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Evaluating Mobile Telecom Apps: An Integrated Fuzzy MCDM Model Using Marketing Mix

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Abstract: App-based marketing has been widely used in the telecommunications industry to both serve and draw in new customers. Typically, telecom providers must invest an amount of company resources to develop and maintain the operations mechanism of information technology platforms (e.g., mobile apps); therefore, it is important to take the issue of marketing effectiveness into account. For example, the mismatch between what telecom providers offer in their mobile apps and customers' marketing requirements plays a significant role in determining unmet knowledge and presentation gaps that are related to the marketing domain. This research intends to propose an integrated Fuzzy MCDM model based on 4Ps (Product, Price, Place, Promotion) and 4Cs (Customer Needs, Cost, Convenience, Communication) models for evaluating mobile telecom applications (MTAs). Therefore, the 4Ps and 4Cs models are extended to develop a hierarchy model for evaluating MTAs. Next, fuzzy theory is applied to handle the subjectiveness of qualitative evaluation criteria while the Analytic Hierarchy Process (AHP) is applied to synthesize the weight and score of the evaluation criteria. The proposed model is applied to evaluate, rank, and analyze the MTA of three telecom providers in the Kingdom of Saudi Arabia (KSA) (e.g., STC, Zain, and Mobily). The conducted case study ensures the usability and applicability of the proposed model. The evaluation results offer several managerial actions for achieving ideal app-based marketing.

Keywords: mobile app; MCDM; marketing mix; telecommunication

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1. Introduction

The modern digital world is supported by the telecommunications industry, which is making connections and information flow more easily. The telecommunications sector is a broad business that includes various technologies and services including traditional landline, mobile phone services, internet service providers (ISPs), cable and satellite TV providers, and app-based communication platforms. A highly effective strategy for increasing business value and attracting more customers is to simplify user engagement processes such as paying bills, managing accounts, accessing customer support, and customizing their services through mobile apps.

The proliferation of the internet, smartphones, and mobile apps has given telecom providers the chance to market their products and services effectively. For example, telecom providers can use mobile apps to provide their customers with exclusive deals and discounts. This helps stimulate customer acquisition and retention by providing value-added incentives. In addition, the use of mobile applications allows telecom providers to deal with their customers directly without the need for intermediaries. Such a benefit will contribute positively to generating additional revenue by bypassing any additional

commissions for commercial traders. Moreover, the use of app-based marketing allows telecom providers to collect data regarding user behavior, preferences, and usage patterns that can be analyzed to gain insights into customer trends, improve their services, and customize marketing campaigns.

Saudi Arabia has made significant strides in technology, especially in the fields of telecommunications. The mobile telecommunications sector has seen rapid growth in the Kingdom, with major telecom providers like STC, Zain, and Mobily playing pivotal roles in delivering mobile services. The smartphone penetration rate in the Kingdom of Saudi Arabia (KSA) is among the highest in the region, making mobile apps a key focus for telecom providers looking to engage with customers [1,2]. In the market, numerous telecom providers employ specialized mobile apps to reach potential customers, promote their services, and complement their business activities. However, to increase customer satisfaction and to ensure future business continuity, telecom providers need to measure how successful their mobile app is [3–5]. This is significant for identifying the gaps between what they are offering and what their customers need [3]. It is also important to identify which features of their apps need further improvements. This raises the challenge of how telecom providers can effectively evaluate the features of their mobile apps. The evaluation of mobile apps is not limited to one aspect but, rather, depends on several criteria that must be taken into consideration. This problem can be described as a multiple-criteria decision-making (MCDM) problem. However, the absence of a standard evaluation model makes the evaluation process more daunting and ambiguous. In addition, the current evaluation methods lack providing guidelines for telecom providers to identify the gaps and features of their mobile app that need further improvements from the perspective of multiple marketing mix models, such as 4Ps (Product, Price, Place, Promotion) and 4Cs (Customer Needs, Cost, Convenience, Communication). These challenges underline the motivation for developing an evaluation model that addresses these gaps and improves decision-making for app-based marketing strategies. Using the 4Ps and 4Cs marketing models to evaluate Mobile Telecom Apps (MTAs) is essential for both identifying areas that require further improvements and for improving the value proposition. Generally, the value proposition is essential for identifying and providing distinctive, user-focused features that set a product apart from its rivals [6]. A solid value proposition addresses customers' requirements and expectations and conveys the main advantages they will receive, giving them a strong incentive to select the product [7]. In the telecommunications industry, MTAs are crucial to providing better consumer experiences in the telecom sector, including streamlined service management, tailored promotions, and easier access to customer service. A well-articulated value proposition fosters customer engagement, drives app adoption, and strengthens loyalty by aligning the app's features with the convenience, cost-effectiveness, and problem-solving capabilities desired by users. Such an evaluation model will assist providers in finding new ways to attract customers, and to develop marketing strategies and differential pricing strategies, all while enhancing the customer experience [8,9].

Therefore, the primary objective of this study is to develop an effective Mobile Telecom App (MTA) evaluation model based on MCDM. The model extends the traditional marketing mix frameworks, combining the 4Ps and 4Cs to provide a comprehensive hierarchy for assessing MTAs. The proposed model seeks to pinpoint and rank the gaps that need further improvements within these MTAs from the perspective of 4Ps and 4Cs marketing mix models. To do so, an integrated evaluation model that combines fuzzy set theory and the Analytic Hierarchy Process (AHP) is proposed. A fuzzy set is applied to address the inherent vagueness and incomplete knowledge surrounding evaluation criteria. The fuzzy set provides a powerful tool called linguistic variables that can be used to handle vagueness inherently existing in the decision-making problem. Next, AHP is recognized as

a superior MCDM method that represents evaluation criteria in the hierarchy model. AHP is used to systematically determine the relative weights of evaluation criteria. Thus, the originality of this study lies in the novel integration of fuzzy MCDM techniques with the marketing mix models to evaluate mobile telecom applications. Unlike previous studies that focus on general performance metrics, this research specifically targets marketing-related criteria. The case study conducted on three leading telecom providers in Saudi Arabia (STC, Zain, and Mobily) demonstrates the practical application and managerial implications of the proposed framework, offering actionable insights for enhancing app-based marketing strategies.

The main contributions of this research study are outlined below:

1. This study aims to extend the 4Ps and 4Cs marketing mix models by presenting a hierarchical evaluation model designed especially for evaluating mobile applications that are provided by telecom companies.
2. The study proposes an integrated MCDM model that combines fuzzy set theory and Analytic Hierarchy Process (AHP) that aims to achieve the following:
    a. Evaluate and rank several alternatives of MTAs.
    b. Assess and rank the areas where MTAs need to be improved.
    c. Suggest a number of strategic recommendations aimed at enhancing MTAs' competitiveness and customer satisfaction.

The six sections of the paper are arranged as follows: Section 2 explores previous research that has utilized MCDM techniques to assess and evaluate mobile applications as well as presents the main concepts of the 4Ps and 4Cs marketing models covered. The integrated MCDM model is presented in Section 3 and is used in Section 4 to assess the MTA provided by three Saudi Arabian telecom companies (e.g., STC, Zain, and Mobily). Section 5 then provides an analysis and discussion of the results. Section 6 suggests directions for future investigation. Section 7 presents the conclusion and limitations.

2. Literature Review

This section provides sufficient background for understanding the research context and its foundation. It is divided into two key sections, where the first section aims to explores previous research that has utilized MCDM techniques to assess and evaluate mobile applications, while the second section focuses on the foundational concepts of the marketing mix models, including the traditional 4Ps and the customer-centric 4Cs.

2.1. Mobile Application Evaluation

In [10], de Andrade et al. introduced a hybrid MCDM approach to evaluate the impact of social welfare and COVID-19 stringency on the perceived utility of food apps. TOPSIS, CO-PRAS, and VIKOR are the three MCDM techniques used to synthesize the evaluation results. The results show that success in COVID-19 control and the perceived utility of food apps positively affect the proportion of unhealthy reviews, whereas social welfare has a negative impact. These findings suggest that since people stay at home more in countries with high COVID-19 control, they consume more unhealthy food through apps.

Albert et al. (2016) [11] developed an evaluation model to evaluate how smartphone apps may contribute to road safety. Risky driving behavior, general acceptance, individual willingness, public support, and potential functionality are the main evaluation criteria used to evaluate the alternatives. Thirty-seven experts participated in the study to evaluate and grade nine types of apps according to evaluation criteria. To aggregate the result, AHP was applied. The study concludes that smartphone apps can be used to serve as a means to control and reduce risky driving behavior. Also, the overall evaluation of apps provided

by the 37 experts suggests that the desired apps for reducing injury crashes are collision warning and texting prevention.

Rajak and Shaw (2019) [12] implemented a model for the evaluation and selection of mobile health apps. An integrated model that consists of AHP and Fuzzy TOPSIS is used to synthesize the evaluation weights and scores and then rank the alternatives. The validation results reveal that the proposed evaluation model can help customers as well as medical practitioners to select the proper mHealth application in this digital world.

In [13], Ibrahim et al. proposed an evaluation model to assess young learners' English mobile apps. In this regard, six E-apps were evaluated by distributing a checklist form among six English learning experts. Listening, speaking, reading, and writing are the main global evaluation criteria. TOBSIS evaluation and ranking technique is used to aggregate the evaluation weight and score and then rank the proposed alternative.

Aggarwal et al. (2019) [14] introduced a hybrid multi-criteria decision-making approach that combined the ELimination and Choice Expressing REality (ELECTRE-TRI) method and step-wise weight assessment ratio analysis (SWARA). The proposed model is used to assess the quality of mobile gaming apps. Several evaluation criteria were proposed specifically to evaluate the quality of mobile gaming apps. The empirical validation ensures the applicability and usefulness of the proposed MCDM model.

Roy and Shaw (2023) [15] developed a fuzzy MCDM decision-making model for m-banking evaluations. The model was used to evaluate and select appropriate m-banking applications among several applications according to the customer's preferences. An expert empirical study was conducted to identify and select evaluation criteria for m-banking. The weight of evaluation criteria was calculated using the fuzzy best–worst method. Next, Fuzzy TOPSIS was implemented to evaluate the alternatives of m-banking applications. The proposed model was validated by conducting a case study. The study concludes that performance quality is the most important criterion in the selection of m-banking apps, followed by functionality and clarity.

Gupta et al. (2022) [16] presented two hybrid MCDM models to evaluate the usability of the five most familiar mHealth apps that focus on type 2 diabetes mellitus. These models are called the Combinative Distance-based Assessment–Fuzzy Analytic Hierarchy Process (CODAS-FAHP) and Multi-Objective Optimization based on Ratio Analysis (MOORA)–Fuzzy Analytic Hierarchy Process. Both the CODAS and MOORA methods are used for determining the different ranks associated with alternatives, while FAHP is used to determine the weight of the evaluation criteria. Ten evaluation criteria that are divided into 29 sub-criteria are used to evaluate the proposed alternatives. Next, the conducted case study is used to measure the stability and validity and to produce a sensitivity analysis of the proposed hybrid evaluation model. The analysis results ensured the applicability and usefulness of the hybrid MCDM model.

Liu et al. (2019) [17] proposed a hybrid evaluation model that is used for improving sustainable mobile healthcare promotion. The MCDM model comprises a decision-making trial and evaluation laboratory (DEMETEL)-based analytic network process (DANP) and a modified VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method. DEMETEL is used to determine the relationship among the evaluation criteria, while ANP is used to calculate the weight of the evaluation criteria. Finally, Modified VIKOR is used to identify the compromised solution of alternatives. The analysis result revealed that social norms, product image, and consumer trust are three key criteria in consumer adoption.

The results of the reviewed papers ensure the applicability of using MCDM techniques to evaluate mobile apps. They prove their effectiveness in providing beneficial feedback and recommendations that can support the decision-making process. Therefore, this study intends to use the fuzzy AHP method to synthesize the weights and scores of the marketing

mix criteria of 4Ps and 4Cs models by using the pairwise comparison matrix. Then, several visualization charts will be developed to map the evaluation results in order to identify gaps within the MTA.

2.2. Marketing Models

In marketing, the 4Ps and 4Cs models are used to understand and handle many facets of customer behavior and marketing strategy. These models present several viewpoints about the marketing mix, which is defined as the controllable elements that affect customer decisions. These models provide marketers with a multitude of views to take into account while formulating and executing their strategy in a constantly shifting market environment. For example, the 4Ps model serves as the cornerstone for any marketing plan and strategy, helping marketers to start with a strong product offering, while the 4Cs allow marketers to understand target customer needs. Hence, these models contribute to building strong customer relationships through effective communication. In the context of telecommunication, these models can contribute significantly to improving MTAs. This can be achieved by using a customer-centric approach to direct the development and marketing initiatives. Hence, the development of MTAs will not only satisfy the functional requirements but also deliver a positive experience that promotes loyalty and advocacy.

