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Original Article

A Hybrid Business-Technical Model for Evaluating IoT Platforms' Functionality, Reliability, and Usability

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Abstract *- The implementation and effectiveness of IoT platforms are crucial for data analysis, process optimization, and service control in various sectors. However, evaluating IoT platforms can be challenging due to the lack of detailed technical indicators related to reliability, functionality, and usability and the need to consider business aspects. This study aims to build a comprehensive model for evaluating IoT platforms that meet both the technical requirements and business needs of companies. The study's objective is to determine the functionality, reliability, and usability sub-criteria and measures necessary to evaluate IoT platforms and the business success factors affecting their relative importance in companies based on comparative studies and experts' views. The Fuzzy Delphi method was utilized for the validation process of the proposed model. The items of the proposed model, including assessment criteria, sub-criteria, measures, and factors affecting their relative importance in companies, reached the experts' agreement, except for two sub-criteria that did not meet the assessment requirements. The final analysis indicates that the assessment model includes three main evaluation criteria, twelve sub-criteria with twelve measures, and five factors that affect their relative importance in companies. This study provides an important contribution to the field of IoT platform evaluation and can help decision-makers select the most suitable platform for their specific needs in various sectors.*

Keywords *- Business-technical model, Business success, Criteria for IoT platform evaluation, Functionality, Reliability, Usability.*

1. Introduction

The fourth industrial revolution has caused significant global economic changes and notably influenced various industries [1]. The use of Internet of Things (IoT) technology has become essential for business success in many critical fields, such as industry, medicine, agriculture, and others. While this technology is very useful, choosing IoT platforms for enterprises without considering the needs of different businesses can reduce the benefits these enterprises can gain [2]. Therefore, decision-making processes associated with selecting IoT platforms that meet business requirements are necessary and important to maximize the business benefits associated with using this technology and have become part of enterprise business decision support systems [3].

Evaluating IoT platforms aims to make optimal use of IoT technology in enterprises practically and effectively and determine their suitability for achieving institutional goals. This will help decision-makers choose the most appropriate platform for application, improve performance, increase efficiency, maximize productivity, and improve the quality of services [4]. The ideal platform possesses the capabilities of functionality, security, usability, reliability, integration, and other technical capabilities appropriate to the organization's needs and objectives. It is supportive of promoting, improving, and advancing its success factors [2].

Organizations increasingly rely on Internet of Things (IoT) platforms to collect, store, process, and analyze data from multiple sources and devices in today's competitive business environment. This data can be utilized to make better business decisions, improve efficiency, and reduce costs [5]. For instance, healthcare organizations can leverage IoT to enhance patient care, make informed business decisions, and reduce costs. By collecting and analyzing data from IoT devices, such as remote patient monitoring devices, drug delivery devices, surgery devices, and telemedicine services, healthcare organizations can gain insights that can be used to identify patients who are at risk of developing complications and intervene early to prevent these complications from occurring; identify patients who are not adhering to their medication regimens and provide them with interventions to improve adherence; identify areas where they can improve the accuracy and safety of surgery; and identify areas where they can improve the quality of care and reduce costs [6–8].

In addition to improving patient care, making better business decisions, and reducing costs, IoT can also be used to support sustainable development and corporate social responsibility initiatives [9]. For example, by using IoT to reduce the number of unnecessary hospital visits, healthcare organizations can reduce their environmental impact. By using IoT to improve the efficiency of their operations, healthcare organizations can reduce their operating costs and reinvest these savings in other initiatives, such as improving patient care or supporting sustainable development.

While IoT platforms offer a wide range of benefits for businesses, significant challenges can limit the realization of these benefits. One of these challenges is that small enterprises, especially in developing countries, may not have the technical knowledge and skills necessary to choose the appropriate platform for their applications [2, 10, 11]. Another challenge is that many different IoT platforms are available, and each platform has its own strengths and weaknesses [11, 12]. Some platforms are better suited for certain industries or applications than others. Additionally, the capabilities of IoT platforms vary widely. Some platforms are more powerful and feature-rich than others [2, 10–12]. In addition, choosing the wrong IoT platform can have a negative impact on a business [13]. For example, a platform that does not meet the functional requirements of a business may not be able to collect the data that the business needs to make informed decisions. Additionally, a platform that does not have the appropriate tools and techniques to detect and address threats to business reliability may put the business at risk [14]. The heavy dependence on technology can exacerbate these challenges, particularly given the security risks associated with the information it handles [15].

In practice, this problem requires multi-criteria decision-making, which involves the following steps: identifying business objectives from the perspective of business theories and models, including identifying the priorities and relative importance of these objectives to the company [16]. These objectives can then be used as benchmarks for comparing the technical characteristics and criteria of different IoT platforms, determining their importance and role in the success of the business, analyzing and identifying key technical characteristics and sub-criteria of platforms that support the achievement of the objectives, including criteria for usage, reliability, and functional suitability, as well as their subsidiary characteristics, prioritization, and relative relevance from the perspective of their respective contributions to the achievement of the objectives [17]; and building a multi-level hierarchical framework, including weighted elements, for the main technical characteristics or criteria and sub-criteria of different IoT platforms. This framework can then be used as a platform assessment tool, enabling stakeholders and companies to evaluate, rank, and choose the appropriate platforms for their businesses [2, 11, 12].

1.1. Problem Statement

To ensure effective data analysis and service control in institutions, overcoming the challenges limiting IoT platform implementation and effectiveness is crucial. Therefore, building frameworks that help companies evaluate IoT platforms that meet their business requirements and objectives is necessary to align the business requirements of enterprises with the technical capabilities of the platforms and determine the success or failure of the application and use of IoT technology.

However, researchers have investigated the problem of evaluating IoT platforms, but several issues remain:

- Lack of detailed technical indicators related to reliability, utilization, and effectiveness
- Ignoring business aspects
- Failure to take into account ambiguous appropriate assessment values that take into account the uncertainty that exists in the case of developing indicators to determine precisely the level of approval

Most of the efforts have resulted in general frameworks that unfairly focus on certain aspects and lack detailed technical indicators related to reliability, utilization, and effectiveness, which need further investigation. For example, Aseman et al. (2019) aimed to provide a comprehensive definition and describe the main characteristics of IoT platforms. However, their work was limited to aspects and characteristics of data management and analysis [17]. Ullah and Smolander (2019) proposed a framework of 21 IoT assessment criteria [11], which included only two reliability criteria (redundancy and disaster recovery) and one usage standard (attractive interface). Abdallah et al. (2019) proposed a quality model of 20 criteria for IoT systems [18], but only three general criteria were proposed for usage, reliability, and functional alignment. These criteria were not defined in detail. Salami and Yari (2018) proposed a five-dimensional framework of 26 criteria, but only three general criteria were defined for accessibility, usability, and reliability [19]. These criteria were not defined in detail. Most studies have focused on the areas of security, integration, and data. For example, De Nardis et al. (2022) used a model with five criteria (communication protocols, data processing, data visualization, integration, and security) to compare IoT platforms for academic research and development [20]. In [21], Bures et al. (2020) provided a comprehensive look at the quality characteristics of IoT solutions, including 16 key features. However, they did not address functional indicators or reliability standards adequately. Ismail et al. (2018) proposed eight criteria for the performance evaluation of open-source IoT platforms, including programming language, supported SDKs, security, device management, data visualization, data analytics, and supported databases [22]. Babun et al. (2021) focused on factors related to communication, security, and privacy [15].

Although previous studies have focused on criteria such as security and data integration, they have overlooked important factors like usability, functionality, and reliability. Additionally, these studies have only provided general frameworks for evaluating alternatives from a technical perspective without explaining how these criteria relate to meeting business requirements. In contrast, using assessment frameworks built solely on technical aspects can lead to confusion among experts and make it challenging for organizations to compare and evaluate different platforms. This can also lead to a bias towards technical solutions that may not meet the overall business requirements. To address this problem, Nylander et al. (2017) suggest integrating business models into the platform selection process [23]. The chosen platform should possess relevant core capabilities that align with the organization's objectives to ensure success.

Furthermore, most of the studies were survey studies, and two studies [2] and [11] used the traditional Delphi technique to measure agreements on the proposed model, which does not consider the uncertainty in many situations.

1.2. Objectives of the Study

In light of these considerations, this paper aims to overcome the limitations observed in existing research by integrating the Fuzzy Delphi method to develop a comprehensive evaluation framework for IoT platforms. The novelty of this work lies in its incorporation of detailed technical indicators related to functionality, reliability, and usability, along with a focus on addressing business aspects.

To achieve this objective, the study addresses the following crucial questions:

Q1- What are the crucial criteria and measures that comprise the evaluation framework of IoT platforms' functionality, reliability, and usability?

Q2- What are the crucial business factors that affect their relative importance in companies?

The research intends to provide a more thorough and comprehensive framework that bridges the gap between technical considerations and business requirements by answering these questions. This framework will enable stakeholders and companies to evaluate and compare different IoT platforms effectively, considering both their technical capabilities and alignment with overall business objectives. By integrating the Fuzzy Delphi method, which allows for considering uncertainty and aggregating expert opinions, this research aims to provide a more robust and comprehensive evaluation framework. This approach will enhance the decision-making process for selecting the most suitable IoT platform, leading to improved alignment with business requirements and increased chances of success.

The study is structured as follows: in Section 2, a literature review is conducted to provide context. It reviews and compares the different models and theories that have been applied to evaluate the contributions of IoT technology to business success. It also reviews and compares the different models and theories applied to evaluate functional alignment, reliability, and usability. This will form the foundation for developing a new hierarchical framework and model for evaluating IoT platforms in enterprises. Section 3 describes the materials and methods used, while Section 4 presents and analyzes the results. Section 5 offers the final Hybrid Business-Technical Model for Evaluating IoT Platforms' Functionality, Reliability, and Usability. The last two sections cover the study's applications, limitations, and future works, followed by a conclusion.

