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Analyzing the Interrelationships of the Challenges in the Bus Rapid Transit System Implementation and their Prioritization: A Case Study in the Philippines

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Abstract

Establishing an efficient transportation infrastructure is part of urban development and could benefit multiple aspects of modern life. However, with the rise in the population, traffic congestion has become apparent and transportation systems urgently need to be improved. This study investigates several challenges that hindered the implementation of the bus rapid transit system implementation in the perspective of a developing country. Expert opinions were gathered using the Delphi method to identify the challenges, while decision-making trial and evaluation laboratory (DEMATEL) and analytic hierarchy process (AHP) methods were used to analyze the interconnectedness of these challenges and prioritize them in terms of the urgency to mitigate them. A total of 18 challenges were listed covering internal and external factors. The results show that *approval during planning*, *communication barriers between consultants and contractors*, and *political will of the government officials* significantly influence other challenges. Moreover, *approval during planning, complexity of implementation, complaints of the affected establishments, coordination between different agencies,* and *impact on public utility jeepney (PUJ) drivers* are the challenges ranked highest in terms of prioritization. These findings will aid the stakeholders in managing the challenges and provide insights and guidelines for developing strategies to overcome them.

Keywords
Bus rapid transit system, Challenges, Delphi, DEMATEL, AHP

1. Introduction
Building an efficient transportation infrastructure is one of the most important issues in modern urban development (Kumari & Kumar Sharma, 2017; Arbués, et al., 2015; Ling, et al., 2024). This is because mobility is crucial for many aspects of modern life, including going to school and commuting to work. However, transport systems continue to experience congestion as the population increases. Kenyon and Lyons (2003) stated that governments are pushing for a modal shift approach to relieve this congestion and persuade individuals to transition from primarily using private vehicles to using public transportation options. The result of increased urbanization has contributed to several growing issues in the transportation system (Yannis & Chaziris, 2022; Pradhan, et al., 2021; Poumanyvong, et al., 2012).

In the Philippines, it is reported that the current status of transportation systems needs modernization due to a lack of development and adequate support for development (Samson, 2023). The nation also experienced a significant economic setback of 2.4 billion PHP (USD 41.5 million) caused by traffic congestion as reported by the Japan International Cooperation Agency (JICA) in 2014 (Philippine Institute for Development Studies, 2024). Accessibility issues, especially for persons with disabilities, further compound the problems faced by the transportation system in the Philippines (Samson, 2023). One of the cities in the Philippines, Cebu City, has experienced issues each day with the increase in registered vehicles, which the roads are unable to accommodate. To address this expanding problem, Cebu City must establish enforceable legislation; otherwise, it will have to deal with everyday congestion and deteriorating road conditions. The vitality of a city is its ability to operate as a vibrant center of economic activity, enabling easy mobility and effective road connections between city neighborhoods and outside areas (Arnado, et al., 2017).

Given its growing population and increasing traffic problems, Cebu City urgently needs to establish a new public transportation system. Cebu City's population increased from 922,611 in 2015 to 964,169 in 2020, accounting for 95.669% of the Central Visayas region's total population (Philippine Statistics Authority, 2020). Throughout the years 2015 to 2020, Cebu City's population grew by 0.93% annually on average. The population of the city has been steadily increasing, and future growth is anticipated. Additionally, a report by the Cebu City Transport Office stated that there is an insufficient public transportation options and an overabundance of private vehicles in Cebu City. Approximately 80% of the vehicles on the roads are privately owned, while 10% are attributed to public transport. Given the increasingly severe traffic congestion in Cebu City, there is a compelling need for an improved public transportation system to address this issue (Montalbo & Brader, 2015). As an effect, the Cebu City local government and the national government started working together to propose the Cebu Bus Rapid Transit Systems implementation (Cedeño, et al., 2023).

Bus Rapid Transit (BRT) is a high-capacity rapid transit system designed to bring together the flexibility and lower fares of buses with the efficiency and dependability of rail transit (Wirasinghe, et al., 2013; Levinson, et al., 2002; Deng & Nelson, 2011). It is essential to recognize that the suitability of the BRT may vary depending on the specific circumstances of each place. This difference is significant to consider, as BRT systems are recognized as significant elements of sustainable urban mobility. However, despite its potential benefits, the implementation of the BRT system in Cebu City faces several significant internal and external challenges that impede its efficient execution. Some of the challenges included limited road space (Fong, 2017; Rogat, et al., 2015; Nello-Deakin, 2019; Zheng & Geroliminis, 2013), the approval process of necessary documents (Mascardo, 2024; Wood, 2019), complaints about the affected establishments (Demecillo, 2017; Yen, et al., 2024; Sohail, et al., 2006), and the complexity of the implementation (Lindau, et al., 2014; Poku-Boansi & Marsden, 2018), among others. It is important to understand these challenges and how they hinder the implementation of a developed transport system, such as the BRT system.

Several studies have addressed the challenges with the implementation of a BRT system. Poku-Boansi and Marsden (2018) conducted an in-depth analysis to introduce the BRT system in Ghana as a government project. Another, Deng and Nelson (2011) evaluated the cost, operational efficiency, and technical performance of BRT. Nguyen et al. (2019), on the other hand, discussed the impediments to BRT implementation in Hanoi, Vietnam. Vergel-Trover (2023) classified the barriers into five themes: coordination, expertise, development, management, and equity. Lastly, Lindau et al. (2014) presented the barriers to planning and implementing BRT in Brazil. Although the mentioned literature works were exemplary, most of the existing studies tackled these challenges individually and some are merely identifying them without necessarily addressing or mitigating them. It is important to address these challenges and understand the complexity they bring in the implementation of the BRT system.

1.1 Objectives

This study aims to respond to the need to address these important issues and provide insights into the complex challenges faced by the BRT system by analyzing and understanding the interrelationship between these challenges and prioritizing which challenges to address first. Through this, the challenges could be mitigated to have a successful BRT system implementation through a set of policy insights and guidelines, especially for developing countries. This study will use the decision-making trial and evaluation laboratory (DEMATEL) technique and the analytic hierarchy process (AHP) model. To visually represent the interdependence of different system components and analyze complex causal relationships among them, the DEMATEL model was utilized. The DEMATEL model has been successfully used in addressing the interrelationships of multifactor case studies (Bagherian, et al., 2024; Quiñones, et al., 2020; Selerio, et al., 2022). Furthermore, the AHP model was applied to pairwise evaluations and comparisons to determine the relative importance of various components, such as criteria and alternatives. AHP has been applied in prioritization problems and evaluation of alternatives (Kumar & Pant, 2023; Tavana, et al., 2023; Maslem, 2024; Marabulas, et al., 2023).

