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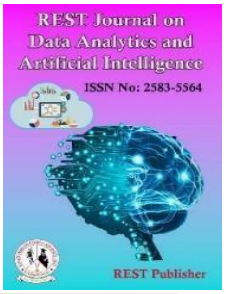

Evaluating Electromagnetic Compatibility Using the TOPSIS Multi-Criteria Decision-Making Method

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Abstract: *Electromagnetic compatibility (EMC) is a critical aspect of electronic and electrical systems, ensuring their ability to function properly within a shared electromagnetic environment without causing or suffering from unacceptable interference. This study employs the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision-making method, to evaluate and rank various EMC parameters. The analysis considers several key EMC factors, including the EMC directive, radiated emissions, conducted emissions, electromagnetic interference (EMI), EMC standards, and electromagnetic susceptibility (EMS). The EMC directive, which serves as a guiding framework for managing electromagnetic disturbances in devices, emerged as the top-ranked criterion, underscoring its pivotal role in regulatory adherence and standardization. Radiated emissions and conducted emissions secured the second and third ranks, respectively, highlighting their substantial impact on EMC performance. Effective management of these emissions is crucial for mitigating potential interference with communication systems, aircraft equipment, and other electronic devices, thereby enhancing the reliability and coexistence of products within the electromagnetic spectrum. Electromagnetic interference (EMI) and EMC standards followed closely, ranking fourth and fifth. EMI shielding and compliance with EMC standards are vital for preventing disruptions caused by electromagnetic radiation and ensuring the smooth operation of electronic circuits and wireless networks. Adherence to these standards promotes interoperability and minimizes the risk of performance degradation. Lastly, electromagnetic susceptibility (EMS) ranked sixth, emphasizing the importance of assessing the sensitivity of electronic devices to electromagnetic energy. By understanding and mitigating EMS, manufacturers can enhance the immunity of their products to external interference, reducing the likelihood of operational issues or physical damage. The TOPSIS method facilitated a comprehensive analysis by considering the ideal and negative ideal solutions, ultimately ranking alternatives based on their proximity to the optimal scenario. The results underscore the multifaceted nature of EMC and the need for a holistic approach that considers various aspects, from regulatory directives to emission control and interference mitigation. By leveraging the TOPSIS method, decision-makers can prioritize and allocate resources effectively, ensuring that EMC challenges are addressed comprehensively and proactively, thereby promoting the harmonious coexistence of electronic systems within the electromagnetic environment.*

Key words: *Electromagnetic Compatibility (EMC), Electromagnetic Interference (EMI), TOPSIS Method, Radiated Emissions, Conducted Emissions, Shielding, Grounding, EMC Standards, EMC Directive and Electromagnetic Susceptibility (EMS)*

