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Sustainable Strategies for the Successful Operation of the Bike-Sharing System Using an Ordinal Priority Approach

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Abstract: Over 700 bike-sharing systems are currently in operation worldwide, and the number of systems has grown quickly in recent years. Rwanda's bike-sharing system has only recently begun operations and has encountered numerous challenges. The current study used an Ordinal Priority Approach (OPA) to examine these challenges and provide an acceptable strategy for overcoming them. Five strategies have been established. These strategies are prioritized using four criteria. The results indicate that "theft" and "damage of some bikes when being returned" are the most critical challenges while the first alternative "improving the current bike infrastructure to better serve the bike share system" is the appropriate strategy to overcome these challenges for a successful operation of the bike share system. Taking into account the findings, recommendations were provided to help local administrative bodies handle these challenges.

Keywords: Strategy; Bike-sharing system; Operation; Ordinal priority approach; Rwanda

1. Introduction

Bike-sharing systems have been adopted globally in recent years as a result of local authorities' efforts to encourage environmentally friendly transportation modes and improvements in information systems [1]. Bike-sharing systems are designed to give people greater satisfaction and flexibility in using bicycles while removing the expense and responsibility connected with bicycle ownership [2]. Shared bikes are particularly well suited for small distance or one-way journeys because they are utilized on an "as-needed" premise and people can decide to take a trip in a short amount of time [3]. Additionally, by encouraging the utilization of bicycles for frequent commutes and leisure travel, bike-sharing systems help cut down on emissions and fuel consumption, alleviate traffic congestion, and help people meet their prescribed exercise goals by incorporating physical work into daily existence [4].

Many cities have recognized the advantages of cycling and have encouraged bike-sharing systems [5]. The primary idea behind these systems is to provide inexpensive or free accessibility to bicycles for shorter journeys in cities as an alternative to automobile transportation. Such arrangements relieve the user of the responsibility of purchasing and maintaining a bicycle. Bike-sharing systems become a component of the public transportation system in the city by offering convenient sites from which the bikes may be taken up and left, which is advantageous to many individuals [6].

Whilst bike-sharing initiatives have been introduced across several European cities since the early 1960s, Rwanda is the first African nation to do so because it has steadily positioned itself to embrace technological advancements. When dock stations are built adjacent to bus crossings and provide a ground-breaking last-mile solution, bike-share systems can easily connect with other means of transportation, according to the documentation from the Netherlands, Copenhagen City Bikes, and Rennes Vélo a la Carte Bikeshare.

The largest disadvantage, though, is theft and vandalism. In the past few years, the excesses of this tendency have resulted in the demise of bike-sharing systems in new markets. Because of frequent reports of stolen and/or damaged bikes, MO Bike ceased operations in Manchester and removed approximately 2000 bikes in September 2018. The bikes were either broken, spray-painted, or thrown into canals. Texas Monthly published a story on how five bike-share firms turned Dallas into "the bike-share capital of America" with more than 18000 bikes, but then lost almost all of them in a single night. Rwanda is not excluded from this situation, although it is extremely difficult to figure out the exact rate of theft and vandalism occurring due to the absence of reliable statistics. This study covers the bike-sharing systems and the major challenges related to them using Kigali city in Rwanda as an example.

Richard [7] demonstrated through a report how Kigali has worked with a public transportation enterprise to offer Rwandans comfortable, efficient, cost-effective, and ecologically friendly micro-mobility solutions. Nardini [8] discusses the benefits of African community bike-sharing systems. He claims that, while the system is intended to make public transportation more accessible, bike-share systems in developing areas have significant challenges. According to Sabiiti [9], bike-sharing systems could be a feasible option for the existing problems users encounter in Kigali city. Diana et al. [10] demonstrated why Rwanda invests in cycling, which contributes to cleaner air and more jobs.

The bike-sharing systems in Africa are one of the topics covered in the literature [7-9]. But up till now, no previous research examined the challenges to their systems and remedial strategies for overcoming them. There are numerous strategies available, and the operators of the bike-share systems need to choose the suitable one. Recommending a strategy for the successful operation of the bike-share systems based on specific criteria can lead to poor decisions. As a result, various criteria should be considered, and an appropriate multi-decision-making tool should be used [11, 12]. When determining which strategy is the most appropriate, multi-decision-making approaches can be quite helpful [13, 14].

