRAS approach to take both a material's advantages and disadvantages into account. The framework will ensure a fair review by taking into account potential benefits and downsides, improving the choice of materials that meet the unique needs of robotic wheelchair chassis.

By attaining these goals, this study seeks to advance the field of material selection for robotic wheelchair chassis by presenting a fresh and integrated MCDM strategy that fills a knowledge gap and improves the decision-making processes in the field of assistive technology. Thus, the following section includes material and methods, results and discussion, conclusion, and future work of the current study.

Table 1. Parameter information for the required proposed study

Criteria	TS 10^8 N/m^2	VMS 10^8 N/m^2	D 10^-01mm	ES 10^-3	C per kg	MD kg/m3	TEC 10^-5/kelvin
M-1	1.5166	1.2700	7.9480	1.0710	47.0000	7200.0000	1.2000
M-2	0.6894	1.2280	7.5440	1.0420	250.0000	2700.0000	2.4000
M-3	3.5690	1.2560	2.6220	0.3562	75.0000	7870.0000	1.1000
M-4	3.4400	1.1980	4.9020	0.6884	1400.0000	4510.0000	0.9000
M-5	8.6170	1.2420	4.3560	0.5965	65.0000	7100.0000	1.1000
M-6	4.8500	1.2740	2.6310	0.3538	255.0000	8027.0000	1.6500
M-7	5.5000	1.1980	4.9020	0.6884	3000.0000	4510.0000	0.9000
M-8	4.0000	1.2770	2.6330	0.3532	100.0000	7850.0000	1.3200
M-9	5.6000	1.2590	2.5610	0.3471	150.0000	7850.0000	1.2000
M-10	9.0000	1.2280	4.5270	0.6251	6900.0000	4730.0000	0.8600
M-11	4.1361	1.2700	2.7680	0.3729	110.0000	7300.0000	1.2000
M-12	4.2051	1.2280	7.0340	0.9715	205.0000	2800.0000	2.2000

3. Material and Methods

The component that is being provided includes the structural analysis of the low cost robotic power wheelchair chassis using various materials and the selected MCDM instruments. The numerous materials that will help with the evaluation have all been thoroughly. Then, in order to prioritize various bits of content, the criterion or parameter weights are calculated using the CRITIC tool. The EDAS and COPRAS methods are used to establish the rank of material for chassis as shown in figure 1.

3.1. Parameter estimation through structural design

The chassis is the most important part that gives a wheelchair strength and stability under various conditions. The chassis, which serves as a framework and supports the wheelchair's body and many components, is depicted in figure 2. There have been numerous recent studies using the finite element method that concentrate on stress analysis on the frame of various wheelchairs [43].The mid-drive power wheelchair frame is subjected to stress analysis using SolidWorks 2019's finite element method. The Finite Element Method uses computing to provide an accurate solution to a challenging mathematical and structural problem by substituting the components for the original suggested structure.

Numerous loading situations, including static loads like compressive, tensile, shear, and fatigue, are applied to a wheelchair's chassis. To find out where the stresses are most intense and to comprehend the issues with the frame, techniques like the finite element approach can be employed. The wheelchair's frame material must also be taken into account. Using alternative materials such ductile Iron (M-1), 1060 Alloy (M-2), Galvanized Steel (M-3), Commercially Pure CP-Ti UNS R50400 (M-4), Gray Cast Iron(M-5), AISI Type 316L stainless steel (M-6), Commercially Pure CP-Ti UNS R50700 Grade 4 (M-7), ASTM A36 Steel (M-8), AISI 4130 Steel (M-9), annealed at 865C (M-10), Annealed Titanium Ti-Mn (M-11), Malleable Cast Iron-2018 Alloy (M-12)could make the frame lighter and enhance the wheelchair's performance. With the help of software like SOLIDWORKS, it would be possible to breakdown and build a mid-drive power wheelchair. Table 2 show some analyses with various materials and the corresponding values.

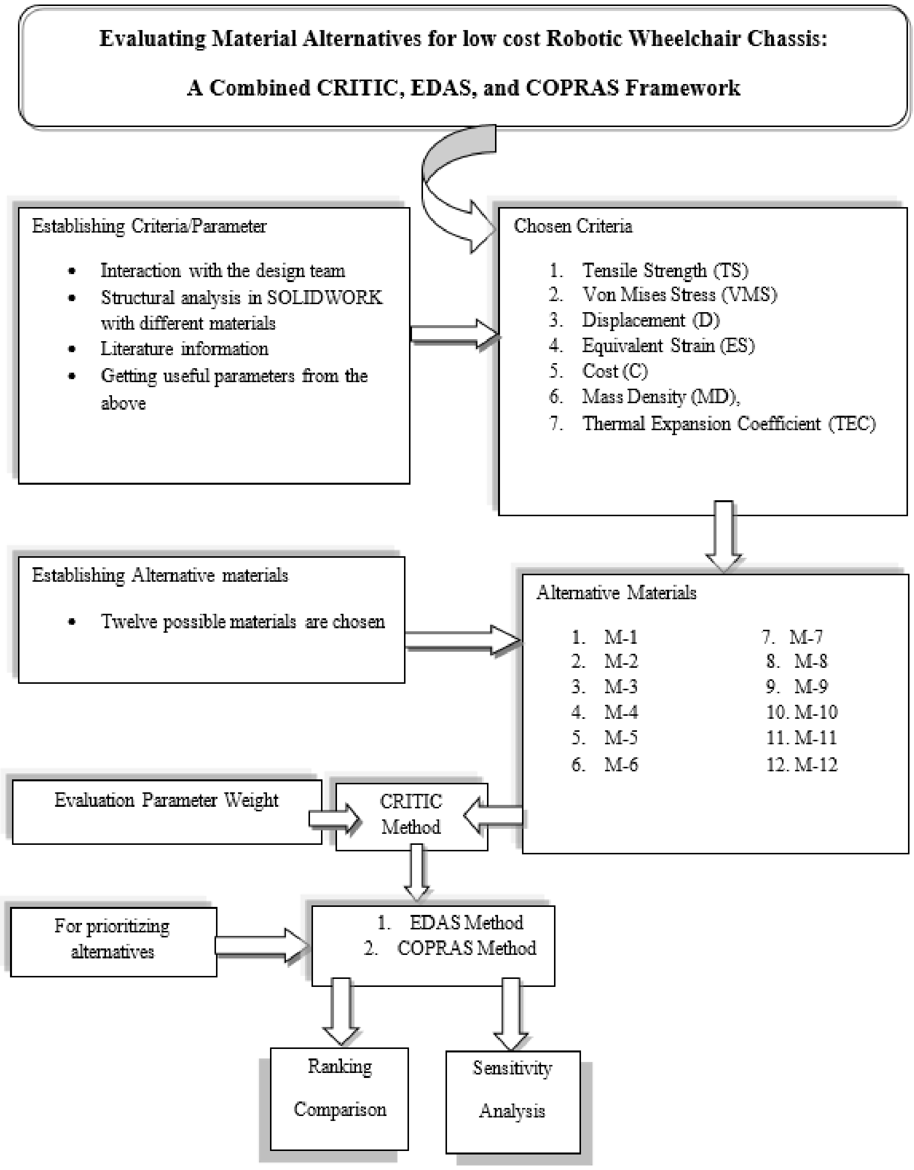
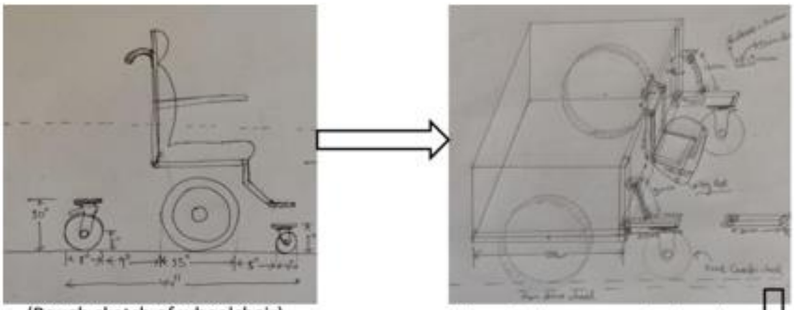
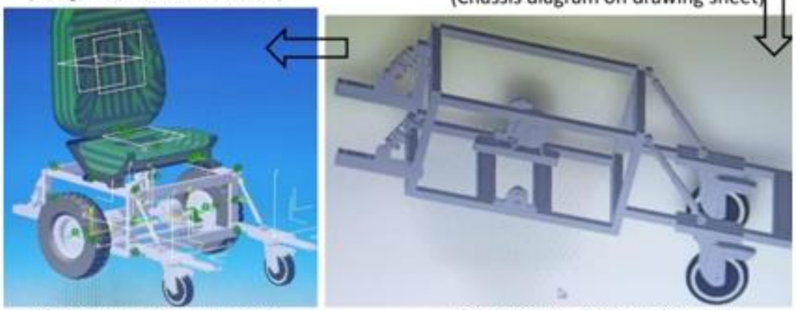


