Critical Success Factors of Electric Mobility Transition in Indonesia: A DEMATEL-Based ANP Approach

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***Abstract* – The high index of poor air quality and the increasing demand for oil fuel pose severe problems for Indonesia. The largest sector contributing to both of these issues is the transportation sector. Electric mobility offers a notable opportunity for decreasing carbon emissions within the transportation domain. Despite the Indonesian government's notable backing of this initiative, the implementation has been slow. Therefore, this study aims to identify the critical factors necessary for a successful transition to electric mobility. This study identifies the factors influencing the transition to e-mobility in the initial stage. Subsequently, these factors are validated and assessed by a panel of nine experts. In the validation phase, data processing involves the use of the Content Validity Index (CVI) and Modified Kappa methods. To assess relationships and prioritize essential success factors, the Decision-making Trial and Evaluation Laboratory-based Analytic Network Process (DEMATEL-based ANP) is applied. This study identifies six dimensions and 24 critical success factors. The political dimension emerges as the most significant, with the top five priorities being government funding, charging infrastructure, value proposition, fuel price, and charging time. The findings can be used to provide recommendations to the government or relevant stakeholders in supporting the shift to electric mobility in Indonesia.**

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1. Introduction

According to IQAir's 2021 World Air Quality Report, Indonesia ranks 17th worldwide for poor air quality. The report states that Indonesia has an air quality index of 34.3 µg/m³, which is roughly seven times higher than the World Health Organization's (WHO) safe limit of 5 µg/m³ [1]. Within the health sector, PM 2.5 is identified as a significant contributing factor to health effects such as high morbidity [2]. Air pollution also impacts the country's economic sector. According to The World Bank Group's Environment and Natural Resources Global Practice report, the annual cost of PM2.5 exposure in Indonesia reached 73,998 million U.S. Dollars in 2019, equivalent to 6.6% of Indonesia's gross domestic product (GDP) [3]. The transportation sector is predicted to continue being one of significant contributor to emissions in Indonesia [4]. This is demonstrated by the substantial number of motor vehicles in Indonesia, which grows by about 5% each year [5]. The extensive fuel use by internal combustion vehicles (ICE) is the most significant contributor to the increase in CO2 in the Earth's atmosphere [6]. Therefore, electric mobility (e-mobility) is emerging as a model for decarbonization within the transportation sector. Electric mobility involves the use of an "electric powertrain" for the transportation of people and goods, thereby supporting sustainable development [7].

The Indonesian government has promoted e-mobility through the implementation of various regulations related to EV to encourage manufacturing and regulations to promote their use. Some of these rules are contained in Presidential Regulation Number 55 of 2019 concerns the expedited implementation of battery-powered electric motor vehicle programs for road transport.

Additionally, Minister of Energy and Mineral Resources Regulation Number 13 of 2020 addresses the establishment of charging infrastructure for battery-powered EV [8]. Despite various supports provided, the growth of electric mobility or decarbonization of the transportation sector in Indonesia is still relatively slow, as noted by Adiatma and Marciano [9], due to several barriers, such as high costs, lack of support in research and development, and limited infrastructure and services [10]. Hence, this study aims to identify and analyze critical factors in the transition to electric mobility from various stakeholders' perspectives. Another objective is to propose an integrated framework to pinpoint the most crucial factors that support the successful transition to e-mobility in Indonesia.

Studies employ the critical success factors (CSFs) to determine the important factors in achieving targets. CSFs are elements that play a crucial role in determining development and can be utilized to obtain a competitive edge [11]. Previous works in the automotive and sustainability industries have utilized CSF, as exemplified by Chen [12], who explored the success factors in Tesla's development. This study offers insights for firms operating in the EV sector by providing insights into Tesla's critical success factors. Another instance is the research carried out by Degirmenci *et al.* [13], which delves into the development of alternative transportation. The study examines the determinants of success in carsharing and electric carsharing services and evaluates the identified factors. For conducting CSF analysis, Multi-Criteria Decision-Making (MCDM) techniques can be employed to evaluate various qualitative and quantitative criteria, aiding in identifying appropriate actions, choices, strategies, or policies among the available options [14].

The model framework created in this study is a network structure that incorporates dependencies and feedback among elements within the decision model, and the method employed is ANP, which stands for analytic network process [15]. To systematically analyze factors, we identify interactions between criteria and determine reciprocal relationships by examining the structure of the cause-and-effect model. For this purpose, we utilize decision making trial and evaluation laboratory (DEMATEL) [16], [17]. Integrating DEMATEL and ANP methods is a strategic approach that addresses the limitations of each method. This approach finds support in the research of Gölcük and Baykasoğlu [18], after comparing various applications of multiple attribute decision making (MADM) methods, concluded that the hybridization of DEMATEL and ANP is one of the most promising approaches for examining the interaction of criteria in MADM.

Furthermore, this method is also supported by several other studies [19], [20], [21].

The key contribution of this study is identifying CSF for the transition to electric mobility from the viewpoints of various stakeholders. While previous studies have identified CSFs using the DEMATEL-based ANP method, to our knowledge, no study focuses on the electric mobility transition in Indonesia. This work is urgently needed to accelerate and optimize the e-mobility transition in Indonesia toward achieving net zero emissions from the transportation sector.

The structure of this paper is as follows: Section 1 provides the research background. Section 2 outlines the theoretical foundation of the research topic and the methodology. Section 3 outlines the steps involved in data collection, validation, and processing, along with the results. Section 4 comprises the analysis and discussion of the results. Lastly, Section 5 provides the conclusions and suggestions.

2. Literature Review

The literature for this research comes from various sources, including scientific publications, official institutional documents, research journals, and books, focusing on the study's object and methodology, such as electric mobility and critical success factors (CSF). This comprehensive review involves an in-depth examination and analysis of these areas, concentrating on the core subjects and methodologies to provide a thorough understanding of the field.