Multi-decision-making techniques are used in a variety of fields and are critical in determining the best option from several choices [15, 16]. These decision-making models are carried out utilizing proper mathematical methodologies. Multi-decision-making approaches are helpful means for assisting policymakers who are involved in the evaluation process. Based on the OPA approach, this study presents a methodology to examine the critical challenges to the operation of the bike-sharing system in Kigali (Rwanda) as well as the appropriate strategy to overcome them.

After the introduction, literature is first provided. Next, the OPA methodology is presented. Then, the application of the methodology is explained. After that, the results are discussed. Finally, the conclusion is given including future directions and limitations.

2. Literature

Two sub-sections sections have been presented below.

2.1 Research Related to the OPA Technique

After the introduction of the Ordinal Priority Approach by Ataei et al. [17], it has been used in several areas such as the choice of supplier in megaprojects [18], healthcare supplier [19], metaverse evaluation for sustainable transport [20], supplier of automobile portions [21], sustainable construction sector [22], multi-phase supplier assessment [23], road safety [24], software application [25], transport planning [26], blockchain technology [27], sustainable mining [28], road maintenance [29], autonomous bus operation [30], personal mobility assessment [31], and robot choice [32].

Table 1. Application of MCDM on bike-sharing systems

Authors	Region	Methodology	Subject
Eren and Turkey [33]	Turkey	FL, AHP, VIKOR	Bike-sharing station site choice
Liang et al. [34]	China	BWM, VIKOR	Bike-sharing enterprise service level
Bahadori et al. [35]	Portugal	AHP, TOPSIS	Station locations of the bike-sharing system
Cheng and Wei [36]	China	DEA, AHP	Bike-sharing spot choice issue
Liu et al. [37]	China	DEMATEL, ANP	Bike-sharing operation enhancement
Kavta and Goswami [38]	India	DEMATEL, ANP, VIKOR	Travel demand management choice
Lee et al. [39]	Republic of Korea	MOORA	Position optimization of the bicycle-sharing scheme
He et al. [40]	China	TOPSIS	Bike-sharing rebalancing development
Hsu et al. [41]	Taiwan	DEMATEL, ANP, VIKOR	Service quality assessment of bike-sharing
Tian et al. [42]	China	BWM, MULTIMOORA	Bike-sharing performance assessment
Kabak et al. [43]	Turkey	AHP, MOORA	Bike-sharing stations assessment

2.2 MCDM on Bike-Sharing Systems Assessment

A wide range of studies has been conducted in the context of evaluating bus-sharing systems. Table 1 shows numerous applications of MCDM techniques used in this topic.

3. Ordinal Priority Approach Methodology

In this study, the strategies are prioritized to find out the appropriate one after assessment of criteria and the expert's significance to overcome the challenges to the bike-sharing system in Kigali City, Rwanda. Following the subsequent research of Ataei et al. [17], three steps have been applied as bellows.

Step 1: Evaluating the impediments parameters to the bike-sharing system.

Step 2: Determination of the ordinal desire of impediment parameters.

Step 3: Establishment of the linear model (1) based on collection data through steps 1 and 2, and analysis of the model through a suitable Excel sheet.

$$
\begin{array}{ll}
\text{Max } Z & \\
\text{S.t.} & \\
Z \leq i\left(j\left(k\left(W_{ijk}{}^{k} - W_{ijk}{}^{k+1}\right)\right)\right) & \forall\, i, j \text{ and } k \\
Z \leq \; ijmW_{ijk}{}^{m} & \forall\, i, j \text{ and } k \\
\sum_{i=1}^{p}\sum_{j=1}^{n}\sum_{k=1}^{m} W_{ijk} = 1 & \\
W_{ijk} \geq 0 & \forall\, i, j \text{ and } k \\
\text{with Z- unconditional in indication} &
\end{array} \tag{1}
$$

After analyzing the model, the significance of alternatives, criteria, and experts is determined through Eqns. (2) to (4), respectively.

$$W_k = \sum_{i=1}^{p}\sum_{j=1}^{n} W_{ijk} \qquad \forall\, k \tag{2}$$

$$W_j = \sum_{i=1}^{p}\sum_{k=1}^{m} W_{ijk} \qquad \forall\, j \tag{3}$$

$$W_i = \sum_{j=1}^{n}\sum_{k=1}^{m} W_{ijk} \qquad \forall\, i \tag{4}$$

The methodology applied in this study employs simple steps for the determination of requisite weights in absence of assistance from other techniques.