2. Literature Review

2.1. IoT for Business Success

Business success is a multifaceted term that encompasses achieving predefined goals and objectives within a business. Atmaja et al. (2023) note that these objectives may include generating revenue, establishing financial stability, and exceeding profits that surpass business expenses [24]. Additionally, In [25], Ayayi and Wijesiri highlight that financial goals are a significant component of business success, while Lee et al. (2023) note that non-financial objectives such as customer satisfaction and employee well-being are equally essential for sustainable success [26]. Therefore, effective planning, executing, and achieving desired results can help businesses achieve a balance between monetary and non-monetary goals, leading to business success. Therefore, business success can be conceptualized as achieving a balance between monetary and non-monetary goals through effective planning, executing, and achieving desired results.

Gayialis et al. (2022) note that manufacturers can leverage IoT technology to achieve predictive maintenance by using sensors to monitor equipment and machines in real-time [27]. According to [28], manufacturers can analyze the sensor data to predict when maintenance is required, reducing downtime and increasing overall efficiency. Additionally, researchers note that IoT devices can improve supply chain efficiency by providing real-time data on the location and status of raw materials, finished goods, and inventory levels, minimizing waste and enabling better supply chain management [29]. Soori et al. (2023) also state that IoT increases productivity by monitoring employee performance, identifying opportunities for improvement, and optimizing production processes [28].

According to [30], enhanced efficiency during the manufacturing process is one of the foremost advantages of IoT in expanding market share and offering a range of benefits for this sector. IoT technology can connect machines and devices, making factories operate streamlined and automated, minimizing human intervention and improving overall productivity. Additionally, manufacturers can use real-time data on machine performance, product quality, and process efficiency provided by IoT to identify and fix issues quickly, thereby further improving productivity.

Furthermore, IoT can provide real-time data on machine performance, product quality, and process efficiency, enabling manufacturers to identify and fix issues, thereby improving overall productivity [31].

In healthcare, IoT has shown its potential to enhance customer satisfaction. Belfiore et al. (2022) note that healthcare providers use remote monitoring and smart sensing technologies to track patients' health conditions and collect data in real-time [8]. This data can be analyzed to identify patterns, diagnose diseases, and provide personalized treatment plans.

Remote patient monitoring ensures that patients receive timely and relevant information about their health and enables them to take better care of themselves, leading to increased patient satisfaction. Studies [32] and [33] provide detailed insights into the role of IoT in healthcare, specifically exploring its use for remote monitoring and smart sensing technologies to track patients' health conditions and collect data in real-time.

2.2. Criteria for Evaluating IoT Platforms' Functionality, Reliability, and Usability

2.2.1. Functionality: Challenges, Requirements, and Criteria for IoT Platform Evaluation

Organizations have different objectives and business orientations, which lead to varying functions they aim to achieve through their reliance on IoT systems [34]. Some organizations rely on simple IoT systems that collect basic data, such as temperature and humidity levels, for monitoring purposes. These systems are used to ensure that the environment is conducive to the organization's operations. Other organizations require more complex IoT systems that collect and analyze motion detection data and sound levels for control purposes, with a higher level of complexity, such as adjusting hardware settings. These systems are used in industries such as manufacturing, where precision is critical.

Some organizations require highly specialized or complex tasks related to their business that require collecting and analysing highly specialized sensor data, such as biometric data. This data type provides advanced automation, such as occupancy pattern-based control and control of highly specialized devices such as medical equipment [7]. In contrast, some organizations require higher functional levels related to collecting and analysing very large amounts of real-time sensor data [35]. These organizations need highly customized automation based on the user's specific preferences and needs, and they need to control highly specialized devices with maximum accuracy.

Also, some businesses require advanced applications that integrate machine learning or artificial intelligence with the system to provide secure data exchange [8]. These applications provide predictive analyses or personalized recommendations based on user preferences.

Additionally, blockchain technology can be integrated into these systems to ensure secure data exchange between different parties. Therefore, the comprehensiveness of the functions provided by an IoT platform should align with the specific requirements of an enterprise's business needs.

In addition, different platforms may provide the same level of functionality, but their appropriateness may vary depending on the specific requirements of an enterprise's business [36]. For example, two platforms may both provide advanced analytics capabilities. However, one platform may be more appropriate for a business that requires real-time processing and analysis of large volumes of data. In contrast, another platform may be more appropriate for a business that requires more complex machine learning algorithms.

2.2.2. Reliability: Challenges, Requirements, and Criteria for IoT Platform Evaluation

Ensuring high reliability on an IoT platform requires a thorough understanding of critical systems and data and the potential risks and impacts of downtime. The authors highlight the importance of reliability in IoT systems for industrial applications [37]. Wang et al. (2020) emphasize that companies must first identify their critical systems and data, then assess the available platforms to choose the one for which reliability risks are minimal [38]. In addition, according to [37] and [38], different businesses have different requirements for reliability. For example, a logistics company may require high reliability to ensure that shipments are always tracked and delivered on time. In contrast, a financial institution may require high reliability to ensure that transactions are always processed accurately and securely. By understanding their specific business needs, companies can choose an IoT platform that meets their reliability requirements while minimizing risks.

However, the reliability capabilities for selecting IoT platforms include fault detection, fault tolerance, and timely recovery [38, 39]. Fault detection refers to an IoT platform's ability to detect when devices are tampered with or failing before faults occur. Fault tolerance, on the other hand, refers to the ability of an IoT platform to continue operating even if one or more components fail. Fault tolerance mechanisms can include redundancy, load balancing, and fail-over mechanisms that ensure critical services remain available even if one component fails [40]. Timely recovery refers to an IoT platform's ability to recover data in the event of an interruption or failure.

From another perspective, different IoT platforms can have different reliability capabilities and mechanisms [37–39]. For example, different IoT platforms may use various algorithms, such as tamper-resistant algorithms and predictive maintenance techniques, to analyze device behavior patterns and identify anomalies for fault detection. Different IoT platforms also have varying redundancy capabilities, such as automatic failover, manual intervention, multiple availability zones, replication of data across multiple data centers, and multi-regional storage. In addition, the load balancing mechanisms on IoT platforms include various mechanisms, such as Elastic Load Balancing, Azure Load balancing, and Cloud Load Balancing [41]. Furthermore, fail-over mechanisms to ensure that critical services remain available even if one component fails can include DNS failover, virtual machine replication for disaster recovery purposes, and the promotion of replica database instances to primary instances in the event of a failure. Different IoT platforms may also have different capabilities and mechanisms for timely recovery, which allows an IoT platform to restore services after a failure or disaster has occurred, ensuring business continuity and minimizing downtime. These capabilities and mechanisms depend on the platform's architecture, features, and integration with third-party solutions.

The specific reliability mechanisms offered by different IoT platforms can vary widely depending on the platform's architecture and design. Therefore, organizations have different objectives and business orientations that lead to varying reliability capabilities they aim to achieve through their reliance on IoT systems. As different IoT platforms can have different reliability capabilities and mechanisms, companies should ensure that the selected platform has the necessary availability, fault detection, redundancy, load balancing, fail-over tolerance, and disaster recovery mechanisms.

2.2.3. Usability: Challenges, Requirements, and Criteria for IoT Platform Evaluation

Usability is a crucial aspect to consider when evaluating IoT platforms. It refers to the extent to which a platform can be used by its intended users to effectively, efficiently, and satisfactorily achieve their goals. Usability can be broken down into several sub-criteria, including usefulness, accessibility, operability, evolvability, learnability, memorability, user error protection, and user interface aesthetics. In this section, we will discuss each of these sub-criteria in more detail and explain why they are important for companies to consider when selecting an IoT platform. Usefulness capabilities are important for companies to meet their specific requirements and goals, which may differ depending on the industry [42]. Different platforms have different usefulness capabilities and mechanisms depending on their design and intended use [3], such as a smart home platform offering remote control of appliances. In contrast, an industrial platform offers predictive maintenance. Therefore, companies must carefully consider their needs and choose a platform that aligns with their goals. For instance, a manufacturing company may require an IoT platform to monitor and optimize their production processes to increase efficiency and reduce costs. In contrast, a healthcare company may require an IoT platform to monitor patients' real-time health data to provide better care and improve patient outcomes. The mechanisms used by these platforms to achieve their usefulness goals may also differ; for instance, a smart home platform might use voice recognition technology, while an industrial platform might use machine learning algorithms [43].

Also, accessibility, operability, and evolvability are critical factors for companies to consider when selecting an IoT platform. They can have a significant impact on the platform's overall effectiveness and adoption [44]. Companies prioritizing these capabilities can ensure that their employees and customers can use the platform effectively, regardless of their individual needs. Different companies have different needs depending on their industry and user base. For example, a healthcare company may require an IoT platform accessible to patients with disabilities or limited mobility. In addition, different platforms also have different accessibility, operability, and evolvability capabilities depending on their design and intended use. For instance, a smart home IoT platform might use voice recognition technology to make it more accessible for users with limited mobility or vision impairments while also being highly operable and evolvable for all users.

Furthermore, the capability of an IoT platform to provide users with an intuitive and easy-to-learn interface [2, 10] is crucial for companies, as it can significantly impact user satisfaction, productivity, and, ultimately, the product's success. An easy-to-learn and use platform can reduce training costs and increase user adoption rates [45]. Additionally, a memorable platform can reduce the time and effort required for users to re-learn how to use it after periods of non-use. Different companies have different needs when it comes to learnability and memorability. For example, a company that develops IoT solutions for healthcare may require a more intuitive interface with clear navigation and minimal distractions.