1. INTRODUCTION

As a result, the physics of electric circuit elements, properties, devices, and systems needs to be reconsidered. The unique functional characteristics of these components make classical design approaches, which are based on macroscopic analysis, invalid for Nano electronics. Traditional considerations like "classical" electromagnetic compatibility (EMC) are grounded in macroscopic electrodynamics. However, "Nanotech," starting from fundamental concepts, suggests that a new era should begin. For instance, in the context of integrated circuits (ICs), designing and implementing EMC (electromagnetic compatibility) solutions traditionally rely on scaling rules that account for parameters like inductances and capacitances based on macroscopic behavior. However, in the realm of Nano electronics, these parameters are influenced by quantum effects, which alter the frequency dependence of electrical parameters, geometry, and temperature. As a result, traditional EMC concepts, such as shielding and fitting, need to be re-evaluated using classical approaches to address these new challenges. Essentially, nanotech introduces fresh complexities in modeling devices and systems, necessitating new design principles and reliable assessment practices for installation and internal evaluations [1]. Switch mode power supplies are renowned for their ability to minimize both physical size and internal power loss. While these benefits are well recognized, the rapid changes in voltage and current due to the high frequencies inherent in these devices pose significant challenges, particularly electromagnetic interference (EMI). As advancements in technology have increased switching frequencies and brought power supplies closer to the systems they power, concerns about EMI have only intensified, demanding greater attention from designers. Consequently, electromagnetic compatibility (EMC) design has become as crucial as achieving efficient power transformation. This discussion aims to highlight some of the key principles and techniques essential for effective EMC design [2]. In the late eighties, various projects on space vector modulation were introduced by different educators, with Hubert and Borojevic being particularly notable contributors in this field. The space vector modulation of matrix transforms enables a complete theoretical voltage transfer rate while adjusting the sinusoidal input current with the phase angle. Most documentation on matrix transforms focuses on modulation techniques and control mechanisms. Only a few individuals are addressing the necessary hardware for matrix converters. Implementing a test bed for these systems requires a solid technical background and is often too advanced for large-scale industrial production. Designing the input filter, a rarely covered topic, is particularly challenging. A few years ago, an innovative company, Eupneic, introduced an experimental integrated IGBT module, reflecting advancements in this area [3]. Electromagnetic compatibility (EMC) of these devices can be improved by mitigating the effects of electromagnetic interference (EMI). EMI can affect the device itself or other devices through the emission of electromagnetic radiation within its environment. Proper EMI shielding is crucial for reducing these electromagnetic waves. This involves the use of conductive films, whose effectiveness is measured by their electromagnetic interference shielding efficiency (EMISE). EMI shielding works through mechanisms such as absorption, reflection, and multiple reflections of electromagnetic waves. Advances in these technologies enhance the ability to achieve safe and reliable performance [4]. In general, testing the Electromagnetic Compatibility (EMC) of Active Implantable Medical Devices (AIMDs) within safety gates is a time-consuming and complex process. This involves placing the AIMD implant in a saline phantom inside a simulated human body, and performing tests at various locations and positions around the security gate. Each security gate requires its own set of tests. To simplify this process and better reflect the emitted signals, a user-friendly simulator has been developed. This simulator performs EMC testing across a wide range of frequencies and field strengths. Furthermore, EMC testing for AIMDs can be streamlined by conducting experiments with the saline phantom "in the air," which simulates the worst-case scenario. This approach allows for testing the implant's resistance in the air, acting as a current return path for the implant case [5]. Compared to some developed countries, China was a latecomer to high-speed rail (HSR). However, since its introduction, China has rapidly advanced its HSR system with numerous large-scale initiatives and innovations. Railways have been a vital mode of transportation in China since their inception, and in the 21st century, HSR has become particularly popular and efficient. By 2019, China achieved a significant milestone with its cumulative HSR operational mileage exceeding 29,000 kilometers. China now possesses the most advanced high-speed rail technology and significant potential for extensive integration. It is becoming the country with the largest volume of construction globally. As part of the "One Belt and One Road" initiative, Chinese high-speed rail has expanded internationally. Dubbed the "HSR Country" and characterized by "HSR Diplomacy," China's high-speed rail sector has emerged as a prominent asset, showcasing formidable construction capabilities and enhancing China's international standing and influence [6]. To simulate the electromagnetic compatibility (EMC) characteristics of systems, finite difference time domain (FDTD) simulations are commonly employed, though they are computationally intensive. To enhance the efficiency of these simulations, the algorithm can be optimized by terminating the simulation after a set number of time steps and then assigning the remaining signal to a multi-layer perceptron (MLP) for further processing. Recent advancements have shown that linear Eigen analysis with predictors can achieve successful prediction results. However, one of the reported challenges is the low success rate of predictions due to the initial weight assignments. This study aims to address this issue, which is crucial for the efficacy of all training algorithms. Furthermore, this research seeks to improve upon previous work by adapting different codes to account for time step sensitivities and by selecting the appropriate input layer width. This problem is addressed using principles from information theory [7]. Furthermore, frequent power switching can generate EMI, leading to harmonics and interharmonics, which have a substantial potential to cause interference. These frequencies may disrupt EMC in radio communication areas or aircraft equipment. By managing this, it is possible to mitigate EMI that could potentially affect aircraft radio or control systems. For the seamless operation of electronic circuits and aerial communication radio systems, as well as the coexistence of electronic control systems, power-conversion systems must be designed to avoid contributing to EMC issues [8]. EMC has traditionally focused on shaping waves and ensuring signal reliability while minimizing power distribution network EMI. This has often involved methods like using copper tape and ferrites after the design phase, which was more of a trial-and-error approach. However, in recent years, the landscape has shifted. Design cycles have slowed down, prompting a significant change in how EMC is approached. There's now a growing demand within the electronics industry for computer-aided design tools that can handle the increasing complexity of designs and data rates, and shorten design cycles. Despite this demand, suitable tools have not always been available, and the underlying physics of noise coupling and immunity are not always well understood. This is partly due to a lack of funding for basic research and CAD tool development, as well as the inherent complexity of the problem [9]. Individual documents in the IEC 61000-2-Y series were published at different times, depending on the availability of relevant data and the genuine interest of the responsible task force. Consequently, there may be minor differences in the data presented in these documents. This is because the electromagnetic environment is not a fixed and constant value; it evolves continuously due to the introduction of new technologies, disruptions, and various trends in the diffusion and distribution of operable equipment. When working on IEC 61000-2-5, it is essential to consistently consider data from the individual documents of that series [10]. The rise of digital systems has significantly impacted frequency allocation. The radio environment has not only seen improvements but also changes in frequency allocation due to advancements in electronics. The situation has become more complex with the advent of various technologies such as laptops and smartphones, which represent cutting-edge, converged wireless communication devices. In these devices, antennas and other radio circuits are fixed in close proximity to each other. This proximity means that out-of-band signal levels often exceed traditional EMC requirements, and the antennas cannot be moved or reoriented. To enhance flexibility and spatial diversity in modern communication systems, antenna arrays, which consist of multiple antennas, are increasingly being used [11]. To assess EMC, current standards are essential, with a focus on frequency-domain approaches. Interruptions are considered permanent, particularly when addressing worst-case scenarios. The size of electronic components is also a significant factor. Due to technological advancements, wireless communication technologies have become widespread globally. This proliferation makes it increasingly challenging to guarantee radio coexistence, as the spectrum is a limited resource. Therefore, to handle high data rates, creating standards with better spectral efficiency and intelligent frequency application is necessary. In the framework of theoretical studies, using advertising parameters and other measurement techniques can enhance EMC results. We propose incorporating these new features into the current EMC standards [12]. Traditionally, current and voltage information is communicated through secondary circuits using current and voltage transformers, also known as measurement converters. Microprocessor devices, which are highly sensitive components in these circuits, can be affected by intermittent electromagnetic processes in voltage measurement transformers. To minimize the impact on primary converters, a safety factor concept is applied. However, this does not protect microprocessor equipment from secondary circuit interference. A solution to this problem in mechanical engineering is to use optical transformers or digital transformers, which digitize signals obtained from primary converters at the installation location [13]. Electromagnetic Compatibility (EMC) refers to the ability of equipment or systems to function satisfactorily in their electromagnetic environment without introducing intolerable electromagnetic interference (EMI) to other devices. By definition, EMC involves three main conditions: During normal operation, the electromagnetic emissions from the equipment or system should not degrade the performance of other devices. The equipment or system should be able to endure electromagnetic disturbances from other devices in the environment without performance impairment. The equipment or system should not cause unacceptable electromagnetic interference that affects the performance of other devices. In essence, EMC is the study of how various devices or systems can operate harmoniously within a shared electromagnetic environment and with limited spectrum resources [14]. To reduce susceptibility to electromagnetic interference (EMI) and enhance electromagnetic compatibility (EMC), the effect of placing filtering elements in circuits has been investigated. However, the practical implementation of such filters is beyond the scope of this article. This section focuses on practical aspects, specifically those commonly found in power systems. Using a base voltage of 50 Hz, the system starts with a sinusoidal component that is then distorted by higher harmonics. To gain a better understanding of orthogonality, active power is calculated in both the time and frequency domains [15].