A key element of both the 4Ps and 4Cs models is the value proposition [18], which serves as a bridge between a company's offerings and customer expectations. A strong value proposition helps companies stand out in a crowded market by highlighting unique features and benefits that make the app more attractive than competitors' offerings [6]. In a market with major telecom providers such as STC, Zain, and Mobily in KSA, differentiation through a clear value proposition allows mobile apps to target specific customer needs, such as better user experience, faster service, or more personalized offerings. For example, offering seamless integration with mobile payment systems, advanced customer support through chatbots, or exclusive content such as live sports events can enhance the value proposition. Additionally, a value proposition that addresses the specific needs of users ensures that the app fulfills customer expectations, increasing overall satisfaction and retention [19]. MTAs with a compelling value proposition foster long-term relationships by delivering real value to customers, such as loyalty rewards, customized data plans, and user-friendly interfaces. Furthermore, the value proposition clearly communicates how an app solves users' problems, enhances their lives, or provides specific benefits that are hard to replicate. The messaging around the value proposition helps in marketing and promotions, driving user adoption and engagement. It sets the tone for how the app is marketed and perceived by the target audience. Moreover, a well-crafted value proposition is a direct response to the customer needs (from the 4Cs model) and the features and benefits offered through the 4Ps. By aligning the app's features with customers' desires and pain points, telecom apps can deliver more relevant and targeted services, which enhance user satisfaction and loyalty [20]. A clear value proposition simplifies the customer's decision-making process by presenting them with an app that clearly meets their needs, not only based on its characteristics or the features it offers [21]. The value proposition influences how users decide which telecom app to download and use, making it a critical element in converting potential customers. Lastly, a strong value proposition becomes a source of competitive advantage by offering something that competitors cannot easily replicate [7]. By continuously improving the value proposition based on customer feedback, telecom providers can secure a dominant position in the market. The following subsequent sections will discuss the concepts and elements of the 4Ps and 4Cs marketing models. The following subsequent sections will discuss the concepts and elements of the 4Ps and 4Cs marketing models.

2.2.1. 4Ps

E. Jerome McCarthy initially presented the 4Ps paradigm in the 1960s. Companies can utilize the 4Ps model to influence the purchase decisions of their customers [22]. The 4Ps are Promotion, Place, Price, and Product. Each element is given a brief description as follows:

1. Product

In the 4Ps, product refers to the tangible or intangible goods and services offered by the company to its target market. Telecom companies use mobile phone apps to facilitate marketing activities by delivering essential services and information effectively to the largest number of customers. MTAs provide a wide range of services for customers, including but not limited to recharge cards, descriptions of available plans and packages, billing statements, payment methods, account balances, usage tracking, subscription management, updating account information, changing plans, viewing past transactions, loyalty rewards, referral bonuses, limited-time discounts, bundle packages, FAQs, troubleshooting guides, and live chat support. In this study, the MTA is the "product", where providers must employ appropriate strategies to ensure that the mobile application fulfills customers' needs and gains a competitive edge over other apps. In [23], the authors mentioned that telecom providers may differentiate themselves from their competitors and obtain a competitive advantage by providing superior app features and innovations. The ability to provide customers with appropriate support and a distinctive set of features will significantly increase customers' willingness to use the app. Customization services based on past customer behavior is another possible feature that could increase customer satisfaction. For example, analyzing customers' usage patterns such as data consumption, call minutes, and messaging habits helps the telecom provider to offer more customized services. This is essential to create personalized subscription plans that can give customers greater flexibility in planning their subscriptions.

2. Price

Generally, a customer's payment for a certain service or product is referred to as the price. Telecom providers should think about pricing strategies that can be integrated into their mobile app to encourage and motivate customers to revisit the app for more transactions. The differentiated pricing strategies indicate that there are a variety of products available to suit the needs and budgets of different online customers, including those with limited financial means. Clear and transparent pricing practices of products and services provided by MTAs enhance the feeling of trust among customers. Such pricing practices will help the customers to understand the pricing structure, which in turn enhances satisfaction with service pricing and encourages them to engage with the app and make repeat purchases [9,24].

3. Place

Place refers to the methods used to make the product or service available to customers. Within the MTA, the primary purpose of the place is to ensure the availability of the mobile app on widely used platforms that offer broad reach to smartphone customers. For example, customers can simply download and install the app from several distribution channels, such as app stores, official websites, social media, and email marketing. Also, they can access it through a variety of platforms, including desktop computers, tablets, and smartphones. Customers are then able to use their chosen devices and internet connections to use the app whenever and wherever they prefer. The MTA's strategic distribution and availability across a range of channels and platforms improves customers' convenience, reach, and speed, which leads to a more satisfying and pleasant user experience.

4. Promotion

Promotion refers to the action taken by the business to convince potential customers to buy its goods or services. This includes direct marketing, public relations, sales promotions, advertising, and personal selling. In the MTA environment, telecom providers may advertise discounts to customers through their apps. Telecom providers can promote discounts to their customers in a number of ways, including in-app notifications, promo codes, app-exclusive deals, personalized offers, limited-time offers, and integration with loyalty programs. Telecom providers can use their mobile app to advertise discounts and exclusive deals to boost customer engagement, encourage app adoption and usage, increase sales, and grow customer loyalty. Moreover, the app serves as a convenient platform for customers by providing them a simple way to find and obtain savings, which in turn enhances the overall customer experience [24].

2.2.2. 4Cs

In 1990, Robert F. Lauterborn [25] introduced the 4Cs marketing model. The model offers a customer-centric perspective on marketing strategy. Customer, cost, convenience, and communication are the four key elements that are emphasized by the 4Cs model for an effective marketing strategy. It is worth mentioning that both cost and price are two sides of the same coin. For this reason, in this research and based on the opinions of experts, cost from the 4Cs model has been excluded and price from the 4Ps model has been adopted as an element that indicates both concepts. A brief discussion regarding each element is presented as follows:

1. Customer

The customer aspect seeks to comprehend and satisfy the target customers' requirements and desires. If telecom providers are to retain their customers, they must understand what customers need and want from their mobile app. This is not something that happens quickly; rather, it requires conducting market research, customer surveys, and usability and user experience testing. Such studies can reveal insights that can inform app development and feature prioritization. In addition, studying user behavior and usage patterns can inform mobile app developers to offer customizable settings and targeted promotions based on user behavior and preferences. Customers' feedback about their needs and wants is important to guide the application's incremental development. Insights from customers' input should inform the launch of new features as well as upgrades and enhancements. This iterative process guarantees that the application remains relevant in the ever-changing market and is in line with changing customer demands. As a result, MTAs can build a loyal user base, drive user engagement and retention, and ultimately achieve long-term success in the market.

2. Convenience

In the 4Cs marketing model, convenience refers to how easily customers can obtain the product or use the service. It aims to minimize the effort and time that customers may require to accomplish specific tasks. Generally, convenience includes several aspects such as simplicity, navigability, and user-friendliness. These aspects significantly contribute to a smooth and efficient user experience. For example, customers are encouraged to explore and use the app via reduced barriers to entry, which are created by simplified onboarding procedures and user-friendly interfaces. Customers are more likely to use the app when they can easily access desired features, particularly the most common actions (e.g., checking their balance or recharging their phone line), and when they can perform these tasks with little effort. Therefore, if the MTA can meet such aspects, it will have a great chance to attract more customers.

3. Communication

Communication is defined as a network of interactions that brings together the company and the customers with the goal of exchanging information about the products or services that the company offers. The primary goal of the communication is to inform customers about the brand, products, and services. In the context of MTAs, communication focuses on the quality of the techniques and approaches used by an MTA to communicate with its target market. For example, response rates to customers' queries, interaction levels, brand mentions, social media interactions, and app store reviews can be considered indicators that reflect the quality of the interaction the app offers to its customers. Communication channels like helplines and in-app chat assistance are excellent tools for customer care, supporting customers with queries about technical issues, account inconsistencies, and recharge difficulties. High-quality communication has a significant impact on customers' experience through clear and consistent communication within the app itself, as well as through other channels like the company website or social media.

3. The Evaluation Model

Evaluating MTAs is not a forward process. It includes multiple criteria, steps, and practices that can be presented through implementing an evaluation model. Such a model will guide the decision-makers to take appropriate actions systematically and consistently. Therefore, an integrated evaluation model for assessing MTAs is proposed. The proposed model comprises two main phases: (1) identifying evaluation criteria; (2) developing a fuzzy AHP model. The phases are described in detail in the following sub-sections.

3.1. Identifying Evaluation Criteria

Evaluation criteria represent constraints that the target is subject to. In this study, the two marketing mix models (4Ps and 4Cs) were extended to determine the evaluation criteria. The elements of these marketing models are used as the main evaluation criteria for the qualitative data analysis. As a result, seven main criteria have been identified, namely, product, price, place, promotion, customer, convenience, and communication. Next, these major evaluation criteria were extended by identifying the sub-criteria. To do so, an interview research methodology was conducted. Besides, the Delphi technique was used to collect the views and opinions of experts about the sub-criteria of the elements of each marketing mix model [26]. The main reason for using the Delphi technique is to achieve consensus among experts when constructing a hierarchy of criteria or making judgments [27]. This consensus-driven approach reduces bias and increases the reliability of the outcomes. In total, twelve experts in the domains of marketing and digital marketing were interviewed. All the experts were professors with PhD degrees and specialists in marketing who are familiar with or have had good experiences with the 4Ps and 4Cs models. Figure 1 represents the three rounds of revisions using the Delphi technique. During the three revision rounds, the deductive content analysis technique [28] has been used to analyze qualitative data. The deductive content analysis technique is a powerful technique to avoid using naive marketing criteria that might have an impact on the evaluation's outcome.

Based on the qualitative analysis results, the 4Ps model has been expanded to encompass 12 sub-criteria, while the 4Cs model has been extended to include 7 sub-criteria. Following their extension, the 19 sub-criteria are categorized into seven distinct clusters aligning with the marketing mix: product C_1, price C_2, place C_3, promotion C_4, customer C_5, convenience C_6, and communication C_7. There was consensus from the experts that in the context of integrating the 4Ps and 4Cs marketing models for evaluating MTAs, the Cost C_4 component of the 4Cs model needs to be excluded from the proposed framework due to several reasons. Firstly, Price from the 4Ps model already encompasses key aspects

of cost-related considerations, including the (1) Pricing Model C_{21}, (2) Pricing Strategy Alignment C_{22}, and (3) Pricing Competitiveness. Secondly, the 4Cs framework emphasizes a customer-centric perspective; while Cost focuses on customer affordability and perceived value, these elements are inherently linked to Price under the 4Ps model. Therefore, instead of duplicating the cost analysis, the model incorporates more nuanced customer-centric factors such as Customer Needs and Preferences C_{51}, and Customer Satisfaction C_{52}, which address how well the app's pricing strategy aligns with consumer expectations. Table 1 presents the distribution of 19 sub-criteria over these eight clusters. Following three rounds, the experts confirmed the final hierarchy of the evaluation criteria. Figure 2 shows the analytical hierarchy structure for the evaluation of MTAs.

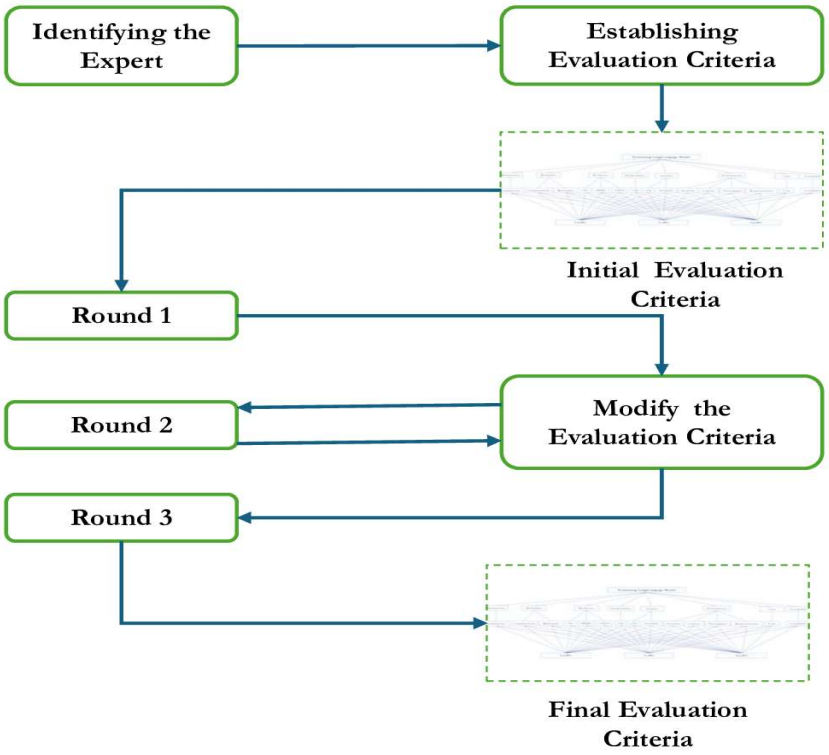


Figure 1. Three rounds of revisions using the Delphi technique.