On the other hand, a company that develops IoT solutions for manufacturing may require a more technical interface with detailed analytics and real-time data. Different platforms also have different capabilities and mechanisms regarding learnability and memorability. For instance, some platforms may use machine learning algorithms to personalize the user experience based on their behavior patterns [46]. Other platforms may provide interactive tutorials to guide users through the learning process.

Furthermore, the capability of an IoT platform to protect users from making errors that could lead to unintended consequences or harm is crucial for companies, as it can significantly impact user satisfaction, safety, and, ultimately, the product's success. A platform that provides effective user error protection can reduce the risk of accidents or data loss caused by user mistakes [47]. Additionally, it can increase user confidence and trust in the product. Different companies have different needs when it comes to user error protection. For example, a company that develops IoT solutions for home security may require a platform with robust error protection features to prevent accidental disarming of alarms or unlocking of doors.

On the other hand, a company that develops IoT solutions for agriculture may require a more lenient error protection system, as mistakes are less likely to result in harm. Different platforms also have different capabilities and mechanisms regarding user error protection. For instance, some platforms may use machine learning algorithms to predict and prevent potential errors before they occur [48]. Other platforms may provide clear and concise error messages with actionable steps on how to correct mistakes.

Finally, the capability of an IoT platform's user interface to be aesthetically pleasing, attractive, and likable for users when they are accomplishing specific tasks is also crucial for companies, as it can significantly impact user satisfaction and, ultimately, the product's success. A platform that provides a visually appealing and intuitive user interface can increase user engagement, reduce frustration, and improve the overall user experience. Different companies have different needs when it comes to user interface aesthetics. For example, a company that develops IoT solutions for healthcare may require a platform with a clean and simple interface to ensure ease of use for elderly patients. On the other hand, a company that develops IoT solutions for gaming may require a more visually stimulating interface to enhance the gaming experience. Different platforms also have different capabilities and mechanisms regarding user interface aesthetics. For instance, some platforms may use color schemes and typography to create a consistent brand identity, while others may use animations and transitions to provide visual feedback.

2.3. The Crucial Factors for Business Success

Modern business theories, such as Customer Relationship Management (CRM), market segmentation and targeting, branding, and financial management, emphasize several key factors for a successful IoT platform. Customer-centricity is a core principle of many modern business theories, emphasizing the importance of building and nurturing customer relationships to drive business success [49]. Alexander Osterwalder developed the Value Proposition Canvas [50], which helps businesses clarify their value proposition and align it with customer needs and expectations.

Additionally, market segmentation and targeting techniques focus on identifying and understanding specific customer groups, enabling businesses to tailor their marketing efforts to the needs and preferences of those groups [51]. A strong brand identity is fundamental to branding theory [52], differentiating a company from its competitors and resonating with customers. Financial management theory emphasizes the importance of sound financial planning, budgeting, and accounting practices to ensure a company's long-term financial stability and success [53]. These theories inform the key factors for a successful IoT platform, which include customer focus, a clear value proposition, defined target markets, a strong brand identity, and a sound financial foundation. The platform must have reliable functionality, usability, and interface design that align with these factors to achieve success.

2.3.1. Customer Focus

Successful businesses must focus on meeting the needs of their customers, and the IoT can help companies achieve this goal by collecting data about customer behavior [36], [37], [39], [47], and [48]. The data can then be used to improve products and services, personalize experiences, and build stronger customer relationships [36]. However, an IoT platform's functionality, reliability, and techniques to support customer focus can vary by industry and customer needs. For example, a manufacturing company may require an IoT platform with strong data collection capabilities to identify equipment problems before they disrupt operations, while a transportation company may need an IoT platform with strong tracking and monitoring capabilities to improve efficiency and safety. In addition, the interface and reliability of the IoT platform are also important. For instance, in manufacturing, the interface needs to be easy for nontechnical workers, while in transportation, it needs to be easy for fleet managers and drivers. Thomas et al. [47] and Oztekin et al. [48] discuss usability evaluation criteria for IoT and eLearning systems, respectively, which are important for ensuring that IoT platforms are user-friendly and meet the needs of nontechnical workers and fleet managers.

2.3.2. Clear Value Proposition

A clear and concise value proposition is essential for businesses to differentiate themselves from their competitors [50]. The IoT platform can play a key role by collecting, analyzing, and visualizing data from sources like sensors, machines, and devices. This data can be used to improve services, increase efficiency, and reduce costs [50]. However, an IoT platform's functionality, reliability, and techniques vary depending on the company's size, industry, and expertise. For instance, a small business may only need a basic IoT platform to collect a few sensor data points, while a large business may require a more complex IoT platform to collect data from thousands of sensors and devices.

Similarly, companies operating in critical environments like hospitals or power plants may need a more reliable IoT platform than those in non-critical environments. Companies monitoring and controlling more equipment may need a more complex platform capable of handling data from multiple sources. Companies with more technical expertise can likely use a more complex platform than those with less expertise.

Wedel and Kamakura [51] discuss the use of IoT in the cotton harvesting and processing industry and how the functionality and reliability of an IoT platform can vary depending on the specific industry. Ray [36] provides a survey of IoT cloud platforms and their capabilities, which is directly relevant to the text as it discusses how the functionality and reliability of an IoT platform can vary depending on the specific platform chosen by a company. Study [52] discusses the importance of strategic brand management and how it can affect a company's expertise in using an IoT platform. This is relevant to the text because it shows how a company's expertise can affect the techniques it uses when leveraging an IoT platform to improve its services, increase efficiency, and reduce costs.

2.3.3. Defined Target Markets

An IoT platform's ability to help companies achieve well-defined target markets depends heavily on its usability and reliability [47]. An IoT platform can collect, analyze, and visualize customer behavior and product usage data to enable targeted marketing and personalized experiences for specific customer groups. However, an unusable or unreliable IoT platform can significantly undermine these efforts [39]. It may be impossible to collect the needed device data for customer segment analysis and campaigns, and even the collected data may be inaccurate, undermining insights and effectiveness [39]. This can cause customer frustration, dissatisfaction, and lost sales. Security issues from an unusable or unreliable platform may also risk data privacy compliance. Therefore, the usability and reliability of an IoT platform are critical to achieving targeted marketing.

Thomas et al. [47] discuss the importance of usability in evaluating IoT platforms for targeted marketing. Study [49] provides insights into how IoT platforms can collect, analyze, and visualize customer behavior and product usage data to enable targeted marketing and personalized experiences for specific customer groups. Osterwalder et al. (2015) [50] discuss the importance of having a clear and concise value proposition for businesses to differentiate themselves from their competitors. Wedel and Kamakura (2012) [51] provide a comprehensive overview of market segmentation's conceptual and methodological foundations, essential for targeted marketing. Keller (2013 [52]) discusses the importance of strategic brand management and how it can affect a company's expertise using an IoT platform. Finally, Brigham et al. (2015) [53] provide insights into financial management, which is essential for companies looking to invest in IoT platforms for targeted marketing.

2.3.4. Strong Brand Identity

An IoT platform can significantly enhance a company's brand identity by improving the customer experience through personalized recommendations, real-time information, and engaging experiences. To achieve this, the IoT platform must support tracking customer behavior, optimizing processes through automation and reporting, and creating engaging experiences [48]. The platform also needs to have an intuitive and easy-to-learn interface for usability and error protection measures for reliability. High reliability through 24/7 availability is also crucial to enable employees to check inventory levels, view orders, and process returns with minimal manual intervention during failures [42]. A reliable and user-friendly IoT platform with a functional and usable design can create improved, engaging customer experiences, ultimately enhancing a company's brand identity.

2.3.5. Sound Financial Foundation

Meeting key functionality, usability, and reliability criteria for an IoT platform is essential to avoiding substantial financial losses for businesses. Non-compliance can increase costs and decrease efficiency through issues like a user-unfriendly design that is difficult for employees and customers to use, leading to decreased adoption and productivity. Usability issues can also cause more errors with negative consequences like lost revenue, damaged reputations from frustrated customers, and even safety risks [47]. An IoT platform that lacks the required functionality may fail to collect the needed operational data, resulting in lost revenue opportunities. Additionally, an unreliable or non-functional IoT platform can damage a company's reputation when IoT-connected devices fail or customer privacy is violated, leading to lost customers, decreased trust and loyalty, and reduced market share. Therefore, To avoid financial losses, decreased efficiency, lost revenue, damaged reputation, decreased adoption, and errors, it is essential to meet the key criteria of IoT platforms, including functionality, usability, and reliability [54 -57].

2.4. Literature Review Analysis

Several models and tools for evaluating IoT platforms have been proposed through the analysis of these studies, which can be observed as follows: Different methods and mechanisms of assessment, such as Delphi, Fuzzy Delphi, and traditional statistical methods, create diversity in the level of depth in the sub-criteria of functional dimensions, reliability, and usage. Most of these studies dealt with these dimensions as general dimensions without elaborating, while others deepened the detailed criteria of one of these areas.

In addition, there are a variety of sub-criteria for functional dimensions (F), Reliability (R), and Usability (U). Most of the studies participate in the following sub-criteria: Two sub-attributes, Functional Completeness (FC) and Functional Appropriateness (FA), are included under the Functionality dimension (ESC-F). Six sub-attributes, including Availability (AV), Fault Detection (FD), Redundancy (RE), Load Balancing (LB), Failover (FO), and Timely Recovery (TR), are included for the Reliability dimension (ESC-R). Six sub-attributes, including Usefulness (US), Accessibility (AC), Operability (OP), Learnability and Memorability (LM), User Error Protection (EP), and User Interface Aesthetics (IA), are included within the Usability dimension (ESC-U). Also, there are a variety of business success factors that affect the relevance of these criteria or sub-criteria in terms of business success drivers.