2.1. Electric Mobility

The electric mobility sector is dedicated to fulfilling mobility requirements within the framework of sustainability through vehicles powered by electric propulsion [22]. E-mobility is catalyzing fundamental changes worldwide in terms of individual mobility. These initiatives are spurred by the imperative to meet corporate benchmarks for fuel efficiency and emissions, as well as by the market's preference for lower vehicle operating expenditures [23]. Both central and local governments in Indonesia have introduced several policies to support the adoption of electric vehicles. However, it is crucial to note that these policies are not explicitly designed to expedite the adoption of electric vehicles but rather aim to address broader issues such as climate change mitigation, air pollution, energy management, and industrial development.

Policies and strategic documents to bolster the uptake of electric vehicles are predominantly crafted at the national level. In contrast, provincial and city government policies and regulations often focus on segmental development, such as electric buses and two-wheelers [10]. Stakeholders in accelerating electric vehicle adoption in Indonesia include the President, KEMENKO-MARVES, Ministry of Industry, PLN, BPPT, the automotive industry, vehicle industry associations, civil society, and university research centers.

2.2. Critical Success Factor (CSF)

As outlined in a study by Esteves [24], the CSF approach has gained prominence over the past three decades, notably due to the contributions of various researchers, including Rockart [25]. For instance, Leidecker and Bruno [26] asserted that efficient dealer organizations and effective control of production costs are crucial success factors in the automotive industry. Critical success factors (CSFs) are fundamental elements within an industry that can greatly impact the performance of companies within that sector. This definition is supported by statements in a study presented by Grant [27], indicating that CSFs encompass all factors within an industrial sector that influence an organization's ability to survive and thrive. According to Rockart [25], some of the benefits derived from applying the CSF approach are assisting stakeholders in determining the factors that should be the focus of management attention and it is imperative for stakeholders to develop effective measurements for critical success factors. This approach also aids in ensuring that these crucial factors receive meticulous and sustained managerial oversight.

3. Research Methodology

The research methodology section discusses the data required for the research process and the steps involved in data processing. This study utilizes both primary and secondary data. Secondary data is collected from literature reviews, while primary data is gathered through questionnaires and in-depth interviews. There are two types of questionnaires: the first validates relevant factors in the e-mobility transition, and the second assesses the influence between these factors. Data processing for the first questionnaire employs the CVI and modified kappa methods, while the second uses DEMATEL based on ANP.

3.1. Data Collection

This study employs both primary and secondary data. Data collection begins with the gathering of secondary data obtained from a literature review to pinpoint critical success factors in the e-mobility transition in Indonesia. From the literature study, seven dimensions comprising 27 factors are identified. For primary data, it is obtained through questionnaire completion and in-depth interviews. At the end of the questionnaire, experts were given space to suggest factors that influence the e-mobility transition in Indonesia. The questionnaire consists of two parts; the first questionnaire aims to validate relevant factors in the e-mobility transition, while the second questionnaire is designed to assess the influence between these factors. Data processing for the first questionnaire involves the content validity index (CVI) method and the modified kappa method, whereas for the second questionnaire, it employs the DEMATEL-based ANP method.

3.2. Data Validation

The selection of experts to be used as primary data sources in a research study must adhere to specific expert criteria. According to Cherubini [11], the following are the criteria for experts based on the research topic (electric mobility):

- At least one interviewee for each subsystem (infrastructure subsystem, vehicle subsystem, etc.).
- At least one key player in each subsystem.
- Expert companies operate at the international level and national level.
- Significant involvement in the national EV initiative.

The following are general criteria for experts [28]:

- Expertise derived from academic knowledge or research.
- Expertise due to a position as a decision-maker.
- Expertise due to specialization, such as a practitioner.

The researcher conducted primary data collection by administering questionnaires and conducting in-depth interviews with nine experts. Experts were selected from various fields, including manufacturing industry, government, NGOs, and energy and sustainability-related associations, to provide perspectives from different angles that could be integrated into comprehensive knowledge in this study. Table 1 contains the expert profiles who have met the criteria:

Table 1. Experts information

Expert	Relevance Background	Experience
1	Industry consultant in climate, energy, and sustainability	> 20 Years
2	Researcher and academic specializing in advanced electric vehicles	> 20 Years
3	Contributor to Indonesia's motorcycle industry	> 20 Years
4	Researcher and academic in advanced electric vehicles; experienced in FGDs in the Indonesian automotive industry	10 - 20 Years
5	Involved in the Indonesian Ministry, contributing to policy and decision-making for the country's industries	10 - 20 Years
6	A key player in the national electric vehicle project, focusing on EV conversion	10 - 20 Years
7	Well-versed in supportive systems for the EV industry (National and International)	10 - 20 Years
8	Manager in a Southeast Asian transportation company building a roadmap toward sustainability	10 - 20 Years
9	Acknowledged for extensive analysis of transportation-related data	< 10 Years

The CVI method is well-proven to support the validity of assessment tools [29], [30]. The CVI method is the most commonly employed approach for evaluating the content validity [31]. The CVI method requires a minimum of three experts but no more than ten [31], [32]. According to Davis [33], CVI validation provides 4 rating indicators (1 = not relevant, 2 = somewhat relevant, 3 = moderately relevant, 4 = highly relevant). With these 4 assessment indicators, it is determined that values 3 and 4 mean relevant or valid, while values 1 and 2 mean irrelevant or invalid. There are two forms in calculating the CVI method, namely Item-level CVI (I-CVI) and Scale-level CVI (S-CVI). The formula for calculating I-CVI and S-CVI can be seen in the following equation:

$$I\text{-}CVI = \frac{Na}{Ne} \tag{1}$$

$$S\text{-}CVI = \frac{\Sigma\, I-CVI}{Ni} \tag{2}$$

Na = Number of Agreement
Ne = Number of Expert
Ni = Number of Items

Several studies recommend a valid or excellent minimum value for I-CVI, as indicated in Table 2. S-CVI is calculated by averaging the I-CVI scores for each item that is interpreted as valid or excellent.