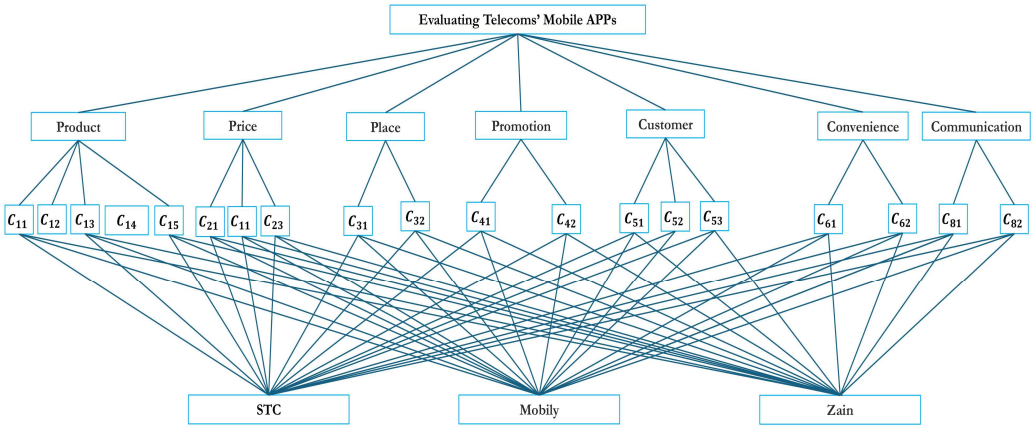


Figure 2. Analytical hierarchy structure for the evaluation of MTAs.

Table 1. MTA evaluation criteria.

Marketing Model	Criteria	Sub-Criteria	Definition
4Ps	Product C_1	Feature Set and Innovation C_{11}	Defined as comprehensive and unique features that meet the needs and expectations of customers and differentiate the app from competitors.
		User Value Proposition C_{12}	Defined as to which extent the MTA can address specific pain points or needs of customers, providing solutions or benefits that are compelling and valuable.
		Problem-Solving Capabilities C_{13}	Refers to the troubleshooting or in-app support features (e.g., chatbots, knowledge bases, or guided tutorials) to assist customers in resolving common issues or technical problems.
		App Performance and Stability C_{14}	Defined as how quickly the MTA can load and respond to user interactions in a stable manner (e.g., free of frequent crashes, freezes, or technical issues), providing a smooth user experience.
		Data Management and Security C_{15}	Defined as to which extent the MTA handle user data responsibly, adhering to privacy regulations and best practices.
	Price C_2	Pricing Model C_{21}	Refers to the structure and clarity of the pricing strategy adopted by the MTA.
		Pricing Strategy Alignment C_{22}	Refers to which extent the adopted pricing model is aligned with the value proposition and features provided by the app.
		Pricing Competitiveness C_{23}	Refers to the ability of a telecom provider to offer prices through the MTA that are attractive and compelling relative to those of similar offerings in the market.
	Place C_3	App Distribution Channels C_{31}	Refers to the availability of the MTA on widely used platforms that offer broad reach to smartphone customers.
		Market Reach C_{32}	Refers to the strong user base and widespread adoption of the MTA.
	Promotion C_4	Advertising and Promotional Campaigns C_{41}	Refers to the strategies applied to attract and acquire the desired target audience.
		Discounts and offers C_{42}	Refers to the strategies that effectively communicate the MTA's unique value proposition and benefits to customers.
4Cs	Customer C_5	Customer Needs and Preferences C_{51}	Defined as the effectiveness of the MTA in meeting the expectations and desires of the target customers.
		Customer Satisfaction C_{52}	Refers to the level of fulfillment experienced by customers after using an MTA.
		Customer Segmentation C_{53}	Defined as the process of dividing a customer base into distinct groups or segments based on shared characteristics, behaviors, preferences, or needs.
	Convenience C_6	Navigability C_{61}	Refers to the ease with which customers can access and utilize MTA features and functionalities.
		User-Friendliness C_{62}	It refers to the ease with which customers can interact with a communications application to achieve their goals effectively and efficiently so that the learning curve for new customers is as minimal as possible.
	Communication C_7	Marketing Communication C_{71}	Refers to the quality of the interaction that the MTA offers to the customers.
		Customer Support C_{72}	Refers to the range of services provided by telecom providers to help customers resolve issues, answer questions, and address concerns related to the MTA.

3.2. Developing a Fuzzy AHP Model

In this phase, a hybrid evaluation and ranking technique is developed by integrating fuzzy set theory and AHP. The preliminary concepts of the proposed hybrid evaluation model are discussed as follows:

3.2.1. Fuzzy Set

The evaluation of MTA with respect to the criteria of 4Ps and 4Cs models is imprecise since these criteria are subjective and have unknown potential values. Decision-making in such an environment is heavily influenced by subjective evaluations that are possibly vague. Fuzzy set theory [29], which was invented to express and handle ambiguity in decision-making, is used in this work to tackle this type of imprecise problem. Fuzzy set theory offers a potent tool called linguistic variables (such as very low, low, high, and very high). These linguistic variables can then be mapped to a numerical variable within the two-valued set {0,1} to effectively model the fuzziness or vagueness that is inherent in decision-making problems.

Definition 1. *Fuzzy Set*.

Consider a universe of discourse, $A = \{a_1, a_2, \ldots.., a_n\}$. Let B be a fuzzy subset of A that represents a set of order couples $\{(a_1, \mu_{\widetilde{B}}(a_1)), (a_2, \mu_{\widetilde{B}}(a_2)), \ldots.., (a_n, \mu_{\widetilde{B}}(a_n))\}$. For every a in A, there exists a number $\mu_{\widetilde{B}}(a)$ in the range $[0, 1]$ representing the membership of a in $\widetilde{B}$. This number is referred to as the membership function.

Definition 2. *Fuzzy Number*.

A fuzzy number is a fuzzy subset in the universe of discourse A that is both convex and normal. There are several types of fuzzy numbers, namely, triangular fuzzy numbers, trapezoidal fuzzy numbers, Gaussian fuzzy numbers, generalized bell fuzzy numbers, and singleton fuzzy numbers. This study adopts a triangular fuzzy number (TFN) to represent the degree of decision-maker judgment. Triangular fuzzy number $\widetilde{B}$ can be represented by three points (x, y, z), where $(x < y < z)$. The membership function $\mu_{\widetilde{B}}(a)$ is defined as

$$\mu_{\widetilde{B}}(a) = \begin{cases} \frac{a-x}{y-x}, & x \le a \le y \\ \frac{z-a}{z-y}, & y \le a \le z \\ 0, & otherwise \end{cases} \quad (1)$$

The operational equations of triangular fuzzy numbers $\widetilde{B}_1 = (x_1, y_1, z_1)$ and $\widetilde{B}_2 = (x_2, y_2, z_2)$ are expressed in Equations (2)–(5) as follows:

Addition fuzzy numbers ($\oplus$):

$$\begin{aligned} \widetilde{B}_1 \oplus \widetilde{B}_2 &= (x_1,\ y_1,\ z_1) \oplus (x_2,\ y_2,\ z_2) \\ &= (x_1 + x_2,\ y_1 + y_2,\ z_1 + z_2) \end{aligned} \quad (2)$$

Multiplication fuzzy numbers ($\bigotimes$):

$$\begin{aligned} \widetilde{B}_1 \bigotimes \widetilde{B}_2 &= (x_1,\ y_1,\ z_1) \bigotimes (x_2,\ y_2,\ z_2) \\ &= (x_1 x_2,\ y_1 y_2,\ z_1 z_2) \end{aligned} \quad (3)$$

Subtraction fuzzy numbers (⊖):

$$\begin{aligned}\widetilde{B}_1 \ominus \widetilde{B}_2 &= (x_1,\ y_1,\ z_1)\ominus(x_2,\ y_2,\ z_2)\\ &= (x_1 - z_2,\ y_1 - y_2,\ z_2 - x_1\ )\end{aligned} \tag{4}$$

Division fuzzy numbers (⊘):

$$\begin{aligned}\widetilde{B}_1 \oslash \widetilde{B}_2 &= (x_1,\ y_1,\ z_1) \oslash (x_2,\ y_2,\ z_2)\\ &= (x_1/z_2,\ y_1/y_2,\ z_2/x_1\ )\end{aligned} \tag{5}$$

Reciprocal fuzzy number:

$$\begin{aligned}\widetilde{B}^{-1} &= (x_1,\ y_1,\ z_1)^{-1} = (1/x_1,\ 1/y_1,\ 1/z_1\ )\\ &\text{For } x_1,\ x_2 > 0;\ y_1, y_2 > 0;\ z_1,\ z_2 > 0\end{aligned} \tag{6}$$

Definition 3. *Linguistic Variables.*

Linguistic variables are variables whose value cannot be given using numbers, only words. Linguistic variables are much closer to human thinking. Besides, due to their ability to model the vagueness or fuzziness inherently in human decision-making, they are more preferred than numbers. This study used a 9-point fuzzy scale using triangular fuzzy numbers to evaluate the MTA. Table 2 shows the fuzzy number, linguistic variables, score linguistic variables, and scale of fuzzy numbers.

Table 2. Fuzzy number, weight linguistic variables, and scale of fuzzy number.

Fuzzy Numbers	Weight Linguistic Variables	Score Linguistic Variables	Scale of Fuzzy Number
$\widetilde{9}$	Absolutely more important	Exceptional (E)	(9, 9, 9)
$\widetilde{8}$	Intermediate	Very Good (VG)	(7, 8, 9)
$\widetilde{7}$	Very strongly more important	Good (G)	(6, 7, 8)
$\widetilde{6}$	Intermediate	Average (A)	(5, 6, 7)
$\widetilde{5}$	Strongly more important	Fair (F)	(4, 5, 6)
$\widetilde{4}$	Intermediate	Below Average (BA)	(3, 4, 5)
$\widetilde{3}$	Weakly more important	Poor (P)	(2, 3, 4)
$\widetilde{2}$	Intermediate	Very Poor (VP)	(1, 2, 3)
$\widetilde{1}$	Equally important	Extremely Poor (EP)	(1, 1, 1)

Definition 4. *Defuzzification.*

Defuzzification is the process of converting fuzzy numbers into crisp values. Several defuzzification methods have been proposed in the literature. The selection of the most suitable defuzzification method depends on the specific characteristics of the decision problem as there is no superior defuzzification method in FAHP. Several methods have been proposed in the literature for defuzzification, including the Centroid Method [29], Mean of Maximum (MoM) [30], Weighted Average Method (WAM) [31], and Graded Mean Integration (GMI) Method [32], where each method has its advantages and limitations. In this study, the Graded Mean Integration (GMI) method is selected over other defuzzification methods due to its mathematical simplicity, ability to handle triangular fuzzy numbers, and balanced integration of uncertainty. The fuzzy number $\widetilde{B} = (x_1, y_1, z_1)$ can be converted into a crisp number by using Equation (7) as follows:

$$P(\widetilde{B}) = B = \frac{x_1 + 4y_1 + z_1}{6} \tag{7}$$

3.2.2. AHP

AHP is one of the most powerful and common MCDM methods. Originally, AHP was introduced by [33]. AHP has been proposed as a decision-making technique to evaluate complex multi-criteria alternatives among one or more decision-makers. It is a powerful decision-making technique that is applied successfully to a wide range of practical decision-making problems in marketing, healthcare, economics, mathematics, supply chain management and logistics, cloud computing, web service, energy and manufacturing, and ecology [34]. The wide applicability is due to its simplicity, ease of use, and flexibility. In this study, AHP is used to synthesize the weights and scores of evaluation criteria and aggregate the final score of each alternative, which allows for ranking them. AHP comprises three principles—decomposition, comparative pairwise judgment, and synthesis of priorities [20], which are described as follows:

Step 1: Decomposition

This phase attempts to address the complicated unstructured multi-criteria decision problem into a hierarchy comprising several levels (e.g., objective, criteria, and alternatives). As presented in Figure 2, the decision problem is structured into a hierarchy of 4 levels. Level 1, the top level in the hierarchy, represents the evaluation process's main goal. Next, level 2 contains 7 evaluation criteria followed by level 3, which contains 19 sub-criteria. Finally, level 4, which is the lowest level, represents the 3 MTAs (STC app, Mobily app, Zain app) under evaluation.