These Business Success Factors (BSF) include a strong Customer Focus (CF), a clear and concise Value Proposition (VP), well-defined Target Markets (TM), a strong Brand Identity (BI), and a sound Financial Foundation (FF). Table 1 presents a summary and analysis of different research studies that have evaluated IoT platforms.

It provides a comparison of these studies, highlighting their similarities and differences on four main axes: (1) General Evaluation Criteria or attributes (EC) addressed by them, including F, R, and U; (2) Sub-criteria evaluation attributes addressed under each main criterion; (3) Business Factors (BSF) affecting the importance of the main criteria and the way they are referred to, Directly (D) or Implicitly (I); (4) The culmination of the study (CS), whether it is Technical (T), Business-oriented (B), Hybrid (H), or an application of an existing model (A).

2.5. Fuzzy Delphi Method

Fuzzy MCDM methods have increased in various fields, including engineering, management, finance, and environmental studies.

Kaufman and Gupta introduced the Fuzzy Delphi Method (FDM) in 1988 [58]. It is a decision-making method that combines the Delphi technique with fuzzy set theory. It is used to make decisions in situations with a lack of clear-cut information or a high degree of uncertainty [59]. The FDM is a powerful decision-making tool that can be used to make better decisions and draw accurate and trustworthy statistical conclusions in various situations. Although relatively new, it has gained popularity in recent years due to its ability to deal with uncertainty and imprecision.

The Fuzzy Delphi Method (FDM) was developed to address the limitations of the traditional Delphi technique [54–56]. While the Delphi technique is a powerful tool that can be used to bring experts together to reach an agreement, it can be time-consuming and expensive [60]. Additionally, it is susceptible to groupthink, a situation where the desire for harmony within a group results in a failure to critically evaluate ideas.

The FDM addresses these limitations by allowing for the pooling of expertise and removing bias. By pooling the expertise of a group of people, the FDM can produce estimates or judgments that are more accurate than those that any one individual could produce. Previous studies indicate that participants can anonymously provide their estimates or judgments through the FDM, which removes bias and ensures that their opinions or personal biases do not influence them.

Table 1. A review and analysis of different IoT platform evaluation studies

	EC			**F**		**R**						**U**						**BSF**					**CS**
	F	**R**	**U**	**FC**	**FA**	**AV**	**FD**	**RE**	**LB**	**FO**	**TR**	**US**	**AC**	**OE**	**LM**	**EP**	**IA**	**CF**	**VP**	**TM**	**BI**	**FF**	
[2]								✓			✓						✓						T
[37]								✓			✓						✓						A
[3]		✓		✓								✓											T
[54]						✓																	T
[14]	✓			✓	✓	✓												✓					H
[21]		✓	✓			✓		✓					✓		✓	✓	✓						T
[18]	✓	✓	✓																				T
[19]		✓	✓					✓				✓	✓	✓	✓	✓							T
[39]		✓				✓	✓	✓	✓	✓													T
[55]																			✓	✓	✓	✓	B
[56]																		✓	✓				B
[57]																		✓			✓	✓	B

The optimal number of experts to include in a Delphi study is not fixed. It can vary depending on several factors, including the issue's complexity, the expert panel's diversity, and the desired confidence level in the results. Therefore, there is no definitive answer to determining the appropriate sample size for a Delphi study. While some researchers have suggested that a sample size of 10–15 experts is sufficient for most Delphi studies [60], other studies have used a sample size of 13–15 experts [59–61]. In some cases, studies have targeted 15 experts with at least ten years of experience [62–63]. The Fuzzy Delphi Method (FDM) involves three distinct phases [54]: literature review, expert review, and FDM analysis. During the literature review phase, information is gathered on the items being addressed. The expert review phase involves creating questionnaires and forming a team of experts to evaluate the data. The FDM analysis phase consists of several steps, including converting scores into fuzzy numbers, aggregating fuzzy rating scores, determining agreement and threshold values, defuzzifying scores, and examining the acceptability of the crisp values to arrive at a final decision. To conduct FDM analysis, three prerequisites are required: a threshold value of 0.2 or less, a 75% or higher expert consensus percentage, and a defuzzification value of 0.5 or higher.

3. Materials and Methods

This section describes the steps used to develop a business-technical integrated framework. The framework has three phases: literature review, expert assessment, and FDM analysis. Figure 1 shows the order and details of the steps in each phase.

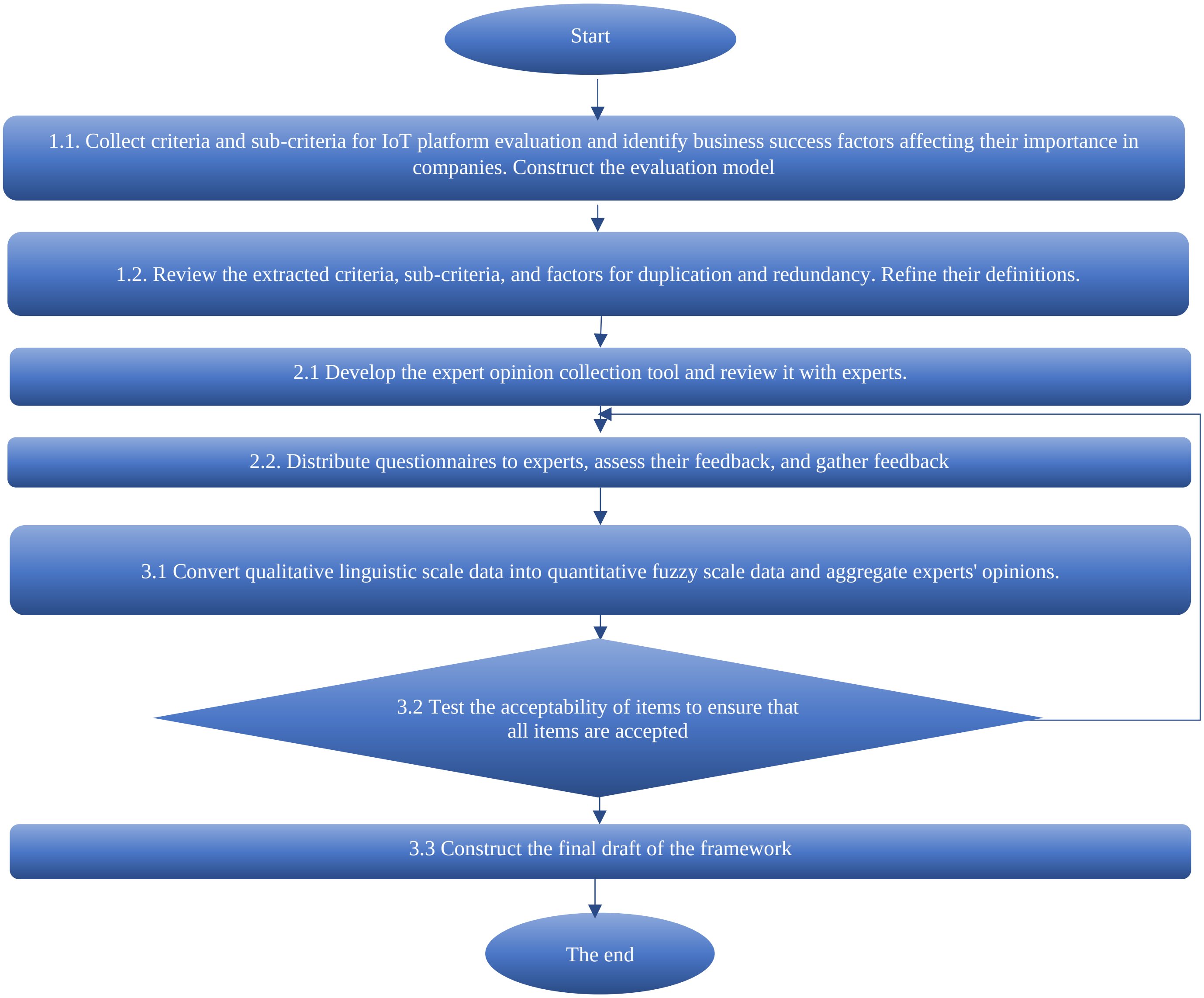

Fig. 1 Methodology of study

3.1. Literature Review

This step aimed to describe, analyze, and model the evaluation problem as a decision-making issue. It also involved analyzing and identifying the evaluation criteria and sub-criteria for IoT platform evaluation and selection and the business factors that affect their importance as a necessary component for implementation. To achieve this, a literature review was conducted on various IoT platform evaluation models, business theories, and business models for IoT implementation. Sources for the review included Google Scholar, Scopus, IEEE, Springer, Elsevier, ResearchGate, and ScienceDirect.

3.2. Expert Assessment

In the Expert Review phase of this study, the Fuzzy Delphi Method (FDM) was used to evaluate the suitability of a proposed model as an evaluation tool for businesses in achieving their objectives. The FDM was used to verify the relevance of key inputs to the proposed evaluation model, which were theoretically extracted as key components. This included assessing the adequacy of functionality, reliability, and usability criteria, sub-criteria, and potential assessment measures that influence the evaluation and selection of IoT platforms, as well as the adequacy of the factors that influence the assessment of the relative importance of these criteria and their sub-criteria from a business perspective.

To design the preliminary survey tool, a group of academics and researchers were consulted, and the questionnaire was structured based on previous studies, including criteria, sub-criteria, and factors identified through a literature review. Five experts reviewed the questionnaire for authenticity and clarity. Subsequently, the survey was distributed to 15 experts, who were selected based on their experience of more than 10 years and their current relevance to the study. The experts' profiles are listed in Table 2. Experts were asked to give their opinions using a five-point linguistic scale, as shown in Table 3.