2. MATERIALS AND METHOD

Electromagnetic Interference (EMI): EMI shielding involves the use of materials to prevent electromagnetic interference from affecting your device. This shielding, typically made of metal, is placed around sensitive electronics to protect them. It encompasses the device's interior, effectively absorbing any airborne interference that could disrupt its functioning.

Electromagnetic Susceptibility (EMS): EMI/EMC sensitivity refers to how susceptible an electronic device is to electromagnetic energy, which can interfere with its normal operations. This interference can manifest as physical damage to the device or cause unwanted operational issues, potentially resulting in property damage, injury, or even loss of life.

EMC Standards: Electromagnetic compatibility (EMC) in devices aims to address electromagnetic interference (EMI) challenges. EMC standards set forth criteria for electrical devices to meet in order to limit the acceptance of EMI within electronic systems. These standards establish thresholds to ensure that devices operate without causing disruption to nearby communication systems or neighboring devices.

EMC Directive: Minimize disruptions and enhance immunity to bolster both current and forthcoming EMC technologies, as outlined in the Electromagnetic Compatibility Directive (EMCD). This directive pertains to managing electromagnetic disturbances in electrical and electronic devices, ensuring they neither generate nor suffer damage from such disturbances.

Radiated Emissions: Other factors contributing to radioactive emissions overlap with those affecting frequency bandwidth or spectrum functionality. These include the allocation of multiple devices, miniaturization of fabricated and integrated electronic circuits, application of shielding or covering, ensuring adequate reflection loss, and managing absorption loss or related complexities.

Conducted Emissions: The emission test being carried out assesses the level of electromagnetic interference emitted by the equipment. This examination covers a frequency range from 30 kHz to 30 MHz and scrutinizes emissions through both power cables and signal lines.

Shielding: The emission test, conducted by the equipment, evaluates electromagnetic interference levels. It covers frequencies ranging from 30 kHz to 30 MHz and involves inspecting emissions through electrical cables and signal lines.

Grounding: Grounding techniques are helpful for managing anxious feelings. They involve focusing on the present moment to distract yourself from overwhelming emotions. Practicing exercises can assist in redirecting attention away from distressing thoughts or situations. These techniques offer a way to create space from painful feelings and are especially beneficial for alleviating nervousness, enhancing mental well-being, and reducing stress.

RF Interference: RF interference in wireless networks refers to disruptions caused by electromagnetic radiation emitted from various electronic devices such as televisions, cell phones, and wireless communication gadgets. These signals, produced by a wide array of electronic devices, can significantly impact the performance of wireless networks.

Signal Integrity: To ensure the smooth functioning of the PCB, Signal Integration (SI) is crucial. It essentially ensures that the signal travels from the source to the receiver without any distortion, maintaining its waveform characteristics intact. This indicates the signal's strength and enables the receiver to interpret it accurately.