Figure 1. Flow chart of proposed study framework



(Rough sketch of wheelchair)

(Chassis diagram on drawing sheet)

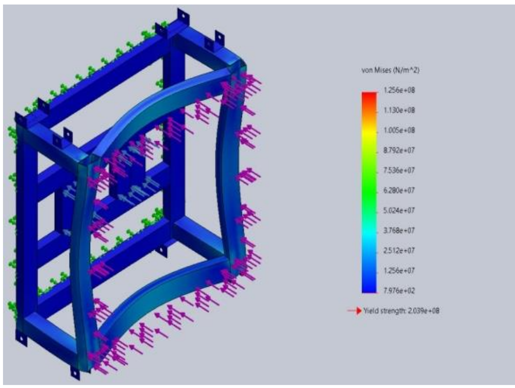
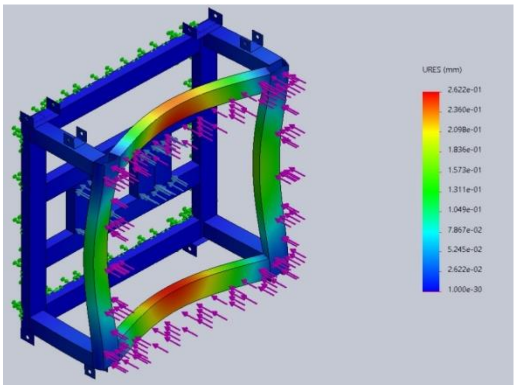
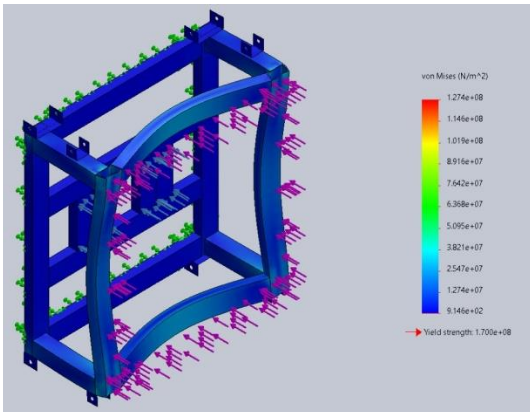
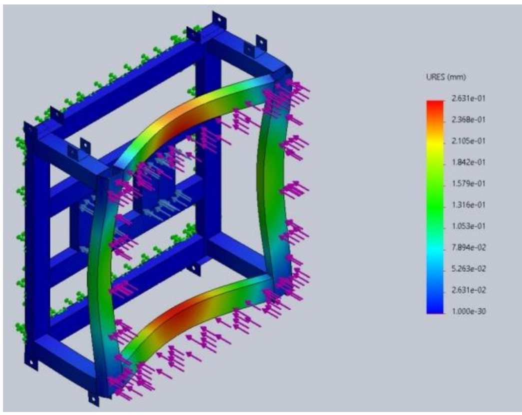


(CAD Model of wheelchair)

(CAD Model of Central Chassis)

Figure 2. Wheelchair Chassis under consideration

Table 2SOLIDWORK Simulation of various materials

Sl. No.	Von Mises Stress	Deformation
1.Galvanized Steel		
2. AISI Type 316L stainless steel		

3.2. Criteria Importance through inter-criteria correlation (CRITIC)

Making decisions when several competing criteria must be taken into account is the subject of the study area known as MCDM. By combining the criteria into a single objective function, traditional MCDM approaches seek to identify a compromise solution. However, these techniques frequently fail to account for the subjectivity and complexity that characterize real-world decision-making situations. A cutting-edge strategy called CRITIC MCDM solves these drawbacks by taking into account the opinions of various decision-making experts or stakeholders. Diakoulaki et al. [44] introduced the CRITIC approach as a mechanism for balancing competing criteria in MCDM. The CRITIC method is outlined in the following steps:

Step-1: Eq. (1), which depicts the behavior of individual options dependent on many factors, is used to build the decision matrix C. The twelve material alternatives' performance entity ratings are represented by "Cij." Table 1 lists the set of criterion or preference parameters and their corresponding values, where 'm' stands for the array of options and 'n' for the set of criteria.