4. Application Method

The data was gathered from distinct experts using the hierarchical framework shown in Figure 1. Five strategies were proposed for allowing a successful operation of the bike-sharing system. These strategies were selected depending on their influence on resolving the system's primary challenges.

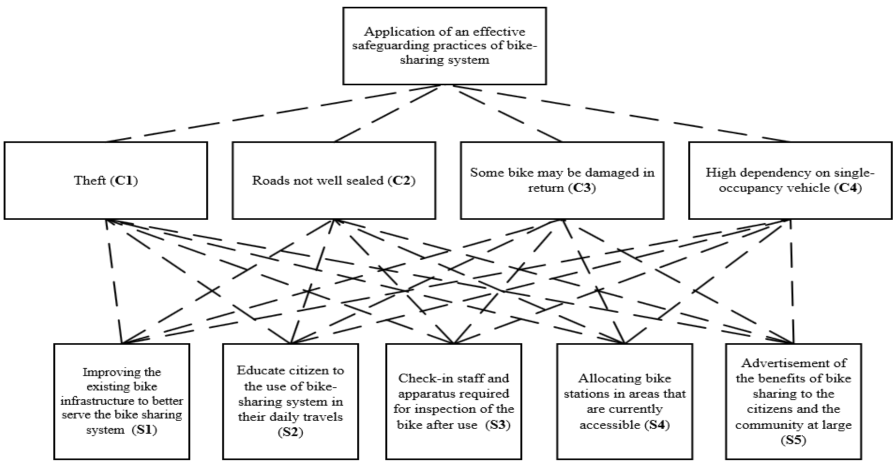

Figure 1. Implementation of an effective bike-sharing system safeguarding procedures

Three experts who are all employed by the public bike-share (PBS) transportation system company took part in the survey. They each work for the company for more than five years. Expert decisions were based on four criteria namely theft (C1), roads not well sealed (C2), some bikes may be damaged in return (C3), and high dependency on the single-occupancy vehicle (C4). Criteria have been ranked according to their severity. The first position is offered to the factor that poses the greatest challenge to the bike-sharing system. Experts 1 and 2 have classified the criteria as follows: C1 > C3 > C2 > C4, while the ranking of expert 3 is C3 > C1 > C4 > C2. Expert 1 has given C1 the first position. According to him, C1 is the most challenging element of the bike-sharing system. Meanwhile, C4 is the last position for expert 1, explaining why C4 is the least challenging element for the bike-sharing system. The OPA is used to prioritize strategies. The benefit of using the model is that it prevents data normalization. Tables 2 and 3 summarize the data gathered.

Table 2. Ranking of criteria

	C1	C2	C3	C4
E-1	1	3	2	4
E-2	1	3	2	4
E-3	2	4	1	3

Table 3. Ranking of strategies

		S1	S2	S3	S4	S5
E-1	C1	2	3	1	4	5
	C3	1	2	5	4	3
	C2	1	3	5	4	2
	C4	2	1	5	4	3
E-2	C1	1	4	3	2	5
	C3	2	5	1	3	4
	C2	1	5	2	3	4
	C4	4	3	5	2	1
E-3	C1	1	4	2	3	5
	C3	1	2	3	4	5
	C2	3	2	1	4	5
	C4	4	2	5	3	1

Note: "E" means an expert

5. Results and Discussion

Table 4. Weights and ranking of components of the OPA

		Weight	Ranking
Experts	E-1	0.55	1
	E-2	0.27	2
	E-3	0.18	3
Criteria	C1	0.44	1
	C2	0.15	3
	C3	0.28	2
	C4	0.13	4