TOPSIS Method: The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon, is a widely recognized method for solving multi-criteria decision-making (MCDM) problems. TOPSIS assesses alternatives based on their similarity to an ideal solution. The technique posits that the best alternative is the one closest to the positive ideal solution and furthest from the negative ideal solution. The positive ideal solution consists of the best possible values for all criteria, while the negative ideal solution comprises the worst possible values for all criteria given the alternatives. Generally, the TOPSIS method is commonly used in MCDM problems. However, experts criticize it for its limitations in dealing with uncertainty. In classical TOPSIS, numerical values are assigned to estimators, but this precise assignment is rarely achievable in real-world scenarios [16]. Using an evaluative approach rather than simple binary logic provides a nuanced understanding of features that better represent members. Jade originally defined Expressive Fuzzy Logic, which, unlike the ambiguous Tarasov framework, offers clearer generalizations of sets. This logic encompasses degrees of membership and non-membership, as well as temporary states, which can express uncertainty or reluctance. Researchers have explored these aspects extensively due to their benefits. For a long time, multi-criteria decision making (MCDM) problems have been a key area of focus for researchers, leading to the development of several MCDM methods. One notable method is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which ranks options based on their proximity to a positive ideal solution and their distance from a negative ideal solution. The Intuitionistic Fuzzy (IF) TOPSIS method is particularly valued because it allows decision makers to express their preferences linguistically, providing a flexible and intuitive decision-making framework [17]. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a highly effective method for decision-making among various alternatives. This technique facilitates disciplined performance through a unified approach. The fundamental principle of TOPSIS is that the optimal alternative is not only closest to the ideal solution but also farthest from the negative (worst) solution. By applying the TOPSIS method, managers can obtain better information from the process, helping them to identify the best possible option while avoiding poor choices. Integrating decision support systems in management is expected to enhance the efficiency of decisions made by decision-makers, ensuring the selected alternative is the most accurate and optimal [18]. This study examines the critical success factors (CSFs) of the SMART approach in developing countries, focusing on samples of city and district builders. The goal is to determine which factors should be prioritized for effective development by identifying and sorting key factors to be considered in developing districts. Specifically, this research aims to identify and discuss key priority factors for the district of Mathura island. The methodology employed is a mixed-method approach, combining both qualitative and quantitative research. During the qualitative research phase, the balanced scorecard method is used for exploratory modeling of critical factors. For the quantitative phase, the Fuzzy TOPSIS analysis method is applied, which involves ranking and multi-criteria decision-making for prioritization [19]. A variety of extensions to fuzzy set theory exist. Among them is the Intuitionistic Fuzzy Set (IFS), a generalization introduced by Tarasov, which extends the basic concept of fuzzy sets in an intuitively straightforward manner. In IFS, each element is characterized by a degree of membership and a degree of non-membership, satisfying the condition that their sum does not exceed 1. This extension provides a nuanced framework for dealing with uncertainty. Building on this, Yage proposed the Pythagorean Fuzzy Set (PFS) as a further extension of IFS. PFS has been shown to be particularly useful for decision-making processes that involve uncertain information. Yage also introduced continuous aggregation operations for Multi-Attribute Decision Making (MADM) based on Pythagorean fuzziness. Additionally, Yage and Abase explored the relationship between Pythagorean membership degrees and complex numbers, offering a new perspective on the synthesis of fuzzy set theories [20]. Machining titanium alloys involves lengthy cycles and high costs due to the time required and expensive tooling. The best cooling methods, which minimize friction and shear zone temperature, significantly improve tool life. Moreover, optimizing machining parameters enhances productivity and reduces overall costs without compromising tool life. All titanium alloy applications, including those involving Ti-6Al-4V and Inconel 718 nickel-based alloys, are affected by this process. Temperature reduction is crucial because these materials have low thermal conductivity, and at cryogenic temperatures, the shear zone impairs heat dissipation [21].

The principle and methodology of machining in l-EDM (Laser-Electrical Discharge Machining) are intricate, primarily due to the numerous parameters involved in the process. These include both electrical and non-electrical parameters that influence the machine's technical characteristics. Significant alterations in these parameters can drastically affect the machine's performance, making the optimization process quite complex. Optimizing these factors in l-EDM involves designing experimental matrices and employing traditional problem-solving techniques, which can be expensive. In l-EDM, the rotational speed of the electrode plays a crucial role in determining productivity, electrode wear, machining accuracy, and the quality of the surface post-machining [22]. Electrical Discharge Machining (EDM), an unconventional machining method, has evolved significantly from traditional machining practices. With numerous machines installed globally, it has garnered substantial interest in manufacturing industries. Modern EDMs boast precision capable of crafting intricate geometries and machining tough materials like heat-treated tool steels, composites, super alloys, and ceramics. As demands grow for enhanced machining properties, superior surface finishes, and reduced wear, EDM continues to adapt and excel in meeting these challenges [23]. A bank functions as a financial institution and an intermediary, accepting deposits and lending those funds. Through capital markets, banks facilitate the movement of capital between customers with surpluses and those in need of funds. Given their significant influence on the economy, banks are highly regulated in most countries. Most operate under a system called fractional reserve banking, where they hold only a small fraction of deposits as reserves and lend out the rest for profit. Despite typically minimal capital requirements, banks play a crucial role in the global economy by providing the capital necessary for innovation, infrastructure, job creation, and overall prosperity [24]. In this paper, Multi-Criteria Decision Making (MCDM) is employed to analyze the mechanical properties of three types of alloys: aluminum alloys, copper alloys, and steel alloys.