2. Challenges in identification and verification

An extensive literature review was conducted to identify the initial list of challenges faced in implementing the BRT system. Keywords such as “BRT implementation,” “BRT barriers in implementation,” “BRT challenges in implementation,” “BRT planning challenges,” and “BRT planning barriers,” among others, were used during the literature search. Local news and government websites were also utilized, including expert suggestions, to form the list of challenges. Then, a standard Delphi method is utilized to improve and verify the challenges of their applicability in the case study location, Cebu City, Philippines. The data collected from different experts underwent several rounds until a consensus with a target agreement of 75% was reached among them (Okoli & Pawlowski, 2004; Landeta, 2006). Summarized in Table 1 are the qualifications of the experts and in Table 2 is the breakdown of the respective affiliations and category of each expert. The final list of challenges identified and verified by each expert after several survey rounds is presented in Table 3. Note that the same set of experts also served as respondents for the data treatment methods discussed in the next sections.

Table 1. Criteria selection for expert respondents

Government	Industry
Three years of professional experience, specifically dedicated to research, government agency work related to urban transportation, or direct involvement in the planning and implementation of BRT systems.	Three years of professional experience, specifically dedicated to industry agency work related to urban transportation, or direct involvement in the planning and implementation of BRT systems.
Experts must have demonstrated participation in BRT initiative decision-making processes and proactive involvement in BRT-related activities.	Experts must have demonstrated participation in BRT initiative decision-making processes and proactive involvement in BRT-related activities.
A prerequisite for evaluation is a proven knowledge base that includes a thorough comprehension of the technical features, challenges to implementation, and innovations found in the BRT system	A prerequisite for evaluation is a proven knowledge base that includes a thorough comprehension of the technical features, identification of the challenges, and innovations found in the BRT system.

Table 2. Demographic of experts

Experts	Affiliation	Category
Expert 1	Department of Transportation	Government
Expert 2	Department of Transportation	Government
Expert 3	Department of Transportation	Government
Expert 4	Local Government Unit	Government
Expert 5	Local Government Unit	Government
Expert 6	Local Government Unit	Government
Expert 7	Cebu City Transportation Office	Government
Expert 8	Cebu City Transportation Office	Government
Expert 9	Land Transportation Franchising and Regulatory Board	Government
Expert 10	Department of Public Ways and Highways	Government
Expert 11	Private Consultant Company	Industry
Expert 12	Private Consultant Company	Industry

Table 3 presents the final list of challenges that hinder the implementation of the Cebu BRT System. It was determined through a combination of expert opinions and a validated review of relevant literature. The Delphi method involved soliciting input from experts in the field, while the literature review helped to ensure comprehensive coverage of known challenges. The validation of data about whether challenges were present or not ("yes" or "no" to challenges) involved cross-referencing with empirical evidence, expert opinions, and stakeholder feedback. The Delphi method itself involves repetitive rounds of feedback and consensus-building among experts, contributing to the validation process. In the final round of the Delphi process, the challenges that reached above 75% consensus were considered significant and were included in the final list. These challenges underwent further analysis using the DEMATEL and AHP methods, discussed in the succeeding sections, to determine their relative importance and interrelationships. These final lists of challenges represent critical factors that need to be addressed in the planning and implementation of the Cebu BRT system to ensure its success.

Table 3. Final list of challenges that hinder the implementation of the Cebu BRT System

Code	Factors	Definition	References
C1	Approval during planning	Approval requires presenting proposals to stakeholders, with any project changes needing the approval of the National Economic and Development Agency (NEDA), the country's agency responsible for economic development.	(Mascardo, 2024; Wood, 2019)
C2	Communication barriers between consultants and contractors	Lack of effective communication between the constructor and consultant involved in a BRT construction project, causing misunderstanding and delays in the project.	(Allansson, 2023; Lindau, et al., 2014)
C3	Complaints of the affected establishments	Establishments affected by road widening for the Cebu BRT system raise concerns of potential disruptions and space loss.	(Demecillo, 2017; Yen, et al., 2024; Sohail, et al., 2006)
C4	Complexity of implementation	Introducing and implementing the BRT system in Cebu City involves technical, logistical, and administrative complexities.	(Lindau, et al., 2014; Poku-Boansi & Marsden, 2018; Carrigan, et al., 2011)
C5	Coordination between different agencies	Different opinions on safety and aesthetics between DOTr, Cebu City Hall, and DPWH lead to disagreements on BRT design decisions.	(Allansson, 2023; McTigue, et al., 2020; Rizvi & Sclar, 2014)
C6	Impact on PUJ drivers	Traditional PUJ drivers may face competition or displacement due to the BRT system.	(Bunachita, 2015)
C7	Lack of identification of potential risks of the design before the implementation	Unforeseen risks that are not considered during the BRT system's design that could impact its implementation.	(Alnsour, 2023; Lindau, et al., 2014)
C8	Land acquisitions	Land acquisition may encounter delays in identifying, negotiating, acquiring, compensating, and legally transferring ownership of a project.	(Sabalo, 2024; Cervero & Dai, 2014; Vergel-Tovar, 2023)
C9	Managing and dealing with traffic congestion	Managing traffic congestion requires altering traffic flow to minimize disruptions and maintain smooth traffic flow.	(Anas, et al., 2021)
C10	Managing private vehicle growth	The increase in the number of privately owned vehicles is leading to congestion, pollution, and competition with the BRT system.	(Trubia, et al., 2020)
C11	Manpower during construction	Challenges include securing skilled workers, managing schedules, ensuring safety, and maintaining productivity during construction.	(Chang & Woo, 2017; Sheth & Sarkar, 2021)
C12	Overlapping of project funds	Overlapping of project funds occurs when multiple developments are planned in the same area, leading to conflicts, disruptions, increased costs, and delays.	(Lindau, et al., 2014; Hidalgo & Gutiérrez, 2013; Hossain, 2006)
C13	Political will of the government officials	Initially, many other politicians supported the Cebu BRT project, but later shifted their stance, opposing its goals and intention.	(Wijaya, et al., 2017; Hossain, 2006; Lindau, et al., 2014)
C14	Removal of skywalk	Some politicians oppose skywalk removal, impacting transportation station placement.	(Dube, et al., 2023; Murakami, et al., 2021)
C15	Rerouting	Rerouting decision-making becomes challenging when adjusting plans, exploring new options, and reaching agreement on new routes.	(Hidalgo & Muñoz , 2014; Krüger, et al., 2021; Agyemang, 2015)
C16	Road safety and security for pedestrians	Ensuring the well-being and protection of people walking on roadways in the presence of BRT infrastructure and other vehicles.	(Hudson, et al., 2023; Vecino-Ortiz & Hyder, 2015)
C17	Road widening	The need for wider roads entails acquiring more space on each side to accommodate vehicles and pedestrians.	(Nguyen & Pojani, 2018; Chang, et al., 2017)
C18	Verification in terms of design of the highways	Highway design verification requires thorough structural analysis for safety and compliance.	(Villarete, 2022)

