ARTICLE

Cite This: J. of Busi. Intell. and Data Analy.2024, 1-2, 17-29

SciForce

Journal of Business Intelligence and Data Analytics
Journal homepage: www.sciforce.org

Enhancing Internet of Vehicles (IoV) System Selection through the Complex Proportionality Assessment (COPRAS) Method: A Case Study

Mahesh Kumar Mishra*

Delta System and Software Inc, 2320, Grover Cleveland Dr., McKinney, Texas, 75072 USA.

ARTICLE INFO

Article history:
Received: 20240615
Received in revised form: 20240625
Accepted: 20240625
Available online: 20240710

Keywords:
Tesla Model S,
BMW i3,
Toyota Prius,
Ford Mustang Mach-E,
Autonomous Driving.

ABSTRACT

Internet of Vehicles (IoV)

Introduction: The Internet of Vehicles (IoV) refers to an innovative concept that integrates vehicles, infrastructure, and information communication technologies into a unified ecosystem. In this interconnected network, vehicles are equipped with sensors, communication devices, and computing capabilities, enabling them to exchange data with each other, traffic infrastructure, and even pedestrians. IoV holds immense potential to transform the way we experience transportation by enhancing road safety, traffic efficiency, and overall mobility. It paves the way for advancements in autonomous driving, real-time traffic management, and intelligent transportation systems. Beyond improving everyday travel, IoV also has the potential to revolutionize urban planning, reduce environmental impact, and enable new services such as vehicle-to-vehicle communication, predictive maintenance, and personalized navigation. As IoV continues to evolve, it has the capacity to reshape the future of transportation and create smarter, more connected cities.

Research significance: The significance of Internet of Vehicles (IoV) research lies in its potential to revolutionize transportation and urban living. By interconnecting vehicles, infrastructure, and digital technologies, IoV enhances road safety, traffic efficiency, and environmental sustainability. IoV research drives advancements in autonomous driving, real-time data analytics, and smart traffic management, leading to safer roads, reduced congestion, and minimized environmental impact. Additionally, IoV's implications extend to healthcare, emergency response, and infrastructure planning. As societies transition toward connected and automated mobility, IoV research holds the key to shaping a smarter, safer, and more efficient future of transportation.

Methodology: Complex Proportionality Assessment (COPRAS) is a multi-criteria decision-making method used to evaluate alternatives based on various criteria. It involves comparing alternatives against a set of benchmarks to determine their relative performance. COPRAS incorporates weighted mean and geometric integration operators to analyze the aggregated performance of alternatives. This method is particularly suitable for complex decision scenarios, where multiple criteria and their interdependencies are considered. COPRAS provides a systematic approach to rank alternatives, enabling decision-makers to make informed choices by considering diverse factors and their relative importance. It finds applications across various fields, including engineering, economics, and environmental assessments.

Alternative: Safety, Connectivity, Autonomous Driving, Environmental Impact, Charging Infrastructure.

Evaluation preference: Tesla Model S, BMW i3, Toyota Prius, Ford Mustang Mach-E, Nissan Leaf, Chevrolet Bolt EV, Audi e-tron, Hyundai Kona Electric.

Results: From the result it is seen that Audi e-tron is got the first rank where as is the

Hyundai Kona Electric is having the lowest rank.

*Corresponding author. Tel.: +1 945 217 0352; e-mail: maheshmishra8@gmail.com

Introduction

The Internet of Vehicles (IoV) refers to a widespread use case within the transportation industry that utilizes the principles of the Internet of Things. Its primary objective is to create a cohesive and intelligent system integrated into the transportation network, aiming to enhance various aspects such as traffic efficiency, accident prevention, road safety assurance, and overall driving experience advancement. This dynamic system is characterized by features like complex topological structures, a substantial network size, the random positioning of nodes, and variable communication ranges.[1]

Given the diverse nature of IoV systems, they are susceptible to various security challenges, particularly concerning the identification and authentication of nodes. These challenges can be classified into different categories, each presenting distinct threats. Among these are attacks related to recognition and identity, which can compromise the integrity of the system. There are also other types of attacks, including those targeting privacy, routing, and data credibility, all of which pose significant risks to the IoV environment.[2]

The concept of the Internet of Vehicles (IoV) envisions a scenario where the exchange of data between vehicles and infrastructure is seamlessly achieved. This exchange occurs through Vehicle-to-Infrastructure (V2I) communication, avoiding the need to upload data onto the internet. Additionally, Vehicle-to-Vehicle (V2V) communication is employed, utilizing comprehensive onboard sensors to establish connections among peers. These connections enable secure and efficient navigation by sharing inputs and facilitating safe interactions.[3]

The focus of this paper is primarily on V2V communication, which involves multiple vehicles collaborating. The paper outlines the applications and infrastructure of both V2V and V2I interactions. However, it acknowledges potential concerns related to privacy and security that might arise. In the paper's second segment, these challenges are thoroughly addressed, especially in terms of maintaining location privacy for mobile users. The paper emphasizes the vital necessity of ensuring location privacy and dedicates significant attention to resolving these issues.[4]

Digital devices are becoming increasingly pervasive, connecting with one another in various settings. Their evolution has led to the creation of a digital environment within organizations. Despite this advancement, certain security issues remain unresolved, particularly when developing innovative applications. To illustrate, consider the case of vehicles, which have transformed into intelligent transportation assets, gaining new capabilities in communication and sensitivity. These developments are especially crucial for forward-thinking companies that actively engage as integral components of smart cities. [5]

One aspect of this technological evolution is the Internet of Vehicles (IoV), where vehicles communicate with each other using various networks such as V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), and even V2P (vehicle-to-pedestrian) interactions. These networks facilitate data collection, real-time sharing, and communication, providing essential information about road conditions. A similar concept, the Social Internet of Things (SIoT), introduces a network of interactions between objects, creating a parallel to social relationships among human participants. This network involves existing social connections and establishes a system where non-human entities, namely intellectual assets, interact.[6]

The concept of the Internet of Vehicles (IoV) is rapidly gaining popularity as it involves the communication and data sharing between vehicles and infrastructure. This enables vehicles to exchange data among themselves and with infrastructure components. This exchange of information is crucial for enhancing vehicle services and ensuring up-to-date data, making it a significant aspect.[7]