Step 2: Comparative pairwise judgment

In this step, all the evaluation criteria and sub-criteria are compared with each other with respect to their importance in evaluating MTAs. To do so, a questionnaire consisting of all the main criteria and sub-criteria is designed and used to collect the pairwise comparison judgments from all decision-makers. A series of pairwise comparison judgments were carried out by using a 9-point fuzzy scale. As a result, fuzzy judgment matrices ($\widetilde{D}$) among all the criteria and sub-criteria in the dimensions of the hierarchy are constructed as shown in Equation (8).

$$\widetilde{D} = \begin{bmatrix} 1 & \widetilde{d}_{12} & \dots & \widetilde{d}_{1n} \\ \widetilde{d}_{21} & 1 & \dots & \widetilde{d}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{d}_{n1} & \widetilde{d}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \widetilde{d}_{12} & \dots & \widetilde{d}_{1n} \\ 1/\widetilde{d}_{21} & 1 & \dots & \widetilde{d}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\widetilde{d}_{n1} & 1/\widetilde{d}_{n2} & \dots & 1 \end{bmatrix} \tag{8}$$

where

$$\widetilde{d}_{ij} = \begin{cases} \widetilde{9}^{-1}, \widetilde{8}^{-1}, \widetilde{7}^{-1}\, \widetilde{6}^{-1}, \widetilde{5}^{-1}, \widetilde{4}^{-1}, \widetilde{3}^{-1}, \widetilde{2}^{-1}, \widetilde{1}^{-1}, \widetilde{1}, \widetilde{2}, \widetilde{3}, \widetilde{4}, \widetilde{5}, \widetilde{6}, \widetilde{7}, \widetilde{8}, \widetilde{9}, 1, & i \neq j \\ 1 & i = j \end{cases}$$

Step3: Synthesis of priorities

The decision-makers' opinions are aggregated and summarized by using Equation (9):

$$x_{ij} = \left(\prod_{k=1}^{k} x_{ijk} \right)^{1/k}, \; y_{ij} = \left(\prod_{k=1}^{k} y_{ijk} \right)^{1/k}, \; z_{ij} = \left(\prod_{k=1}^{k} z_{ijk} \right)^{1/k} \tag{9}$$

where $\widetilde{B} = (x_{ij}, y_{ij}, z_{ij})$ and k is the number of decision-makers.

Next, the Geometric Mean (GM) method is applied to normalize the weight values of the evaluation criteria and sub-criteria. The GM method is a significant method that aims to reduce judgment inconsistency. In addition, the GM method is less sensitive to extreme values compared to the arithmetic mean, which make it more appropriate when

dealing with subjective and qualitative judgments [35]. The operational equations of the GM method are expressed in Equations (10) and (11) as follows:

$\widetilde{\mathrm{GM}}_i$ of the jth row associated with the fuzzy comparison matrix:

$$\widetilde{\mathrm{GM}}_i = \left[\prod_{\mathrm{k}=1}^{\mathrm{r}} \mathrm{d}_{\mathrm{ijk}}\right]^{1/\mathrm{r}} \tag{10}$$

Subsequently, the defuzzification method is applied to convert the fuzzy weight of evaluation criteria and sub-criteria into crisp value as described in Definition 4. This is followed by normalized weights for the jth row of the crisp comparison matrix.

$\widetilde{\mathrm{W}}_i$ normalized weight values:

$$\widetilde{\mathrm{W}}_i = \frac{\widetilde{\mathrm{GM}}_i}{\sum_{i=1}^{r} \widetilde{\mathrm{GM}}_i} \tag{11}$$

To ensure the validity of the AHP pairwise comparison process, the consistency ratio (CR) was calculated for each pairwise comparison matrix using Equation (12). If the value of CR is less than 0.010, the pairwise comparison matrix is considered accepted; otherwise, the decision maker needs to revise the judgment.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}, \quad CR < 0.1 \tag{12}$$

where

CI is the consistency index measured by $\mathrm{CI} = \frac{\lambda_{max}-n}{\mathrm{n}-1}$, where λ_{max} is the largest eigenvalue and n is the number of children (criteria or sub-criteria).

RI is a random index measured by the $\mathrm{RI} \approx \frac{2(\mathrm{n}-1)}{\mathrm{n}(\mathrm{n}-1)}$.

Next, the global weight of sub-criteria is calculated by multiplying their local weight with the weight of the main criteria.

Finally, the fuzzy performance decision matrix $\widetilde{A}$ is constructed to calculate the performance of the alternatives with respect to the evaluation criteria. Decision makers used the score linguistic variables, as defined in Definition 3 and Table 2.

$$\widetilde{A} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} \widetilde{\mathrm{S}}_{11} & \widetilde{\mathrm{S}}_{12} & \dots & \widetilde{\mathrm{S}}_{1n} \\ \widetilde{\mathrm{S}}_{21} & \widetilde{\mathrm{S}}_{22} & \dots & \widetilde{\mathrm{S}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{\mathrm{S}}_{m1} & \widetilde{\mathrm{S}}_{m2} & \dots & \widetilde{\mathrm{S}}_{mn} \end{bmatrix} \end{array} \tag{13}$$

where

$$\begin{array}{l} i = 1, 2, \dots m; \; j = 1, 2, \dots, \mathrm{n} \\ \widetilde{S}_{ij} = \frac{1}{K}\left(\widetilde{\mathrm{S}}_{ij}^{1} \oplus \dots \oplus \widetilde{\mathrm{S}}_{ij}^{k} \oplus \dots \oplus {}^{1}\widetilde{\mathrm{S}}_{ij}^{K}\right) \end{array} \tag{14}$$

$\widetilde{S}_{ij}$ represents the fuzzy performance score of the alternative A_i with respect to criterion C_j evaluated by kth decision-makers calculated by Equation (14). Equations (9)–(12) are applied to calculate the crisp value of the performance score of each alternative. The overall performance score of each alternative can be obtained by multiplying the performance decision matrix by a vector of criteria weights D and summing overall criteria by using Equation (15).

$$FS_i = \sum_{j=1}^{n} d_j.s_{ij}, \; \forall \; i \tag{15}$$

where

d_j is the global weight of criterion j;
s_{ij} is the normalized performance score of the ith alternative based on the jth criterion.

4. An Empirical Case Study of the MTA

An empirical study was introduced to explain the suggested fuzzy MCDM model for decoding customer preferences in Saudi Arabia's MTA market and show how effective it is at evaluating and ranking MTAs. Saudi Arabia has three domestic MTA providers: STC, Mobily, and Zain. A group of decision-makers consisting of fifteen experts was invited to conduct pairwise comparison judgments. Six of them were from academic and research centers, where they teach and present training topics related to marketing and mobile commerce. The remaining experts were professionals who have wide experience in developing and designing mobile apps.

4.1. Weight of Evaluation Criteria

In accordance with the approach outlined in the preceding sections, the decision goal was originally established for evaluating and ranking the performance of MTAs in KSA. Second, in Section 3.1, the result of qualitative analysis shows that the 4Ps marketing mix has been expanded to encompass 17 sub-criteria, while the 4Cs framework has been extended to include 12 sub-criteria categorized into eight distinct clusters. Then, by following three rounds of the Delphi technique, the experts confirmed the final hierarchy of the evaluation criteria, as shown in Figure 2.

Following that, the AHP method was utilized to construct the hierarchy structure for evaluating MTAs and to determine the weights of each criterion. Initially, the experts were requested to complete a series of pairwise comparisons using a 9-point fuzzy scale to answer the questions. In total, forty-one questions were created to provide pairwise comparisons of the evaluation criteria. These questions were divided into twenty-one questions to compare the degree of importance of evaluation criteria in level 2, and twenty questions were used for evaluating sub-criteria in level 3. For example, "Considering the evaluation of MTA, how would you rate the relative importance of product compared to price?". Decision makers convert the linguistic variables to fuzzy numbers easily using Definition 3 and Table 2. Due to space limitations, the full set of pairwise comparisons of the evaluation criteria and sub-criteria were omitted. A sample of pairwise comparison judgment criteria of MTAs from decision maker 1 is shown in Table 3.

Table 3. Pairwise comparison judgment criteria of MTA from decision maker 1.

	Product	**Price**	**Place**	**Promotion**	**Customer**	**Convenience**	**Communication**
Product	$\tilde{1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{4}$
Price	$\tilde{1}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}^{-1}$	$\tilde{5}$	$\tilde{5}$
Place	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{1}$
Promotion	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}$	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{2}$	$\tilde{3}$
Customer	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$
Convenience	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$
Communication	$\tilde{4}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{3}^{-1}$	$\tilde{5}^{-1}$	$\tilde{3}$	$\tilde{1}$

Secondly, the weight of each evaluation criterion assigned by decision-makers is aggregated and summarized using Equation (9). This is followed by normalizing the weight values of the evaluation criteria and sub-criteria using Equations (10) and (11). The normalized fuzzy weight of evaluation criteria and sub-criteria are then defuzzied into crisp value using Equation (7). Table 4 presents a sample set of the crisp value obtained from the defuzzification process on the evaluation criteria from decision maker 1.

Table 4. Crisp value of pairwise comparison judgment criteria of MTA from decision maker 1.

	Product	Price	Place	Promotion	Customer	Convenience	Communication
Product	1	3.00	5.00	3.00	1.00	2.00	5.00
Price	0.33	1	1.00	1.00	0.20	0.33	1.00
Place	0.20	1.00	1	3.00	0.20	0.33	4.00
Promotion	0.33	1.00	0.33	1	0.20	0.33	3.00
Customer	1.00	5.00	5.00	5.00	1	3.00	5.00
Convenience	0.50	3.00	3.00	3.00	0.33	1	2.00
Communication	0.20	1.00	0.25	0.33	0.20	0.50	1
λ_{max} = 7.503		CI = 0.084		RI = 1.35		CR = 6.2%	

Thirdly, the consistency ratio (CR) was calculated for each pairwise comparison matrix using Equation (12). The consistency ratio reading of 0.011 was below the permitted threshold value. The decision matrix of the main evaluation criteria is presented in Table 5. Further, the full decision matrix that includes a goal, evaluation perspective (e.g., 4Ps and 4Cs), global weight of evaluation criteria, and local weight of evaluation criteria is presented in Table 6.

Table 5. Pairwise comparison judgment criteria.

	Product	Price	Place	Promotion	Customer	Convenience	Communication
Product	1	2.186724	2.605171	3.346955	1	1.551846	2.267933
Price	0.457305	1	2.141127	1.820564	0.72478	1.430969	1.888175
Place	0.383852	0.467044	1	1.37973	0.44093	0.802742	1.245731
Promotion	0.298779	0.54928	0.72478	1	0.367098	0.581811	1.148698
Customer	1	1.37973	2.267933	2.72407	1	2.141127	2.036168
Convenience	0.644394	0.698827	1.245731	1.718772	0.467044	1	1
Communication	0.44093	0.529612	0.802742	0.870551	0.491119	1	1
Priority	24.10%	15.70%	9.50%	7.90%	21.80%	11.70%	9.20%
CR	1.1%						

Table 6. Weighted criteria and sub-criteria of MTA from the perspective of 4Ps and 4Cs.

Goal	Marketing Model	Criteria	Weight	Sub-Criteria	Local Weight	Global Weight
Evaluating Telecom Mobile's App	4Ps	Product C_1	0.2409	Feature Set and Innovation C_{11}	0.211	0.0509
				User Value Proposition C_{12}	0.155	0.0373
				Problem-Solving Capabilities C_{13}	0.114	0.0275
				App Performance and Stability C_{14}	0.258	0.0622
				Data Management and Security C_{15}	0.262	0.0632
		Price C_2	0.1574	Pricing Model C_{21}	0.554	0.0872
				Pricing Competitiveness C_{22}	0.446	0.0702
		Place C_3	0.0953	App Distribution Channels C_{31}	0.318	0.0304
				Market Reach C_{32}	0.682	0.065
		Promotion C_4	0.0792	Advertising and Promotional Campaigns C_{41}	0.445	0.0353
				Discounts and offers C_{42}	0.555	0.0439
	4Cs	Customer C_5	0.2182	Customer Needs and Preferences C_{51}	0.392	0.0855
				Customer Satisfaction C_{52}	0.361	0.0789
				Customer Segmentation C_{53}	0.247	0.0539
		Convenience C_6	0.1173	Navigability C_{61}	0.500	0.0587
				User-Friendliness C_{62}	0.500	0.0587
		Communication C_7	0.092	Marketing Communication C_{71}	0.420	0.0387
				Customer Support C_{72}	0.580	0.0533

According to the results shown in Table 6, the main evaluation criteria are sorted in descending order of importance based on the given weights as follows: product (0.2409), customer (0.2182), price (0.1574), convenience (0.1173), place (0.0953), communication (0.0920), and promotion (0.0792). This indicates that the product is the most critical criterion in evaluating MTAs. This is followed by the customer, which is almost as important, while price, convenience, and place are moderately important. Lastly, communication and

promotion are the least important. From the perspective of the 4Ps, product is the most important criterion for evaluating MTAs. This means that the sub-criteria of the product such as feature set and innovation, user value proposition, problem-solving capabilities, app performance and stability, and data management and security are very critical requirements in MTAs to ensure a high level of user satisfaction. Price is the second most critical criterion, which suggests that customers are probably willing to pay for high-quality products. This gives an indicator to the telecom providers to design pricing strategies that align with the value offered by the product. This is followed by place, which does not weigh as heavily as the product or pricing. Among the 4Ps, promotion has the least weight. This suggests that although promotion might be helpful, effective advertising and promotional campaigns will not compensate for deficiencies in the product or price. From the perspective of the 4Cs, the customer has the highest weight. This ensures that understanding customer needs and preferences, ensuring customer satisfaction, and customer segmentation are significant for evaluating the MTA. Besides, this assures the telecom providers of the importance of a user-centric approach during app development. Next, convenience ranks as the second most important criterion. This suggests that its sub-criteria, navigability and user-friendliness, are crucial for attracting and retaining customers. Finally, the communication that included customer service and marketing communication received the third ranking.