3.3. FDM analysis

3.3.1. Fuzzification

This process aimed to convert the collected scores into their equivalent fuzzy numbers. The key and crucial issue in the FDM process is the fuzzy numbers [60]. They address the ambiguity or inaccuracy of experts' opinions. They are a presumption of standard real numbers (R), which refer to a set of connected values rather than the single value represented by the Likert scale levels [58]. In order to define the fuzzy set in the subset of R (X), a two-part combination is used, with the first part corresponding to the "x" component and the second part reflecting how much of that element is a member of that set.

To assess whether an item refers to or does not refer to that set, a numerical membership function ($\mu(x)$) is utilized. In this study, a triangular fuzzy number (TFN) is used to translate the experts' Likert scale-based responses into their equivalent fuzzy numbers, as clarified in Table 2. The TFN consists of three values (a, b, and c), the minimum (a), the reasonable (b), and the maximum (c), and is constrained to the range [0, 1]. Every expert's response had a degree of ambiguity that a fixed Likert scale-based score scale could not process.

Table 2. Experts' profiles

E	Organization	Position	Experience
E1	Training & Consulting Center	IT Operation Manager	>10 years
E2	Non-government organization	Data Analyst	>12 years
E3	Hospital	Development Manager	>13 years
E4	Non-government organization	Network Engineer	>17 years
E5	Hospital	IT Engineer	>18 years
E6	Software Production Company	Systems Analyst	>11 years
E7	Software Production Company	Programmer	>13 years
E8	Communications Company	ICT Engineer	>14 years
E9	Government Hospital	IT Engineer	>14 years
E10	Government University	Assoc. Prof	>18 years
E11	Government University	Assoc. Prof	>11 years
E12	UST Hospital	IT Engineer	>10 years
E13	UST University	Academic	>15 years
E14	Security Solutions Company	Security Expert	>13 years
E15	Government University	Assoc. Prof	>10 years

Table 3. The conversion between the Likert scale and TFN scale

Likert scale	Linguistic variable	TFN
1	Strongly disagree	(0.0,0.0,0.2)
2	Disagree	(0.0,0.2,0.4)
3	Not sure	(0.2,0.4,0.6)
4	Agree	(0.4,0.6,0.8)
5	Strongly agree	(0.6,0.8,1.0)

3.3.2. Aggregating the Fuzzy Rating Scores

The average fuzzy rating scores (aggregated scores) of experts (n) on each item were calculated for each item (i) using Equation (1):

$$\widetilde{AS} = (a_i, b_i, c_i) = (\frac{1}{n}\sum_{r=1}^{n} a_{ri} . \frac{1}{n}\sum_{r=1}^{n} b_{ri} . \frac{1}{n}\sum_{r=1}^{n} c_{ri}) \quad (1)$$

Here, (a_r, b_r, c_r) denotes the fuzzy score given by the eth decision-maker for a fixed item (i), and n is the total number of experts.

3.3.3. Testing the Acceptability of the Evaluated Items

There are three prerequisites for a factor to be accepted [58, 59]: a threshold value (TV) for identifying the agreement degree of experts, which should be equal to or less than 0.2; expert agreement percentage (PEA) of 75% or greater, and an overall crisp score value greater than or equal to an alpha-cut value of 0.5. To determine the level of consensus among experts, the threshold value was calculated using Equation (2), where the average threshold value for each factor (i) was determined as the average level of consensus among experts on that factor.

$$D_{ri} = \sqrt{\frac{(a_i - a_{ri})^2 + (b_i - b_{ri})^2 + (c_i - c_{ri})^2}{3}} \quad (2)$$

The percentage of expert agreement (EA), which represents the percentage of the frequency of accepted values (threshold value ≤ 0.2) for each item, should be ≥ 75%. It is calculated using Equation (3):

$$EA = \frac{\text{The frequency of } D_{ri} \leq 0.2}{n} x100 \quad (3)$$

The defuzzification process aimed to convert the average fuzzy rating scores for each item (i) to their crisp equivalent number. The defuzzification process is the priority identification process of items through establishing the weights or importance level of the items and ranking the items to report whether to approve or disapprove. In this study, the simple center of gravity approach was used to calculate the defuzzification value, as shown in Equation (4).

$$DS_i = \frac{(a_i + b_i + c_i)}{n} \quad (4)$$

If the fuzzy number average has a defuzzification value ≥ value α cut (0.5), the item will be approved.

4. Results and Discussion

4.1. Proposed New Model for Evaluating IoT Platforms' Functionality, Reliability, and Usability

A multi-criteria decision-making (MCDM) problem is one in which a decision-maker must choose between a set of alternatives, each of which has a number of attributes. The decision-maker must assign weights to each attribute and then use these weights to rank the alternatives. The main components of an MCDM problem are alternatives, attributes, weights, and ranking. Alternatives refer to the set of possible choices that the decision-maker can make, and attributes describe the characteristics of the alternatives that the decision-maker cares about. Weights denote the importance of each attribute to the decision-maker, while the ranking is the order of the alternatives based on their scores on the attributes.

Based on this and after a literature review of several models for evaluating IoT platforms' functionality, reliability, and usability in Section 2.2, the following main criteria and sub-criteria must be taken into consideration as technical attributes for evaluating IoT platforms: Functionality (Functional Completeness (FC), Functional Appropriateness(FA)), Reliability (Availability (AV), Fault Detection (FD), Redundancy (RE), Load Balancing (LB), Fail-Over (FO), and Timely Recovery(TR)), and Usability (Usefulness (US), Accessibility (AC), Operability (OP), Learnability and Memorability (LM), User Error Protection (EP), and User Interface Aesthetics (IA)).

In addition, a literature review in Section 2.3 found that the importance of attributes varies for companies depending on their role in business success. The weights assigned to attributes are affected by a list of factors that must be considered when assigning weights. These Business Success Factors (BSF) include a strong Customer Focus (CF), a clear and concise Value Proposition (VP), well-defined Target Markets (TM), a strong Brand Identity (BI), and a sound Financial Foundation (FF). The proposed model consists of four main steps, and its framework includes five business factors that affect the determination of the importance of the three main assessment attributes and 14 sub-attributes and measures, which are distributed as follows:

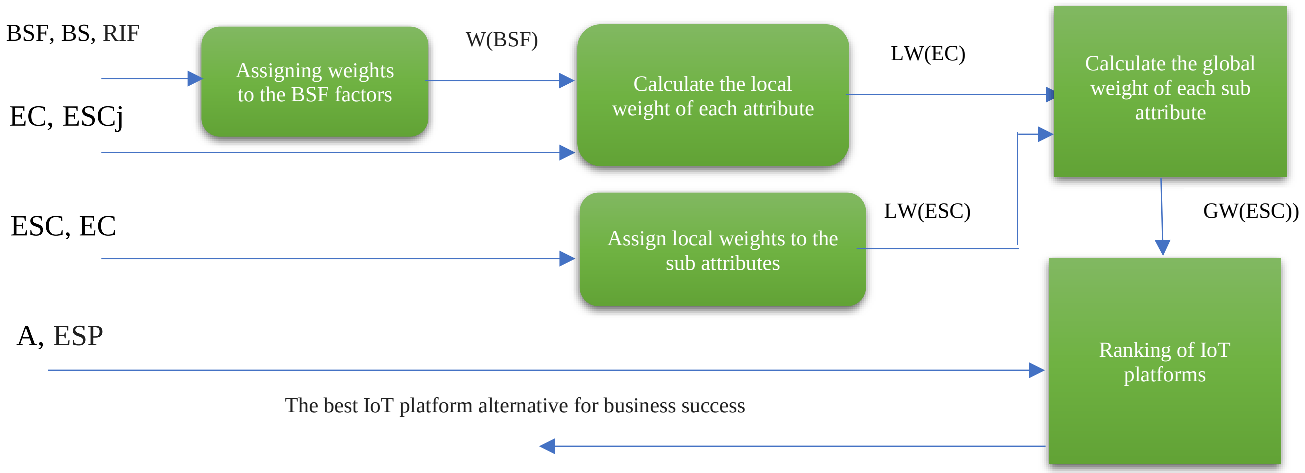

Fig. 2 Assessment model

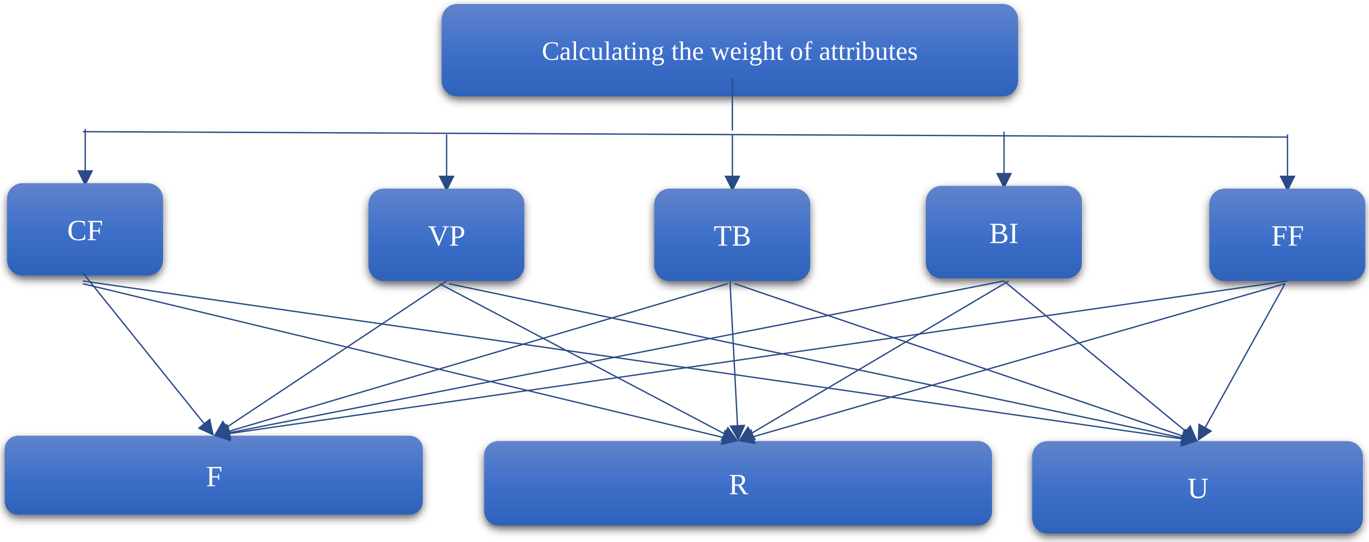

Fig. 3 Framework for calculating the weight of attributes (functionality, reliability, and usability) on the BSF factors