Step-2: This objective weighting approach uses Equation (2), which normalizes the decision matrix's best-worst form. Table 3 displays the standard deviation (σ_j) for the column of each parameter using Equations (3) and (4) as well as the normalized performance grades C_{ij}^{N}after applying Equation (2).

$$C = (C_{ij})_{m\times n} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdots & C_{1j} & \cdots & C_{1n} \\ C_{21} & C_{22} & C_{23} & \cdots & C_{2j} & \cdots & C_{2n} \\ C_{31} & C_{32} & C_{33} & \cdots & C_{3j} & \cdots & C_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{i1} & C_{i2} & C_{i3} & \cdots & C_{ij} & \cdots & C_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{m1} & C_{m2} & C_{m3} & \cdots & C_{mj} & \cdots & C_{mn} \end{bmatrix} \quad (1)$$

$$C_{ij}^{N} = \frac{C_{ij} - \text{Worst}\ (X_{ij})}{\text{Best}(C_{ij}) - \text{Worst}(C_{ij})} \quad (2)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(C_{ij}^{T} - \bar{C}_j)^2}{m-1}} \quad , j = 1, 2\ldots\ldots\ldots\ldots n \quad (3)$$

Where, $\bar{C}_j = \frac{\sum_{i=1}^{m} C_{ij}^{T}}{m-1}$, j = 1, 2………..n (4)

Step-3:A symmetric matrix (S) according to equations (5) and (6) is created, and each element of this array is represented by the linear correlation coefficient (LCC) between the j_{th} parameter's column and the $(j+1)_{th}$ parameter's column.

$$S = [S_{j,j+1}]_{n\times n} \quad , j = 1, 2, 3, \ldots n \quad (5)$$

$$S_{j,j+1} = \text{Correlation}[C_{ij}^{N} j_{th} \text{ parameter}, C_{ij}^{N}(j + 1)_{th} \text{ parameter}] \quad (6)$$

Step-4: The j_{th} variable, which is dependent on the symmetric matrix, is used to produce the measure of conflict (MC) based on Eq. (7). The information indication for the parameter j increases as measure MC_jincreases.

$$MC_j = \sum_{j+1=1}^{n} (1 - S_{j,j+1}) \quad (7)$$

Step-5: The value of information (AI_j) is now calculated and displayed in Table 5 employing Eq. (8).

$$AI_j = \sigma_j \times MC_j \quad (8)$$

Step-6: To help priorities the material choices, generate the ultimate objective scores for every variable (W_j) as shown in Table 4 by using Eq. (9) and normalizing the AI_j values.

$$W_j = \frac{AI_j}{\sum_{j=1}^{n} AI_j} \quad , \quad j = 1,2,3\ldots\ldots\ldots\ldots n \quad (9)$$

The decision-making process offered by CRITIC is transparent and trustworthy since it is based on the underlying decision facts and takes into account how different criteria are related to one another. It is frequently used in conjunction with other MCDM methods to establish impartial weights for assessing various solutions.

Table 3 Normalization Decision Matrix

Criteria	**TS**	**VMS**	**D**	**ES**	**C**	**MD**	**TEC**
M-1	0.0995	0.9114	1.0000	0.0000	1.0000	0.1552	0.7792
M-2	0.0000	0.3797	0.9250	0.0401	0.9704	1.0000	0.0000
M-3	0.3465	0.7342	0.0113	0.9874	0.9959	0.0295	0.8442
M-4	0.3310	0.0000	0.4346	0.5285	0.8026	0.6602	0.9740
M-5	0.9539	0.5570	0.3332	0.6555	0.9974	0.1740	0.8442
M-6	0.5006	0.9620	0.0130	0.9907	0.9696	0.0000	0.4870
M-7	0.5789	0.0000	0.4346	0.5285	0.5691	0.6602	0.9740
M-8	0.3984	1.0000	0.0134	0.9916	0.9923	0.0332	0.7013
M-9	0.5909	0.7722	0.0000	1.0000	0.9850	0.0332	0.7792
M-10	1.0000	0.3797	0.3650	0.6160	0.0000	0.6189	1.0000
M-11	0.4147	0.9114	0.0384	0.9644	0.9908	0.1365	0.7792
M-12	0.4230	0.3797	0.8303	0.1374	0.9769	0.9812	0.1299

Table 4 Objective Weights by CRITIC

Criteria	**TS**	**VMS**	**D**	**ES**	**C**	**MD**	**TEC**	**MCj**	**Wj**
TS	0.0000	1.1319	1.4169	0.5919	1.5604	1.1534	0.4962	1.8620	0.1121
VMS	1.1319	0.0000	1.4002	0.5679	0.5212	1.7842	1.0924	2.3149	0.1393
D	1.4169	1.4002	0.0000	1.9993	1.0364	0.2973	1.4499	2.8589	0.1721
ES	0.5919	0.5679	1.9993	0.0000	0.9484	1.7254	0.5529	2.4696	0.1486
C	1.5604	0.5212	1.0364	0.9484	0.0000	1.3466	1.4242	2.0326	0.1223
MD	1.1534	1.7842	0.2973	1.7254	1.3466	0.0000	1.4498	2.9763	0.1791
TEC	0.4962	1.0924	1.4499	0.5529	1.4242	1.4498	0.0000	2.0996	0.1264

3.3. EDAS Method

EDAS is an effective MCDM tool created specifically to address decision-making issues involving numerous factors. Assessing the separation among every option and the average solution in the multi-dimensional parameter space is one of the methodological phases in EDAS. The EDAS approach, one of the suitable MCDM techniques, uses the average solution to assess options while accounting for PDA (positive distance from average) and NDA (negative distance from average). This method allows for an assessment of all possible solutions to a decision-making problem in terms of a number of factors, many of which conflict when higher PDA and lower NDA values are present. The operating steps of EDAS are described as follows:

Step-1: The decision matrix in Eq. (1) must be created in the first step. The outcomes are displayed in Table 1 and are exactly the same as those from CRITIC technique previously employed.