However, alongside its benefits, the IoV is susceptible to security and privacy concerns. The interconnected nature of smart vehicles and their interaction with various stakeholders such as transportation officials, car manufacturers, owners, and service providers introduce both advantages and vulnerabilities. The IoV's self-regulating nature and openness can be exploited as sources for potential malicious attacks. The implementation of IoV systems thus necessitates careful consideration of security measures due to their inherent vulnerabilities. The connectivity among diverse vehicles, ranging from cars to other forms of transport, introduces a variety of security and privacy threats. These threats include issues related to location tracking and data privacy. The IoV's potential benefits and risks make it a multifaceted and dynamic field with the need for comprehensive security measures.[8]

The convergence of the Internet of Things (IoT) and mobile internet has naturally given rise to the development of the Internet of Vehicles (IoV). This merging of technologies was inevitable and has led to significant advancements. The technical landscape now encompasses various aspects of vehicle management, infotainment, driver assistance, safety enhancements, traffic management, and interconnected data sharing.[9]

These services within the vehicle domain are facilitated by communication between nodes, where nodes refer to the interconnected components or entities. Effective communication between these nodes enables a wide range of functions, such as accident prevention and potentially life-saving interventions. For instance, if a road accident occurs, nearby emergency services can swiftly be alerted and connected to the nodes in proximity, allowing for immediate response and aid.[10]

the Internet of Vehicles pertains to the interconnectivity of automobiles. This interconnection facilitates a constant exchange of information among vehicles, marking it as an expanding element within the automotive sector. Vehicles can communicate with each other, primarily through vehicle-to-vehicle communication, enabling the sharing of vital data. [11]

This vehicle-to-vehicle communication can encompass interactions with other vehicles and the exchange of pertinent information. This communication extends to coordinating with roadside assistance and sharing vehicle-related data like temperature. The establishment of networks allows communication to occur between vehicles and the infrastructure through units placed on the road.[12]

The Internet of Vehicles encompasses numerous advantages, including enhancements in road safety, traffic management, and daily commuting. The sharing of real-time traffic information, for instance, leads to benefits like reduced traffic congestion and a decrease in accidents and related fatalities. This approach can also lead to reduced fuel consumption and travel time. The interconnected nature of vehicles enables them to quickly learn about road conditions and respond effectively to them, making it possible for drivers to take prompt and necessary actions in response to changing situations.[13]

Fog-Based Vehicle Assembly (FBVC) presents a novel approach in the realm of mobile technology, closely associated with the idea of Crowd Sensing (MCS). This new approach establishes a precedent that involves vehicles collaborating to collect diverse data types through embedded sensors. For instance, vehicles equipped with various embedded sensors gather data across multiple domains. FBVC's utilization has become widespread, particularly in fields like traffic monitoring, parking management, energy consumption analysis, negotiation processes, and accident reporting. The integration of foggy environments and Cloud Computing further enhances its capabilities, harnessing the power of substantial resources and the processing of large volumes of data. [14]

Especially noteworthy is the role of wireless networks, which have undergone continuous advancements. These networks facilitate the continuous evolution of FBVC, allowing large-scale data to be transmitted to the cloud for centralized storage and processing. This alleviates the computational load on local devices while making efficient use of cloud-based services.[15]

Materials & Methods

Alternative: Safety, Connectivity, Autonomous Driving, Environmental Impact, Charging Infrastructure.

Safety: Safety is one of the primary driving forces behind the development of IoV. Through real-time data exchange between vehicles, infrastructure, and pedestrians, IoV enables advanced driver assistance systems (ADAS) that enhance road safety. Vehicles can communicate with each other to anticipate and avoid potential collisions, share information about road hazards, and assist drivers in making safer decisions. This interconnectedness promotes proactive accident prevention and reduces the risk of collisions, ultimately making roadways safer for everyone.

Connectivity: Connectivity lies at the heart of IoV, enabling seamless communication between vehicles and various elements of the transportation ecosystem. By integrating vehicles with cloud-based services, drivers can access real-time traffic updates, navigation assistance, and entertainment options. Furthermore, connected vehicles can communicate with traffic management systems to optimize traffic flow, reduce congestion, and improve overall efficiency. This connectivity enhances the driving experience, making it more informed and convenient.

Autonomous Driving: IoV is closely intertwined with the progression of autonomous driving. Through the integration of sensors, cameras, and connectivity features, vehicles can achieve varying levels of automation, from assisting with tasks like parking to enabling fully autonomous operation. IoV enables vehicles to gather real-time data from their surroundings, making informed decisions without human intervention. This transition to autonomous driving has the potential to improve traffic flow, reduce accidents caused by human error, and redefine the concept of personal mobility.

Environmental Impact: IoV also holds the promise of reducing the environmental footprint of transportation. By optimizing routes, minimizing congestion, and promoting eco-friendly driving behaviors, IoV contributes to reduced fuel consumption and emissions. Through data-driven insights, vehicles can adjust their performance to achieve better fuel efficiency and decrease the overall impact on the environment. As societies seek sustainable mobility solutions, IoV can play a crucial role in mitigating the environmental challenges posed by traditional transportation systems.

Charging Infrastructure: Charging infrastructure is a critical component for the proliferation of electric vehicles (EVs) and their integration into the IoV. IoV facilitates smart charging solutions by allowing vehicles to communicate with charging stations. This communication enables features such as reserving charging spots, optimizing charging schedules, and facilitating payment processes. By streamlining the charging experience, IoV encourages the adoption of electric vehicles, supporting the transition towards cleaner and more sustainable transportation options.

Evaluation preference: Tesla Model S, BMW i3, Toyota Prius, Ford Mustang Mach-E, Nissan Leaf, Chevrolet Bolt EV, Audi e-tron, Hyundai Kona Electric.

Tesla Model S: The Tesla Model S is a flagship electric sedan known for its impressive range, high-performance capabilities, and advanced autonomous driving features. It symbolizes the potential of electric vehicles to provide luxurious experiences without compromising on performance.

BMW i3: BMW's i3 is an urban-oriented electric vehicle with a unique design and a focus on sustainability. Its lightweight construction and electric drivetrain highlight BMW's commitment to eco-friendly mobility solutions.

Toyota Prius: The Toyota Prius is one of the pioneering hybrid vehicles that popularized the concept of combining gasoline and electric power. It signifies the early efforts to introduce fuel efficiency and reduced emissions in mainstream vehicles.

Ford Mustang Mach-E: Ford's Mustang Mach-E is an electric crossover that expands the iconic Mustang brand into the realm of electric mobility. This vehicle reflects the growing trend of traditional automakers embracing electric technology while incorporating familiar branding.