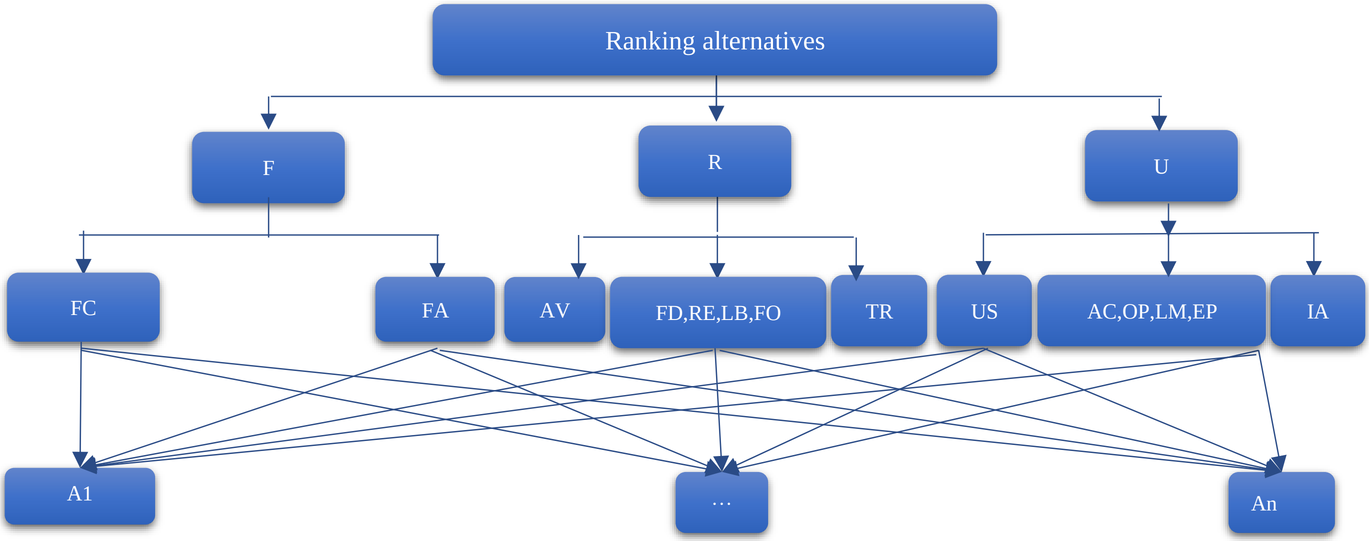

Fig. 4 Alternatives ranking framework

4.1.1. Assessment Model

Assessment model with four implementation steps, as illustrated in Figure 2. The goal is to select the best IoT platform alternative to help businesses maximize their success. The ideal alternative will have the functionality, reliability, and usability to meet the needs of businesses of all sizes.

The following processes can be used to select the best IoT platform alternative:

- Assigning weights to the factors affecting the weights assigned to attributes:

Decision-makers can use methods such as a scoring system or a paired comparison method to assign weights to the factors in accordance with their importance in achieving business success. The inputs for this process are the role of the factors in achieving business success (BS), a list of factors that will be evaluated (BSF), and the relative importance of each factor in achieving business success (RIF). The output of this process is a set of factors' weights (W (BSF)).

- Calculating the weight of attributes (functionality, reliability, and usability) on the BSF factors:

Decision-makers can use methods such as a scoring system to assign scores to the attributes of each BSF factor in accordance with their role in achieving business success. The weight of each attribute is then calculated using any ranking method, such as the simple additive weighting (SAW) method. In SAW, the weight of each attribute is calculated by multiplying the weight of the factor by the attribute's score on that factor. The weights are then assigned to the attributes by normalizing their total weights.

The inputs for this process are the weights of the factors affecting their importance (W (BSF)), a list of attributes that will be evaluated (EC), and the importance evaluation score of each attribute on each factor (ESCj). The output of this process is a set of normalized weights of the functional (F), Reliability (R), and Usability (U) attributes (W(EC)). Figure 3 illustrates the framework of those two steps.

- Assigning weights to the sub-attributes and calculating the overall global weight of the sub-attributes:

The weights of the sub-attributes should reflect their importance within their respective main attributes. The inputs for this process are a list of sub-attributes that will be evaluated (ESC), their respective main attributes (EC), and the relative importance of each sub-criterion that reflects its importance within its respective main attribute (RISC). The output of this process is a set of local weighting vectors of the evaluated sub-attributes (LW(ESC)). After that, the overall global weight of each sub-attribute (GW (ESC)) is calculated by multiplying the weight of the main attribute by the weight of the sub-attribute within that main attribute.

- Ranking alternatives (A):

This step starts with collecting data on each alternative platform. This data can be used to calculate scores for each platform on each sub-attribute (ESP). The scores for each platform on each sub-attribute are then used as input for the ranking model. The ranking model can be built using various methods, such as pairwise comparisons, MCDA, or machine learning. The ranking model is then used to rank the alternatives, considering the sub-attributes importance (GW (ESC)). The final output of this process is a ranking of the alternative IoT platforms, with the best platform ranked first. Figure 4 illustrates the framework of those last two steps.

4.1.2. Five BSF Factors Affect the Determination of the Importance of the Three Main Assessment Attributes

These factors are a strong Customer Focus (CF), a clear and concise Value Proposition (VP), well-defined Target Markets (TM), a strong Brand Identity (BI), and a sound Financial Foundation (FF).

Customer Focus (CF)

The ability of the IoT platform to help companies collect and utilize customer behavior data for improving products and services, personalizing experiences, and building stronger customer relationships. This includes analyzing customer data and delivering relevant insights to enhance the customer experience.

Clear Value Proposition

The ability of the IoT platform to help companies provide the necessary functionality, reliability, and techniques is essential for a clear and concise value proposition. This includes optimizing processes, reducing costs, and improving efficiency to provide a competitive advantage.

Defined Target Markets

The ability of the IoT platform to help companies achieve targeted marketing and personalized experiences for specific customer groups is crucial. This includes collecting accurate and reliable device data for customer segment analysis and campaigns to avoid customer frustration, dissatisfaction, lost sales, and potential issues that may risk data privacy or reliability.

Strong Brand Identity

The ability of the IoT platform to improve the customer experience through personalized recommendations, real-time information, and engaging experiences is crucial to enhancing a company's brand identity.

Sound Financial Foundation

The ability of the IoT platform to help companies avoid substantial financial losses is crucial. This includes providing the necessary operational data to minimize losses from increased costs, decreased efficiency, lost revenue, damaged reputation, decreased adoption, and errors.

4.1.3. The Three Main Attributes that are Evaluated and Selected for an IoT Platform are Functionality (F), Reliability (R), and Usability (U)

Functionality Refers to the capabilities of an IoT platform to provide the required functions and features that meet the specific needs of an organization or industry. These functions and features range from simple data collection and monitoring to complex tasks such as advanced automation, predictive analysis, and machine learning. Reliability Refers to the ability of an IoT platform to provide continuous and dependable services without interruption or failure.

Table 4. Evaluation sub-attributes and their definitions

D	SA	Definition
F	FC	The platform's ability to perform all the necessary functions required by the business.
	FA	The platform's ability to perform specific functions required for a particular use case
R	AV	The platform's ability to operate continuously without interruption.
	FD	The platform's ability to identify and address potential issues before they cause significant problems
	RE	The platform's ability to maintain continuity of service in the event of a failure.
	LB	The platform's ability to optimize resource allocation and prevent overloading of any particular component.
	FO	The platform's ability to maintain service continuity and prevent disruption in the event of a failure.
	TR	The platform's ability to quickly recover from failures or outages and resume normal operations.
U	US	The platform's ability to meet business needs and provide value to users.
	AC	The platform's ability to accommodate a diverse range of users and their needs.
	OP	The platform's ability to provide the necessary features and functions for users to accomplish their goals, as well as allowing them to easily adjust, manage, and control the platform based on their individual preferences.
	LM	The platform's ability to enable users to intuitively determine the current use of the platform or use it after periods of non-use without memory recall
	EP	The platform's ability to prevent or minimize user errors and their impact.
	IA	The platform's ability to provide an engaging and user-friendly interface that enhances the user experience.