Table 2. Minimum Valid I-CVI Value [29], [33], [34]

Total Experts	Minimum Value Interpretation	Source
2	≥ 0,8	[31]
3 - 5	1	[27]
≥ 6	≥ 0,83	[27]
6-8	≥ 0,83	[32]
≥ 9	≥ 0,78	[32]

While the CVI method is well proven and widely used for content validity, it does have inherent weaknesses. Specifically, it fails to determine the minimum value agreement adjustment and carries the potential to cause agreement inflation due to the risk of chance agreement [29]. In a study conducted by Polit *et al.* [29], an alternative method to enhance the CVI has been discussed, namely by incorporating the Modified Kappa method. Wynd *et al.* [35] argue that the modified kappa method is an important complement to the CVI because it provides information related to the level of agreement beyond chance agreement.

Cohen's Kappa, also known as Modified Kappa, is frequently employed to test inter-rater reliability. This method assesses the agreement among experts regarding the relevance of the item, without explicitly calculating the assessment of its irrelevance [36]. The evaluation criteria for the kappa method consist of several categories and it can be seen in Table 3.

Table 3. Evaluation score for the kappa method[37], [4]

Kappa Score	Interpretation
<0.40	Poor
0.40 – 0.59	Fair
0.60 – 0.74	Good
0.75 – 1.00	Excellent

To calculate k*, the probability of chance agreement needs to be determined first. The formula for binomial random variables can be seen in the following equation:

$$p_c = \left[\frac{N!}{A!\,(N-A)!}\right] .5^n \tag{3}$$

Pc = Probability of Chance Agreement
N = Number of Experts
A = Number of Experts who Interpret Excellent

Furthermore, k* is calculated using the proportion of relevant agreement or using the I-CVI method and the probability of chance agreement. The formula for obtaining the k* (modified kappa) value can be seen in the following equation:

$$k* = \frac{I-CVI \ - p_c}{1 \ - p_c} \quad (4)$$

After conducting content validation using the CVI and modified kappa methods, the researcher will obtain relevant factors to support the transition of electric mobility in Indonesia. Table 4 presents a list of validated factors and their definitions. This factor list will serve as a source for further data processing in questionnaire 2 to obtain factor weighting and understand their interrelationships.

Table 4. Data validation for critical success factor

Dimension	Code	Factors	Kappa*	Interpretation
Marketing **(D1)**	M1	Value proposition	1.00	Excellent
	M2	Product-service bundle price	0.89	Excellent
	M3	Advocacy campaigns	0.26	Poor
	M4	EV variety	0.89	Excellent
	M5	Brand endorsement	0.10	Poor
Economy **(D2)**	E1	Fuel Price	0.89	Excellent
	E2	Electricity price	1.00	Excellent
	E3	Battery price	0.76	Excellent
Technology **(D3)**	TE1	Battery technology	0.76	Excellent
	TE2	Advanced navigation	0.26	Poor
	TE3	Partnership with main players	0.89	Excellent
	TE4	Battery lifetime	0.89	Excellent
	TE5	Supply chain	0.60	Good
	TE6	Interoperability	0.89	Excellent
Politics **(D4)**	P1	Governmental funding	0.89	Excellent
	P2	Energy and climate policy	0.76	Excellent
	P3	Standardisation	0.60	Good
	P4	Program target	0.76	Excellent
	P5	Soft landing policy	0.26	Poor
	P6	Political will	0.89	Excellent
Society **(D5)**	S1	User acceptance	0.76	Excellent
	S2	Alternative transport system	0.26	Poor
	S3	Operating costs	1.00	Excellent
	S4	Cost of ownership	1.00	Excellent
	S5	The ease of use	1.00	Excellent
	S6	Social influence	1.00	Excellent
Technical **(D6)**	TI1	Range	1.00	Excellent
	TI2	Charging concepts	0.26	Poor
	TI3	Charging time	1.00	Excellent
	TI4	Safety	1.00	Excellent
	TI5	Charging infrastructure	1.00	Excellent

3.3. Decision Making Trial and Evaluation Laboratory (DEMATEL)

The DEMATEL method is a systematic factor analysis technique used to identify interactions among criteria and visualize the cause-and-effect model structure through a graph generated by matrix calculations [38]. DEMATEL is particularly suitable for studying and analyzing complex and interconnected issues. From a study conducted by Kumar *et al.* [39], the DEMATEL method has been utilized to assess the innovative capabilities of real estate companies. In that research, the authors derived factors from a literature review, subsequently ranked the criteria, and proceeded to assess the innovative capabilities of real estate companies through the use of DEMATEL. Through this method, researchers can model and enhance their understanding of a problem, grasp the dimensions and interacting factors, and provide viable solutions by examining the visualization of the influential network relationship map (INRM), commonly referred to as the network relationship map (NRM) [17].

3.4. Analytic Network Process (ANP)

ANP is a measurement method based on pairwise comparisons that relies on expert judgments to establish priority scales [40]. ANP is concerned with decisions without assuming the independence of elements at higher levels from elements at lower levels and also independence among elements at the same level. This allows for the existence of a network structure, dependencies, and feedback among elements in the decision model [41]. ANP allows for interactions and feedback among elements within clusters and between clusters as well as alternatives. There are three main elements in the ANP model, namely clusters, nodes, and dependencies. Through feedback, all alternatives can depend on criteria and interdepend among themselves.

3.5. DEMATEL-Based ANP

The DEMATEL method has been extensively used in combination with the ANP method. As a robust approach for modeling cause-and-effect relationships, the utilization of the DEMATEL method has increased. The ANP method has also become a widely used multiple criteria decision making (MCDM) approach. Other MCDM methods assume that one factor is independent of another, while the ANP method assumes interdependence among factors, making it suitable for use.