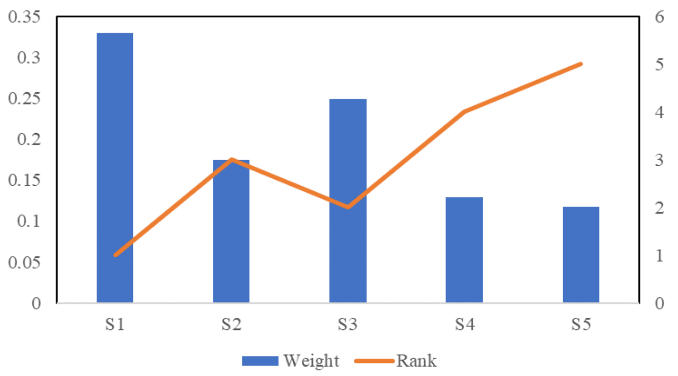

Figure 2. Strategies for the successful operation of bike-sharing systems

In this section, the model's three components—experts, criteria (challenges), and alternatives (strategies)—were each given a weight using Eqns. (2)-(4). They were then ranked in decreasing order, with a lower weight denoting a lower rank. Table 4 displays the expert and criteria weights and rankings.

As indicated in Table 4, the theft factor (C1) has occupied the first position with a weight of 0.44. This result confirms those analyses of Midgley [44] and Fishman and Schepers [45] which indicate that theft is among one the most frequent problems of bike-sharing systems. The least significant criterion remains the fourth criterion C4 (high dependency on the single-occupancy vehicle). When considering the alternatives (strategies), “S1-improving the existing bike infrastructure to better serve the bike share system” is the most appropriate strategy followed by “S3- check-in staff and apparatus required for inspection of the bike after use” (See Figure 2).

6. Conclusion

An effective strategy framework is proposed for the successful operation of the bike-sharing system based on the challenges to the bike-sharing system. Based on the literature review, four criteria are evaluated- theft, roads not well sealed, some bikes may be damaged in return, and high dependency on the single-occupancy vehicle. The survey incorporates the perspectives of three professionals. The theft criterion is found to be the most challenging problem for the bike-sharing system, followed by the damage to certain bikes when being returned while the least complicated issue is the reliance on single-occupancy vehicles. The most appropriate strategy is to improve the current bike infrastructure to better serve the bike share system.

Given the detrimental effects of these issues on bike-sharing systems, it is initially recommended that local administrative organizations, particularly the City of Kigali, create more bike lanes to alleviate concerns about inadequate cycling infrastructure. Furthermore, to ensure the security of bike stations and bikes/scooters, these local administrative organizations should ensure that stations/bikes are outfitted with tracking systems such as GPS to avoid theft. This research is important because it will be helpful to the government of Rwanda in developing regulations and laws that could enhance Rwanda's means of transportation.

This study is new in the Kigali city context, involving the application of decision-making tools to examine the critical factor impeding the successful operation of the bike-sharing system and figure out how to overcome them. The implemented technique demonstrated not only how decisions were made without a decision-making matrix, but also the experts' capacity to selectively evaluate components for which they have sufficient knowledge and experience. According to the application outcomes, the applied technique can be described as an appropriate evaluation process that regulators and administrators may utilize to draw important judgments in the bike-sharing systems. As a result, the method described here can be applied in a variety of circumstances.

The method's main weakness is that it doesn't take into account circumstances where experts are unsure about their decisions. This study can be expanded by including more requirements on the mathematical modeling during the optimization of multi-criteria due to some very dynamic natural circumstances and the procedural necessity of unclear and misinformation. Another weakness in this study is the evidence that just four criteria and the views of three experts were accounted for. Future studies may use additional criteria subdivided into categories based on social, economic, and environmental factors for an in-depth examination. Additionally, there should be a wider variety of professional backgrounds. Furthermore, a national study that looks at more than merely Kigali City is necessary.

Data Availability

The data supporting our research results are included within the article.

Acknowledgment

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Conflicts of Interest

There are no conflicts of interest related to this work publication.

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