Step-2: Find the average response for each of the parameter using Eq. (10), as indicated below:

$$AV = [AV_j]_{1\times n} \text{ Where, } AV_j = \frac{\sum_{i=1}^{m} a_{ij}}{m} \quad (10)$$

Step-3: Applying Eq. 11, 12, 13, and 14, establish the PDA and NDA matrix structures according to the kind of factor (benefit or cost), and the appropriate values are displayed in table 5 and 6 as follows:

If j_{th} factor is beneficial,

$$PDA_{ij} = \frac{\max(0,(a_{ij}-AV_j))}{AV_j} \quad (11)$$

$$NDA_{ij} = \frac{\max(0,(AV_j-a_{ij}))}{AV_j} \quad (12)$$

Ifj_{th} factor is cost,

$$PDA_{ij} = \frac{\max(0,(AV_j-a_{ij}))}{AV_j} \quad (13)$$

$$NDA_{ij} = \frac{\max(0,(a_{ij}-AV_j))}{AV_j} \quad (14)$$

Step-4: Determine the weighted sum of PDA and NDA (SP_i and SN_i) for all alternatives using Eq. 15 and 16, and indicated as follows:

$$SP_i = \sum_{j=1}^{n} w_j\, PDA_{ij} \quad (15)$$

$$SN_i = \sum_{j=1}^{n} w_j\, NDA_{ij} \quad (16)$$

Where, w_j is the weight of j_{th} factor.

Step-5: Normalize the score of SP and SN for all alternatives using Eq. (17) and (18), and indicated as follows:

$$NSP_i = \frac{SP_i}{max_i(SP_i)} \quad (17)$$

$$NSN_i = 1 - \frac{SN_i}{max_i(SN_i)} \quad (18)$$

Table 5 PDA for wheelchair material

Criteria	TS	VMS	D	ES	C	MD	TEC
M-1	0.0000	0.0209	0.7523	0.0000	0.9551	0.0000	0.1017
M-2	0.0000	0.0000	0.6633	0.0000	0.7611	0.5528	0.0000
M-3	0.0000	0.0096	0.0000	0.4275	0.9283	0.0000	0.1765
M-4	0.0000	0.0000	0.0808	0.0000	0.0000	0.2530	0.3263
M-5	0.8759	0.0000	0.0000	0.0413	0.9379	0.0000	0.1765
M-6	0.0558	0.0241	0.0000	0.4313	0.7563	0.0000	0.0000
M-7	0.1973	0.0000	0.0808	0.0000	0.0000	0.2530	0.3263
M-8	0.0000	0.0265	0.0000	0.4323	0.9044	0.0000	0.0119
M-9	0.2191	0.0121	0.0000	0.4421	0.8567	0.0000	0.1017
M-10	0.9593	0.0000	0.0000	0.0000	0.0000	0.2165	0.3562
M-11	0.0000	0.0209	0.0000	0.4007	0.8949	0.0000	0.1017
M-12	0.0000	0.0000	0.5508	0.0000	0.8041	0.5362	0.0000

Table 6 NDA for wheelchair material

Criteria	TS	VMS	D	ES	C	MD	TEC
M-1	0.6698	0.0000	0.0000	0.7214	0.0000	0.1926	0.0000
M-2	0.8499	0.0129	0.0000	0.6748	0.0000	0.0000	0.7966
M-3	0.2230	0.0000	0.4219	0.0000	0.0000	0.3036	0.0000
M-4	0.2511	0.0370	0.0000	0.1064	0.3379	0.0000	0.0000
M-5	0.0000	0.0016	0.0396	0.0000	0.0000	0.1760	0.0000
M-6	0.0000	0.0000	0.4199	0.0000	0.0000	0.3296	0.2352
M-7	0.0000	0.0370	0.0000	0.1064	1.8669	0.0000	0.0000
M-8	0.1292	0.0000	0.4195	0.0000	0.0000	0.3003	0.0000
M-9	0.0000	0.0000	0.4354	0.0000	0.0000	0.3003	0.0000
M-10	0.0000	0.0129	0.0019	0.0047	5.5939	0.0000	0.0000
M-11	0.0996	0.0000	0.3897	0.0000	0.0000	0.2092	0.0000
M-12	0.0846	0.0129	0.0000	0.5615	0.0000	0.0000	0.6469

Table 7 Appraisal score and corresponding Rank

Options	NSP_i	NSN_i	AS_i	RANK
M-1	0.8557	0.6845	0.7701	4
M-2	1.0000	0.5663	0.7832	3
M-3	0.6555	0.7788	0.7172	7
M-4	0.3280	0.8684	0.5982	10
M-5	0.7880	0.9439	0.8659	1
M-6	0.5429	0.7657	0.6543	9
M-7	0.4002	0.6371	0.5186	11
M-8	0.5881	0.7956	0.6918	8
M-9	0.6844	0.8127	0.7485	5
M-10	0.6246	0.0000	0.3123	12
M-11	0.6034	0.8316	0.7175	6
M-12	0.9443	0.7432	0.8438	2

Step-6: Evaluate the appraisal score (AS_i) for all alternatives/options using Eq. (19), and indicated as follows:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (19)$$

Where, $0 \leq AS_i \leq 1$

Step 7: Using a declining assessment score, alternatives are rated from best to worst. The option with the highest AS_i value is the best option among the alternatives. Table 7 displays the values of NSP_i, NSN_i, appraisal score, and associated rank generated by the CRITIC-based EDAS approach.

3.4. COPRAS Method

In order to address complex decision-making scenarios, COPRAS is a potent MCDM technique. The COPRAS methodology includes a series of pair-wise comparisons to determine the collective dominance index for each option. The fundamental tenet of COPRAS is to aggregate the individual dominance values to produce a global ranking of options. When tackling challenging decisions including interrelated criteria, COPRAS is especially helpful since it considers positive as well as negative effects among the criteria, resulting in more precise and meaningful rankings [45]. The operational procedures of COPRAS are described as follows:

Step-1: The decision matrix in Eq. (1) must be created in the first step. The outcomes are displayed in Table 1 and are exactly the same as those from CRITIC technique previously employed.

Step-2: After that, Eq. (2) will be used to normalize the choice matrix. It should be made clear that unlike the CRITIC method, the COPRAS technique does not use reciprocal values to convert the minimizing parameters into maximizing criteria. All COPRAS criteria should be linearly normalized using Eq. (2), regardless of whether they are minimizing or maximizing.

Step-3: Apply Eq. (20) to calculate the weighted values.

$$W_{ij} = N_{ij} \times w_j \text{ Where, i=1, 2…., m: j=1, 2…... n} \quad (20)$$

"W_{ij}" are the weighted values of the j_{th} parameter and i_{th} alternative. w_j are the weights of the j_{th}parameters. The weighted normalized matrix is shown in Table 8.