As shown in Figure 3, the sub-criteria are then sorted in ascending order according to their global weights: customer needs and preferences (0.0855), customer satisfaction (0.0789), market reach (0.065), data management and security (0.0632), app performance and stability (0.0622), navigability (0.0587), user-friendliness (0.0587), pricing model (0.0872), pricing competitiveness (0.0702), customer segmentation (0.0539), customer support (0.0533), feature set and innovation (0.0509), discounts and offers (0.0439), marketing communication (0.0387), user value proposition (0.0373), advertising and promotional campaigns (0.0353), app distribution channels (0.0304), and problem-solving capabilities (0.0275).

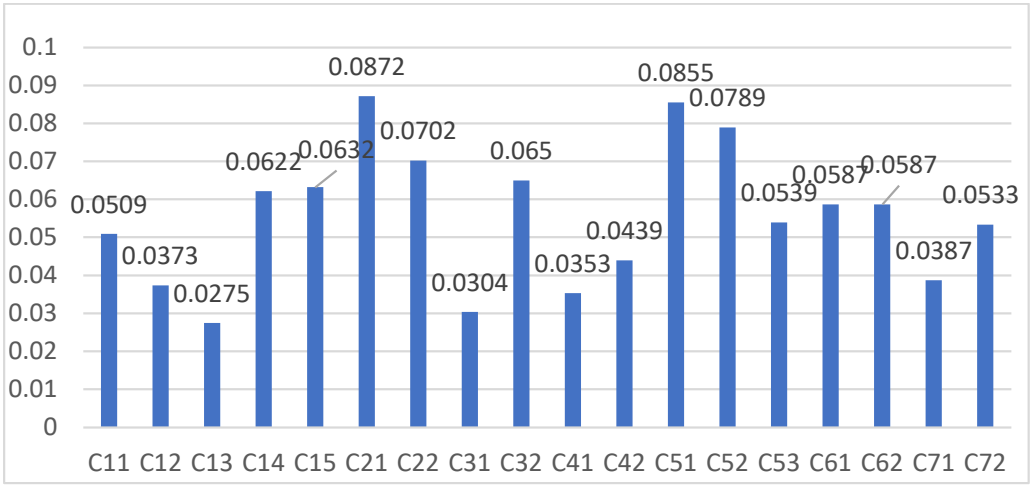


Figure 3. Weighted criteria and sub-criteria of MTAs from the perspective of 4Ps and 4Cs.

Based on the average value of the global weight (Avg = 0.0527), these sub-criteria are categorized into three areas according to their priority. For example, the category of high-priority criteria involves customer needs and preferences, customer satisfaction, navigability, and user-friendliness from the 4Cs perspective, as well as market reach, data management and security, and app performance and stability from the 4Ps perspective. This implies that telecom providers need to pay more attention to these seven criteria for achieving sustainable competitive advantages in the mobile marketplace. The second category of sub-criteria is categorized as moderate-priority criteria, which include pricing

model, pricing competitiveness, customer segmentation, customer support, feature set and innovation, pricing strategy alignment, and discounts and offers. Apparently, giving more attention to this category is essential for ensuring an effective MTA. Low-priority criteria is the third category that comprises marketing communication user value proposition, advertising and promotional campaigns' app distribution channels, and problem-solving capabilities. However, focusing on enhancing user experience, support, and targeted marketing is necessary for comprehensive evaluation and strategy.

4.2. MTA Performance Evaluation

The main goal of the proposed model is to evaluate and rank the performance of MTAs in Saudi Arabia's telecommunication market from the perspectives of 4Ps and 4Cs marketing models. After conducting the pairwise comparison, the experts were asked to use the score linguistic variables as defined in Definition 3 and Table 2 to construct a fuzzy performance decision matrix $\widetilde{A}$. Then, the performance of the alternatives $\widetilde{S}_{ij}$ is calculated with respect to each sub-criterion using Equation (14). The crisp values of the performance score of each alternative are shown in Table 7. To wrap up the suggested evaluation model, the overall performance score of each alternative is obtained by multiplying crisp values of the performance score of each alternative with the global weight of sub-criteria and summing the overall score by using Equation (15), as shown in Table 7.

On the basis of Table 7, the Zain app had the best overall performance score (0.3993). In contrast, the Mobily app had the lowest performance score (0.2611). The STC app achieved a performance score of (0.3434), placing it in the middle rank among the evaluated apps. The ranking of alternative as $(\text{Zain} > \text{STC} > \text{Mobily})$ is achieved when all criteria are taken into account. However, focusing on individual perspectives (e.g., overall alternative performance in terms of 4Ps or 4Cs) can lead to different rankings. For example, the STC app had the best overall performance score (0.2340) in terms of 4Ps perspective, followed by the Zain app (0.2009) and Mobily app (0.1401), sorted as $(\text{STC} > \text{Zain} > \text{Mobily})$. In terms of the 4Cs perspective, the Zain app had the best overall performance score (0.1984) followed by the Mobily app (0.121), and the STC app had the lowest performance score (0.1094), sorted as $(\text{Zain} > \text{Mobily} > \text{STC})$.

Table 7. The final priority weights and ranking of MTA.

Goal	Marketing Model	Criteria	Weight	Sub-Criteria	Global Weight	Alternatives with Local Weights			Performance Score		
						STC	Mobily	Zain	STC	Mobily	Zain
Evaluating Telecom Mobile Apps	4Ps	Product C_1	0.2409	Feature Set and Innovation C_{11}	0.0509	0.3617	0.2712	0.3672	0.0185	0.0138	0.0187
				User Value Proposition C_{12}	0.0373	0.3394	0.2788	0.382	0.0127	0.0104	0.0143
				Problem-Solving Capabilities C_{13}	0.0275	0.2246	0.3642	0.4114	0.0062	0.0101	0.0114
				App Performance and Stability C_{14}	0.0622	0.2951	0.2785	0.4265	0.0184	0.0174	0.0266
				Data Management and Security C_{15}	0.0632	0.5940	0.2105	0.0376	0.1957	0.0124	0.0133
		Price C_2	0.1574	Pricing Model C_{21}	0.0872	0.2951	0.2573	0.4477	0.0258	0.0225	0.0391
				Pricing Competitiveness C_{22}	0.0702	0.3510	0.1810	0.4682	0.0247	0.0128	0.0329
		Place C_3	0.0953	App Distribution Channels C_{31}	0.0304	0.4416	0.2736	0.285	0.0135	0.0084	0.0087
				Market Reach C_{32}	0.065	0.5262	0.2803	0.1936	0.0343	0.0183	0.0126
		Promotion C_4	0.0792	Advertising and Promotional Campaigns C_{41}	0.0353	0.5407	0.1871	0.2723	0.0191	0.0067	0.0097
				Discounts and offers C_{42}	0.0439	0.5284	0.1642	0.3076	0.0232	0.0073	0.0136
	4Cs	Customer C_5	0.2182	Customer Needs and Preferences C_{51}	0.0855	0.2489	0.1874	0.5638	0.0213	0.0161	0.0483
				Customer Satisfaction C_{52}	0.0789	0.2656	0.2642	0.4703	0.0210	0.0209	0.0372
				Customer Segmentation C_{53}	0.0539	0.3431	0.3238	0.3333	0.0185	0.0175	0.0180
		Convenience C_6	0.1173	Navigability C_{61}	0.0587	0.2617	0.3295	0.4089	0.0154	0.0194	0.0241
				User-Friendliness C_{62}	0.0587	0.2006	0.3009	0.4986	0.0118	0.0177	0.0293
		Communication C_7	0.0920	Marketing Communication C_{71}	0.0387	0.2226	0.2992	0.4783	0.0087	0.0116	0.0186
				Customer Support C_{72}	0.0533	0.2374	0.3334	0.4293	0.0127	0.0178	0.0229
							4Ps Score		0.2340	0.1401	0.2009
							4Cs Score		0.1094	0.1210	0.1984
							Overall Performance Score		0.3434	0.2611	0.3993

5. Result Analysis and Discussion

Generally, a well-designed mobile app is vital to providing efficient services and has the potential to grow market share [8,23]. In addition, Tang (2018) concluded that mobile apps are seen by many service companies as a way to deliver better customer service, leading to increased sales and improved profitability [36]. If an MTA is to fulfill its potential, there must be a clear understanding of the various issues involved. Therefore, Figures 4–6 report the weight performance score for each criterion and sub-criteria related to the evaluation of MTAs. This aims to highlight strengths and thoroughly examine the gaps that need further improvement.

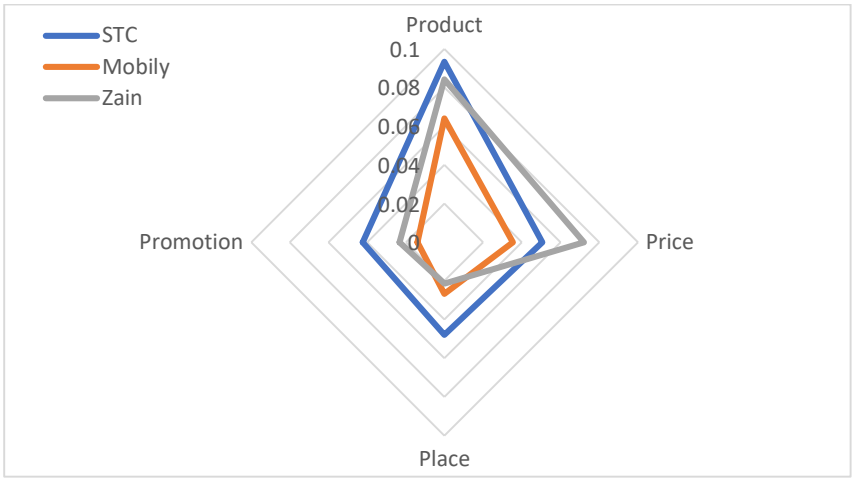
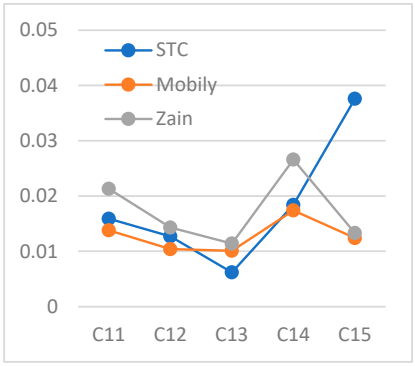
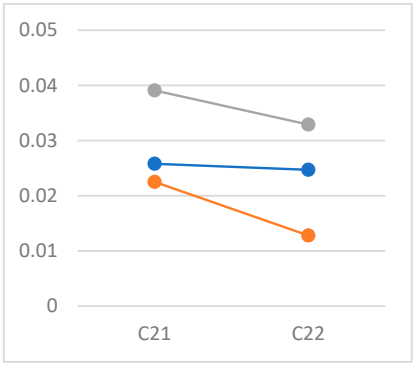


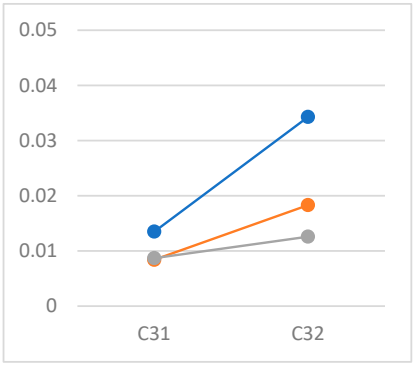
Figure 4. Performance comparison between the STC app, Mobily app, and Zain app from 4Ps perspective.