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) is used as a tool to evaluate these properties. Important mechanical characteristics of these alloys are taken into account to identify the best alloy from the list of candidate alternatives. Single numbers are used to describe these properties because they are typically expressed as numerical values due to their complexity. The TOPSIS method is well-suited for this evaluation and selection problem because it is an easy-to-understand MCDM technique with a robust mathematical foundation. The Grey TOPSIS method is particularly effective in assessing the mechanical properties of the alloys considered in this study, helping engineers select the most suitable material by enhancing the evaluation procedure [25]. Due to increasing competition in the global market, companies, particularly those operating internationally, require knowledgeable and skilled managers to stay competitive. Selecting the right managers is crucial to achieving the company's objectives. This study proposes using the Fuzzy Technique for Order Selection by Convergence of Exploration Optimum Solution (TOPSIS) method to recruit new employees for middle management positions. The objective is to determine the alternative and criterion weights for selecting a middle manager using the Fuzzy TOPSIS method. To demonstrate the application of this method, the study implements it with real-life data on a middle management selection problem within an organization [26]. The financial performance of these transactions was analyzed on a country-by-country basis. The study aimed to compare the financial performance results achieved by banks in Turkey. Through this research, the emerging trends in the Turkish banking sector and the growing number of participating banks will be identified. This study will also provide valuable insights for potential customers and researchers interested in this field. Additionally, by evaluating the operations of banks in Gulf Cooperation Council (GCC) member countries, the research is expected to contribute significantly to the existing literature. This comparison between banking in Turkey and other countries highlights the unique aspects and different outcomes of previous studies [27]. The TOPSIS method, originally developed by Hwang and Yoon, addresses multi-criteria decision-making problems. This technique aims to identify a solution that is closest to the ideal positive solution and farthest from the ideal negative solution. In essence, the best alternative maximizes beneficial criteria and minimizes cost criteria. Conversely, the least favorable solution increases cost criteria while reducing beneficial criteria. Though widely applied in various decision-making scenarios, particularly under uncertain conditions, its application in the selection of primary crushers has not yet been reported [28]. To evaluate how the Internet of Things (IoT) will transform the manufacturing sector, we employed the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) approach. TOPSIS is a multi-criteria decision-making tool that ranks alternatives based on their proximity to an ideal solution, making it suitable for our analysis with multiple evaluation criteria. Our study included 50 manufacturing companies, which served as the alternatives. We assessed the impact of IoT on four key criteria in the industrial sector: productivity, efficiency, profitability, and customer satisfaction. These criteria were chosen to comprehensively measure the effect of IoT on manufacturing operations. To collect data, we conducted a survey among these 50 manufacturing companies, asking them to provide information on their performance relative to the four criteria. Using the TOPSIS method, we ranked the companies based on their performance in each criterion. The closer a company's performance was to the ideal solution, the higher it ranked, providing a clear indication of the effectiveness of IoT integration in their operations. This approach allowed us to systematically assess and compare the impact of IoT across multiple dimensions, providing valuable insights into its transformative potential in the manufacturing sector [29]. The extracted ore from each mine is directed to its designated drop-off location, then transported out via suitable means. These points are situated along the Oribodi border for accessibility. The ore retrieval process involves accessing and extracting it to the surface through various connecting access points, with a focus on minimizing these access points (referred to as "orbodies"). We employ Kruskal's algorithm to efficiently map out the network, incorporating Steiner points as needed for optimization. Essentially, our approach revolves around network optimization, aiming for the most efficient layout possible. In this pursuit, we identify key nodes of high mass concentration, often referred to as the "base of the stem," to serve as optimal trunk locations within the network [30].

3. RESULTS AND DISCUSSION

TABLE 1. Electromagnetic compatibility

	Shielding	**Grounding**	**RF Interference**	**Signal Integrity**
Electromagnetic Interference (EMI)	22.20	95.25	28.18	89.41
Electromagnetic Susceptibility (EMS)	22.50	65.35	58.68	85.23
EMC Standards	66.30	45.15	78.35	87.65
EMC Directive	99.40	85.25	14.35	60.70
Radiated Emissions	88.40	75.65	14.28	80.90
Conducted Emissions	**10**	**24**	**15**	**10**

Interoperating the data in Table 1 using the TOPSIS method involves several steps. First, we need to normalize the data to bring it on a common scale. This is done by dividing each value in the table by the square root of the sum of squares of all values in the respective column. Next, we assign weights to each criterion based on its importance. These weights reflect the relative significance of each criterion in the decision-making process. Once the data is normalized and weighted, we can calculate the Euclidean distance between each alternative and the ideal solution (for maximization criteria) or the negative ideal solution (for minimization criteria). Finally, we determine the relative closeness to the ideal solution for each alternative, which provides a ranking of alternatives based on their overall performance in electromagnetic compatibility.

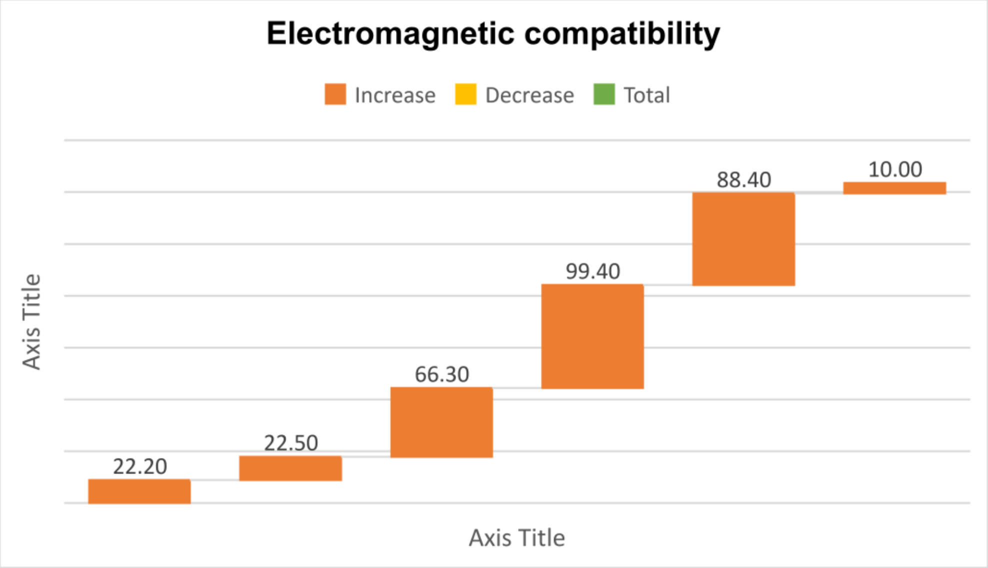

FIGURE 1. Electromagnetic compatibility

Figure 1 presents data on electromagnetic compatibility using the TOPSIS method. It comprises various criteria such as shielding, grounding, RF interference, and signal integrity, with corresponding values for different aspects like electromagnetic interference, susceptibility, standards, and directives, aiding in assessing overall electromagnetic compatibility performance.