3. Methods

3.1. DEMATEL implementation

The DEMATEL model visually represents complex causal relationships among elements of a system using matrices or diagraphs. Its purpose is to analyze the interdependence among factors, construct an impact-relation map to visualize causal relationships, and identify critical factors within the system (Bagherian, et al., 2024). Following the collection of data on the challenges encountered in BRT implementation, progression to the next phase involved administering a set of interview guide questions for the DEMATEL model to identify the cause-and-effect relationships among these challenges. The invited experts were guided in answering the DEMATEL model questions, utilizing the fundamental scales outlined in Table 4. The experts assigned numerical values ranging from 0 to 4 based on these fundamental scales. These fundamental scales used in DEMATEL were based on the study by (Quiñones, et al., 2020)

Table 4. Fundamental scales for DEMATEL model

Numerical	Linguistic Variable Definitions	Code
0	No influence	NO
1	Very low influence	VLI
2	Low influence	LI
3	High influence	HI
4	Very high influence	VHI

The basic process for the DEMATEL model involves defining the scale, building the direct-relation matrix, computing the normalized matrix, calculating the direct/indirect connection matrix T, prominence and relation calculation, drawing cause and effect relation calculations, results, and analysis. The step-by-step presentation and equation for the DEMATEL procedure as used by Lee et al. (2013) are as follows:

Step 1: Create an evaluation scale that reflects the intensity of the influence using the linguistic scale set in Table 4. The direct-relation matrix presents the judgment of the experts using such linguistic variables. A sample taken from one of the expert responses is shown in Table 5. The sequence of the challenges is arranged in consistent with Table 3.

Step 2: Convert the initial direct-relation matrix into numerical variables set in Table 4. A sample of the converted initial direct-relation matrix is shown in Table 6. The scores from the experts will form an $n \times n$ matrix on non-negative responses.

Step 3: Aggregate the responses of H experts to make the initial direct-relation matrix as calculated using Eq. 1. The resulting matrix $A = \left[a_{ij}\right]_{n \times n}$ is shown in Eq. 2.

$$A = \left(a_{ij}\right) = \frac{1}{H}\sum_{k=1}^{H} b_{ij}^{(k)} \tag{1}$$

$$A = \begin{matrix} C1 \\ C2 \\ \vdots \\ C18 \end{matrix} \begin{pmatrix} 0 & 3.20 & \cdots & 3.10 \\ 2.20 & 0 & \cdots & 2.60 \\ \vdots & \vdots & \ddots & \vdots \\ 2.80 & 2.00 & \cdots & 0 \end{pmatrix} \tag{2}$$

Step 4: Obtain the normalized direct-relation matrix D using Eq. 3 and Eq. 4.

$$s = \max\left(\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij}\right) \tag{3}$$

$$D = \frac{A}{s} \tag{4}$$

Table 5. Sample initial direct-relation matrix using the linguistic variables (Expert 1)

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**
C1		VHI	VHI	VHI	VHI	VHI	VHI	VHI	LI	VHI	NO	VHI	VHI	VHI	VLI	VHI	VHI	VHI
C2	NO		VHI	VHI	HI	NO	VHI	NO	NO	VHI	VHI	NO	NO	LI	NO	VHI	NO	LI
C3	VHI	VHI		VHI	VHI	LI	VHI	NO	NO	VHI	VHI	NO	VHI	VHI	VHI	VHI	VHI	VHI
C4	VHI	LI	VHI		VHI	VLI	VHI	NO	NO	NO	VLI	NO	VLI	VHI	VHI	VHI	NO	VHI
C5	VHI	LI	VHI	VHI		LI	VHI	VHI	LI	VHI	VLI	NO	VHI	VHI	VHI	VHI	VHI	VHI
C6	LI	NO	NO	LI	VHI		VHI	NO	NO	VHI	LI	NO	VHI	VHI	VHI	VHI	VHI	NO
C7	VHI	NO	VHI	VHI	VHI	VHI		VHI	NO	VHI	NO	NO	LI	VHI	LI	VHI	VHI	VHI
C8	VHI	NO	NO	LI	VHI	NO	VHI		NO	LI	NO	NO	VHI	NO	NO	NO	VHI	VHI
C9	NO	NO	VLI	LI	NO	LI	NO	NO		LI	NO	NO	NO	NO	LI	VHI	VHI	VHI
C10	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI		NO	NO	VHI	VHI	VHI	VHI	VHI	VHI
C11	NO	VHI	VHI	VHI	NO	NO	NO	NO	NO	NO		NO	NO	VHI	NO	NO	NO	NO
C12	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		NO	NO	NO	NO	NO	NO
C13	VHI	NO	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI	NO	NO		VHI	VHI	VHI	VHI	VHI
C14	VHI	VHI	VHI	VHI	VHI	NO	VHI	NO	NO	VHI	LI	NO	VHI		VHI	VHI	NO	VHI
C15	NO	NO	VHI	VHI	VHI	VHI	NO	NO	VHI	VHI	NO	NO	VHI	VHI		VHI	NO	NO
C16	VHI	VHI	VHI	VHI	VHI	VHI	VHI	NO	VHI	VHI	NO	NO	VHI	NO	NO		NO	VHI
C17	VHI	NO	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI	NO	NO	VHI	NO	NO	NO		VHI
C18	VHI	NO	VHI	VHI	VHI	NO	VHI	VHI	NO	NO	NO	NO	NO	NO	NO	VHI	VHI	