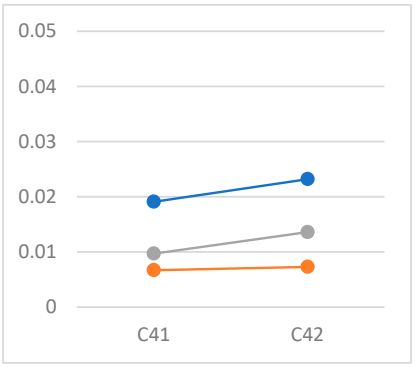
(a) Product



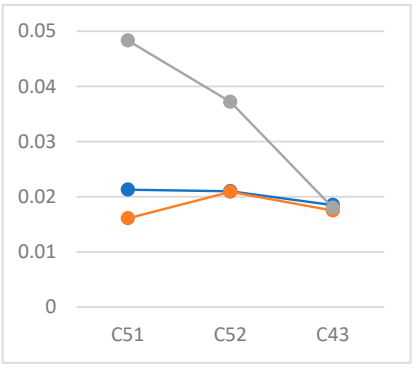
(b) Price



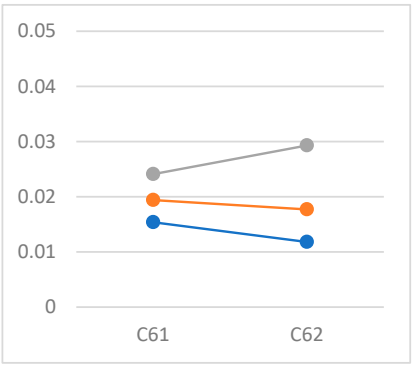
(c) Place



(d) Promotion

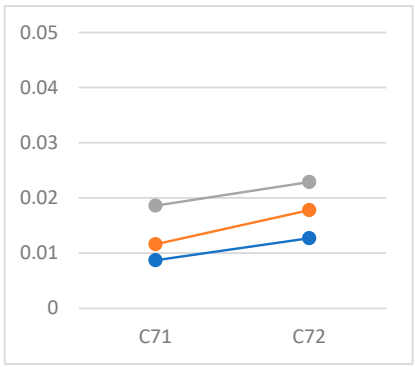


(e) Customer



(f) Convenience

Figure 5. *Cont.*



(g) Communication

Figure 5. Performance comparison between the STC app, Zain app, and Mobile app for each criterion.

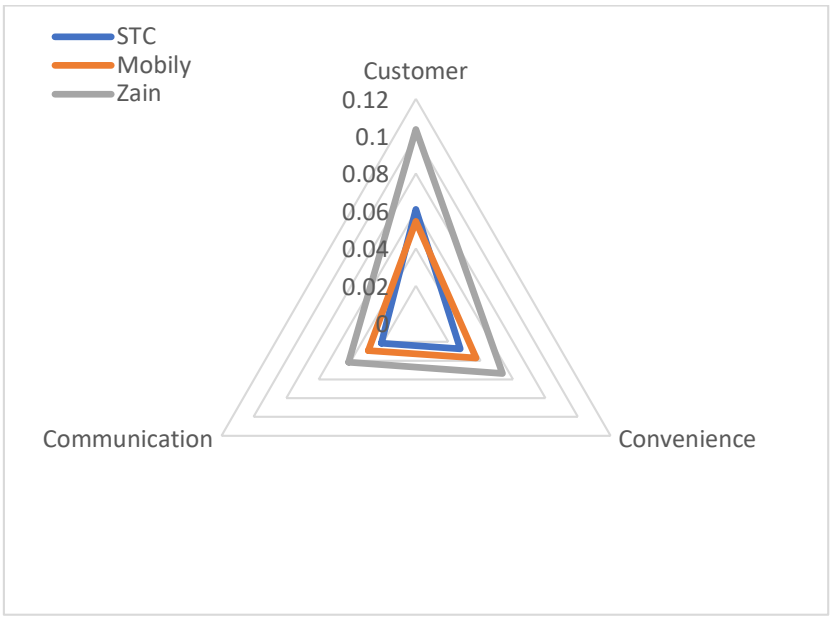


Figure 6. Performance comparison between STC, Zain, and Mobile from 4Cs perspective.

5.1. Product

As shown in Figure 4, STC has the highest weighted performance score of product criterion. Zain follows closely behind STC, indicating that it also has a strong product offering. Mobily has the lowest performance score in this category, indicating that several sub-criteria under the product criterion need further improvements. In detail, the following subsequent sections discuss the strengths and weaknesses of the product sub-criteria with respect to each alternative.

5.1.1. Feature Set and Innovation

As reported in Figure 5a, the Zain app has a slightly higher score for the feature set and innovation criterion (0.0187) than the STC app (0.0185). The Mobily app showed the lowest score value of (0.0138). The difference between the Zain and STC apps are minimal. This minimal difference implies that customers would find STC's app nearly as innovative and feature-rich as Zain's app. However, although innovation and feature sets are compulsory and powerful tools for mobile apps, they need to be implemented with a commitment to a smooth user experience. Several studies strongly agree with the significant positive relationships between perceived convenience and perceived usefulness in using mobile apps [8,9,37]. Therefore, it is possible that this slight superiority of the Zain app over the

STC app is not directly due to the innovation or rich features offered by both apps but, rather, due to the superiority of the Zain app in terms of convenience C_6, as shown in Figure 5f. Notably, both the Zain and STC apps have a robust set of features and innovations comparable to Mobily's. This study suggests several strategic recommendations for the Mobily app to support its competitiveness and attract potential customers. For example, Mobily should focus more on differentiating its features and innovations by introducing unique features that are not available in STC's and Zain's apps. To do so, Mobily needs to conduct competitors' analysis to identify what features they offer that the Mobily app lacks. Before development, Mobily needs to prioritize features that address customers' needs and fine-tune and enhance the app's features and usability, which could contribute to closing the gap with competitors. This is consistent with the findings of the study performed by [23], which state that a telecom may gain a competitive edge and set itself apart from its competitors by offering higher-quality app features and innovations.

5.1.2. User Value Proposition

With respect to user value proposition, the Zain app obtains the highest weighted performance score (0.0143), followed by the SCT app (0.0127) and Mobily app (0.0104) (see Figure 5a). This arrangement is not surprising as the Zain app offers a compelling combination of feature set and innovation, better pricing, high customer satisfaction, more convenience, and stronger customer support, as shown in Figure 5a, Figure 5b, Figure 5e, Figure 5f, and Figure 5g, respectively, which collectively enhance the user experience and perceived value. Besides, the STC app is perceived as valuable by the experts due to the good mix of data management and security (Figure 5a), advertising and promotional content (Figure 5d), and marketing communication (Figure 5g). This result supports the findings of the literature [6,8,23,36], which discovered that customer service quality, service content quality, and customer support quality of MTAs are considered direct predictors of perceived value. If Mobily wants to enhance its competitive position, improvement of user value proposition is a pressing need. Various plans of action such as improving the pricing model, increasing customer satisfaction, and enhancing convenience and marketing communication are possible to reduce the gap between Mobily and its competitors until a comprehensive plan that takes into consideration all 4Ps and 4Cs evaluation criteria is developed. The reason behind choosing these criteria to be improved over others is that Mobily achieves a level close to competitors on them.

5.1.3. Problem-Solving Capabilities

In Figure 5a, we found that the Zain app has the best-weighted performance score (0.0114), the STC app has the worst score (0.0062), and the Mobily app comes in the middle in terms of problem-solving capabilities. The superiority of the Zain app over other alternatives is due to the comprehensive suite of tools, including a knowledge base for FAQs/How to, multiple contact channels (WhatsApp, call, X), and the ability to open support tickets and report fraud. Such a comprehensive suite of tools reflects robust problem-solving capabilities, flexibility, and convenience in resolving issues, which indeed leads to higher user satisfaction. The Mobily app is not as comprehensive as the Zain app, as it lacks the breadth of contact options that the Zain app provides, but it still has a score better than the STC app. Customers have access to a knowledge base of "How to" and contact support directly, which enhances problem-solving effectiveness. Both the Zain and Mobily apps have the opportunity to support problem-solving capability by employing new artificial intelligence technology such as chatbots. Chatbots can save time and offer more flexibility and convenience in solving problems [37]. The STC app has the lowest score, which reflects the limitations in problem-solving capabilities. The

STC app offers only a chatbot that provides instant assistance and automates responses to common queries. However, consumers must engage with the STC app chatbot in-depth before opening a ticket, which makes problem resolution slower and potentially more frustrating for customers. Such a chatbot's interaction may not be effective or user-friendly. The study conducted in [37] ensures that chatbots for customer service may strengthen the user experience. This implies that the interaction design of chatbots should be carefully considered. In addition, relying only on the chatbot gives consumers fewer tools with which to troubleshoot problems on their own. This might put further strain on the chatbot. Therefore, this study suggests that the STC provider cloud should try to shorten the ticketing process and include self-help tools. Such improvements can provide consumers with answers to frequently asked queries and eliminate the need for lengthy conversations.

5.1.4. App Performance and Stability

As shown in Figure 5a, the app performance and stability category is led by the Zain app with a score of (0.0266). This implies that the Zain app has smoother performance and a more stable user experience as it has fewer crashes and better response times over other alternatives. With the scores of (0.0184) and (0.0174), the STC app and Mobily app seem to have significant performance and stability issues. Detailed analysis of the STC and Mobily apps reported several problems that cannot be considered occasional issues. For example, (1) top-up balance failures where customers are having trouble topping up their balance due to frequent crashes and app failures to retain the page for entering bank passwords; (2) credit transfer problems where the "pay with card" option fails with "Oops" errors; and (3) instability, where the app freezes, crashes, displays blank screens, and requires frequent uninstalls and reinstalls for basic functionality. Consequently, these issues make the app frustrating and unreliable for basic tasks. As a result, the frequent need to remove and reinstall the application, together with crashes and freezes, results in a poor overall user experience. In the literature, many studies strongly affirmed that app performance and stability have a positive impact on customer satisfaction and engagement with mobile apps [36]. This study suggests several improvements and actions that might enhance the overall app performance and stability, including (1) well-maintained and optimized backend infrastructure, (2) conducting thorough testing to identify and fix bugs, (3) using more informative error messages, and (4) actively incorporating user feedback in the process of updates and maintenance.

5.1.5. Data Management and Security

As shown in Figure 5a, the STC app gives better scores for data management and security (0.0376). The Zain and Mobily apps perform nearly on par (0.0133, 0.0124). The STC app has more advanced security features than other apps, which gives it an advantage over them. The STC app applies strict security procedures before granting the user access to the application services. For example, the STC app applies multiple authentication factors (user id, one-time password). In addition, it uses a trusted device method using real-time verification calls, which ensures that the person attempting to log in is genuinely the authorized user. Moreover, a verification SMS with a log-out link is included within the log-in procedure, which allows customers to immediately terminate any unauthorized sessions. Such security features will significantly mitigate security breaches by reducing the risk of account compromise and minimizing damage from unauthorized access. However, this security approach is a double-edged sword. The STC app needs to balance between advanced security features and convenience. Customers who log in regularly may find it frustrating when they receive repeated calls for verification. Therefore, it is imperative to provide a smooth and user-friendly experience to avoid frustration. This is one of the

factors that illustrates the STC app's poor degree of convenience, as seen in Figure 5f. The advantage the Zain app has over other apps is that it allows customers to manage security features by providing them with three functionalities:

1. Active session: This allows the user to view and terminate active sessions.
2. Number security: This allows customers to view who is managing any other line, who created an account under it, and who has limited or full access. The user has the privileges to delete, reset, upgrade, or downgrade their access.
3. Account security: This allows customers to enable and manage the use of biometrics for verification.

Mobily has to make major security and data management improvements in order to improve overall performance, competitiveness, and sustain customer loyalty. This is in line with the empirical study of mobile commerce and customer security perception in Saudi Arabia conducted by [30]. They found that to sustain customer loyalty, customers must have a positive perception regarding the security of mobile apps.

5.2. Price

Figure 4 shows that the Zain app has the greatest weighted performance score (0.0699) for the pricing criteria, followed by the STC app (0.0523) and Mobily app (0.0359). The performance of the alternatives in detail with regard to the pricing sub-criteria is covered in the next sections.

5.2.1. Pricing Model

The analysis results, as shown in Figure 5b, show that the Zain app clearly outperforms its competitors in pricing models, as it achieved the highest performance value. This result may be somewhat surprising since pricing models are often similar in telecommunications companies (either prepaid or postpaid). The Zain app demonstrates this superiority due to a feature that was added to the pricing models, which enables customers to create their own internet and call plan that suits their needs and pay only for what they use. The Zain app differentiates itself by offering compelling pricing plans and bundles compared to the STC and Mobily apps. Price levels of the customers vary among different people, products, needs, brand credibility, income levels, and time. Therefore, STC and Mobily need to be more daring in their pricing strategy to offer better value for money to customers. As Figure 5d illustrates, the STC app attains a high degree of promotion compared to the Mobily app; so, this study suggests that they should redeploy resources to improve the price structures and offer compelling pricing plans and bundles. Mobily has to improve several areas of its pricing models. This study suggests several improvement areas related to the pricing model to attract a wider audience: (1) offering attractive bundles at competitive prices; (2) developing innovative pricing structures; (3) providing flexible and customizable pricing plans; (4) developing and enhancing loyalty programs to reward long-term customers with exclusive offers, discounts, and benefits; and (5) providing personalized offers and services based on AI data analysis.