However, the network structure in the ANP method is predetermined 'a priori' and the ANP questionnaire survey is considered too complex, with no systematic methodology for generating criteria. Therefore, a method is needed to enhance the ANP method. Considering the shortcomings of the DEMATEL method, which does not provide an absolute degree of relationship, and the ANP method, which has its limitations, there is an integration method called DEMATEL-based ANP that can overcome these difficulties. This method is supported by research by Gölcük and Baykaso˘glu [16], who compared various applications of MADM methods and concluded that the hybridization of DEMATEL and ANP is one of the most promising approaches for exploring the interaction of criteria in MADM. The DEMATEL-based ANP method is a combined method that utilizes the total relation matrix (T) obtained in the DEMATEL method to generate an unweighted supermatrix in the ANP method.

The DEMATEL-based ANP method was chosen in this study based on several studies [42], [18], as it has the capability to:

- Analyze causality (interaction) among criteria, visualize it, and then prioritize it.
- Enhance modeling capabilities and support the ANP methodology to function more effectively.
- Simplify the questionnaire filling process compared to traditional ANP due to not using a 9-scale.
- Refine the DEMATEL and ANP methods, where the criteria structure is obtained from the DEMATEL method, and then the ANP method is used to select the optimal model.

The steps involved in the computation of the DEMATEL-based ANP method are delineated as follows Khan *et al.* [43]:

1. Obtain the **matrix of direct influence**
   This step involves obtaining matrices from expert panels indicating the influence of factor i on factor j, represented by $x_h = x_{ij}^h$ (5)
2. Form the **direct relation matrix (Z)**
   The direct relation matrix (Z) can be calculated using the formula bellow:
$$z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix} \quad (6)$$
3. Form the **normalized direct relation matrix (D)**
   This can be achieved by employing the average matrix Z and applying the equations provided below:
$$D = \lambda * Z \quad (7)$$
$$\lambda = min \left[\frac{1}{max1 \le i \le n \sum_j^n Zij}, \frac{1}{max1 \le i \le n \sum_i^n Zij} \right] \quad (8)$$
4. Calculate the **total relation matrix (T)**
   The total relation matrix (T) can be derived using the equations provided below:
$$T = D\,(I - D\,)^{-1} \quad (9)$$
5. Form the **Network Relationship Map (NRM)**
   The computation of the network relationship map (NRM) stems from equations (10) and (11). The row sums in the T matrix, designated as Di, signify the influence of factor i on other factors, while the column sums in the T matrix, labeled as Ri, depict the impact of other factors on factor j. By utilizing the values $Di + Ri$ and $Di - Ri$, the NRM can be constructed, showcasing the influence of one factor on another through arrows. To identify individual influences among factors, a threshold value (TV) must be determined. This TV is computed as the average of the total relation matrix (T) for each dimension and factor. If an element in the total relation matrix (T) exceeds this threshold, an arrow appears on the NRM, indicating a direct relationship between the factors.
$$D_i = \sum_{i=1}^{n} T_{ij} \quad \forall i \quad (10)$$
$$R_j = \sum_{j=1}^{n} T_{ij} \quad \forall j \quad (11)$$
6. Form the **normalized total relation matrix (T^{norm})**
   The total relation matrix for factors (Tc) and dimensions (Td) can be normalized using the following equations:
$$T_D^{norm} = \begin{bmatrix} \frac{t_D^{11}}{r_1} & \cdots & \frac{t_D^{1j}}{r_1} & \cdots & \frac{t_D^{1m}}{r_1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{t_D^{i1}}{r_i} & \cdots & \frac{t_D^{ij}}{r_i} & \cdots & \frac{t_D^{im}}{r_i} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{t_D^{m1}}{r_m} & \cdots & \frac{t_D^{mj}}{r_m} & \cdots & \frac{t_D^{mm}}{r_m} \end{bmatrix} \quad (12)$$
$$r_1 = \sum_{j=1}^{m} t_D^{1m} \; ; \; r_i = \sum_{j=1}^{m} t_D^{ij} \; ; \; r_m = \sum_{j=1}^{m} t_D^{mm}$$
   The normalized total relation matrix for dimension T_D^{norm} will be:
$$T_D^{norm} = \begin{bmatrix} t_D^{norm11} & \dots & t_D^{norm1j} & \dots & t_D^{norm1m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{normi1} & \cdots & t_D^{normij} & \cdots & t_D^{normim} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ t_D^{normm1} & \dots & t_D^{normmj} & \dots & t_D^{normmm} \end{bmatrix} \quad (13)$$
   The total relation matrix for factors (Tc) is organized into clusters based on various dimensions. In each cluster, every element is divided by the number of rows in that specific cluster, as demonstrated in equation (14):

$$T_c = \begin{array}{c} \\ D_1 \begin{matrix} C_{11} \\ C_{12} \\ \vdots \\ C_{1n_1} \end{matrix} \\ D_j \begin{matrix} C_{j1} \\ C_{j2} \\ \vdots \\ C_{jn_2} \end{matrix} \\ D_m \begin{matrix} C_{m1} \\ C_{m2} \\ \vdots \\ C_{mm_n} \end{matrix} \end{array} \overset{\begin{matrix} D_1 & & D_j & & D_m \\ C_{11} \dots C_{1n_1} & & C_{j1} \dots C_{jn_2} & & C_{m1} \dots C_{mm_n} \end{matrix}}{\begin{bmatrix} \frac{t_C^{11}}{r_{11}} & \dots & \frac{t_C^{1j}}{r_{1j}} & \dots & \frac{t_C^{1m}}{r_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{t_C^{i1}}{r_{i1}} & \dots & \frac{t_C^{ij}}{r_{ij}} & \dots & \frac{t_C^{im}}{r_{im}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{t_C^{m1}}{r_{m1}} & \dots & \frac{t_C^{mj}}{r_{mj}} & \dots & \frac{t_C^{mm}}{r_{mm}} \end{bmatrix}} \quad (14)$$

7. Form the **unweighted supermatrix (W)**
   The normalized total relation matrix T_C^{norm} is obtained by normalizing the total relation matrix (T). Subsequently, T_C^{norm} is transposed to produce the unweighted supermatrix (W).