Step-4: Using Eq. (21), the relative significance (Q_i) of each alternative possibility is evaluated.

$$Q_i = S_{+i} + \frac{S_{-min}\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}(S_{-min}/S_{-1})}, \; S_{-min} = \min(S_{-i}) \quad (21)$$

In the aforementioned Eq. (21), "S_{+i}" and "S_{-i}" represent for the weighted value summation of the maximizing and minimizing factors, respectively, which may be determined using Esq. (22) and (23). Among the Si values, "S_{-min}" is the lowest value.

$$S_{+i} = \sum_{j=1}^{n} W_{+ij} \rightarrow \sum_{i=1}^{m} S_{+i} = \sum_{i=1}^{m}\sum_{j=1}^{n} W_{+ij} \quad (22)$$

$$S_{-i} = \sum_{j=1}^{n} W_{-ij} \rightarrow \sum_{i=1}^{m} S_{-i} = \sum_{i=1}^{m}\sum_{j=1}^{n} W_{-ij} \quad (23)$$

"W_{+ij}" and "W_{-ij}" are the weighted values of the maximizing and minimizing factors/parameters, respectively, where i=1, 2...., m; j=1, 2...., n.

Step-5: Finally, Eq. (24) is used to calculate the alternatives' quantitative utility (Ui).

$$U_i = \left[{Q_i}/{Q_{max}}\right] * 100, \text{ Where i=1,2,……,m} \quad (24)$$

"Q_{max}" is the maximum relative significance value.

Equations (21) to (24) are utilized for separating the weighted normalized matrix's quantitative utility vectors for each wheelchair material according to how well they may be used for selecting the most suitable material. The relative relevance, quantitative utility values, and ranking of the options are shown in Table 9.

Table 8. Weighted normalized matrix for wheelchair material

Options	TS	VMS	D	ES	C	MD	TEC
M-1	0.0031	0.0119	0.0251	0.0213	0.0005	0.0178	0.0095
M-2	0.0014	0.0115	0.0239	0.0207	0.0024	0.0067	0.0189
M-3	0.0073	0.0117	0.0083	0.0071	0.0007	0.0195	0.0087
M-4	0.0070	0.0112	0.0155	0.0137	0.0136	0.0112	0.0071
M-5	0.0175	0.0116	0.0138	0.0119	0.0006	0.0176	0.0087
M-6	0.0099	0.0119	0.0083	0.0070	0.0025	0.0198	0.0130
M-7	0.0112	0.0112	0.0155	0.0137	0.0292	0.0112	0.0071
M-8	0.0081	0.0119	0.0083	0.0070	0.0010	0.0194	0.0104
M-9	0.0114	0.0118	0.0081	0.0069	0.0015	0.0194	0.0095
M-10	0.0183	0.0115	0.0143	0.0124	0.0672	0.0117	0.0068
M-11	0.0084	0.0119	0.0088	0.0074	0.0011	0.0181	0.0095
M-12	0.0085	0.0115	0.0222	0.0193	0.0020	0.0069	0.0173

Table 9. The Relative Significance (Qi) and Quantitative Utility scores (Ui) of individual possibilities

Options	Q_i	U_i	U_i **in %**	Rank
M-1	0.0837	0.8530	85%	7
M-2	0.0806	0.8213	82%	9
M-3	0.0868	0.8844	88%	5
M-4	0.0806	0.8215	82%	8
M-5	0.0981	1.0000	100%	1
M-6	0.0805	0.8209	82%	10
M-7	0.0728	0.7423	74%	11
M-8	0.0849	0.8657	87%	6
M-9	0.0887	0.9038	90%	3
M-10	0.0659	0.6714	67%	12
M-11	0.0884	0.9013	90%	4
M-12	0.0891	0.9088	91%	2

The three adopted MCDM tools, CRITIC, COPRAS, and EDAS, offer valuable decision-making support through distinct methodologies and principles. CRITIC focuses on identifying informative factors/criteria, COPRAS handles complex decision scenarios with interdependent criteria, and EDAS evaluates the distance between each alternative and the average solution.

4. Results and Discussion

All of the suggested materials for constructed wheelchair chassis are compared using the EDAS and COPRAS methods and rated based on the weighted value of the CRITIC approach. The relative significant value (Q_i) of the COPRAS method and the appraisal score (AS_i) for EDAS are both calculated for each of the 12 alternative materials. In the section that follows, the results of the two procedures are covered in great depth. The final overall ranking of the options utilizing the MCDM models that were employed to priorities the materials is shown in Table 10. For the two MCDM techniques, Table 10 shows the preferred ranked list of the twelve materials in decreasing order. Let's take a quick look at one of the most important findings from this inquiry on decision-making.To start, Table 10's two rankings from two MCDM approaches show that M-5 receives the highest ranking from EDAS and COPRAS among all the possibilities. In actuality, there is no room for doubt regarding the best material among those suggested materials to build the robotic wheelchair's chassis because the two approaches employed yield the same best solution. Even though the two techniques indicate that M-10 is the poorest material for the intended study, determining the inferior option from the recommended ranking in response to negative influence is difficult. In most multi-criteria analyses, it's just as important to choose the best option as it is to understand the absolute worst alternative. Additionally, the following is the hierarchy of material importance for prototype designers' stakeholders:

- M-5>M-12>M-2>M-1>M-9>M-11>M-3>M-8>M-6>M-4>M-7>M-10 based on CRITIC-EDAS method
- M-5>M-12>M-9>M-11>M-3>M-8>M-1>M-4>M-2>M-6>M-7>M-10based on CRITIC-COPRAS method

As illustrated in Table 10, a total of five more MCDM methods (SAW, WPM, WASPAS, ARAS, and TOPSIS) are also utilized to rank a total of twelve alternative materials. The M-5 alternative material is the best among the materials chosen for wheelchair chassis construction, according to all fiveextra MCDM techniques. The article suggests a final priority ranking for the options in Table 10 by integrating all seven rankings and applying the Copeland voting principle to determine the one best option from the list. As a result, stakeholders in wheelchair chassis will be able to rank the twelve materials according to their noteworthy qualities, from best to worst effective.

4.1. Sensitivity Analysis on CRITIC based EDAS and COPRAS Method

This segment looks at the toughness and reliability of the two MCDM instruments that have been used so far. Sensitivity investigation is an algorithmic operation used to examine and confirm the uniformity of a technique. Under certain instances, the stake holders may be obligated to get their own views and suggestions referring to the knowledge and expertise. For such situations, there is a higher risk of ambiguity and partiality, which could lead to some erroneous conclusions. By varying the parametric weights or decision elements of parameter, sensitivity investigation is used to estimate the precision and stability. In this article, seven distinct parameters are used to evaluate material alternatives to aid in design and development of a central chassis prototype.

Following the identification of the "most essential parameter (MEP)" based on the weights predicted using the criteria weighting approach, the weight sensitivity analysis is carried out by adjusting the weight of the MEP to examine the influence of the proposed model on its ranking effectiveness. The phases of the sensitivity analysis procedure according to weight change are presented.