5.2.2. Pricing Competitiveness

Figure 5b revealed that the Zain app has the best performance-weighted score for pricing competitiveness compared to the STC app and Mobily app. In Figure 5b, Zain's app shows its superiority in terms of pricing model over other alternatives. The reason for this is that Zain is working to implement competitive pricing models and better pricing strategies; it also expresses the extent of Zain's app compliance with the application of these strategies. The Zain app provides its customers with many innovative pricing plans (e.g., pay-as-you-go and flexible subscription plans), which shows how bold it is in employing such

competitive pricing plans. For example, Zain kept up its roaming service on data bundles, offering data services at competitive rates while roaming in the Gulf Cooperation Council (GCC) and a number of other countries. This allowed customers to stay in communication with one another on social media and the internet without having to purchase extra data while in the roaming country. STC has moderately competitive pricing and offers some competitive pricing elements. This study suggests that STC needs to focus on balancing cost with service quality and additional features, offering reasonable value without being the cheapest. Understanding the pain points related to the subscription price from the customer's point of view is another recommendation suggested by this study. This will give STC the opportunity to adjust pricing strategies according to the customer's needs and preferences. Again, the Mobily app scored the lowest on this sub-criterion, which means it is less competitive compared to the STC and Zain apps. The reasons behind this low score are not only related to whether they offer high or low prices, but could also be due to the lack of discounts and promotions compared to the Zain and STC apps; further, customers may see that Mobily app plans offer less value for the price compared to its competitors. As shown in Figure 5d, Mobily recorded the lowest level under the promotion criterion. This implies that one of the recommended strategies that Mobily might need to apply is to enhance the promotions. Besides, Mobily needs to revise its pricing strategy with the goal of identifying the cost areas that can be reduced without compromising service quality. In addition, this study suggests applying differential pricing strategies such as customer segment-based pricing, geographic-based pricing, time-based pricing, usage-based pricing, and loyalty-based pricing. In [9], Natarajan et al. (2017) mentioned that applying differential pricing strategies can not only increase sales but also improve profits. Such strategies could help Mobily to increase its market penetration, improve its revenues, enhance customer satisfaction and loyalty, achieve a competitive advantage, and achieve better demand management.

5.3. Place

As seen in Figure 4, the STC app leads in place as its score is the highest score. This indicates that the STC app has the most extensive app distribution channels and market reach among the three alternatives. In contrast, the Zain app has the lowest score under this criterion. This means that the Zain app relies on limited distribution channels and might suffer from a narrow market focus. While the Mobily app ranked second, it was not by a significant margin compared to its competitor, the Zain app.

5.3.1. App Distribution Channels

Figure 5c indicates that the STC app has the highest score in app distribution channels (0.0135). Both the Zain and Mobily apps achieved comparable scores in the app distribution channels, with Mobily scoring 0.0084 and Zain scoring 0.0087, indicating close performance. In fact, all alternatives use the same distribution channels, such as app stores, official websites, social media, and email marketing, which raises the question of why the STC app achieved a higher score when the distribution channels are similar. Actually, the STC app has distinguished itself from its competitors in its advertising and promotional campaigns (Figure 5d), market reach (Figure 5c), and marketing communication capabilities (Figure 5g). The STC app has a huge distribution network of more than 70,000 points of sale and has more than 230 branches [38]. Both Zain and Mobily providers need to support their app distribution channels. This study recommends using a mix of distribution channels such as influencer marketing, tech blogs and review sites, and in-app promotions. Furthermore, conducting demographic-specific campaigns that run promotions targeting specific demographics to increase downloads and usage can be beneficial.

5.3.2. Market Reach

As seen in Figure 5c, the STC app appears to have the best score of marketing reach (0.0343). The Mobily app has a score of (0.0183), which is lower than the STC app but better than the Zain app (0.0126). This highlights that the STC app has the broadest customer base among the alternatives. The STC app reached a large portion of the target market compared to the Mobily and Zain apps. Obviously, the number of downloads reflects the number of customers who have installed the app, which might be considered as a direct indicator of the telecom provider's reach in the market. On the Google Play Store, the STC app has received over 10+ million downloads compared to the Mobily app (5+ million) and Zain app (5+ million). Generally, the STC app has the highest number of downloads, which signifies a larger user base and market reach. The Zain app faces challenges in reaching potential customers compared to the STC and Mobily apps. This weakness in market reach indicates that despite the Zain app having an excellent product and service offering, it may not be effectively communicating its value to a broad enough audience. As shown in Figure 5d, both the Zain and Mobily apps are not performing well in terms of advertising and promotional campaigns. Therefore, this study suggests several potential strategies to improve market reach, such as (1) enhancing marketing campaigns by allocating more resources to marketing efforts to boost visibility and (2) developing creative and engaging marketing campaigns that highlight Zain's app strengths and differentiate it from competitors.

5.4. Promotion

As shown in Figure 4, STC has the highest score in terms of Promotion (0.0423). This reveals the superiority of STC in terms of advertising and promotional campaigns, as well as its ingenuity in designing discounts and offers. Zain is ranked second in this category with a score of 0.0233. Mobily shows the lowest achievement in this category (0.014). The subsequent sections discuss the possible reasons behind these scores and also suggest some recommended strategies that may improve the performance of alternatives in terms of advertising and promotional campaigns, discounts, and offers.

5.4.1. Advertising and Promotional Campaigns

Obviously, STC achieved the best score in terms of advertising and promotional campaigns (see Figure 5d). The strength of the STC app's advertising and promotional activities is evidenced by the numerous local and international awards it won [31]. These awards attest to the success of STC's marketing and promotion initiatives. Also, they reflect the intensity and diversity of investments made by the STC in advertising and promotional campaigns. The results of this achievement were reflected positively in the number of times the application was downloaded across various distribution channels (see Sections 5.3.1 and 5.3.2). The Zain app is ranked lower than the STC app but better than the Mobily app with a score of 0.0097. Zain's advertising approach is deemed to be somewhat effective. They participate in appropriate marketing campaigns, yet they are not as aggressive or effective as the STC app. In advertising and promotional campaigns, the Mobily app scores the lowest (0.0067). As a result of this limitation, the brand may have lower visibility compared to the STC and Zain apps. This study suggests allocating more resources to advertising and promotional campaigns to improve visibility. Also, it suggests enhancing digital marketing for more effective engagement with targeted audiences. In addition, this study recommends using a contextualized location-based advertising marketing strategy that aims to deliver highly relevant ads that are more likely to capture customers' attention. Several studies [8,39,40] ensure that contextualized location-based advertising positively affects consumers' perceived value.

5.4.2. Discounts and Offers

As shown in Figure 5d, the STC app has the highest score in terms of discounts and offers (0.0232), followed by the Zain app with the second-ranked score (0.0136). Mobily scores the lowest under this criterion (0.0073). The STC app was able to maintain its leadership in the market by taking advantage of special targeted offers called "only for you" that depend on a targeted marketing strategy, which is enabled by intelligent analyses of marketing campaigns, sales, customer base management, and loyalty programs called the "Qitaf loyalty program". The Zain app offers some discounts and promotions, but not as much as the STC app. Recently, the Zain app launched a new rewards program called "Zain Plus", which is relatively new compared to the "Qitaf loyalty program". Mobily offers fewer discounts and promotions compared to the STC and Zain apps. Mobily also has a loyalty program called "Neqaty". Although the STC, Mobily, and Zain apps provide discounts and have loyalty programs, the variations in the alternatives' ratings for offers and discounts might be due to several reasons, such as (1) frequency and variety of discounts, (2) the effectiveness and attractiveness of loyalty programs, (3) promotion and communication strategies, (4) customer experience and satisfaction, (5) customization and personalization of offers, (6) competitive positioning, and (7) overall market perception. Mobily and Zain need to pay more attention to their discount and offer programs. This study suggests increasing the discount program by applying several solutions such as expanding the discount range, implementing seasonal and event-based offers, and increasing the frequency of promotion. Several studies [8,41,42] have confirmed that frequent discounts have a positive effect on the purchase behavior of customers, leading to customer loyalty, an increase in the usage of apps, and increases in the value and profitability of the business. They ensure that customers with the highest monetary discount and discount frequency provide the highest value for the business. Despite the impression that frequent discounting has positive effects on purchase intentions, it can have negative results in the long run. Furthermore, in [43], Liu et al. (2021) found that higher discount expectations will negatively influence customers' purchase incidence and actual purchase behavior. Therefore, this study suggests that telecom providers should design their app discount strategy carefully to avoid negative effects. Also, in order to improve their competitiveness, they need to take customer discount expectations into account during the development of their app discount strategy. In addition, artificial intelligence and other cutting-edge technology might make it easier for telecom providers such as Zain and Mobily to implement either temporary and/or permanent discount strategies. For instance, they could target various customers in real-time based on their unique demographic and behavioral traits.

5.5. Customer

As shown in Figure 6, Zain has the highest score in terms of customers. This implies the superiority of Zain in addressing customer-related aspects, particularly in the "Customer Needs and Preferences" and "Customer Satisfaction" sub-criteria. Both STC and Mobily have scores that are quite close to each other, which indicates that their performance in customer criterion is very similar. The following sub-sections discuss the detailed comparison of these alternatives.

5.5.1. Customer Needs and Preferences

As shown in Figure 5e, the Zain app performs noticeably better than the Mobily and STC apps in recognizing and satisfying customer needs and preferences. The Mobily app has a score of 0.0161, while the STC app has a score of 0.0213. This indicates that the STC app outperforms the Mobily app in this particular domain. The difference between the STC app and Mobily app is small, indicating that their performance is quite close. Zain's app's

high ranking suggests that it has a strong user-centric strategy, providing features (see Figure 5a) and usability (see Figure 5f) that outperform other alternatives. In addition, Zain is likely to update its app to align closely with what its customers desire. The STC app has a moderate performance score. This means that the STC app comprehends the requirements and inclinations of its customers quite well, though there is room for improvement. To close the gap with the Zain app, both the Mobily and STC apps need to improve their tactics in order to better understand and cater to the demands and preferences of their customers. Additionally, they must give priority customer feedback and take their suggestions into account while developing and updating their apps.

5.5.2. Customer Satisfaction

In terms of customer satisfaction, the Zain app has the best performance score (0.0372), which reflects the app's effectiveness in meeting customer expectations. The performance scores of the STC app (0.0210) and Mobily app (0.0209) are equal and significantly lower than that of the Zain app (see Figure 5e). As discussed earlier, the Zain app showed its superiority over the STC and Mobily apps in several aspects such as feature set and innovation, user value proposition, problem-solving capabilities, app performance and stability, pricing model, pricing strategy alignment, pricing competitiveness, customer needs and preferences, navigability, user-friendliness, and customer support. Experts believe that Zain's app's success in customer satisfaction is due to a cumulative outcome of its dominance in the majority of evaluation criteria. This is consistent with the findings in previous literature. For example, ref. [23] ensured that the feature set and innovation have a significant impact on overall customer satisfaction. Consequently, Xu et al. (2015) [20] indicated that Mobily's app performance and stability have a positive effect on satisfying mobile app customers. In [9], Natarajan et al. (2017) found that there is a direct positive relationship between customer satisfaction and price. Interestingly, ref. [23] concluded that customer satisfaction and user value proposition have direct positive influences on the continual usage intention of mobile apps. The strengths that characterize the Zain app are considered gaps in the apps of both Mobily and Zain, which need further improvement if both companies are looking to improve their competitiveness.

5.5.3. Customer Segmentation

As seen in Figure 5e, the performance scores of customer segmentation of three alternatives are slightly different: STC app (0.0185), Zain app (0.0180), and Mobily app (0.0175). This indicates that all three telecom providers are effectively segmenting their customer bases. The reasons for this close scoring might be attributed to several underlying factors common to the telecom industry. For example, similar customers with comparable needs and preferences are frequently served by MTAs. Thus, this consistency in the customer base's demographics may lead to comparable segmentation tactics. In addition, all telecom providers often have access to advanced technologies and data analytics tools. As a result, there is a good chance that customers will be segmented according to comparable attributes including usage patterns, demographics, and behavioral data. Furthermore, similar segmentation models are produced by the general consistency of customer behavior in terms of mobile usage, data consumption, and service choices across different locations. Moreover, the three main services provided by telecom providers (e.g., voice, data, and messaging) are essentially comparable. This similarity in service portfolios necessitates similar segmentation tactics and strategies to target customer groups effectively. This study suggests that if telecom providers need to further distinguish themselves, they need to concentrate on unique customer insights, innovative segmentation techniques, and exclusive personalized offerings that go beyond industry standards.

While the similarity in segmentation strategies highlights industry-wide standards, differentiation becomes crucial for sustaining a competitive advantage. Studies conducted by [6,44] suggests that if providers seek to further distinguish themselves, they must prioritize unique customer insights, innovative segmentation techniques, and exclusive personalized offerings that extend beyond standard practices. A well-crafted MTA value proposition can help achieve this by delivering on its promises in ways that foster trust and build loyalty among customers. In [19], Weinstein (2001) found that delivering value propositions that align with customer-specific needs enhances trust by demonstrating that providers understand and address unique user pain points. Moreover, fostering loyalty requires leveraging segmentation insights to deliver value through exclusive loyalty programs, personalized offers, and innovative features that reflect customer preferences [19,20]. Telecom providers can segment users based on lifetime value or service usage to create reward systems that encourage retention. For instance, STC, Zain, or Mobily could offer loyalty points that convert into data bonuses or premium services for high-value customers.