TABLE 2. Normalized Data

Electromagnetic Interference (EMI)	0.1458	0.5598	0.2686	0.4902
Electromagnetic Susceptibility (EMS)	0.1478	0.3841	0.5592	0.4673
EMC Standards	0.4354	0.2654	0.7467	0.4805
EMC Directive	0.6527	0.5011	0.1368	0.3328
Radiated Emissions	0.5805	0.4446	0.1361	0.4435
Conducted Emissions	0.0657	0.1411	0.1429	0.0548

In Table 2, employing the TOPSIS method, the data has been normalized to facilitate comparison across different criteria. Each criterion, such as neonatal presentation, asymptomatic presentation, unilateral renal presentation, and concentrating defect, is assigned a value representing its relative importance. This normalization process standardizes the data, allowing for a fair assessment of each criterion's contribution to the overall electromagnetic compatibility. With values ranging between 0 and 1, higher values indicate a stronger presence of the respective criterion. These normalized values are instrumental in subsequent calculations to determine the most favorable alternatives based on their proximity to the ideal solution.

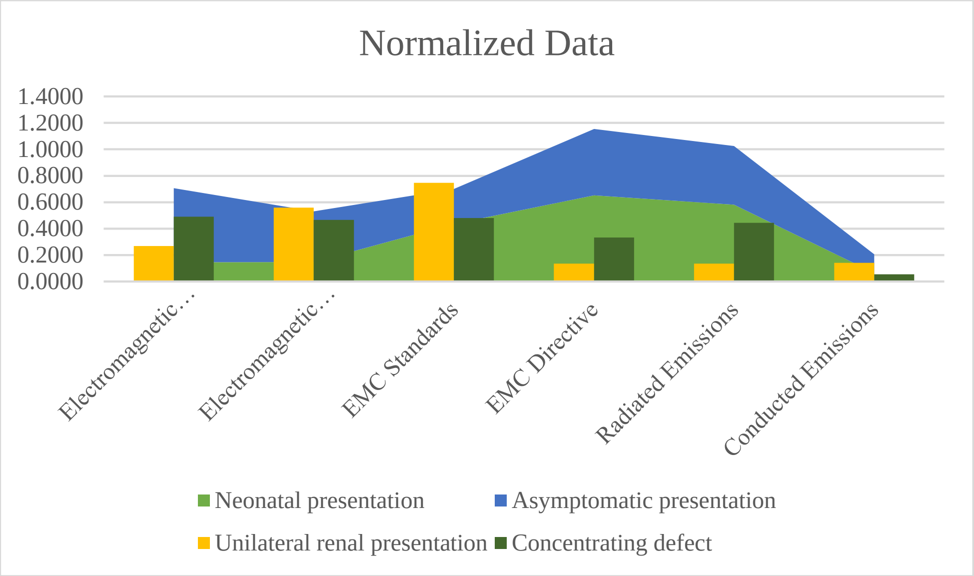

FIGURE 2. Normalized Data

Figure 2 displays normalized data using the TOPSIS method, facilitating comparison among different criteria like neonatal presentation, asymptomatic presentation, unilateral renal presentation, and concentrating defect. Values ranging from 0 to 1 represent the relative significance of each criterion, aiding in evaluating electromagnetic compatibility performance across various aspects.

TABLE 3. Weightages

Weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

In Table 3, weightages for each criterion are provided, crucial for the TOPSIS method, which involves assigning relative importance to different factors. Each criterion, such as neonatal presentation, asymptomatic presentation, unilateral renal presentation, and concentrating defect, receives an equal weightage of 0.25, ensuring a balanced assessment of electromagnetic compatibility across various dimensions. These weightages reflect the decision-maker's perspective on the significance of each criterion in the evaluation process, allowing for a fair and comprehensive analysis of alternatives based on their performance in meeting the specified criteria.

TABLE 4. Weighted normalized decision matrix

Electromagnetic Interference (EMI)	0.0364	0.1400	0.0671	0.1225
Electromagnetic Susceptibility (EMS)	0.0369	0.0960	0.1398	0.1168
EMC Standards	0.1088	0.0663	0.1867	0.1201
EMC Directive	0.1632	0.1253	0.0342	0.0832
Radiated Emissions	0.1451	0.1112	0.0340	0.1109
Conducted Emissions	0.0164	0.0353	0.0357	0.0137

Table 4 presents the weighted normalized decision matrix, a crucial step in the TOPSIS method. Each criterion, including electromagnetic interference (EMI), electromagnetic susceptibility (EMS), EMC standards, EMC directive, radiated emissions, and conducted emissions, is evaluated based on its normalized value and weighted according to Table 3. This matrix reflects the combined influence of both the importance of each criterion (weightages from Table 3) and the performance of alternatives (normalized values from Table 2), enabling a comprehensive comparison. The values in the matrix represent the product of the normalized values and corresponding weightages, providing insights into the relative significance of each criterion in the decision-making process.