Table 5. Evaluation sub-attributes and their measures

D	SA	Measures
F	FC	To what extent does the IoT platform meet all the functional requirements specified by the company?
	FA	How well does the IoT platform accomplish specific tasks and objectives related to a particular IoT application?
R	AV	How often does the platform provide the service or specific data as part of the service?
	FD	How well does the IoT platform detect when devices are tampered with or failing before faults occur?
	RE	How well does the IoT platform provide backup or duplicate components, such as servers, storage devices, or network connections, to ensure that critical services remain available even if one component fails?
	LB	How well does the IoT platform distribute workloads across multiple servers or devices to ensure that no single device is overloaded and that all devices are being used efficiently?
	FO	How well does the IoT platform automatically switch services from a failed component to a backup component in the event of a failure?
	TR	How quickly does the IoT platform recover services and data in emergency situations to minimize disruption of business operations?
U	US	To what extent does the IoT platform simplify and streamline the reasonable solving of real problems and tasks while achieving expected outcomes under specific conditions and offering features and functionality to users?
	AC	How well can the IoT platform be used by users with specific needs, such as those with disabilities or limited technical knowledge, to accomplish specific tasks within a particular work environment?
	OP	How well does the IoT platform meet the users' needs by providing the necessary features and functions while allowing them to easily adjust, manage, and control the platform based on their preferences?
	LM	How well does the IoT platform provide users with an intuitive and easy-to-learn interface that allows them to achieve a reasonable level of performance with minimal semantic distance, implementation efforts, and time? How well does the platform enable users to intuitively determine the current use of the platform or use it after periods of non-use without memory recall?
	EP	To what extent does the IoT platform protect users from making errors that could lead to unintended consequences or harm, including features such as confirmation dialogues, undo/redo functionality, and error messages that provide clear guidance on correcting mistakes?
	IA	To what extent is the IoT platform's user interface pleasing, attractive, and likable for users when they accomplish specific tasks?

Usability Refers to the extent to which an IoT platform can be used effectively, efficiently, and satisfactorily by its intended users to achieve their goals. The usability of an IoT platform should align with an organization's or industry's specific needs and requirements.

4.1.4. Evaluation Sub-Attributes and their Measures

Tables 4 and 5 provide a summary of the proposed sub-attributes and their measures

4.2. FDM Analysis Results

The FDM analysis phase produced results presented in Tables 6, 7, 8, and 9. These results were obtained by analysing assessment data from 15 experts who participated in the study. The experts were asked to evaluate the Five BSF factors that impact the determination of assessment attributes and the three primary attributes (Functionality, Reliability, and Usability) considered when selecting an IoT platform. The experts also identified 14 sub-attributes that can be used as potential measures for the proposed model.

4.2.1. FDM Analysis of proposed BSF Factors Affecting the Determination of the Importance of the Assessment Attributes

All five factors received very high favourable ratings, ranging from 'agree' to 'strongly agree' on the linguistic scale, except for the 'clear value proposition' and 'strong brand identity' factors, which received high favourable scores of 'not sure,' 'agree,' and 'strongly agree.' A fuzzy rating was used to convert these linguistic scale values, as shown in Table 3. A factor is considered acceptable if it meets the FDM rules (section 3.1.3), which require a minimum threshold value (TV) of 0.2 or higher, an expert agreement percentage (PEA) of 75% or greater, and a crisp score value (defuzzification value (DV)) of 0.5 or greater. Table 6 demonstrates that all five variables met these criteria, with a TV of 0.2, an EAP of 75%, and a DV of 0.5. Table 6 illustrates that all five factors met the requirements of FDM, with expert agreement ranging from 80% to 100%, except for the 'strong brand identity' factor, which achieved 80%. This means that the factors were accepted with 100% agreement for 'a strong customer focus' and 'sound financial foundation' factors, 93% for 'clear value proposition' and 'defined target markets' factors, and 80% for 'a strong brand identity.' The defuzzification values for these factors were 0.787, 0.747, 0.720, 0.707, and 0.680, respectively.

The acceptance of all factors indicates that they impact the determination of the importance of the three main assessment attributes of an IoT platform: Functionality (F), Reliability (R), and Usability (U). Each of these five factors plays a vital role in the success of an IoT platform and should be carefully considered when determining the importance of its functionality, reliability, and usability. The variation in defuzzification values indicates that the factor 'strong customer focus' (CF) ranked first, followed by 'clear Value Proposition' (VP) and defined Target Markets (TM) among the key factors in terms of priority. This means that the IoT platform should be selected with the customer in mind, and companies can collect and utilize customer behaviour data to improve products and services, personalize experiences, and build stronger customer relationships. By analysing customer data and delivering relevant insights, the IoT platform can enhance the customer experience, leading to increased customer satisfaction, loyalty, and retention. The IoT platform selected is recommended to provide the necessary functionality, reliability, and techniques to meet customers' specific needs and effectively communicate its benefits to potential customers.

A clear value proposition can help companies optimize processes, reduce costs, and improve efficiency, providing a competitive advantage and increasing customer adoption. While a strong Brand Identity (BI) is ranked last among the five factors, it can help establish customer trust and loyalty and enhance the overall customer experience. However, according to experts, it may not be as critical as other factors, which may be because it is not as critical in the early stages of an IoT platform's development. Maintaining customer loyalty and differentiating the platform from competitors can become increasingly important. The 'sound financial foundation' factor ranked fourth, which may be because its importance varies depending on the specific context and goals of the business. For a start-up company, a sound Financial Foundation (FF) may be more critical initially to ensure the company's survival and growth.

4.2.2. FDM Analysis of Proposed Three Main Attributes

All three main attributes (Functionality (F), Reliability (R), and Usability (U)) received very favourable ratings, ranging from 'agree' to 'strongly agree' on the linguistic scale. Table 6 also demonstrates that all three attributes met the FDM analysis requirements.

Table 6. Experts' consensus results of the proposed BSF factors affecting the determination of the importance of the assessment attributes

F	Fuzzification Process			Defuzzification Process	Rank	Result
	TFN	TV (d) ≤ 0.2	PEA ≥ 75%	DV ≥ 0.5		
CF	(0.586,0.786,0.986)	0.025	100	0.787	1	Accepted
VP	(0.546,0.746,0.946)	0.085	93	0.747	2	Accepted
TM	(0.52,0.72,0.92)	0.107	93	0.720	3	Accepted
FF	(0.506,0.706,0.906)	0.100	100	0.707	4	Accepted
BI	(0.48,0.68,0.88)	0.144	80	0.680	5	Accepted

Table 7. Experts' consensus results of the proposed assessment attributes

F	Fuzzification Process			Defuzzification Process	Rank	EA
	TFN	TV (d) ≤ 0.2	PEA ≥ 75%	DV ≥ 0.5		
F	(0.573,0.773,0.973)	0.046	100	0.773	1	Accepted
R	(0.56,0.76,0.96)	0.064	100	0.760	2	Accepted
U	(0.546,0.746,0.946)	0.078	100	0.747	3	Accepted

Table 7 shows that all five factors met the requirements of FDM, with an expert agreement of 100%. The defuzzification values for these criteria were 0.773, 0.760, and 0.747 for Functionality (F), Reliability (R), and Usability (U), respectively. The acceptance of all the main attributes indicates that they impact the selection of IoT platforms and are all essential for the success of an IoT platform. Each of these three attributes plays a vital role in the success of an IoT platform and should be carefully considered when companies select the platform. The variation in defuzzification values for the three main assessment attributes of an IoT platform evaluation (Functionality (F), Reliability (R), and Usability (U)) indicates the relative importance of each attribute based on the criteria used in the evaluation process. A defuzzification value of 0.773 for Functionality (F) indicates that it is the most critical attribute in the evaluation process, with a higher level of importance compared to Reliability (R) and Usability (U). This means that the IoT platform should provide the necessary functions and features that meet the specific needs and requirements of the organization or industry. A defuzzification value of 0.760 for Reliability (R) indicates that it is also a crucial attribute but slightly less important than Functionality (F). This means the IoT platform should provide continuous and dependable services without interruption or failure, ensuring data integrity and business continuity. A defuzzification value of 0.747 for Usability (U) indicates that it is also an important attribute but less critical than Functionality (F) and Reliability (R). This means that the IoT platform should be usable and effectively meet the needs of its intended users, but it is not as critical as the other two attributes.

4.2.3. FDM Analysis of the Proposed Fourteen Sub-Attributes and their Potential Measure of the Proposed Model

The attributes of the evaluation criteria received varied assessments from the five linguistic variables, indicating that there may have been some differences of opinion among the experts.

As shown in table 8, the acceptance of the Functional Completeness (FC) and Functional Appropriateness (FA) sub-attributes of the Functionality criteria with 87% and 80% agreement, respectively, suggests that there was a relatively high level of consensus among the experts on the importance of these factors in evaluating the IoT platform.

The defuzzification values of 0.604 and 0.650 for FC and FA, respectively, indicate these sub-attributes' relative weight and importance in the evaluation process. A higher defuzzification value indicates a higher level of importance or priority assigned to the sub-attribute in the evaluation process. In this case, the higher defuzzification value of 0.650 for FA suggests that it is a more important sub-attribute for evaluating the Functionality criteria compared to FC, which received a defuzzification value of 0.604.