Step-1: Estimate the weight elastic coefficient (W_{ec}). W_{ec} is a value that indicates the corresponding balance among various weights in respect of specific modifications to the weight of the MEP during sensitivity analysis. For the MEP, the score will always be specified as "1". Eq. (25) is utilized for the remaining criterion and the corresponding values are shown in table 11.

$$W_{ec} = \frac{w_c^o}{1-w_s^o} \tag{25}$$

Where, w_c^o is the original score of the changed weight.
w_s^o is the weight of MEP.

Step-2: Evaluate factorΔx which denotes the amount of change performed to the weight set based on the correspondingW_{ec}. The weighting of the MEP should be kept to a minimum. If not, weights could have negative values, violating the weight constancy restriction. WhenΔxfactor is positive, relative toughness increases; when it is negative, relative toughness decreases. The boundaries for Δx are expressed as the quantity of the greatest weight shift among the MEP in both the negative and positive aspects. Eq. (26) is used for determining the variable Δx's limit and the corresponding values are shown in table 11.

$$-w_s^o \le \Delta X \le MIN\{\frac{w_c^o}{W_{ec}}\} \tag{26}$$

Step-3: Determine the new parameter weight (w_{ns}, w_{nc}) using eq. (27) with respect to MEP and the corresponding values are shown in table 12.

$$w_{ns} = w_s^o + W_{ec} \times \Delta x; \quad w_{nc} = w_c^o - W_{ec} \times \Delta x \tag{27}$$

This fresh collection of weight parameters will constantly satisfy the standard requirement for weight proportionality, i.e. $\sum w_{ns} + \sum w_{nc} = 1$.

Any modification in the parameters weights, which are then determined by the ordering technique, may drastically change the sequence of the options in some circumstances. A sensitivity study was undertaken to determine whether a scenario like this exists and to guarantee the application's stability and sturdiness. The weight change limiting limits ($\boldsymbol{\Delta x}$) for the parameter "W6" are calculated. This is between -0.1791 and 0.8209. Beyond these limits, the weights of criteria "W5" will take negative values. Once these limits were defined, the new weight was calculated with 22 sets of scenarios using eq. (27) as shown in table 12. It is also shown in table 12 that when $\boldsymbol{\Delta x} = \mathbf{0}$, the criteria weights are equal to the original weight.

Table 10. Option's ranking with Copeland voting rule

Ranking of Material Options	EDAS RANK	COPRAS RANK	SAW RANK	WPM RANK	WASPAS RANK	ARAS RANK	TOPSIS RANK	Copeland Voting Rule
M-1	4	7	2	4	2	2	6	3
M-2	3	9	7	9	9	6	9	7
M-3	7	5	5	3	4	5	7	4
M-4	10	8	11	10	11	11	3	10
M-5	1	1	1	1	1	1	1	1
M-6	9	10	12	8	12	12	10	12
M-7	11	11	6	11	10	8	11	11
M-8	8	6	10	6	7	9	8	8
M-9	5	3	8	7	6	10	4	6
M-10	12	12	3	12	8	4	12	9
M-11	6	4	9	5	5	7	5	5
M-12	2	2	4	2	3	3	2	2

Table 11. W_{ec} with varying weights

Parameters	Calculated weights	W_{ec}	Δx
w6	0.1791	1	
w1	0.1121	0.1365	0.8209
w2	0.1393	0.1697	0.8209
w3	0.1721	0.2096	0.8209
w4	0.1486	0.1811	0.8209
w5	0.1223	0.1490	0.8209
w7	0.1264	0.1540	0.8209

Table 12. New parameter weight (w_{ns}, w_{nc})

Scenario	Δx	W1	W2	W3	W4	W5	W6	W7	Total
S1	-0.1791	0.1365	0.1697	0.2096	0.1811	0.1490	0.0000	0.1540	1
S2	-0.1500	0.1326	0.1648	0.2035	0.1758	0.1447	0.0291	0.1495	1
S3	-0.1000	0.1257	0.1563	0.1930	0.1668	0.1372	0.0791	0.1418	1
S4	-0.0500	0.1189	0.1478	0.1826	0.1577	0.1298	0.1291	0.1341	1
S5	0.0000	0.1121	0.1393	0.1721	0.1486	0.1223	0.1791	0.1264	1
S6	0.0500	0.1052	0.1309	0.1616	0.1396	0.1149	0.2291	0.1187	1
S7	0.1000	0.0984	0.1224	0.1511	0.1305	0.1074	0.2791	0.1110	1
S8	0.1500	0.0916	0.1139	0.1406	0.1215	0.1000	0.3291	0.1033	1
S9	0.2000	0.0848	0.1054	0.1302	0.1124	0.0925	0.3791	0.0956	1
S10	0.2500	0.0779	0.0969	0.1197	0.1034	0.0851	0.4291	0.0879	1
S11	0.3000	0.0711	0.0884	0.1092	0.0943	0.0776	0.4791	0.0802	1
S12	0.3500	0.0643	0.0799	0.0987	0.0853	0.0702	0.5291	0.0725	1
S13	0.4000	0.0575	0.0714	0.0882	0.0762	0.0627	0.5791	0.0648	1
S14	0.4500	0.0506	0.0630	0.0777	0.0672	0.0553	0.6291	0.0571	1
S15	0.5000	0.0438	0.0545	0.0673	0.0581	0.0478	0.6791	0.0494	1
S16	0.5500	0.0370	0.0460	0.0568	0.0490	0.0404	0.7291	0.0417	1
S17	0.6000	0.0302	0.0375	0.0463	0.0400	0.0329	0.7791	0.0340	1
S18	0.6500	0.0233	0.0290	0.0358	0.0309	0.0255	0.8291	0.0263	1
S19	0.7000	0.0165	0.0205	0.0253	0.0219	0.0180	0.8791	0.0186	1
S20	0.7500	0.0097	0.0120	0.0149	0.0128	0.0106	0.9291	0.0109	1
S21	0.8000	0.0028	0.0035	0.0044	0.0038	0.0031	0.9791	0.0032	1
S22	0.8209	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	1

Figure 3 and figure 4 depicts the ranks obtained by recalculating the performances of CRITIC EDAS AND CRITIC COPRAS MCDM using the 22 weight sets in Table 12.In Figure 3, the ranking of materials using the CRITIC EDAS method is shown, considering 22 different sets of weights for various criteria. The criteria with the highest weights have a significant impact on the rankings. In this case, the mass density criterion, representing the weight of the chassis material, is of utmost importance. For the optimal material (M-5), its rank remains stable within the first 5 sets of weights. This means that as long as the mass density is given a high weight in the decision-making process (within the first 5 sets of weights), M-5 maintains its top rank. However, if the weight assigned to the mass density is changed beyond the first 5 sets of weights, the rank of material M-5 can change. This indicates that the material's ranking is sensitive to the weight assigned to the mass density criterion. If the importance of mass density diminishes relative to other criteria, it may no longer be the optimal choice, leading to a change in its ranking among the available materials. Weighting criteria differently can significantly impact the final decision in multi-criteria decision-making processes.