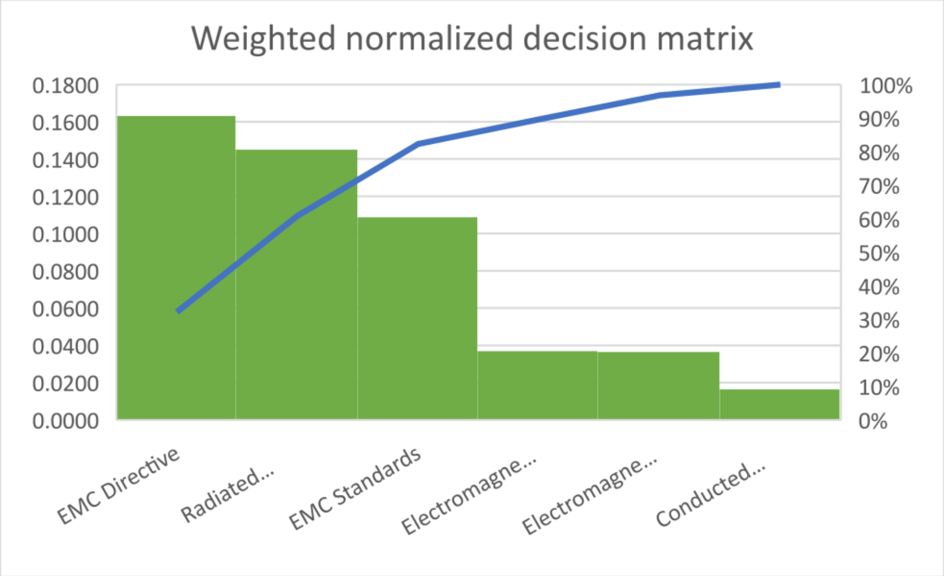

FIGURE 3. Weighted normalized decision matrix

In Figure 3, the weighted normalized decision matrix, computed using the TOPSIS method, is illustrated. Each criterion, such as electromagnetic interference (EMI), electromagnetic susceptibility (EMS), EMC standards, EMC directive, radiated emissions, and conducted emissions, is assigned a weighted score, representing its importance in the decision-making process. These scores facilitate a comprehensive evaluation of alternatives based on their performance across different criteria.

TABLE 5. Positive and Negative Matrix

Positive Matrix				**Negative matrix**			
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225
0.1632	0.1400	0.0340	0.0137	0.0164	0.0353	0.1867	0.1225

In Table 5, the weighted normalized decision matrix for the TOPSIS method is depicted. The positive matrix represents the scores for each criterion in the decision-making process, while the negative matrix showcases the worst-case scenario or least favorable scores. Each row corresponds to a different alternative, and each column represents a specific criterion such as electromagnetic interference (EMI), electromagnetic susceptibility (EMS), EMC standards, EMC directive, radiated emissions, and conducted emissions. These values aid in determining the ideal and negative ideal solutions, pivotal for calculating the distance between each alternative and these reference points to ascertain the most suitable option**.**

TABLE 6. Final Result of Electromagnetic compatibility

	SI Plus	**Si Negative**	**Ci**	**Rank**
Electromagnetic Interference (EMI)	0.1703	0.1602	0.4846	4
Electromagnetic Susceptibility (EMS)	0.1992	0.0796	0.2856	6
EMC Standards	0.2074	0.0975	0.3199	5
EMC Directive	0.0710	0.2333	0.7666	1
Radiated Emissions	0.1030	0.2139	0.6751	2
Conducted Emissions	0.1803	0.1861	0.5079	3

In Table 6, the final result of the electromagnetic compatibility matrix, generated through the TOPSIS method, is presented. Each criterion, including electromagnetic interference (EMI), electromagnetic susceptibility (EMS), EMC standards, EMC directive, radiated emissions, and conducted emissions, is evaluated based on its positive (Si Plus) and negative (Si Negative) scores, as well as the calculated closeness coefficient (Ci). The rank column indicates the relative performance of each criterion, with lower ranks indicating better suitability. This final result enables decision-makers to identify the most optimal alternatives concerning electromagnetic compatibility, considering various aspects such as interference, susceptibility, and emissions.