Table 6. Sample initial direct-relation matrix using numerical variables (Expert 1)

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**
C1		4	4	4	4	4	4	4	2	4	0	4	4	4	1	4	4	4
C2	0		4	4	3	0	4	0	0	4	4	0	0	2	0	4	0	2
C3	4	4		4	4	2	4	0	0	4	4	0	4	4	4	4	4	4
C4	4	2	4		4	1	4	0	0	0	1	0	1	4	4	4	0	4
C5	4	2	4	4		2	4	4	2	4	1	0	4	4	4	4	4	4
C6	2	0	0	2	4		4	0	0	4	2	0	4	4	4	4	4	0
C7	4	0	4	4	4	4		4	0	4	0	0	2	4	2	4	4	4
C8	4	0	0	2	4	0	4		0	2	0	0	4	0	0	0	4	4
C9	0	0	1	2	0	2	0	0		2	0	0	0	0	2	4	4	4
C10	4	4	4	4	4	4	4	4	4		0	0	4	4	4	4	4	4
C11	0	4	4	4	0	0	0	0	0	0		0	0	4	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
C13	4	0	4	4	4	4	4	4	4	4	0	0		4	4	4	4	4
C14	4	4	4	4	4	0	4	0	0	4	2	0	4		4	4	0	4
C15	0	0	4	4	4	4	0	0	4	4	0	0	4	4		4	0	0
C16	4	4	4	4	4	4	4	0	4	4	0	0	4	0	0		0	4
C17	4	0	4	4	4	4	4	4	4	4	0	0	4	0	0	0		4
C18	4	0	4	4	4	0	4	4	0	0	0	0	0	0	0	4	4	

The sum of row i of matrix A is $\sum_{j=1}^{n} a_{ij}$, which represents the total direct effect of factor i to the other factors. And so, the largest total direct effect of all factors is represented by $\max_{1\le i\le n} \sum_{j=1}^{n} a_{ij}$. Similarly, the sum of column j of matrix A is $\sum_{i=1}^{n} a_{ij}$ and the largest total direct effect of factor j received for all factors is represented by $\max_{1\le j\le n} \sum_{i=1}^{n} a_{ij}$. Matrix D is then obtained by dividing each element of A by scalar s. The resulting matrix D is shown in Eq. 5.

$$D = \begin{pmatrix} 0 & 0.0584 & \cdots & 0.0566 \\ 0.0401 & 0 & \cdots & 0.0474 \\ \vdots & \vdots & \ddots & \vdots \\ 0.0511 & 0.0365 & \cdots & 0 \end{pmatrix} \tag{5}$$

Step 5: Compute the total relation matrix. The total influence is summed up by $D,\ D^2,\ D^2, \ldots, D^\infty$. The direct and indirect relationships in the T matrix can be calculated as shown in Eq. 6 and the resulting T is shown in Eq. 7.

$$T = \lim_{n\to\infty} (D + D^2 + \ldots + D^m) = D(1 - D)^{-1} \tag{6}$$

$$T = \begin{pmatrix} 0.2903 & 0.2918 & \cdots & 0.3277 \\ 0.2850 & 0.2020 & \cdots & 0.2781 \\ \vdots & \vdots & \ddots & \vdots \\ 0.2758 & 0.2205 & \cdots & 0.2147 \end{pmatrix} \tag{7}$$

Step 6: Determine the values of D_i and R_j, as well as the degree to which the factors have an influence, using the direct or indirect relation matrix using Eq. 8 and Eq. 9.

$$D_i = \sum_{i=1}^{n} t_{ij} \quad for\ i = 1, 2, \ldots, n \tag{8}$$

$$R_j = \sum_{j=1}^{n} t_{ij} \quad for\ j = 1, 2, \ldots, n \tag{9}$$

Step 7: Determine the relationship (D−R) and prominence (D+R) and illustrate the diagram of the relationship between causes and effects.

3.2. AHP implementation

Thomas Saaty's AHP measures intangible factors through paired comparisons using a 1 to 9 scale, resulting in priorities for the factors and establishing priority weights for alternatives by organizing objectives. Its purpose is to offer solutions to decision and estimation problems involving multiple criteria (Kumar & Pant, 2023). After gathering data on the challenges in implementing the BRT and identifying the causal relationships between the factors, the process moved forward with the third set of interview guide questions for the AHP questionnaire to prioritize factors based on their importance. Guidance was provided to the invited experts in answering the AHP model questions, where they compared the significance of the challenges in BRT system implementation and utilized the fundamental scale used in AHP to respond. This scale is shown in Table 7.

The hierarchy framework, priority analysis, and consistency verification are the three fundamental concepts of AHP (Saaty, 1987; Al-Harbi, 2001). Analytical hierarchy is a process based on variable weight. AHP based on the variable weight method can effectively cope with the fixed weight of traditional AHP. Based on determining the weight of the experts, the weight given by the expert is corrected by real data, which makes the changed weight closer to the real result.

Table 7. Fundamental scale in AHP data gather procedure

Intensity of Importance	Definitions	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over other
5	Strong importance	Experience and judgment strongly favor one activity over other
7	Very strong importance	An activity is favored very strongly over another
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

The steps for AHP implemented by Saaty (1987) are the following:

Step 1: Construct a pairwise comparison matrix among expert responses using the relative scale presented in Table 7. A sample from an expert response is shown in Table 8. The reciprocals of the expert responses are already shown in the table as well.

Step 2: Normalize the matrix by dividing each element with the sum of all the elements in their corresponding column j. The resulting matrix is shown in Table 9.

Step 3: Determine the hierarchical synthesis to weight the eigenvectors by the weights of the criteria and the sum is calculated by the weighted eigenvector entries corresponding to those in the lower levels of the hierarchy.

Step 4: Calculate the consistency ratio CR for each pairwise comparison matrix by dividing the consistency index CI with the random index RI. The equation for CI is presented in Eq. 10.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{10}$$

Step 5: Aggregate the results by getting the average of each element for those responses that are consistent. And obtain hierarchy weights from the aggregated responses following Steps 2 and 3.