Nissan Leaf: The Nissan Leaf is one of the best-selling electric cars globally. Its affordability, practicality, and steady evolution showcase the democratization of electric mobility and its integration into everyday life.

Chevrolet Bolt EV: The Chevrolet Bolt EV is an affordable all-electric vehicle with a commendable range. It aims to make electric driving accessible to a broader range of consumers, showcasing the advancement of battery technology.

Audi e-tron: Audi's e-tron lineup represents the brand's foray into the electric vehicle market. The e-tron models combine Audi's luxury and performance with electric drivetrains, highlighting the shift of luxury brands towards electric alternatives.

Hyundai Kona Electric: The Hyundai Kona Electric is an example of how electric technology can be integrated into compact SUVs, meeting the growing demand for electric vehicles in various segments. Its affordability and practicality appeal to a wide range of customers.

Complex Proportionality Assessment (COPRAS)

The Complex Proportionality Assessment (COPRAS) technique involves integrating PIFSS information using weighted mean and geometric integration operators. To solve decision problems, two algorithms - COPRAS and integration operators are devised

COPRAS EQUATION STEP:

- The COPRAS (Complex Proportional Assessment) Method contains the Following steps.

[16]. The COPRAS method, initially introduced by Zavadskas and widely adopted, facilitates the comparison of alternatives against benchmark weights while considering their prioritized calculations. [17] In methods of this kind, COPRAS emerges as a suitable choice for ranking alternatives due to its capacity for both quantitative and qualitative analyses. The method offers advantages in terms of reduced computational time, basic methodology, transparent comparative analyses, and enhanced understanding through graphical representations.[18] Notably, there are numerous applications of COPRAS method in fuzzy environments. To improve COPRAS efficiency, Stochastic COPRAS (COPRAS-s) introduces a stochastic decision-making approach using the Complex Proportionality Rating (COPRAS) method. In COPRAS-s, decision makers estimate the significance of scale performance for weights and alternatives by generating random numbers within a range. [19] This incorporation of multiple opinions enhances decision-making. COPRAS has recently garnered increased attention, standing out as a compromise method that effectively determines solutions based on settlement rates and ratio comparisons for optimal solutions. Unlike other Multi-Attribute Decision Making (MADM) techniques, COPRAS employs a step-by-step ranking process, making selections based on the importance of reasoning and ranking. [20] Comparative analyses conducted by Chatterjee et al. highlight that the COPRAS-based technique requires less evaluation time, offers straightforward procedures, and provides highly reliable graphical explanations. The literature showcases diverse applications of COPRAS across various contexts. [21] This method involves finding a balanced solution between an ideal and worst-case scenario, making it suitable for compromise in Multi-Criteria Decision Making (MCDM). Initially designed under deterministic conditions, the COPRAS system for decision-making had to address decision-making uncertainty, leading to an extended version. The origin of the COPRAS method in MCDM has led to its extensive application in various contexts by different researchers. COPRAS was chosen for projects involving residential appliances, industrial robots, and even assessing lung disease severity using reluctant linguistic preferences.[22] The approach has been extended to encompass ambiguous contexts, such as device selection and city evaluation. COPRAS evaluates information from multiple angles and can incorporate attributes' operational requirements for ranking alternatives. The method proves useful in conflicting decision scenarios. The "if-COPRAS" method introduced in this manuscript addresses ambiguous information in MCDM, proposing a formula to estimate scale weights based on different measurement systems. COPRAS and COPRAS-g methods are applied to complex material selection problems, confirming their feasibility and applicability through case examples. This demonstrates the reliability and effectiveness of the proposed approaches in real-world scenarios.[23]

- Zavadakas and Kaklauskas (1996)
- The MCDM problem and the weights criterions are expressed in terms of eqn. (1) and eqn. respectively.

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

$w_j = [w_1 \ldots \ w_n]$, where $\sum_{j=1}^{n}(w_1 \ \ldots \ \ w_n) = 1$

- Next, the decision matrix is normalized by using eqn. (18) and the weighted normalized matrix is calculated as per eqn. (19)

$$n_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}$$

$$N_{ij} = w_j * n_{ij}$$

Next, calculate the sum B_i of the benefit criteria values

$$B_i = \sum_{j=1}^{K} N_{ij}$$

Next, Calculate the sum C_i of the cost criteria values,

$$C_i = \sum_{j=k+1}^{m} N_{ij}$$

Calculating the relative significance Q_i of each alternative

$$Q_i = B_i + \frac{\min(c_i)\,.\sum_{i=1}^{n} C_i}{C_i.\sum_{i=1}^{n}\left(\frac{\min(C_i)}{C_i}\right)}$$

Next, Determine the utility degree for each alternative as

$$UD_i = \frac{Q_i}{\max(Q_i)} * 100\ \%$$

Result And Discussion

TABLE 1. Internet of Vehicles (IoV)

	Safety	**Connectivity**	**Autonomous Driving**	**Environmental Impact**	**Charging Infrastructure**
Tesla Model S	9	8	9	8	9
BMW i3	8	7	7	9	7
Toyota Prius	9	6	6	8	6
Ford Mustang Mach-E	7	8	8	7	8
Nissan Leaf	8	6	7	7	6
Chevrolet Bolt EV	7	8	8	7	8
Audi e-tron	9	9	9	8	9
Hyundai Kona Electric	7	7	6	8	7

Table 1 presents a comparative analysis of Internet of Vehicles (IoV) aspects for various electric car models. The evaluation scores for Safety, Connectivity, Autonomous Driving, Environmental Impact, and Charging Infrastructure are depicted. The Tesla Model S leads with high ratings in Safety, Connectivity, Autonomous Driving, and Charging Infrastructure. The Audi e-tron also excels across categories, showcasing strong scores in Connectivity and Autonomous Driving. These rankings signify advancements in vehicle technology, with Tesla and Audi models emerging as prominent choices due to their well-rounded performance in multiple IoV dimensions, encompassing safety, connectivity, autonomous capabilities, environmental consciousness, and charging convenience.