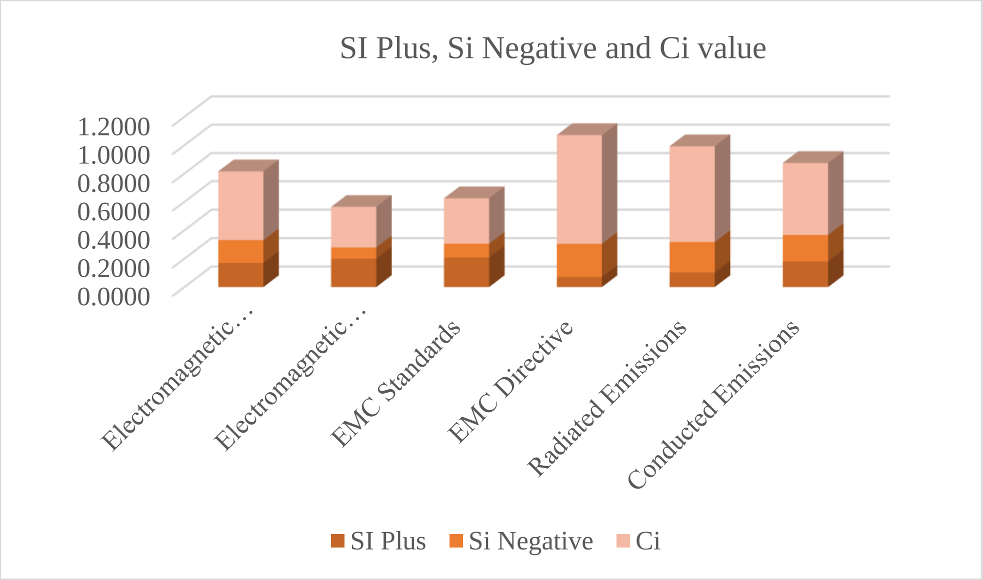

FIGURE 4. Result of Electromagnetic compatibility

Figure 4 displays the final outcome of the electromagnetic compatibility matrix using the TOPSIS method. It showcases the positive (Si Plus) and negative (Si Negative) scores, the calculated closeness coefficient (Ci), and the corresponding rank for each criterion, aiding in selecting the most optimal alternatives for electromagnetic compatibility assessment.

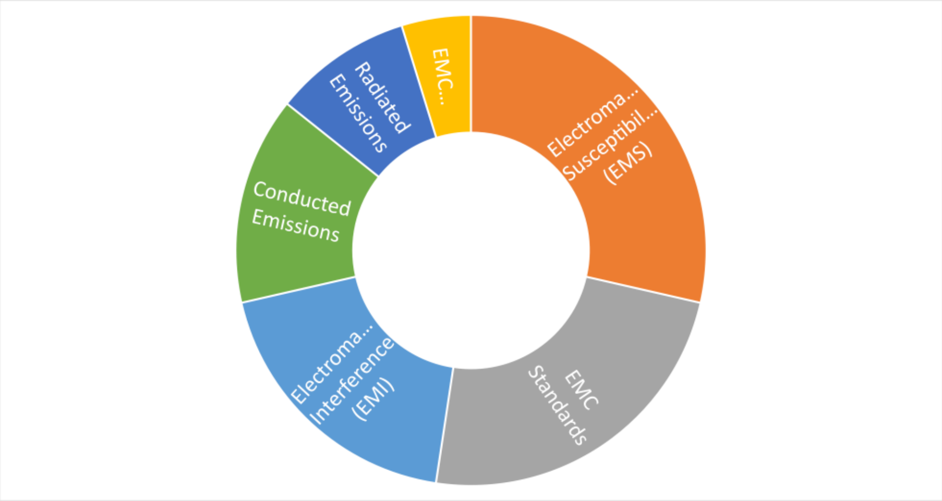

FIGURE 5. Rank

In Figure 5, the ranks based on the TOPSIS method for various electromagnetic compatibility (EMC) parameters are presented. The Electromagnetic Interference (EMI) secures the fourth position, indicating its moderate impact within the context considered. Electromagnetic Susceptibility (EMS) follows at sixth place, suggesting a relatively lower priority. EMC Standards attain the fifth rank, emphasizing their importance in ensuring compliance. The EMC Directive stands out at the topmost position, highlighting its pivotal role in regulatory adherence and standardization. Radiated Emissions claim the second spot, underscoring their significant influence. Conducted Emissions secure the third rank, showcasing their notable impact within the EMC framework. These rankings provide valuable insights for effective EMC management and compliance strategies.

4. CONCLUSION

The application of the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method has proven to be an effective approach for evaluating electromagnetic compatibility (EMC) across various criteria. This multi-criteria decision-making technique allows for a comprehensive analysis by considering the ideal and negative ideal solutions, ultimately ranking alternatives based on their proximity to the optimal scenario. The analysis presented in this study highlights the significance of different EMC parameters, such as the EMC directive, radiated emissions, conducted emissions, electromagnetic interference (EMI), EMC standards, and electromagnetic susceptibility (EMS). By employing the TOPSIS method, these criteria were systematically assessed, and their relative importance was determined through a structured decision-making process. The EMC directive emerged as the top-ranked criterion, underscoring its pivotal role in regulatory compliance and standardization within the EMC domain. This directive serves as a guiding framework for managing electromagnetic disturbances in electrical and electronic devices, ensuring they neither generate nor suffer from such disturbances. Adherence to this directive is crucial for maintaining a harmonious electromagnetic environment and minimizing interference. Radiated emissions and conducted emissions secured the second and third ranks, respectively, reflecting their substantial impact on EMC performance. Effective management of these emissions is essential to mitigate potential interference with communication systems, aircraft equipment, and other electronic devices. By addressing these emissions, manufacturers can enhance the reliability and coexistence of their products within the electromagnetic spectrum. Electromagnetic interference (EMI) and EMC standards followed closely, ranking fourth and fifth, respectively. EMI shielding and compliance with EMC standards are vital for preventing disruptions caused by electromagnetic radiation and ensuring the smooth operation of electronic circuits and wireless networks. Adherence to these standards promotes interoperability and minimizes the risk of performance degradation due to electromagnetic disturbances. Lastly, electromagnetic susceptibility (EMS) ranked sixth, highlighting the importance of assessing the sensitivity of electronic devices to electromagnetic energy. By understanding and mitigating EMS, manufacturers can enhance the immunity of their products to external interference, reducing the likelihood of operational issues or physical damage. The results of this study emphasize the multifaceted nature of EMC and the need for a holistic approach that considers various aspects, from regulatory directives to emission control and interference mitigation. By leveraging the TOPSIS method, decision-makers can prioritize and allocate resources effectively, ensuring that EMC challenges are addressed comprehensively and proactively.

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