4. Results and discussion

In the adjacency matrix, the value of 1 indicates that the challenge in row i has a direct influence or impact on the challenge in column j. Conversely, a value of 0 means that the challenge in row i does not have a direct influence or impact on the challenge in column j. The adjacency matrix features the impact given (IG) column that presents the total number of challenges that a particular challenge directly influences or impacts. It is calculated by summing the values in each row. Additionally, it features an impact received (IR) row, which presents the total number of challenges that directly influence or impact a particular challenge. It is calculated by summing the values in each column.

From the DEMATEL results, the adjacency matrix analysis is shown in Table 10. Challenge C5 is identified with the highest IG count, with a value of 17, indicating its significant influence on other challenges in implementing the Cebu BRT System. Coordination issues affect nearly all identified challenges, except for C13. Challenges like C6, C9, and C11 have low or zero IG values, which means that they address specific aspects of the project without significantly affecting others. However, despite their lower impact, these challenges still pose risks to project success if not properly managed. In terms of the IR count, C5, C10, and C13 exhibit high values of 14, indicating significant influence from other challenges. Only 14 out of 18 challenges are impacted by others, while C11 has zero IR value suggesting it can be addressed independently.

Table 8. Sample pairwise comparison matrix (Expert 8)

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**
C1	1	2	2	3	3	2	2	1	2	1	2	2	1	2	3	4	3	3
C2	1/2	1	2	2	2	2	3	2	3	2	2	2	3	2	2	2	2	2
C3	1/2	1/2	1	3	3	3	4	3	3	3	2	2	2	3	3	4	3	2
C4	1/3	1/2	1/3	1	3	3	4	3	4	3	3	3	3	2	2	2	3	3
C5	1/3	1/2	1/3	1/3	1	4	6	5	4	4	5	4	5	5	6	6	6	6
C6	1/2	1/2	1/3	1/3	1/4	1	4	4	3	3	4	2	4	4	4	3	3	3
C7	1/2	1/3	1/4	1/4	1/6	1/4	1	5	4	5	5	5	4	4	5	4	4	4
C8	1	1/2	1/3	1/3	1/5	1/4	1/5	1	3	4	4	3	4	5	4	5	2	4
C9	1/2	1/3	1/3	1/4	1/4	1/3	1/4	1/3	1	4	4	4	3	3	2	2	2	2
C10	1	1/2	1/3	1/3	1/4	1/3	1/5	1/4	1/4	1	4	4	3	4	4	3	3	3
C11	1/2	1/2	1/2	1/3	1/5	1/4	1/5	1/4	1/4	1/4	1	5	5	4	6	4	5	4
C12	1/2	1/2	1/2	1/3	1/4	1/2	1/5	1/3	1/4	1/4	1/5	1	4	3	3	3	3	4
C13	1	1/3	1/2	1/3	1/5	1/4	1/4	1/4	1/3	1/3	1/5	1/4	1	4	4	4	3	3
C14	1/2	1/2	1/3	1/2	1/5	1/4	1/4	1/5	1/3	1/4	1/4	1/3	1/4	1	4	4	3	3
C15	1/3	1/2	1/3	1/2	1/6	1/4	1/5	1/4	1/2	1/4	1/6	1/3	1/4	1/4	1	4	5	3
C16	1/4	1/2	1/4	1/2	1/6	1/3	1/4	1/5	1/2	1/3	1/4	1/3	1/4	1/4	1/4	1	6	5
C17	1/3	1/2	1/3	1/3	1/6	1/3	1/4	1/2	1/2	1/3	1/5	1/3	1/3	1/3	1/5	1/6	1	3
C18	1/3	1/2	1/2	1/3	1/6	1/3	1/4	1/4	1/2	1/3	1/4	1/4	1/3	1/3	1/3	1/5	1/3	1

Table 9. Sample normalized matrix (Expert 8)

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**
C1	0.1008	0.1905	0.1905	0.2143	0.2050	0.1071	0.0755	0.0373	0.0658	0.0309	0.0533	0.0515	0.0230	0.0424	0.0558	0.0722	0.0523	0.0517
C2	0.0504	0.0952	0.1905	0.1429	0.1367	0.1071	0.1132	0.0746	0.0986	0.0619	0.0533	0.0515	0.0691	0.0424	0.0372	0.0361	0.0349	0.0345
C3	0.0504	0.0476	0.0952	0.2143	0.2050	0.1607	0.1509	0.1119	0.0986	0.0928	0.0533	0.0515	0.0461	0.0636	0.0558	0.0722	0.0523	0.0345
C4	0.0336	0.0476	0.0317	0.0714	0.2050	0.1607	0.1509	0.1119	0.1315	0.0928	0.0800	0.0773	0.0691	0.0424	0.0372	0.0361	0.0523	0.0517
C5	0.0336	0.0476	0.0317	0.0238	0.0683	0.2143	0.2264	0.1865	0.1315	0.1237	0.1333	0.1030	0.1152	0.1060	0.1116	0.1084	0.1047	0.1034
C6	0.0504	0.0476	0.0317	0.0238	0.0171	0.0536	0.1509	0.1492	0.0986	0.0928	0.1066	0.0515	0.0921	0.0848	0.0744	0.0542	0.0523	0.0517
C7	0.0504	0.0317	0.0238	0.0179	0.0114	0.0134	0.0377	0.1865	0.1315	0.1546	0.1333	0.1288	0.0921	0.0848	0.0930	0.0722	0.0698	0.0690
C8	0.1008	0.0476	0.0317	0.0238	0.0137	0.0134	0.0075	0.0373	0.0986	0.1237	0.1066	0.0773	0.0921	0.1060	0.0744	0.0903	0.0349	0.0690
C9	0.0504	0.0317	0.0317	0.0179	0.0171	0.0179	0.0094	0.0124	0.0329	0.1237	0.1066	0.1030	0.0691	0.0636	0.0372	0.0361	0.0349	0.0345
C10	0.1008	0.0476	0.0317	0.0238	0.0171	0.0179	0.0075	0.0093	0.0082	0.0309	0.1066	0.1030	0.0691	0.0848	0.0744	0.0542	0.0523	0.0517
C11	0.0504	0.0476	0.0476	0.0238	0.0137	0.0134	0.0075	0.0093	0.0082	0.0077	0.0267	0.1288	0.1152	0.0848	0.1116	0.0722	0.0872	0.0690
C12	0.0504	0.0476	0.0476	0.0238	0.0171	0.0268	0.0075	0.0124	0.0082	0.0077	0.0053	0.0258	0.0921	0.0636	0.0558	0.0542	0.0523	0.0690
C13	0.1008	0.0317	0.0476	0.0238	0.0137	0.0134	0.0094	0.0093	0.0110	0.0103	0.0053	0.0064	0.0230	0.0848	0.0744	0.0722	0.0523	0.0517
C14	0.0504	0.0476	0.0317	0.0357	0.0137	0.0134	0.0094	0.0075	0.0110	0.0077	0.0067	0.0086	0.0058	0.0212	0.0744	0.0722	0.0523	0.0517
C15	0.0336	0.0476	0.0317	0.0357	0.0114	0.0134	0.0075	0.0093	0.0164	0.0077	0.0044	0.0086	0.0058	0.0053	0.0186	0.0722	0.0872	0.0517
C16	0.0252	0.0476	0.0238	0.0357	0.0114	0.0179	0.0094	0.0075	0.0164	0.0103	0.0067	0.0086	0.0058	0.0053	0.0046	0.0181	0.1047	0.0862
C17	0.0336	0.0476	0.0317	0.0238	0.0114	0.0179	0.0094	0.0186	0.0164	0.0103	0.0053	0.0086	0.0077	0.0071	0.0037	0.0030	0.0174	0.0517
C18	0.0336	0.0476	0.0476	0.0238	0.0114	0.0179	0.0094	0.0093	0.0164	0.0103	0.0067	0.0064	0.0077	0.0071	0.0062	0.0036	0.0058	0.0172