$$W = (T_C^{norm})' = \begin{array}{c} D_1 \begin{matrix} C_{11} \\ C_{12} \\ \vdots \\ C_{1n_1} \end{matrix} \\ D_j \begin{matrix} C_{j1} \\ C_{j2} \\ \vdots \\ C_{jn_2} \end{matrix} \\ D_m \begin{matrix} C_{m1} \\ C_{m2} \\ \vdots \\ C_{mm_n} \end{matrix} \end{array} \overset{\begin{matrix} D_1 & & D_j & & D_m \\ C_{11} \dots C_{1n_1} & & C_{j1} \dots C_{jn_2} & & C_{m1} \dots C_{mm_n} \end{matrix}}{\begin{bmatrix} w^{11} & \dots & w^{j1} & \dots & w^{m1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w^{1j} & \dots & w^{ij} & \dots & w^{mj} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w^{1m} & \dots & w^{im} & \dots & w^{mm} \end{bmatrix}} \quad (15)$$

8. Form the **weighted supermatrix (W*)**
   The weighted supermatrix (W*) is formed by multiplying the unweighted supermatrix (W) with the transpose of T_D^{norm}.

$$W^* = (T_D^{norm})' \times W = \begin{bmatrix} t_D^{norm11} \times w^{11} & \dots & t_D^{normj1} \times w^{j1} & \dots & t_D^{normm1} \times w^{m1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{norm1j} \times w^{1j} & \dots & t_D^{normji} \times w^{ji} & \dots & t_D^{normmj} \times w^{mj} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ t_D^{norm1m} \times w^{1m} & \dots & t_D^{normjm} \times w^{jm} & \dots & t_D^{normmm} \times w^{mm} \end{bmatrix} \quad \dots (16)$$

9. Obtain **factor weights**
   The global priority vector establishes the weights of influence $w = (w1, \dots, wj, \dots, wn)$ from $\boldsymbol{W^{limit}} = \lim_{\alpha \to \infty} (W^*)^{\alpha}$ for factors is obtained by iterating the weighted supermatrix (W*) until a stable supermatrix is achieved. The values of the elements in the limit supermatrix represent the weights of each factor.

4. Results and Discussions

This chapter presents an analysis of the processed data, covering the relationship of critical success factors (CSFs) in the NRM and their respective weights. The evaluation is based on the insights of researchers, the expertise of professionals in the field, and supporting literature sources.

4.1. The Relationship of Critical Success Factors

The relationship of CSF can be observed from data processing using the DEMATEL-based ANP method. With this method, researchers can model and enhance understanding of a problem, comprehend the interacting dimensions and factors, and provide viable solutions by examining the visualization of the network relationship map (NRM) [17]. Two types of NRM are formed, namely NRM between dimensions and NRM between CSFs within each dimension. NRM is constructed based on the values of $Di + Ri$ and $Di - Ri$. $Di + Ri$ indicates the importance of inter-criteria relationships, while $Di - Ri$ represents the strength of influence between criteria. If $Di - Ri$ is negative, the criteria are classified into the effect group. Conversely, if $Di - Ri$ is positive, the criteria are assigned to the cause group. Figure 1 illustrates the NRM between dimensions.

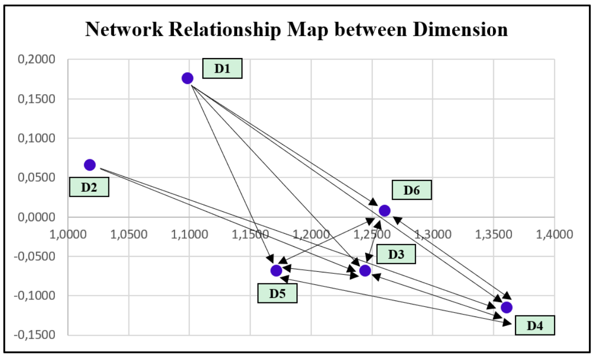
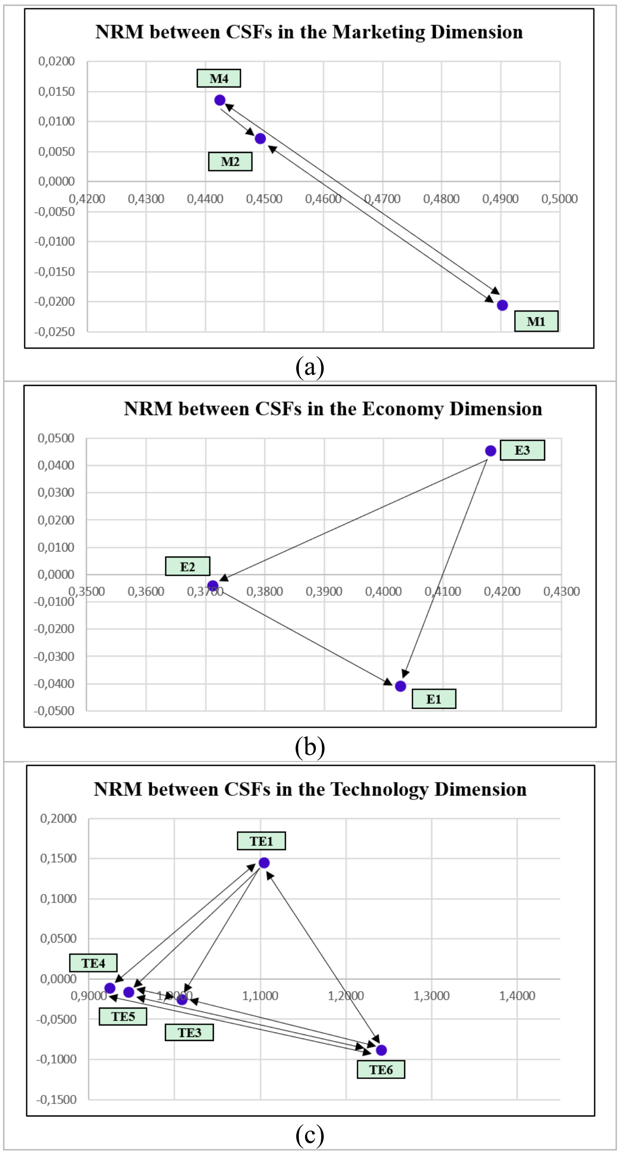