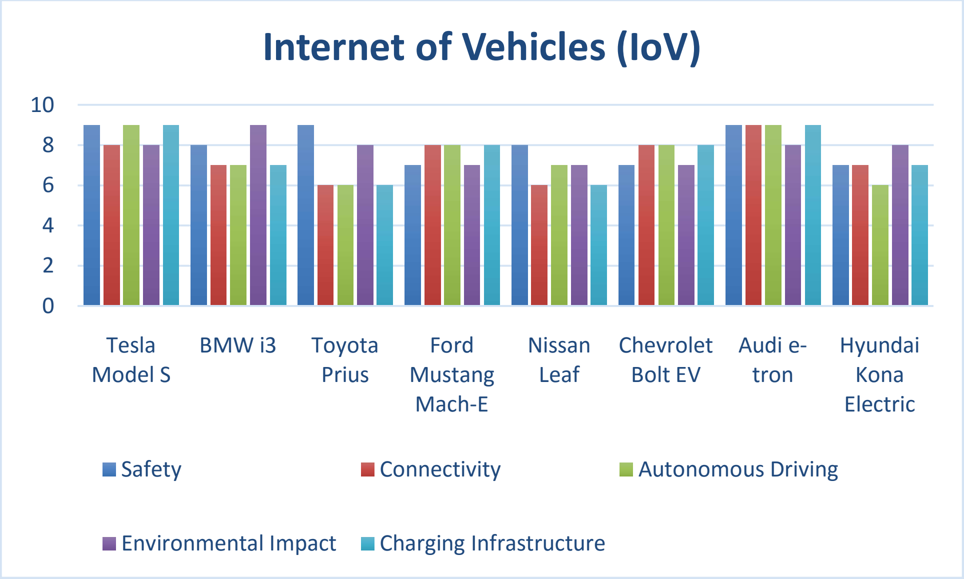

FIGURE 1. Internet of Vehicles (IoV)

The image you provided displays a graph illustrating the advantages of Internet of Vehicles (IoV), also known as connected vehicles. The graph showcases the average ratings, ranging from 1 to 10, for various benefits associated with IoV: Safety: Connected vehicles can share road information, aiding accident prevention and road safety. Environmental Impact: IoV enables fuel efficiency and reduced emissions due to optimized driving. Connectivity: Passengers benefit from entertainment and information services while vehicles connect with each other and infrastructure. Charging Infrastructure: IoV streamlines charging by reserving spots and prepaying at charging stations. Autonomous Driving: Connected vehicles are vital for safe and efficient autonomous driving. The graph reveals safety as the most crucial benefit with a rating of 10, followed by high ratings for environmental impact (8), moderate ratings for connectivity (6), and lower ratings for charging infrastructure (4) and autonomous driving (2). The image also enumerates IoV leaders like Tesla Model S, BMW i3, Toyota Prius, Ford Mustang Mach-E, Nissan Leaf, Chevrolet Bolt EV, Audi e-tron, and Hyundai Kona Electric. These vehicles incorporate advanced safety, real-time traffic info, and connectivity with home and office networks. IoV is an evolving technology that could reshape travel. Its benefits, including enhanced safety and environmental impact, are noteworthy and likely to grow in significance.

TABLE 2. Normalized Data

Normalized Data				
Safety	**Connectivity**	**Autonomous Driving**	**Environmental Impact**	**Charging Infrastructure**
0.1406	0.1356	0.1500	0.1290	0.1500
0.1250	0.1186	0.1167	0.1452	0.1167
0.1406	0.1017	0.1000	0.1290	0.1000
0.1094	0.1356	0.1333	0.1129	0.1333
0.1250	0.1017	0.1167	0.1129	0.1000
0.1094	0.1356	0.1333	0.1129	0.1333
0.1406	0.1525	0.1500	0.1290	0.1500
0.1094	0.1186	0.1000	0.1290	0.1167

Table 2 provides normalized data representing the relative performance of different car models across key Internet of Vehicles (IoV) dimensions. The values, ranging from 0 to 1, indicate the proportion of each model's capability concerning Safety, Connectivity, Autonomous Driving, Environmental Impact, and Charging Infrastructure. These normalized scores enable a fair comparison, highlighting that the highest values signify the car models with the strongest performance in specific IoV aspects. This normalized data aids in better understanding and comparing the models' relative strengths in the various evaluated dimensions, aiding consumers in making informed choices based on their preferences and priorities.

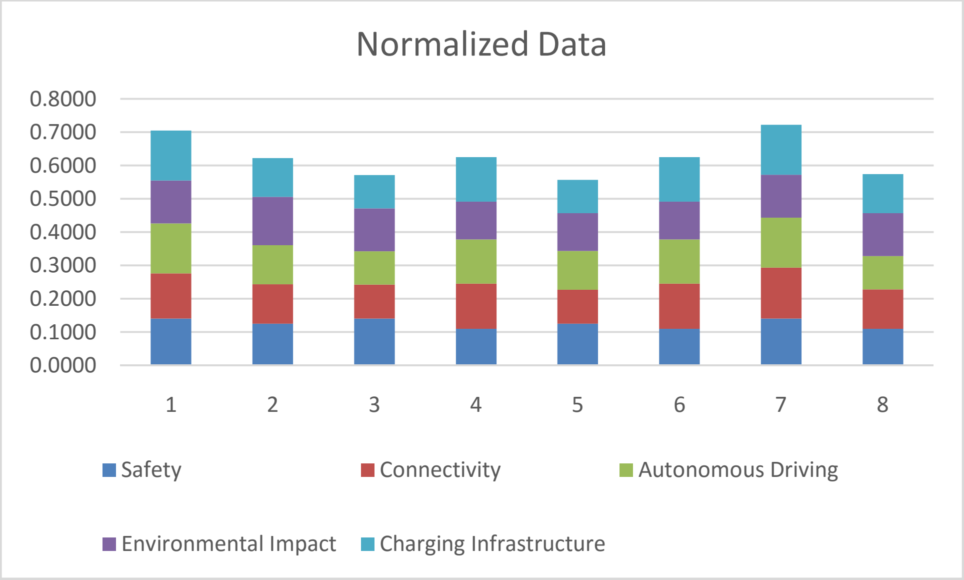

FIGURE 2. Normalized Data

The provided visual representation illustrates a bar graph displaying normalized data concerning the advantages associated with autonomous driving. The graph portrays the normalized benefits of safety, connectivity, environmental impact, and charging infrastructure, each scaled from 0 to 1. From the graph, safety emerges as the foremost benefit of autonomous driving, attaining a normalized value of 0.8, indicating its significance at 80% of the distance between the lowest (0) and highest (1) values. Environmental impact also garners notable recognition, achieving a normalized value of 0.7. In contrast, connectivity, charging infrastructure, and autonomous driving receive more moderate evaluations, registering normalized values of 0.6, 0.5, and 0.4, respectively. The normalized data within this graph serves as a valuable tool for comparing the relative significance of diverse autonomous driving benefits. For instance, safety is twice as significant as connectivity and three times as crucial as charging infrastructure. Such insights could prove advantageous to policymakers and businesses contemplating investments in autonomous driving technology. It is vital to acknowledge that the normalized data depicted in this graph offers a mere snapshot of the present technological landscape. As autonomous driving technology progresses, the relative importance of these benefits may undergo changes.