With 22 distinct sets of weight allocations for various criteria, Figure 4 illustrates how materials are ranked using the CRITIC COPRAS technique. As with the last explanation, a key component of the rankings is the mass density criterion, which indicates the weight of the chassis material. The rank of the ideal material (M-5) does not change during the first six weight sets. This indicates that M-5 keeps its top spot among the materials as long as the mass density is given a high weight during the decision-making process (inside the first six sets of weights). However, the rank of material M-5 may alter if the weight allocated to the mass density criterion is altered after the first six sets of weights. This sensitivity to the mass density criterion's weight suggests that the mass density criterion's relative importance to other criteria affects the material's ranking. M-5's top ranking among the available materials may vary if its weight of mass density is reduced in comparison to other factors. This illustrates how important criterion weighting is in determining the ultimate choice in multi-criteria decision-making processes.

Finally, It demonstrates that allocating various weights to parameters across 22 sets induces an alteration in the sequence of some options, confirming that the framework is sensitive to weight coefficient modifications.

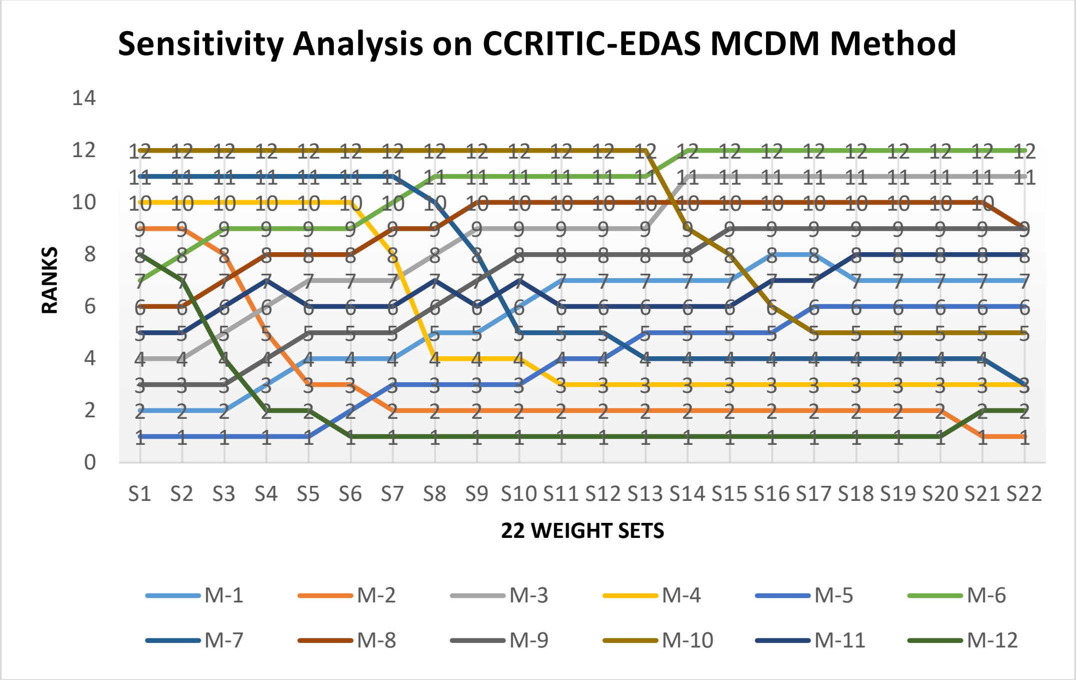


Figure 3. CRITIC EDAS Sensitivity Analysis

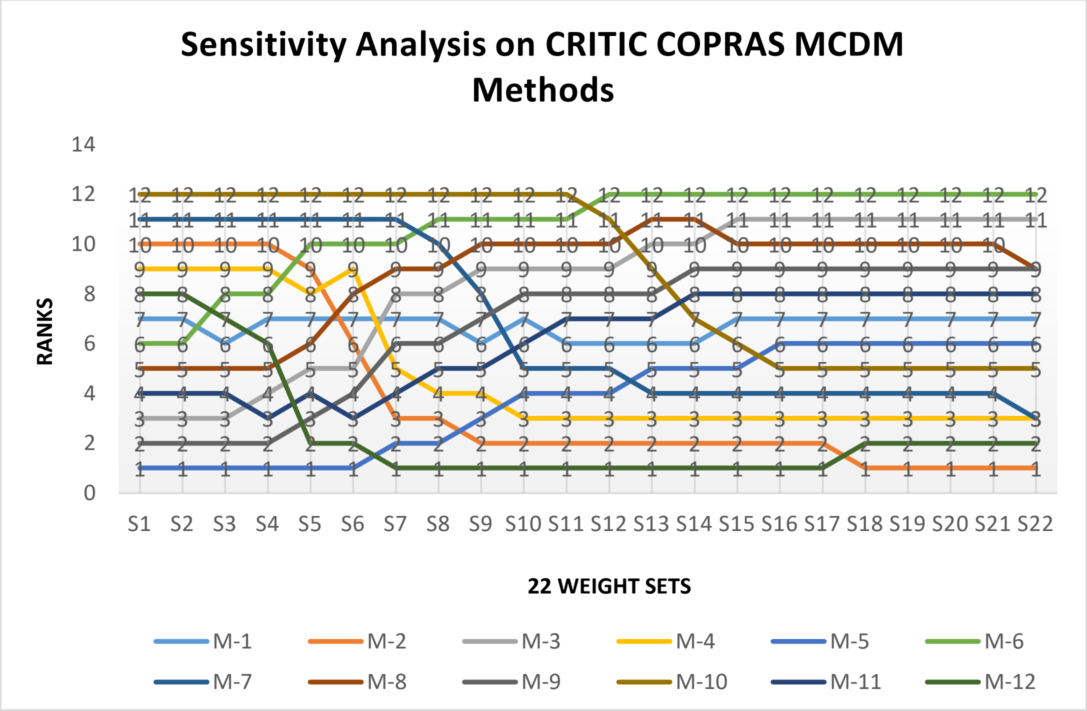


Figure 4. CRITIC COPRAS Sensitivity Analysis

5. Conclusions

The CRITIC framework plays a crucial role in determining the importance of different material properties in the design of a robotic wheelchair chassis by assigning appropriate weights to each criterion. In this approach, while all seven criteria may appear to have relatively equal weightage, mass density carries the maximum weight of 0.1791, indicating its significance.