Figure 1. Network relationship map between dimension

Based on its level of importance, the politics dimension (D4) occupies the first position, having the highest value of $Di + Ri$ at 1.3607, mapped on the x-axis. This indicates that if something is done wisely in the politics dimension, it will have a more significant impact because this dimension has the highest degree of importance. In terms of its influence level, the marketing (D1), economy (D2), and technical (D6) dimensions are classified as causes, where these three dimensions tend to influence other dimensions. The technology (D3), politics (D4), and society (D5) dimensions are classified as effects because they have negative values of $Di - Ri$. In Figure 1, it can also be observed that no other dimension influences the marketing (D1) and economy (D2) dimensions. This may be because the marketing and economy dimensions tend not to feel any effects or impacts when other dimensions are in motion. Dimensions in the effects group imply that if other dimensions, such as marketing (D1), economy (D2), and technical (D6), undergo changes, the dimensions in the effects group will be significantly influenced.

As an example, if the value proposition (CSF in the marketing dimension) is intensified in Indonesia, then user acceptance (CSF in the society dimension) will experience its positive impact, such as a high level of user acceptance, where users will accept the innovation because the system has been built according to users' needs.

Based on the results of data processing, it is determined that in each CSF dimension, at least one CSF has a significant influence. Therefore, the number of NRM that can be formed is six, corresponding to the number of existing dimensions. NRM can be formed by mapping the values of $Di + Ri$ on the x-axis, the values of $Di - Ri$ on the y-axis, and mapping arrows to the dimensions that have a significant influence. The NRM among CSF within dimensions is illustrated in Figure 2.



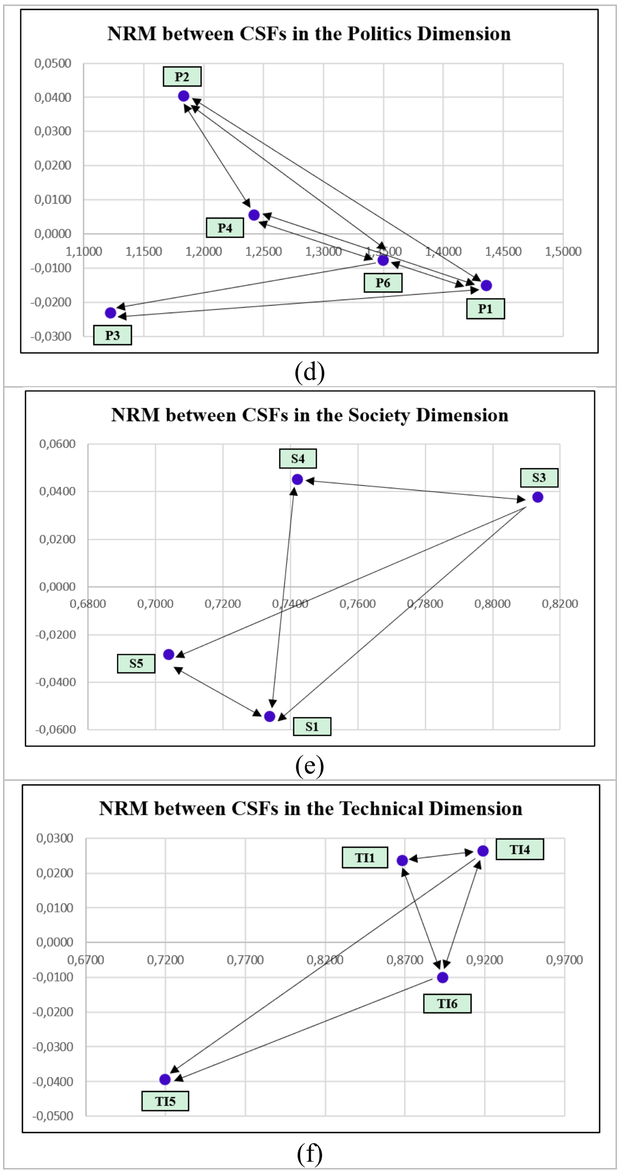


Figure 2. Network relationship map between CSFs within dimension: a) Marketing Dimension, b) Economy Dimension, c) Technology Dimension, d) Politics Dimension, e) Society Dimension, f) Technical Dimension

The influence of critical success factors (CSF) in the marketing dimension reveals that CSF's value proposition is the most crucial in the e-mobility transition. A robust value proposition affects the public's perception of the benefits of services and makes them the best choice [44]. The EV variety CSF tends to have the most influence on other CSFs. For example, the abundance of electric vehicle variations or models significantly enhances the value proposition or increases the performance variety of vehicles [45].

In the influence among CSFs in the economic dimension, the battery price CSF is the most important. This is due to the high price of batteries, a key component of electric vehicles. Any influence on this CSF results in a higher impact [46]. The battery price CSF tends to have the most influence.

For instance, there is a relationship between plug-in hybrid vehicles' total cost of ownership (TCO), where TCO fluctuates based on fuel and electricity costs [47].

In the technology dimension, interoperability is the most critical CSF. Interoperability in EV charging ensures flexible charging opportunities. This system can integrate using data/information, facilitating customers' use of services [48]. Battery technology CSF tends to have the most influence. This is because advancements in battery technology drive the development of other factors in this dimension [47], [49].