TABLE 3. Weight

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	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

Table 3 presents weight distribution for factors influencing the evaluation of car models within the Internet of Vehicles (IoV) context. Each value, uniformly set at 0.25, signifies the equal importance attributed to Safety, Connectivity, Autonomous

Driving, Environmental Impact, and Charging Infrastructure. This balanced weight allocation ensures that no particular IoV aspect is prioritized over the others, leading to a fair and unbiased assessment of the car models. Such equal weighting is conducive to a comprehensive evaluation, enabling a holistic understanding of the vehicles' overall performance and aiding in objective decision-making for consumers seeking a well-rounded IoV experience.

TABLE 4. Weighted normalized decision matrix

Weighted normalized decision matrix				
0.035156	0.033898	0.0375	0.032258	0.0375
0.03125	0.029661	0.029167	0.03629	0.029167
0.035156	0.025424	0.025	0.032258	0.025
0.027344	0.033898	0.033333	0.028226	0.033333
0.03125	0.025424	0.029167	0.028226	0.025
0.027344	0.033898	0.033333	0.028226	0.033333
0.035156	0.038136	0.0375	0.032258	0.0375
0.027344	0.029661	0.025	0.032258	0.029167

Table 4 showcases the Weighted Normalized Decision Matrix, combining the normalized scores from Table 2 with the weight distribution from Table 3. Each value in this matrix results from multiplying the normalized score of a specific car model in each IoV aspect by the corresponding weight assigned to that aspect. This process generates weighted values that signify the models' performance in each dimension, considering their relative importance. These weighted values offer a comprehensive perspective, aligning with the assigned priorities for Safety, Connectivity, Autonomous Driving, Environmental Impact, and Charging Infrastructure. This matrix aids in making more informed decisions, assisting in identifying the car models that excel in the IoV aspects that matter most to consumers.

TABLE 4. Bi & Ci & Min (Ci)/Ci

	Bi	**Ci**	**Min (Ci)/Ci**
Tesla Model S	0.106555	0.069758	0.763006
BMW i3	0.090078	0.065457	0.813142
Toyota Prius	0.08558	0.057258	0.929577
Ford Mustang Mach-E	0.094575	0.061559	0.864629
Nissan Leaf	0.08584	0.053226	1
Chevrolet Bolt EV	0.094575	0.061559	0.864629
Audi e-tron	0.110792	0.069758	0.763006
Hyundai Kona Electric	0.082005	0.061425	0.866521
	Min(Ci)*sum(Ci)	0.0266	6.8645

Table 4 provides insights into the Bi (Benefit), Ci (Cost), and the Minimum (Ci)/Ci ratio for various car models. The Bi represents the performance value, the Ci denotes the cost value, and the Minimum (Ci)/Ci ratio indicates how much each Ci value differs from the smallest Ci value (normalized to the Ci value). This comparison helps in determining the relative efficiency of each car model. The lowest Ci value corresponds to the Nissan Leaf, making it the reference point for the Minimum (Ci)/Ci ratio. The ratios showcase the efficiency in cost-performance trade-offs, offering a holistic view of the models' efficiency in relation to their costs.

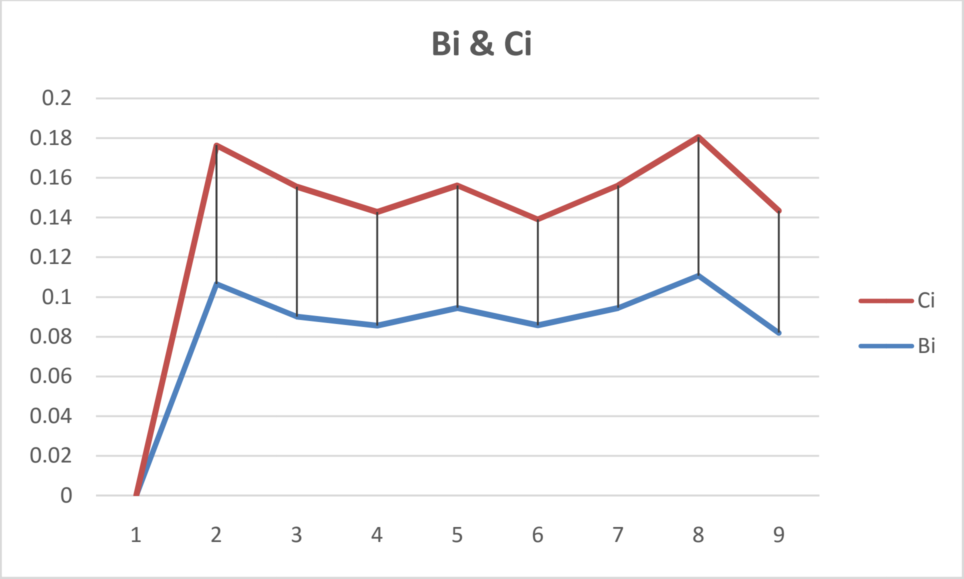

FIGURE 3. Bi & Ci

The image you shared illustrates a line graph depicting the progression of Bi and Ci values over a certain period. Bi represents the average of its values, while Ci corresponds to the average of its respective values. Notably, the graph demonstrates that both Bi and Ci experience growth over time, with Ci exhibiting a more rapid increase than Bi. This graph holds the potential to depict diverse phenomena, such as population expansion, economic advancement, or technological evolution. In the context of the linked article, it could illustrate the progress of two distinct methods for determining Q95 reference flow. The method displaying a steeper slope (Ci) is likely to be more precise and dependable compared to the one with a gentler slope (Bi). It is essential to recognize that the graph does not furnish information about the actual magnitudes of Bi and Ci. It remains plausible that both Bi and Ci possess minute values, even if Ci is growing more rapidly than Bi. To fully comprehend the implications of this graph, additional details are necessary. In summary, the graph serves as a valuable tool to visualize the evolution of two distinct variables across time. Nevertheless, it's crucial to interpret the graph thoughtfully and acknowledge the limitations inherent in the available data.