Table 10. Adjacency matrix

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**	**IG**
C1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	**16**
C2	1	0	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	0	**12**
C3	1	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	**12**
C4	1	0	1	0	1	1	1	0	0	1	0	0	1	1	1	1	1	1	**12**
C5	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	**17**
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
C7	1	0	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	1	**13**
C8	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	**3**
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
C10	1	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	**14**
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
C12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
C13	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	**16**
C14	1	0	1	1	1	1	1	0	0	1	0	0	1	0	1	1	1	1	**12**
C15	1	0	1	1	1	1	1	0	0	1	0	0	1	1	0	1	1	0	**11**
C16	1	0	1	1	1	1	1	0	0	1	0	0	1	1	1	0	1	1	**12**
C17	1	0	1	1	1	1	1	1	0	1	0	0	1	1	1	1	0	1	**13**
C18	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	0	0	**4**
IR	**12**	**2**	**11**	**11**	**14**	**12**	**11**	**6**	**2**	**14**	**3**	**0**	**14**	**11**	**11**	**13**	**11**	**10**	

Table 11 categorizes challenges based on net influence (D-R values), distinguishing between challenges primarily causing (net cause) or being influenced by (net effect) others. To analyze the results, three challenges were categorized as net causes including C1, C2, and C13. This indicates that these three challenges significantly influence other challenges within the system and play a pivotal role in shaping the implementation process of the Cebu BRT System. The C1 has a D+R value of 11.5266, indicating a strong relationship with other challenges. This value suggests that changes or influences in the approval process during planning have a substantial direct impact on other challenges in the system, and vice versa. Additionally, C1 has a positive D-R value of 0.5018, which was categorized as a net cause, signifying its significant influence on other challenges within the system. The results of the D+R and D-R of C1 imply that given the importance of approval during planning for the Cebu BRT project, it represents a prerequisite for its continuation. Without the necessary approvals from relevant stakeholders and authorities, such as local government councils, regional development councils, and NEDA, the project cannot progress further which in turn causes other challenges to occur. Essentially, resolving issues related to C1 may positively affect the resolution of other challenges or mitigate their impact.

Table 11. Categorization of the challenges of BRT system implementation

Code	Challenge	D	R	D+R	D-R	Category
C1	**Approval during planning**	**6.0142**	**5.5124**	**11.5266**	**0.5018**	**net cause**
C2	**Communication barriers between consultants and contractors**	**5.111**	**4.6339**	**9.7449**	**0.4771**	**net cause**
C3	Complaints of the affected establishments	5.5922	5.73444	11.3266	-0.1423	net effect
C4	Complexity of Implementation	5.3865	5.5568	10.9433	-0.1703	net effect
C5	Coordination between different agencies	6.1129	6.114	12.2269	-0.0011	net effect
C6	Impact on PUJ Drivers	4.4024	5.5202	9.9226	-1.1178	net effect
C7	Lack of Identification of potential risks of the design before the implementation	5.6481	5.7905	11.4386	-0.1424	net effect
C8	Land Acquisitions	4.6295	5.1019	9.7314	-0.4724	net effect
C9	Managing and Dealing with Traffic Congestion	4.2869	4.6534	8.9403	-0.3665	net effect
C10	Managing Private Vehicle Growth	5.6675	6.0733	11.7408	-0.4058	net effect
C11	Manpower during Construction	3.838	4.6566	8.4946	-0.8186	net effect
C12	Overlapping of Project Funds	3.1976	4.1369	7.3345	-0.9393	net effect
C13	**Political will of the government officials**	**6.0428**	**5.9938**	**12.0366**	**0.049**	**net cause**
C14	Removal of Skywalk	5.3679	5.5305	10.8984	-0.1626	net effect
C15	Rerouting	5.2881	5.7501	11.0382	-0.462	net effect
C16	Road Safety and Security for Pedestrians	5.3236	6.0002	11.3238	-0.6766	net effect
C17	Road Widening	5.3706	5.6895	11.0601	-0.3189	net effect
C18	Verification in terms of design of the highways	4.7037	5.2951	9.9988	-0.5914	net effect

Similarly, the C2 has a D+R value of 9.7449, indicating its relationship with other challenges. This means that influence in the C2 can have a direct impact on other challenges in the system, and vice versa. Additionally, the C2 also has a positive D-R value of 0.4771 and was categorized as a net cause, indicating its significant influence on other challenges within the system. The results of the D+R and D-R of the C2 imply the need to communicate with the contractor and the consultant in both their respective native languages and in English since it adds layers of complexity to the communication process. The C2 can hinder effective information conveyance, leading to misunderstandings, delays in the decision-making process, and potentially causing other challenges to occur. Resolving issues related to C2 may positively mitigate the impact of the other challenges in the system.