In the influence among CSFs in the political dimension, governmental funding is the most critical CSF. This may be due to the assertion that subsidies play a crucial role in accelerating e-mobility transitions [50]. Additionally, from the experts' perspective, the current adoption challenge for EVs is cost-related. Energy and climate policy CSF tends to have the most influence. This is because strict policies related to environmental protection require other CSFs, such as governmental funding (P1), political will (P6), and standardization (P3). In the influence among CSFs in the society dimension, operating costs are the most critical CSF. This is because one of the primary advantages of EVs is their low operating costs, where the maintenance costs of EVs are one-tenth that of internal combustion engine (ICE) vehicles [46], [51]. Cost of ownership CSF tends to have the most influence. This is because if ownership costs are very high, it will reduce the interest of potential customers in purchasing electric vehicles [52].

In the influence among CSFs in the technical dimension, charging time is the most critical CSF. This is due to the primary adoption constraint of EVs, one of which is the relatively long charging time compared to ICE vehicles, which needs immediate development [45], [46], [53]. Charging time CSF tends to have the most influence. According to one of the experts, this is because if fast charging is desired, charging infrastructure must continue to be developed, and other factors in this dimension will follow its progress.

4.2. The Weights of Critical Success Factors

The analysis of weighting critical success factors (CSFs) through the DEMATEL-based analytic network process (ANP) method is divided into two parts: dimension weighting analysis and CSF weighting analysis (local and global). The results of CSF and dimension weighting can be seen in Table 5.

Table 5. Dimensional and CSF weighting results

Dimension	Weight	Code	Local Weight	Local Rank	Global Weight	Global Rank
Marketing (D1)	0.1295	M1	0,3653	1	0,0473	3
		M2	0,3211	2	0,0416	13
		M4	0,3136	3	0,0406	16
Economy (D2)	0.1340	E1	0,3506	1	0,0470	4
		E2	0,3179	3	0,0426	11
		E3	0,3315	2	0,0444	8
Technology (D3)	0.1832	TE1	0,1849	3	0,0339	22
		TE3	0,2003	2	0,0367	20
		TE4	0,1840	4	0,0337	23
		TE5	0,1765	5	0,0323	24
		TE6	0,2543	1	0,0466	7
Politics (D4)	0.2057	P1	0,2317	1	0,0477	1
		P2	0,1777	5	0,0366	21
		P3	0,1834	4	0,0377	19
		P4	0,1946	3	0,0400	17
		P6	0,2127	2	0,0438	9
Society (D5)	0.1722	S1	0,2483	2	0,0428	10
		S3	0,2707	1	0,0466	6
		S4	0,2412	3	0,0415	14
		S5	0,2398	4	0,0413	15
Technical (D6)	0.1754	TI1	0,2423	3	0,0425	12
		TI4	0,2667	2	0,0468	5
		TI5	0,2208	4	0,0387	18
		TI6	0,2702	1	0,0474	2

The dimension that occupies the first position is politics, followed by technology, technical, society, economy, and marketing. Politics holds the first position as the most influential dimension in the transition to e-mobility in Indonesia, with a weight of 0.2057 or 20.57%. This is consistent with expert opinions and existing literature, which highlight the significant EV sales in some countries since 2009, driven by government policy support during the initial stages of market penetration [54]. In addition, the adoption of EVs also heavily depends on demand-side policies, such as tax reductions, financial subsidies, and parking privileges [53], [55]. On the other hand, the dimension that occupies the last position as the least influential in the e-mobility transition is marketing. This may be because Indonesia is still in the transitional or market penetration stage, requiring price adjustments and an enhancement of the value proposition.

The global CSF weighting is an overall assessment of CSFs. Local CSF weighting is an assessment based on CSFs within each dimension. In this analysis, the researcher will examine and discuss the top 5 globally weighted CSFs.

Governmental funding with a weight of 0.0477 or 4.77% holds the top position or highest priority as a critical success factor (CSF) in supporting or accelerating e-mobility in Indonesia. Central and local governments in large countries have developed ambitious EV adoption by implementing various policies.

These policies include subsidies for EV purchases, tax credit assistance, subsidies for reducing charging station installation costs at specific locations, and a range of non-financial policies such as parking privileges, subsidized electricity for charging, and road usage privileges [50]. This CSF is also supported by the results of the National Conference of State Legislatures in 2017, where 46 out of 50 states issued incentive policies (direct & indirect) to promote EV adoption in their respective regions.

Charging infrastructure with a weight of 0.0474 or 4.74% holds the second position. This is because the availability of electric charging stations, as the primary power source for EVs, is still limited, and the high uncertainty in this infrastructure hinders EV adoption in Indonesia. According to research by Kolz and Schwartz [46], Expanding charging infrastructure and advancements in charging technology are critical factors for the success of electric mobility. Kong *et al.* [56] suggests that the quantity of charging infrastructure needs to exceed the minimum requirements to meet driving needs, enhancing EV owner convenience by reducing wait times. Additionally, considering that electric buses in China already make up 50% of the total, addressing the high demand for daily charging requires the development of adequate charging infrastructure [57].

Value proposition with a weight of 0.0473 or 4.73%, occupies the third position. Electric mobility is considered a disruptive innovation, which can create new markets or replace existing ones with more appealing business ideas that align with consumer needs [43]. Literature from Bosch Global Software Technologies suggests that certain disruptive innovations include electric vehicle (EV) fuel and maintenance costs being 10 times cheaper than internal combustion engine (ICE) vehicles, EVs being 5 times more efficient than ICE vehicles, the declining technology costs associated with Li-ion batteries over time, and the convenience of home charging. Incomplete information about product attributes, such as quality and inadequate external pricing, can lead to market adoption failures.

Therefore, effective and comprehensive communication of innovations to the public is essential. Additionally, a strong value proposition influences people to perceive how the service benefits them and is the best choice [44].