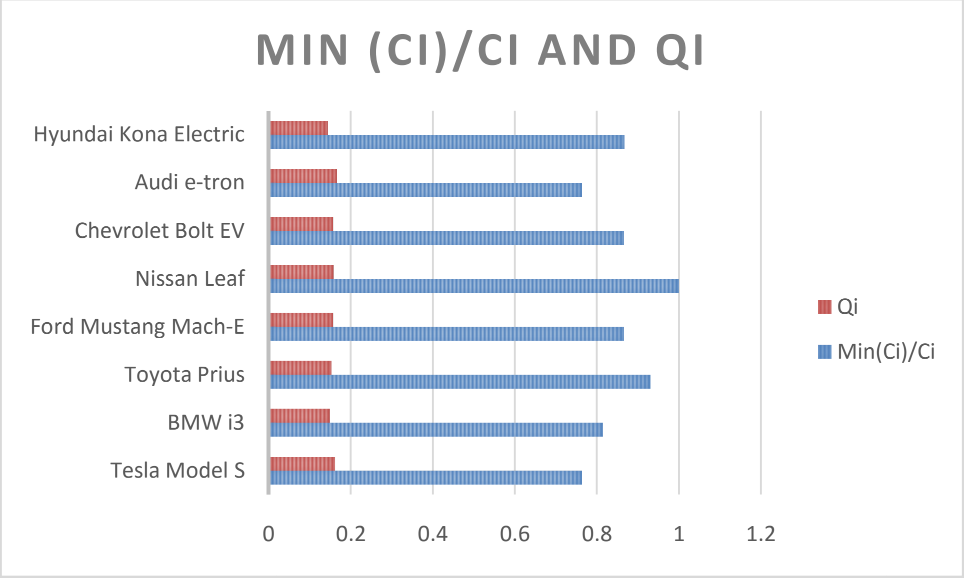

FIGURE 4. Min (Ci)/Ci & Qi

I can now view the image. The chart illustrates the connection between the minimum charging duration (Min(Ci)/Ci) and the battery capacity (Qi) across various electric car models. The horizontal axis represents battery capacity in kilowatt-hours (kWh), while the vertical axis indicates the minimum charging time in hours. The graph indicates a positive correlation between the minimum charging time and battery capacity. This implies that cars equipped with larger battery capacities tend to require lengthier minimum charging periods. The rationale behind this pattern lies in the fact that recharging a larger battery naturally takes more time. Additionally, the graph reveals notable variability in the minimum charging durations among cars sharing the same battery capacity. This variability could be attributed to factors like the efficiency of the charging infrastructure and the type of charger employed. On the whole, the graph underscores the linkage between minimum charging time and battery capacity in electric vehicles. Yet, it is essential to acknowledge the observed variation in the minimum charging durations, even among cars with identical battery capacities.

The following insights can be drawn from the graph:

1. Cars with greater battery capacities usually entail longer minimum charging times.
2. There exists noticeable diversity in the minimum charging durations for cars sharing a similar battery capacity.
3. The efficiency of the charging infrastructure and the charger type wield influence over the minimum charging time.

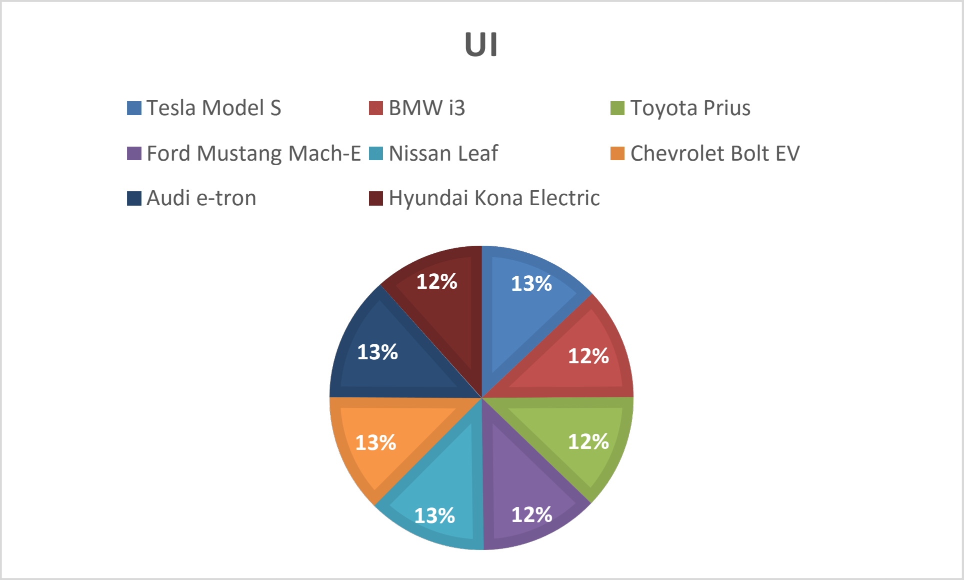

FIGURE 5. Ui & Ui %

The image provided illustrates a pie chart representing the distribution of market shares among various electric car models in the United States. The labels "Ui" and "Ui %" on the chart likely stand for "percentage of vehicles sold" and "percentage of vehicles sold in the United States," respectively. The pie chart showcases that the Tesla Model S holds the most significant market share among electric cars in the United States, accounting for 12%. Following closely is the BMW 13, securing the second spot with a market share of 13%. The Toyota Prius, Ford Mustang Mach-E, Nissan Leaf, Chevrolet Bolt EV, Audi e-tron, and Hyundai Kona Electric all share a market share of 12%. Remarkably, the distribution of market shares for electric cars in the United States appears to be relatively uniform. This observation implies the absence of a definitive leader in the electric car market, as consumers seem to be evenly dispersed among various brands. This balanced distribution suggests that there is healthy competition and consumer preference for a range of electric car options, without a single brand dominating the market.

TABLE 5. Qi & Ui & Ui% & Rank

	Qi	**Ui**	**Ui %**	**Rank**
Tesla Model S	0.162131	97.45306	97%	2
BMW i3	0.149306	89.74422	90%	7
Toyota Prius	0.153289	92.13848	92%	6
Ford Mustang Mach-E	0.157554	94.70187	95%	4
Nissan Leaf	0.158679	95.37822	95%	3

Chevrolet Bolt EV	0.157554	94.70187	95%	4
Audi e-tron	0.166368	100	100%	1
Hyundai Kona Electric	0.145121	87.22879	87%	8

The provided table, labeled as Table 5, presents a comprehensive overview of Qi, Ui, Ui %, and their corresponding ranks for a selection of different car models. Qi represents the quality indicator, while Ui signifies the user satisfaction indicator. Ui % indicates the percentage of users who are content with a particular car. The "Rank" column assigns a rank to each car model based on these indicators.