The C13 exhibits a strong relationship with other challenges, with a D+R value of 12.0366, indicating a significant influence on the system. Categorized as a net cause, C13's positive D-R value of 0.049 signifies its substantial impact on other challenges. Political decisions and support are pivotal for project progression, impacting funding, permits, and overall momentum. Opposition or changing directives from officials can disrupt the project. Concerns voiced by councilors further highlight potential challenges stemming from political interactions, potentially delaying the progress of the CBRT project.

Addressing these root causes, such as C1, C2, and C13, should be prioritized, as they can potentially mitigate or prevent other challenges from occurring or escalating. By prioritizing the resolution of these net causes, organizations can create a more stable foundation for the implementation process. For instance, C1 and C13 are somewhat interrelated since city-wide projects always need the approval and agreement from the government. Without this initial step, the project itself will not be executed at all. C2 involves the people directly involved in the project. As such, this will ultimately hinder construction of the project and would cause further delays if miscommunications take place. Additionally, by mitigating these root causes effectively, there may be fewer ripple effects throughout the system, resulting in a more streamlined and efficient implementation process. However, addressing challenges should not only just be done on challenges classified as root causes since unaddressed challenges could still cascade into larger problems, making the BRT project even more delayed due to its complexity.

On the other hand, fifteen challenges were categorized as having net effects. These challenges have negative D-R values, indicating that they are significantly influenced by various factors within the system. These challenges are often the effects or consequences of other root causes within the system. Addressing these net effect challenges may require more comprehensive solutions that target the root causes or interdependencies with other challenges (Figure 1).

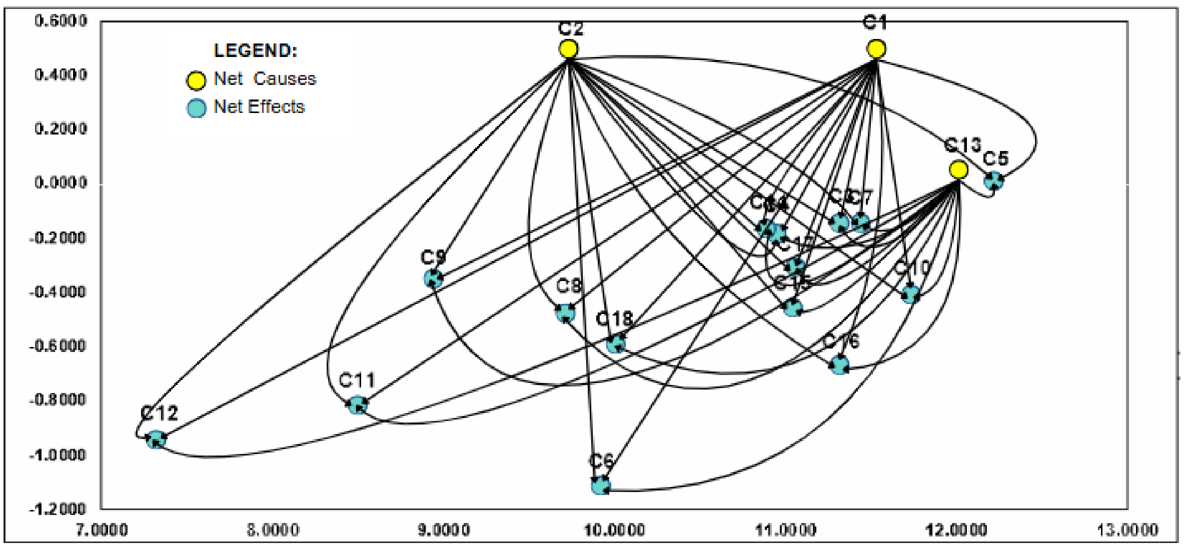

Figure 1. Impact relationship map

Displayed in Fig. 1 is the DEMATEL impact relationship map, depicting causal connections between factors in the system. Yellow dots represent net cause factors (C1, C2, and C13) while blue dots represent net effect factors (C3-12 and C14-C18). Arrows indicate connections, with direction and thickness denoting strength and direction of influence. The significance of each factor is interpreted through the horizontal vector (D+R), which not only reflects its direct impact on the entire system but also considers how other system factors influence it. In this analysis, C5 is the most crucial factor due to its high D+R value of 12.2269, indicating a significant influence on the system. As a net effect factor, C5 is central in system dynamics, ranking highest in importance, followed closely by C3, C1, C4, and C12, highlighting their critical roles in forming the system's relationships. On the vertical axis, the D-R vector shows the degree of a factor's influence on the system.

Upon analyzing the data, it becomes evident that factors C1, C2, and C13 serve as net cause factors, applying significant positive influence to other factors in the system. Among these, C13 emerges with the highest D+R value, highlighting its crucial role in influencing the interactions among factors. Conversely, factors C3-C12 and C14-C18 are identified as net effect factors, and negative D-R values mean that these elements are prone to external factors. Even though they have lower D+R values, factors like C6, C11, and C12 still have notable negative D-R values, showing their significant impact on the system. This analysis reveals that various factors in the system interact in a complex way. Some factors have a direct impact, while others are more influenced by external factors.

For the AHP results, out of all the experts, only Expert 3's response was considered as it passed the consistency ratio even after reconducting the AHP process. The AHP ranking results are presented in Table 8. It provides the factors significant to the implementation of the BRT system in Cebu City, along with their respective AHP weights and ranks. The AHP weights signify the relative importance of each factor; with higher weights indicating greater significance. Additionally, the table ranks these factors based on their AHP weights, providing a clear prioritization of factors for BRT implementation challenges.