Fuel price with a weight of 0.0470 or 4.7%, holds the fourth position. It is known that fuel subsidies in Indonesia are still substantial. The depleting oil reserves, especially over the last three years, contribute to the rise in fuel prices. Finance Minister Sri Mulyani has mentioned the need for an additional subsidy budget of Rp 198 trillion to prevent an increase in fuel prices. This situation is increasingly detrimental to the country because the government acknowledges that these subsidies do not target the right beneficiaries and do not reduce poverty but rather widen the wealth gap. Therefore, policies related to fuel prices are crucial in supporting the transition to e-mobility. If fuel subsidies are reduced and directed to the right recipients, there is a high likelihood that the middle-class population would consider switching to electric vehicles, starting with convenient and superior public transportation, such as e-buses. Research by Arnob [58], observes the relationship between fluctuating fuel prices and the increasing number of electric vehicles. The study concludes that as the number of electric vehicles in the market grows, the demand for oil in the global market slightly decreases. This is positive, considering that fossil fuels are non-renewable energy sources that need to be conserved.

Charging time with a weight of 0.0468 or 4.68% holds the fifth position. A widely recognized distinction between EV and ICE is the charging time, with ICE vehicles powered by gasoline or diesel and EVs relying on electric power. Charging an ICE vehicle takes about 5-10 minutes, while an EV requires a minimum of 1 hour. According to an expert, the impact of ultra-fast charging, with charging times of less than 10 minutes, will revolutionize the adoption of electric mobility. This aligns with the literature study by Wolbertus and Hoed [59], emphasizing that fast charging is essential to accelerate charging and save energy costs for owners, thereby reducing barriers to electric vehicle adoption. Figure 3 below illustrates the bar graph of the global CSF weights.

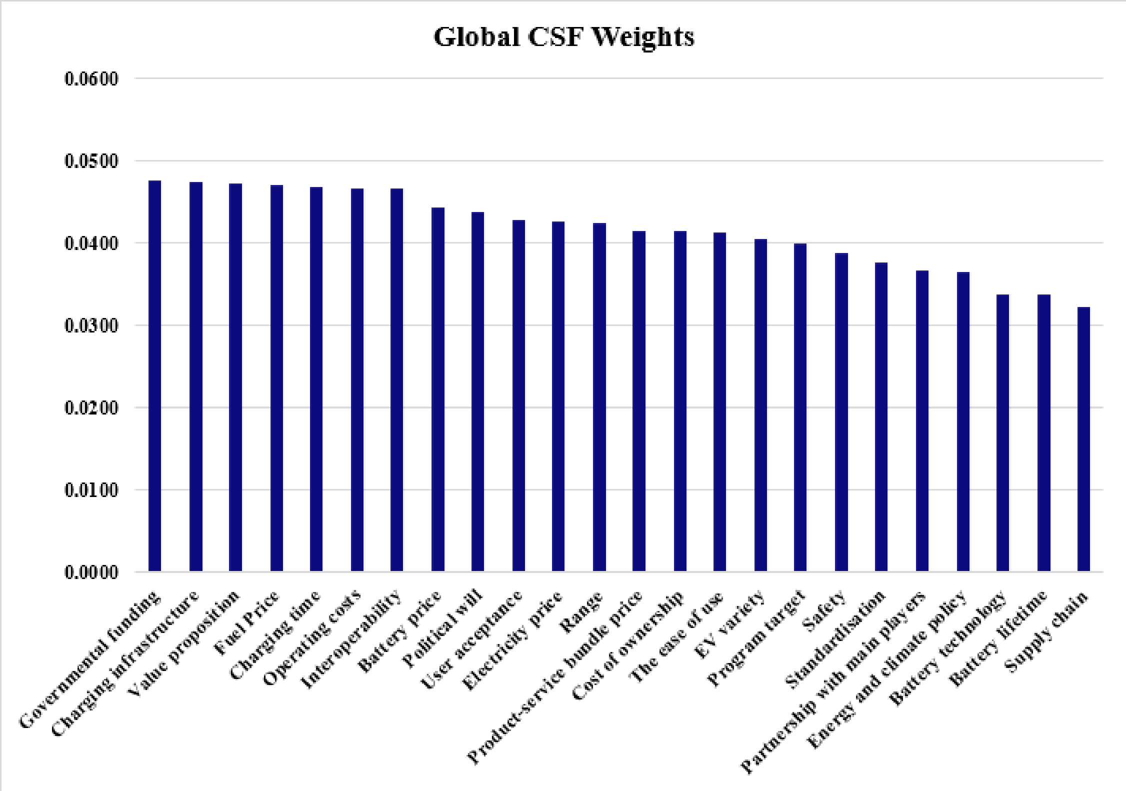


Figure 3. Global CSF weights bar chart

5. Conclusion

E-mobility is a crucial concept to be implemented in Indonesia for positive impacts on health, the environment, and the economy. However, the adoption of e-mobility in Indonesia is relatively slow compared to China, Europe, and some other countries. In this study, a critical success factor (CSF) analysis is undertaken to pinpoint influential factors in implementing e-mobility designs with the aim of achieving strategic plans.

This study identifies valid critical success factors (CSFs), explores the relationships between CSFs, and determines the weighting of CSFs influencing the implementation of e-mobility in Indonesia. The study results reveal that CSFs, derived from literature reviews and expert opinions, form six dimensions with 24 critical success factors. The top five prioritized critical success factors for the transition to electric mobility in Indonesia are governmental funding, charging infrastructure, value proposition, fuel price, and charging time. The dimension highlighting politics as most crucial emphasizes the significant impact of strategic political measures on the transition to electric mobility. It emphasizes how well-devised political strategies and interventions can profoundly influence and shape the adoption and advancement of e-mobility initiatives.

In terms of priority level, the highest weighting or top priority for global CSFs supporting e-mobility is governmental funding. This CSF is also supported by the results of the National Conference of State Legislatures in 2017, where 46 out of 50 states issued incentive policies (direct and indirect) to promote EV adoption in their respective regions.

For future research, it is advisable to involve more experts from government sectors, as the dimension with the highest global weighting in this study is politics. Additionally, it is suggested to develop strategic plans for each identified critical success factor (CSF). Furthermore, future studies can delve deeper into each type of transportation, such as CSFs for e-buses, e-cars, and e-motorcycles.

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