Both the CRITIC-EDAS and CRITIC-COPRAS methods consistently identify material M-5 (Gray cast iron) as the optimal choice for designing the wheelchair chassis. What's interesting is that other multi-criteria decision-making (MCDM) methods, such as SAW, WPM, WASPAS, ARAS, and TOPSIS, also arrive at the same conclusion as CRITIC-EDAS and CRITIC-COPRAS. This consensus across different MCDM techniques enhances the confidence in the choice of M-5.

Furthermore, the sensitivity analysis reveals that variations in the weight coefficients used in the methods also contribute to their stability. In essence, the robustness of the methods is confirmed through the sensitivity analysis, indicating that the conclusions are reliable and not overly sensitive to changes in weightings. This stability enhances the credibility of the chosen material for the wheelchair chassis, providing assurance in its selection for practical application.

The outcomes of using these frameworks brought to light the complex trade-offs between structural design, cost, and material attributes. By providing a structured method to handle the complexity of material selection, particularly in the context of cutting-edge low-cost assistive technology, this research adds to the body of knowledge. The knowledge acquired from this study can assist engineers, designers, and policymakers in making decisions that are in line with user needs, performance standards, and sustainability objectives as technology developments continue to shape the market for robotic wheelchairs.

5.1. Practical Implication

The multiple applications of the proposed study have implications for a wide range of stakeholders in the fields of engineering, robotics, materials science, and assistive technology. First off, for engineers and designers working on the development of robotic wheelchairs, the framework provides an orderly and systematic manner to choose material options. The CRITIC framework helps assign the appropriate weights to different criteria according to the priorities and conditions of the project. The EDAS approach considers both quantitative and qualitative characteristics, providing a comprehensive understanding of the materials' performance in a range of areas. Selecting the optimal option is aided by the COPRAS method's ability to compare materials in a sophisticated manner.

Second, the study has significant implications for raw material suppliers and manufacturers that supply the parts needed to assemble robotic wheelchair chassis. The comprehensive assessment framework aids providers in understanding the various aspects that influence material selection. With this expertise, they are able to tailor their materials to the specific needs of the assistive technology industry, which eventually promotes the creation of more advanced and suitable materials for robotic wheelchair applications.

The study's conclusions are important for legislators and regulatory bodies that are involved in the development and application of assistive technology. Figure 5 illustrates how the results of the proposed study are used to develop a functional prototype. For those with disabilities who want a robust, durable, and affordable robotic wheelchair for daily use, the whole cost is likewise affordable.

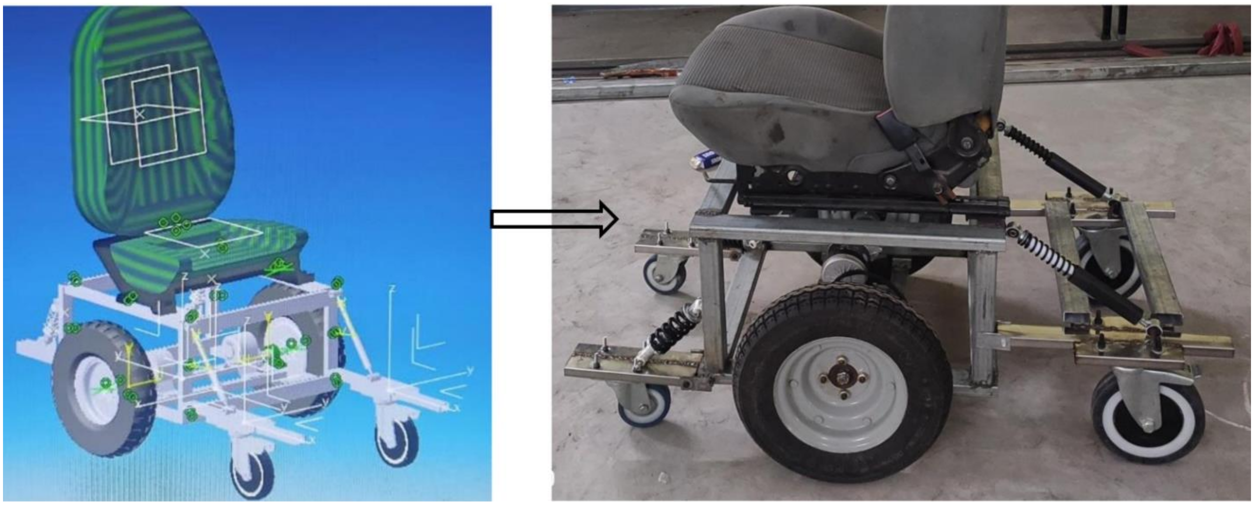


Figure 5. CRITIC-EDAS-COPRAS appliedwheelchair Chassis

5.2. Limitation

Despite the study's benefits and actions, a few drawbacks need to be taken into account.

- First, the correctness and dependability of the input data are necessary for the integrated CRITIC, EDAS, and COPRAS framework to function well. A poor analysis and a biased choice of materials could result from inaccuracies or biases in the data. The subjective nature of assigning weights and scores to criteria within these frameworks also involves a component of human judgment that could change among various evaluators, thereby affecting the outcomes.
- Second, the framework that is being provided places a lot of reliance on the evaluation criteria used. Even if the study's selection of criteria encompasses a wide variety of elements, there may be more pertinent characteristics or newly discovered features of materials that were overlooked. The review could be less thorough if some criteria were excluded, and it could also miss significant factors that could affect the performance and selection of the material.
- The combined CRITIC, EDAS, and COPRAS framework provides a thorough method for assessing material options for robotic wheelchair chassis, but these drawbacks highlight the need for careful results interpretation and the significance of ongoing improvement and adaptation as the field of materials science and assistive technology continues to advance.

5.3. Future Work

This study lays the groundwork for future studies that will evaluate several types of materials for robotic wheelchair chassis. Several directions for future research arise, building on the insights obtained from the combined CRITIC, EDAS, and COPRAS architecture. The usefulness of the framework could be increased by adding more sophisticated decision-making strategies. Investigating cutting-edge approaches like fuzzy logic or hybrid models may improve the precision and effectiveness of material selection procedures. Customized material selection criteria are required since different devices have different functional and design requirements. The platform might be modified to handle the particular issues raised by additional assistive robotics applications, which could provide insightful information about the larger area.

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Conflicts of interest

There are no potential conflicts of concern in this research, according to the investigators.

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