Table 12. AHP weight and ranking of the challenges

Code	Challenge	AHP weight	Rank
C1	Approval during planning	10.51%	1
C2	Communication between the consultants and contractors	6.52%	7
C3	Complaints of the affected establishments	8.62%	3
C4	Complexity of implementation	8.67%	2
C5	Coordination between different agencies	8.54%	4
C6	Impact on PUJ drivers	7.14%	5
C7	Lack of identification of potential risks of the design before the implementation	4.84%	8
C8	Land acquisitions	3.78%	14
C9	Managing and dealing with traffic congestion	7.05%	6
C10	Managing private vehicle growth	3.60%	16
C11	Manpower during construction	3.34%	17
C12	Overlapping of project funds	4.01%	12
C13	Political will of the government officials	4.17%	11
C14	Removal of skywalk	3.98%	13
C15	Rerouting	4.20%	10
C16	Road safety and security for pedestrians	3.61%	15
C17	Road widening	3.10%	18
C18	Verification in terms of design of the highways	4.31%	9

In Table 12, the highest-ranked factor, with an AHP weight of 10.51%, is C1, indicating its critical importance in the successful implementation of the BRT project. This suggests that obtaining approval from relevant authorities during the planning phase must be prioritized for project success. Approval during planning encompasses various crucial steps, including initial feasibility studies, detailed engineering and design plans, surveys, stakeholder presentations, and approval by local government councils and regional development councils. Final approval by NEDA is also pivotal. Any changes in alignment during this phase result in increased costs and necessitate resubmission to NEDA for budget approval. As such, the comprehensive nature of approval during planning underscores its significance as the primary challenge that must be prioritized.

Similarly, factors like C4 rank second, C3 rank third, and C5 rank fourth, which are closely followed, highlighting their significant roles in the implementation process. The complexity arises from the need for multiple compliance permits, resulting in administrative delays and hindrances to project execution. This complexity is exemplified by the requirement for environmental permits for tasks such as the removal of structures like skywalks, traffic medians, and trees. Additionally, exploring regulatory procedures and meeting environmental criteria intensifies difficulty, posing significant obstacles to the project's immediate progress. Complaints from affected establishments highlight concerns about disruptions and delays in land acquisition distribution, likely stemming from the need to widen roads for the Cebu BRT project. Despite the Cebu City Hall Land Acquisition and Planning's allocation of funds for affected establishments, delays in document processing for allocation distribution have caused establishments to frequently inquire about payment distribution timelines. Additionally, the initiation of package 2 adds another layer of complexity, as land acquisition and planning from the Cebu City Hall are currently in the process of determining which establishments will be affected by the BRT project package 2. Given the significant impact on local businesses and the urgency to maintain project momentum, addressing these challenges promptly ranks as a third priority.

Furthermore, factors such as C10 and C11 have lower priority in the project's implementation. C10 is challenging as it is beyond the control of the agencies involved, who primarily focus on regulating public transportation services and implementing traffic rules. C11 is also of lower priority, as it is managed by contractors and consulting agencies. In addition, the consulting company has observed that its personnel do not consistently follow safety measures, such as wearing safety gear during work hours. This lack of adherence to safety protocols can pose a challenge, particularly during excavation work where the risks are high, requiring focused attention on safety at all times.

Overall, this AHP-weighted ranking offers a structured framework for prioritizing efforts and resources, enabling project stakeholders to focus on addressing the most critical challenges first. By comprehending the relative importance of each factor, decision-makers can allocate resources efficiently and devise strategies to mitigate potential risks, enhancing the likelihood of BRT project success. Additionally, understanding the nuances of factors like miscommunication and private vehicle growth will contribute to a more holistic and effective project management approach, enhancing the project's overall chances of success.

By integrating all the results from the DEMATEL net causes analysis and the AHP weight prioritization ranking, proposed mitigating measures are formulated based on the results of the DEMATEL-AHP analysis. Whereas, based on the DEMATEL results, C1, C2, and C13 are categorized as net causes. Mitigating measures are proposed to eliminate or minimize these net causes of problems to prevent their recurrence and their net effects. Moreover, the AHP results identify C1, C4, and C5 as high-priority areas. These factors should receive immediate attention to mitigate risks and ensure the success of the project. A total of five challenges were provided with mitigating measures to address the identified issues comprehensively based on the DEMATEL-AHP results.

5. Policy insights

Based on the results of the study, several mitigating measures can be recommended to the local government of the case study location regarding the implementation of the BRT system. The study utilized DEMATEL and AHP analyses to identify key challenges and prioritize mitigation strategies. The majority of the challenges that need prioritizing are related to communication. In general, communication barriers should be eradicated to ensure a successful implementation of the BRT system in the case study location. Using the results, the first challenge identified to be addressed is C1, highlighted as a crucial factor influencing other challenges. To address this, the stakeholders should hold regular meetings, establish effective communication methods to express stakeholders’ concerns, and a thorough approval process to ensure project progression. Another significant challenge is C11, which is on the communication barriers between interracial and stakeholders. It will be necessary to develop cross-cultural communication strategies such as translators, universal engineering language adaption, and visual aids to enhance understanding. Additionally, C13 is also recognized as pivotal, requiring proactive engagement, ongoing monitoring, and decisive action to navigate challenges and ensure project continuity. Moreover, the C3 poses a significant challenge that requires attention to environmental permitting, heritage assessment, and legal negotiations to streamline processes and expedite approvals. Furthermore, C2 requires the need for transparent communication, stakeholder engagement, and alternative measures to address grievances and mitigate negative impacts effectively. These mitigating measures provide a comprehensive approach for the successful implementation of the Cebu BRT System, emphasizing the importance of proactive management, stakeholder collaboration, and adaptive strategies to overcome challenges and achieve project objectives.

6. Conclusion

The study successfully applied DEMATEL in classifying which challenges could significantly affect others and AHP in prioritizing which challenges should be addressed first. Experts were gathered from different government sectors and industry sectors directly involved in the BRT system implementation. It has been identified that *approval during planning* (C1), *communication barriers between consultants and contractors* (C2), and *political will of the government officials* (C13) are categorized as the net causes of the other challenges. Challenges such as *complaints of the affected establishments* (C3), *complexity of implementation* (C4), *coordination between agencies* (C5), and *impact on PUJ drivers* (C6) should be prioritized along with the previously mentioned challenges. The results of the study can be a basis to address the interrelated challenges and help the stakeholders in mitigating them. Policies can be drafted from the results to set as guidelines to guarantee successful BRT system implementation. This study can be improved by enhancing the implementation of AHP, as only one expert response has passed the consistency ratio. Other methodologies to address the challenges can also be proposed.

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