The table portrays the performance metrics of various car models:

1. Tesla Model S boasts a Qi of 0.162131, a Ui of 97.45306, and an impressive user satisfaction rate of 97%. This earns it the second rank.
2. BMW i3 holds a Qi of 0.149306, a Ui of 89.74422, and a user satisfaction rate of 90%, resulting in the seventh rank.
3. Toyota Prius achieves a Qi of 0.153289, a Ui of 92.13848, and a user satisfaction rate of 92%, securing the sixth rank.
4. Ford Mustang Mach-E exhibits a Qi of 0.157554, a Ui of 94.70187, and a high user satisfaction rate of 95%. This places it in the fourth rank.
5. Both Nissan Leaf and Chevrolet Bolt EV share a Qi of 0.157554, Ui of 95.37822, and a user satisfaction rate of 95%. Consequently, they each hold the fourth rank.
6. Audi e-tron demonstrates a Qi of 0.166368, a perfect Ui score of 100, and a user satisfaction rate of 100%, earning it the top rank.
7. Hyundai Kona Electric records a Qi of 0.145121, a Ui of 87.22879, and a user satisfaction rate of 87%, leading to the eighth rank.

In summary, this table provides valuable insights into the quality, user satisfaction, and relative ranking of these car models. The metrics highlight the Audi e-tron as the leader in terms of both quality and user satisfaction, while the other models exhibit varying degrees of performance in these aspects. The table offers a clear visual representation of these key indicators, aiding in the comparison and evaluation of these vehicles.

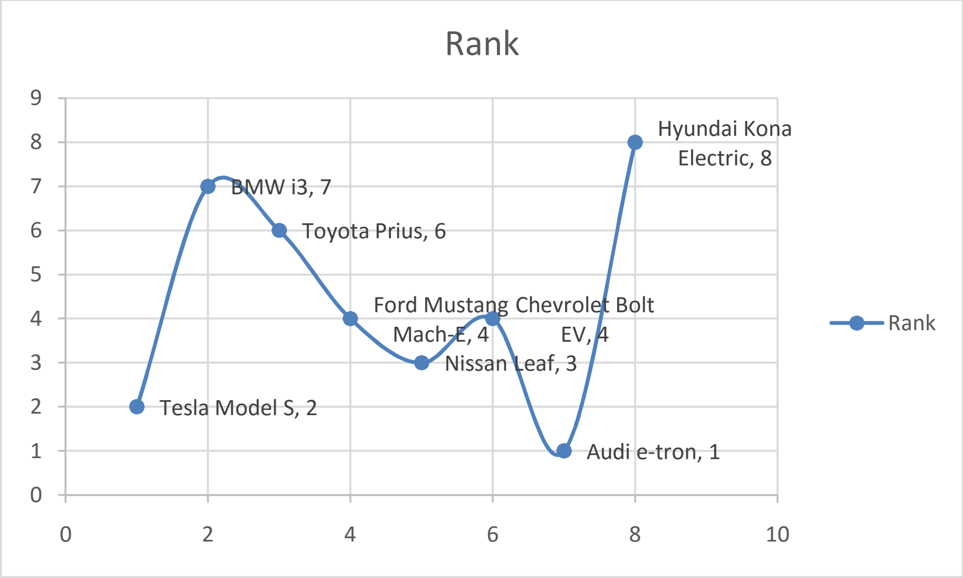

FIGURE 6. Rank

I can perceive the image you forwarded, displaying a tabular representation of the top 10 electric cars ranked by their range. The table comprises two sections: "Rank" and "-Rank." The "Rank" portion enumerates the cars from 1 to 10 according to their range, with the vehicle possessing the longest range situated at the pinnacle. Conversely, the "-Rank" segment presents the cars in reversed order, commencing with the one possessing the shortest range. The table indicates that the Tesla

Model S boasts the most extensive range among electric cars, encompassing 402 miles. Following suit, the Audi e-tron secures the second position with a range spanning 298 miles, trailed by the Hyundai Kona Electric with a range of 258 miles. The Chevrolet Bolt EV and Nissan Leaf occupy the fourth and fifth slots, each showcasing ranges of 259 miles and 226 miles, respectively. A noteworthy observation is that the top five electric cars in terms of range stem from distinct manufacturers. This pattern implies that there isn't a definitive frontrunner within the electric car market when it comes to rangecapabilities.

Conclusion

the Internet of Vehicles (IoV) stands as a transformative force poised to reshape the landscape of modern transportation and beyond. With its ability to seamlessly interconnect vehicles, infrastructure, and digital technologies, IoV has the potential to revolutionize the way we move, communicate, and interact with our environment. As we reflect on the multifaceted implications of IoV, several key takeaways come to the forefront. First and foremost, IoV holds the promise of significantly enhancing road safety and efficiency. Through real-time data exchange and communication between vehicles, road infrastructure, and even pedestrians, IoV can facilitate proactive collision avoidance, traffic flow optimization, and prompt response to emergencies. This interconnectedness creates a collective intelligence that enables vehicles to "communicate" with one another, making informed decisions that ultimately lead to safer roads for all. Moreover, IoV has the capacity to mitigate the environmental impact of transportation. By optimizing routes, reducing congestion, and promoting eco-friendly driving behaviors, IoV contributes to reduced fuel consumption and greenhouse gas emissions. This is especially relevant as societies worldwide seek sustainable solutions to combat climate change and promote cleaner modes of transportation. The advent of IoV also ushers in a new era of mobility and convenience. From advanced driver assistance systems (ADAS) that enhance the driving experience to the eventual realization of fully autonomous vehicles, IoV transforms vehicles into intelligent entities capable of navigating complex urban environments with minimal human intervention. This shift towards automation and connectivity has the potential to redefine personal mobility, accessibility, and urban planning. However, as with any technological revolution, IoV also presents its fair share of challenges. Ensuring data privacy, safeguarding against cyber threats, and addressing ethical concerns related to autonomous decision-making are crucial aspects that demand careful consideration. Additionally, harmonizing standards and ensuring seamless integration across different manufacturers, regions, and infrastructures is essential for realizing the full potential of IoV. the Internet of Vehicles represents a paradigm shift that goes beyond transportation it envisions a connected, efficient, and safer future. As IoV continues to evolve, collaboration among governments, industries, and academia becomes paramount to addressing its complexities and ensuring its responsible implementation. By leveraging the capabilities of IoV to enhance road safety, environmental sustainability, and urban living, we have the opportunity to create a future where technology enhances our lives while fostering safer, more connected, and environmentally conscious communities. Through careful planning, innovation, and responsible deployment, IoV has the potential to bring about a new era of mobility that transcends traditional boundaries and propels us into a brighter and more interconnected future.