5.6. Convenience

As shown in Figure 6, the Zain app is the most convenient with a score of 0.0534. The convenience score of the Mobily app is 0.0371, which puts it behind the Zain app but above the STC app. Lastly, the STC app gives the lowest convenience score (0.0272). The highest score of the Zain app indicates that the app is designed to be accessible and very user-friendly. The Mobily app offers an acceptable level of convenience but has room for improvement compared to the Zain app. The STC app is perceived as less convenient by experts, indicating a need for significant enhancements to improve user experience. The detailed comparison of these alternatives is discussed in the following sub-sections.

5.6.1. Navigability

As seen in Figure 5f, the easiest app to use to obtain information and perform tasks is the Zain app, which has the greatest navigability score. The Mobily app has a greater navigability score than the STC app but a lower score than the Zain app, which is regarded as having a moderate level of navigability. The STC app has the lowest score in navigability, which implies the difficulty in navigating the app compared to the Mobily and Zain apps. There is a consensus among all experts that the content and features of the Zain app are logically organized in a well-structured UI. Zain's app's UI is composed of well-organized navigation components (such as buttons, menus, tabs, and icons). Additionally, the app's links are all informative and easy to understand, making it easier for customers to figure out where to go next. Although Mobily's interface is well-organized, it might not be as comprehensive as Zain's app. For instance, even if they offer dependable navigation components, there may be a few little discrepancies that require improvement. Furthermore, while Mobily's app included informative buttons and links, it lacked the accuracy of Zain's app. The clarity and descriptiveness of links and buttons are essential for improving app navigability. For the STC app, multiple experts attributed the deterioration in the degree of navigability to several underlying problems within the app, such as the following:

- Limited visibility of navigation options: The experts found that some important options are hidden at the bottom of the screen or require scrolling without obvious access.
- Inconsistent iconography: Icons that are used to express some functionalities are confusing and mixed with text labels. This makes the process of identifying functionality challenging, especially for new customers.
- Unclear affordance for clickable items: The interactive nature of certain elements is not immediately apparent. The experts encountered some icons that seemed non-clickable

at first but then turned out to be clickable. Such a design makes it difficult to predict which icons are interactive.

- Hidden functionalities: Some important options are hidden deeply within menus or are not readily apparent. This will make it hard for customers to find these additional functionalities, which in turn leads to them being deprived of benefiting from the services of these functionalities.
- Lack of hierarchy: When every piece is given equal emphasis, it might be difficult to determine which is most important.
- Mixed mental models and information overload: It might be confusing to combine shop features with irrelevant features. For example, customers expect a homepage for the basic line functionalities, not for advertising and offering, managing, shortcuts, exploring packages, and upgrading.

STC's app developers need to give more attention to enhancing the overall app structure. For example, reorganizing the app's layout is necessary to create a more logical and intuitive structure for content and features. Also, conducting user testing to identify weak points and areas for improvement in the application architecture is important. Besides, STC's app developers need to ensure consistent navigation within the app interfaces and sections. This study suggests the use of unified navigation elements (menus and buttons) throughout all sections of the app. Maintaining visual consistency to help customers understand navigation patterns can contribute to enhancing overall app navigability. Lastly, links need to be optimized. Developers need to make sure that all links and buttons are clear, descriptive, and indicate exactly where they will lead. Enhancing the visibility of links and buttons and making them easily accessible is important to avoid hiding some important and beneficial functionalities.

5.6.2. User-Friendliness

As shown in Figure 5f, the Zain app dominates the rest of the apps in terms of user-friendliness as it achieved the highest score (0.0293). It was closely followed by the Mobily app, which showed fairly good performance (0.0177). The STC app achieved the worst score among these alternatives (0.0118). Experts attributed the superiority of the Zain app to several reasons, such as having a cleaner and simpler design. It makes effective use of whitespace and organizes information in a more structured way. Key functions are prominently displayed with clear icons. In addition, Zain's app interface is clearer and easier to read. This is due to the use of well-spaced texts that improve readability. Furthermore, the instructions are clear so the user can quickly understand what actions to take. Moreover, the design of Zain's app directs the user's attention to important actions without overwhelming them. Mobily's app score is higher than STC's but still far lower than Zain's, suggesting that while it is generally user-friendly, there are still a few areas that may require improvement. The user-friendliness score indicates that STC's app is not up to par. Experts have identified a number of issues that contributed to this outcome, including issues with readability and layout, complexity and cluttered interface, redundant login prompts, frequent freezing and crashing, accessibility of important features, and ease of navigation. The layout and design of the app give the impression that many things are vying for the user's attention. Such a crowded design with many elements close together can make it visually overwhelming for customers to find what they are looking for. Experts have noted that navigation is complicated by the excessive number of steps and clicks needed to obtain information or finish activities. In addition, the app regularly crashes or freezes on many occasions. This instability will make customers become frustrated and negatively impact their whole experience. Various studies conducted by researchers all across the globe affirmed that perceived ease of use and perceived enjoyment have a

positive impact on customer satisfaction and engagement with mobile apps [9]. Therefore, if both Mobily and STC want to increase the competitiveness of their apps, they must improve the user experience of their apps by focusing on simplification, intuitive design, consistent navigation, ensuring easy access to basic features, and maintaining a balance between aesthetics and functionality.

5.7. Communication

As shown in Figure 6, the Zain app has the highest performance in terms of communication. This indicates that Zain's app has high-quality techniques and approaches to communicate with its target customers. This means that the Zain app applies highly competitive communication strategies, which reflect its superiority in terms of marketing communication and customer support. Next, the performance of the STC app is slightly better than that of the Mobily app but significantly lower than the Zain app. Lastly, the Mobily app has the lowest performance score among the alternatives. Generally, both STC and Mobily need to improve their strategy regarding communication and reflect this strategy as functions and services available through their apps. Further analysis and discussion are presented in the following sections.

5.7.1. Marketing Communication

In Figure 5g, the Zain app has the highest marketing communication effectiveness. This implies that the Zain app adopts the highest quality customer interaction tools. The application provides a variety of communication channels (e.g., WhatsApp, call, social media) that enhance customer interaction with the company. The performance score of marketing communication in Zain's app (0.0186) is more than twice as high as STC's (0.0087), and Mobily's app is approximately 33% more effective than STC's app. This substantial disparity implies that Zain's app marketing communication plans and execution are considerably more successful. Therefore, STC has to analyze its marketing communication tactics in order to pinpoint areas in need of improvement. Besides, although the Mobily app is performing better than the STC app, Mobily should look into strategies employed by the Zain app to further improve its marketing communication. Hence, this study suggests a number of techniques, including performing comprehensive auditing of the marketing communication strategies that are already in use; seeking input from the target audience; and providing specific enhancements like enhanced customization, more captivating content, and quicker customer service response times. Incremental improvements would bridge the gap between the Mobily and Zain apps on the one hand and between the STC and Zain apps on the other hand.

5.7.2. Customer Support

As seen in Figure 5g, the Zain app has the most effective customer support as it has the highest performance score (0.0229). The Mobily app has a moderate performance score (0.0178), which indicates that it offers decent customer support but is not as effective as the Zain app. The STC app has the lowest performance score among the three alternatives (0.0127). Zain's app has several strong features that led to its superiority over other alternatives. For example, it offers comprehensive customer support tools that contain a variety of options including a knowledge base and the ability to submit tickets and contact information, report fraud, and give feedback. Such integrated support channels can lead to quick response time and a high-resolution rate to customer inquiries and issues. Mobily's app customer support page offers a few different ways to access help, but it is not as comprehensive as Zain's. For example, Mobily's app lacks an open ticket feature and the apparent absence of a dedicated fraud reporting option. This could lead to increased customer efforts and a lower resolution rate. STC's app integrates chatbots

for customer support. It is unfair to deny the advantages of chatbots as they offer many benefits, such as 24/7 availability, instant responses, and cost savings. However, there are also several drawbacks that companies like STC may face when using chatbots for customer support. For example, chatbots lack the personal touch and empathy that humans possess. Also, chatbots may not be able to provide adequate support for complex issues; further, the resolution time frames may be prolonged if escalation to human agents is required. In addition, the experts find that comprehensive customer support tools are more efficient than depending only on chatbots, which require a long conversation to find a solution. Strong performance in customer support positively contributes to higher customer loyalty and a positive brand reputation [23]. Therefore, addressing chatbot limitations and enhancing human support options could lead to improving the competitiveness of the STC and Mobily apps.

6. Future Research

This study might be expanded in the future by investigating other approaches to improve the assessment of MTAs utilizing fuzzy MCDM models. Given the delicate nature of transactions carried out through mobile platforms, adding more criteria to the evaluation framework—such as user privacy, QoS, and ethical considerations—is one encouraging avenue. Comparative research between different countries or global MTAs (e.g., My eir app and MyBell App) would improve the generalizability of the suggested model by providing insightful information about variations in user preferences, legal frameworks, and marketing tactics. Furthermore, by including dynamic feedback mechanisms, real-time evaluation systems that use machine learning techniques for dynamic weight modification and continuously adapt to user feedback and market changes may be made possible. Incorporating AI-driven personalization features to evaluate the effect of tailored promotional offers on customer satisfaction and engagement is another productive research avenue that could improve the model's promotion and communication criteria. Furthermore, the suggested fuzzy MCDM framework may prove versatile and successful in a variety of fields if it is applied to other industry sectors, including healthcare, e-commerce, and financial services. It is also advised to conduct longitudinal research to assess the long-term effects of model-guided changes on market share, client retention, and overall company performance. These potential avenues for further study would greatly aid in the ongoing creation of thorough assessment techniques for mobile applications across a range of sectors.

7. Conclusions

Telecom providers are turning to app-based marketing to gain a competitive edge due to the pressures resulting from the current fierce competition. Telecom providers are interested in how to create an ideal MTA by taking into account the role of the apps in technology, service, and marketing constructs. This study proposed a hybrid model comprising the 4Ps model, 4Cs model, Fuzzy set, and AHP for evaluating MTA effectiveness. The model used several visualization charts to map the evaluation results in order to identify the gaps within the MTA and provided some directions to telecom providers on how to improve overall MTA performance. First, an expert interview was conducted to extend the elements of the 4Ps and 4Cs models by identifying the sub-criteria that are related to the context of MTAs under each element. Second, the hierarchy structure was implemented and fuzzy AHP was applied to compute the weight of each criterion and sub-criteria. Third, a fuzzy performance decision matrix is constructed to calculate the performance of each alternative with respect to the evaluation criteria. Finally, three MTAs (e.g., STC app, Mobily app, Zain app) in the KSA were ranked in descending order. The evaluation results showed that the Zain app has a superior overall performance, the STC

app was second-ranked, and the Mobily app was the worst. In terms of 4Ps, the STC app was the best-ranked, followed by the Zain app and the Mobily app. Zain's app was the best ranked in terms of 4Cs, followed by the Mobily and STC apps. Both line and radar charts provided detailed insights into the performance of the MTAs. Line and radar charts provide comprehensive insights into MTA performance. The telecom providers may allocate resources more wisely by evaluating their competitive advantages and disadvantages in comparison to competitors and making necessary improvements to their present mobile app to reach the target level. The evaluation results showed that the Zain app has the highest competitive capabilities in terms of feature set and innovation, user value proposition, problem-solving capabilities, app performance and stability, pricing model, pricing competitiveness, customer needs and preferences, customer satisfaction, accessibility, user-friendliness, and customer support. However, it has the lowest competitive capabilities in terms of market reach. This indicates that despite the Zain app having an excellent product and service offering, it may not be effectively communicate its value to a broad enough audience. The STC app showed higher competitive capabilities than other competitors in terms of data management and security, app distribution channels, market reach, advertising and promotional campaigns, branding and messaging, customer segmentation, and marketing communication. The Mobily app showed acceptable performance in terms of problem-solving capabilities, market reach, accessibility, and user-friendliness. To apply app-based marketing effectively, the telecom providers should put efforts into improving these gaps associated with their apps. In addition, this study recommends that telecom providers leverage the opportunities provided by artificial intelligence to improve and develop their applications. Artificial intelligence provides a wealth of opportunities for telecom service providers to enhance their mobile applications by providing many features including personalized usage insights, chatbots and virtual assistants, automated ticket resolution, tailored offers and plans, content recommendations, natural language search, voice assistants, automated notifications, customer engagement, customer feedback analysis, contextual help, multilingual support, and anomaly detection. However, this study has some limitations that are related to generalizability and qualitative data. Initially, survey information was gathered from a limited number of visits to every app within a designated period. Therefore, conducting similar evaluations at various periods is likely to yield different findings because of the extremely dynamic nature of these apps. Secondly, expert opinions are used to assign the weight of evaluation criteria and to determine the performance of each alternative. Expert opinions are inherently subjective and can be influenced by personal experiences, biases, and preconceived notions. This can lead to biased conclusions that may not accurately reflect reality.

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