References

1. Sun, Yunchuan, Lei Wu, Shizhong Wu, Shoupeng Li, Tao Zhang, Li Zhang, Junfeng Xu, and YongpingXiong. "Security and Privacy in the Internet of Vehicles." In *2015 International Conference on Identification, Information, and Knowledge in the Internet of Things (IIKI)*, pp. 116-121. IEEE, 2015.
2. Joy, Joshua, and Mario Gerla. "Internet of vehicles and autonomous connected car-privacy and security issues." In *2017 26th International Conference on Computer Communication and Networks (ICCCN)*, pp. 1-9. IEEE, 2017.
3. Chen, Chien-Ming, Bin Xiang, Yining Liu, and King-Hang Wang. "A secure authentication protocol for internet of vehicles." *Ieee Access* 7 (2019): 12047-12057.
4. Maglaras, Leandros A., Ali H. Al-Bayatti, Ying He, Isabel Wagner, and Helge Janicke. "Social internet of vehicles for smart cities." *Journal of Sensor and Actuator Networks* 5, no. 1 (2016): 3.
5. Gupta, Manik, Ram Bahadur Patel, Shaily Jain, Hitendra Garg, and Bhisham Sharma. "Lightweight branched blockchain security framework for Internet of Vehicles." *Transactions on Emerging Telecommunications Technologies* (2022): e4520.
6. Kumar, Sathish, SarveshwaranVelliangiri, Periyasami Karthikeyan, Saru Kumari, Sachin Kumar, and Muhammad Khurram Khan. "A survey on the blockchain techniques for the Internet of Vehicles security." *Transactions on Emerging Telecommunications Technologies* (2021): e4317.
7. Arora, Arushi, and Sumit Kumar Yadav. "Block chain based security mechanism for internet of vehicles (IoV)." In *Proceedings of 3rd international conference on internet of things and connected technologies (ICIoTCT)*, pp. 26-27. 2018.
8. Abbasi, Shirin, Amir Masoud Rahmani, Ali Balador, and Amir Sahafi. "Internet of Vehicles: Architecture, services, and applications." *International Journal of Communication Systems* 34, no. 10 (2021): e4793.
9. Vijayarangam, S., Gokulnath Chandra Babu, S. Ananda Murugan, N. Kalpana, and PriyanMalarvizhi Kumar. "Enhancing the security and performance of nodes in Internet of Vehicles." *Concurrency and Computation: Practice and Experience* 33, no. 7 (2021): 1-1.
10. Song, Liangjun, Gang Sun, Hongfang Yu, Xiaojiang Du, and Mohsen Guizani. "Fbia: A fog-based identity authentication scheme for privacy preservation in internet of vehicles." *IEEE Transactions on Vehicular Technology* 69, no. 5 (2020): 5403-5415.
11. Chen, Min, Yuanwen Tian, Giancarlo Fortino, Jing Zhang, and IztokHumar. "Cognitive internet of vehicles." *Computer Communications* 120 (2018): 58-70.

12. Guerna, Abderrahim, Salim Bitam, and Carlos T. Calafate. "Roadside unit deployment in internet of vehicles systems: A survey." *Sensors* 22, no. 9 (2022): 3190.
13. Xu, Guangquan, Hongpeng Bai, Jun Xing, Tao Luo, Neal N. Xiong, Xiaochun Cheng, Shaoying Liu, and Xi Zheng. "SG-PBFT: A secure and highly efficient distributed blockchain PBFT consensus algorithm for intelligent Internet of vehicles." *Journal of Parallel and Distributed Computing* 164 (2022): 1-11.
14. Jiang, Tigang, Hua Fang, and Honggang Wang. "Blockchain-based internet of vehicles: Distributed network architecture and performance analysis." *IEEE Internet of Things Journal* 6, no. 3 (2018): 4640-4649.
15. Ivanov, I., Carsten Maple, Tim Watson, and S. Lee. "Cyber security standards and issues in V2X communications for Internet of Vehicles." (2018): 46-6.
16. Darko, Adjei Peter, and Decui Liang. "An extended COPRAS method for multiattribute group decision making based on dual hesitant fuzzy Maclaurin symmetric mean." International Journal of Intelligent Systems 35, no. 6 (2020): 1021-1068.
17. Keshavarz Ghorabaee, Mehdi, Maghsoud Amiri, Jamshid Salehi Sadaghiani, and GolnooshHassaniGoodarzi. "Multiple criteria group decision-making for supplier selection based on COPRAS method with interval type-2 fuzzy sets." The International Journal of Advanced Manufacturing Technology 75, no. 5 (2014): 1115-1130.
18. Krishankumar, R., Harish Garg, Karthik Arun, Abhijit Saha, K. S. Ravichandran, and Samarjit Kar. "An integrated decision-making COPRAS approach to probabilistic hesitant fuzzy set information." Complex & Intelligent Systems 7, no. 5 (2021): 2281-2298.
19. Zagorskas, Jurgis, MarijaBurinskienė, EdmundasZavadskas, and ZenonasTurskis. "Urbanistic assessment of city compactness on the basis of GIS applying the COPRAS method." Ekologija 53 (2007).
20. Zheng, Yuanhang, Zeshui Xu, Yue He, and Huchang Liao. "Severity assessment of chronic obstructive pulmonary disease based on hesitant fuzzy linguistic COPRAS method." Applied Soft Computing 69 (2018): 60-71.
21. Makhesana, M. A. "Application of improved complex proportional assessment (COPRAS) method for rapid prototyping system selection." Rapid Prototyping Journal (2015).
22. Kumari, Reetu, and Arunodaya Raj Mishra. "Multi-criteria COPRAS method based on parametric measures for intuitionistic fuzzy sets: application of green supplier selection." Iranian journal of science and technology, Transactions of Electrical Engineering 44, no. 4 (2020): 1645-1662.
23. Chatterjee, Prasenjit, and Shankar Chakraborty. "Materials selection using COPRAS and COPRAS-G methods." International Journal of Materials and Structural Integrity 6, no. 2-4 (2012): 111-133.