Table 8. Experts' consensus results of the proposed Sub-Attributes of the proposed model

A	SA	Fuzzification Process			Defuzzification Process	Local Rank	Global Rank	EA
		TFN	TV (d) ≤ 0.2	PEA ≥ 75%	DV ≥ 0.5			
F	FC	(0.586,0.786,0.986)	0.107	87	0.604	1	10	Accepted
	FA	(0.546,0.746,0.946)	0.137	80	0.650	2	9	Accepted
R	AV	(0.573,0.773,0.973)	0.050	93	0.773	1	2	Accepted
	FD	(0.573,0.773,0.973)	0.050	93	0.773	1	2	Accepted
	RE	(0.533,0.733,0.933)	0.107	87	0.733	2	4	Accepted
	LB	(0.28,0.48,0.68)	0.171	67	0.480	5	12	Rejected
	FO	(0.306,0.493,0.693)	0.171	67	0.497	4	11	Rejected
	TR	(0.466,0.666,0.866)	0.142	80	0.667	3	7	Accepted
U	US	(0.546,0.746,0.946)	0.085	93	0.747	2	3	Accepted
	AC	(0.506,0.706,0.906)	0.112	93	0.707	3	5	Accepted
	OP	(0.586,0.786,0.986)	0.25	100	0.787	1	1	Accepted
	LM	(0.493,0.693,0.893)	0.100	100	0.693	4	6	Accepted
	EP	(0.586,0.786,0.986)	0.25	100	0.787	1	1	Accepted
	IA	(0.466,0.666,0.866)	0.142	80	0.667	5	8	Accepted

Table 9. Experts' consensus results of the proposed potential measures of the proposed model

A	M	Fuzzification Process			Defuzzification Process	Local Rank	Global Rank	EA
		TFN	TV (d) ≤ 0.2	PEA ≥ 75%	DV ≥ 0.5			
F	FC	(0.56,0.76,0.96)	0.064	100	0.760	2	3	Accepted
	FA	(0.506,0.706,0.906)	0.112	93	0.707	1	6	Accepted
R	AV	(0.586,0.786,0.986)	0.25	100	0.787	1	1	Accepted
	FD	(0.546,0.746,0.946)	0.085	93	0.747	3	4	Accepted
	RE	(0.573,0.773,0.973)	0.050	93	0.773	2	2	Accepted
	TR	(0.493,0.693,0.893)	0.100	100	0.693	4	7	Accepted
U	US	(0.573,0.773,0.973)	0.050	93	0.773	1	2	Accepted
	AC	(0.56,0.76,0.96)	0.064	100	0.760	2	3	Accepted
	OP	(0.52,0.72,0.92)	0.107	93	0.720	4	5	Accepted
	LM	(0.506,0.706,0.906)	0.112	93	0.707	5	6	Accepted
	EP	(0.546,0.746,0.946)	0.078	100	0.747	3	4	Accepted
	IA	(0.573,0.773,0.973)	0.050	93	0.773	1	2	Accepted

Functional Completeness (FC) is important because an IoT platform must provide all the necessary functions and features to meet the organization's or industry's specific needs and requirements. However, an IoT platform may meet all the functional requirements but may not be well-suited for a particular IoT application or use case. On the other hand, Functional Appropriateness (FA) refers to how well the IoT platform accomplishes specific tasks and objectives related to a particular IoT application or use case. This sub-attribute is important because the IoT platform must be able to perform specific tasks and achieve the intended outcomes effectively.

So, the experts may have assigned a higher level of importance to Functional Appropriateness (FA) compared to Functional Completeness (FC) because an IoT platform that is well-suited for a particular IoT application or use case and can effectively accomplish specific tasks and objectives is more valuable than an IoT platform that merely meets all the functional requirements but may not be optimized for a particular use case.

As for the reliability sub-criteria, two attributes, namely Load Balancing (LB) and Failover (FO), had lower agreement (67%) and defuzzification values of 0.480 and 0.497, respectively. These items are considered unacceptable as they did not meet all three requirements of the FDM analysis. Their PEA is less than 75%, and their DV is less than 0.5.

The other reliability attributes, namely Availability, Fault Detection, Redundancy, and Time Recovery, met the FDM requirements with experts' agreement rates of 93%, 93%, 87%, and 80%, and defuzzification values of 0.773, 0.773, 0.733, and 0.667, respectively. Availability and Fault Detection had the highest agreement rates of 93% among all the sub-criteria, indicating a high level of consensus among the experts. Redundancy had a lower, but still acceptable, agreement rate of 87%, indicating a slightly higher degree of variability in the interpretations of this factor. Time Recovery had the lowest agreement rate of 80% but still met the FDM requirements and is considered acceptable. The defuzzification values for Availability and Fault Detection were the highest among all the sub-criteria, indicating that they are the most important sub-criteria. Redundancy had a defuzzification value of 0.733, indicating that it is still important but to a slightly lesser degree. Time Recovery had a defuzzification value of 0.667, indicating that it barely met the FDM requirements.

As for the usability sub-criteria, all sub-attributes of Usability (US), Accessibility (AC), Operability (OP), Learnability and Memorability (LM), User Error Protection (EP), and User Interface Aesthetics (IA) met the FDM requirements with experts' agreement rates of 93%, 93%, 100%, 100%, 100%, and 80%, and defuzzification values of 0.747, 0.707, 0.787, 0.693, 0.787, and 0.667, respectively. Operability (OP), Learnability and Memorability (LM), and User Error Protection (EP) had the highest agreement rates of 100% among all the sub-criteria, indicating a high level of consensus among the experts. Usefulness (US) and Accessibility (AC) had lower, but still acceptable, agreement rates of 93%, indicating a slightly higher degree of variability in the interpretations of these factors. User Interface Aesthetics had the lowest agreement rate of 80% but still met the FDM requirements and is considered acceptable. The defuzzification values for Operability (OP) and User Error Protection (EP) were the highest among all the sub-criteria, indicating that they are the most important sub-criteria. Usefulness (US) and Accessibility (AC) had defuzzification values of 0.747 and 0.707, respectively, indicating that they are still important but to a slightly lesser degree. Learnability and Memorability

(LM) and User Interface Aesthetics (IA) had defuzzification values of 0.693 and 0.667, respectively, indicating that they are still important but to a slightly lesser degree.

Furthermore, Table 9 indicates that all potential measures for the accepted sub-attributes met the requirements of the FDM.

5. Designing the Final Model for Evaluating IoT Platforms' Functionality, Reliability, and Usability

This study utilized systematic analysis and Fuzzy Multi-Criteria Decision-Making (F-MCDM) approaches to address the problem of evaluating the functionality, reliability, and usability of IoT platforms. The study aimed to determine IoT platforms' main technical and business components and requirements and create an MCDM model for solving this problem in companies. The proposed model included three main evaluation attributes: functionality, reliability, and usability, each with sub-attributes and measures identified through a literature review.

The model also considered five factors that affect the determination of the importance of evaluation attributes, including customer focus, value proposition, target markets, brand identity, and financial foundation. The proposed model was validated through a Fuzzy Delphi assessment, which confirmed the three main criteria, their sub-criteria, and the factors that impact their importance. However, two sub-criteria related to load balancing and failover were exceptions to this validation.

The final validated model included three criteria, twelve sub-criteria, five factors affecting their importance, and twelve measures. The experts involved in the validation process identified the components based on their familiarity with reality and the environment.

Overall, this study addresses the limitations of previous studies by providing a comprehensive and practical approach to IoT platforms' usability, reliability, and functionality evaluation. Firstly, it considers twelve sub-criteria and measures, unlike previous studies that only addressed some of them ([2], [3], [14], [18], [19], [21], [37], [39], and [54]). Secondly, it takes into account crucial business success factors that were overlooked in previous studies, except for one that only theoretically emphasized the importance of customer focus [14]. Thirdly, it integrates the business model with IoT platform evaluation, which was not done in previous studies that focused on the business model [20, 55-57]. Fourthly, unlike previous studies that used the traditional Delphi method [2], this study uses the Fuzzy Delphi method to deal with uncertainty problems during evaluation and to address the issue of marginal values obtained in evaluation.

6. Study Applications, Limitations, and Future Works

This study provides an important contribution to the field of IoT platform evaluation and can help decision-makers select the most suitable platform for their specific needs. However, it should be noted that the study focused only on evaluating three criteria: functionality, reliability, and usability, and did not address other evaluation dimensions of IoT platforms. Additionally, the business factors considered in the proposed model were related only to these three criteria and did not take into account other important business factors related to the other criteria, such as security and communication. Furthermore, the study did not discuss the practical application of the proposed model in companies, nor did it explore the suitability of various MCDM techniques for its implementation.

Future research could expand the proposed model to include other important evaluation dimensions of IoT platforms, such as security, interoperability, and scalability. Additionally, future studies could consider a more comprehensive set of business factors that affect the selection of an IoT platform. Moreover, further research could explore the practical application of the proposed model in real-world scenarios and evaluate its effectiveness in supporting decision-making processes. Finally, future work could investigate the suitability of different MCDM techniques for implementing the proposed model and identify the most appropriate techniques for different scenarios.

7. Conclusion

Choosing the right IoT platform is critical for the success of IoT initiatives. It can help companies realize the full potential of IoT technology and drive innovation, efficiency, and growth. To achieve this, companies need to consider their specific needs and choose an IoT platform that aligns with their business goals, provides the required functionality, is reliable, and is easy to use.

This study highlights the need for a comprehensive model for evaluating IoT platforms that aligns business requirements with functionality, reliability, and usability technical capabilities. Based on comparative studies, the authors determined the functionality, reliability, and usability sub-criteria and measures necessary to evaluate IoT platforms and the business success factors affecting their relative importance in companies. The study then built a comprehensive model for evaluating IoT platforms that meet both technical requirements and business needs for all sectors. This model includes three criteria, 14 sub-criteria and measures, and five factors affecting their relative importance in companies.

The Fuzzy Delphi method was utilized to validate the proposed model. All items reached the experts' agreement except for two sub-criteria, load balancing and failover, which did not meet the assessment requirements. The final validated model includes three main criteria (usability, reliability, and functionality), 12 sub-criteria and measures (Functional Completeness (FC), Functional Appropriateness (FA), Availability (AV), Fault Detection (FD), Redundancy (RE), Timely Recovery (TR), Usability (usefulness (US), Accessibility (AC), Operability (OP), Learnability and Memorability (LM), User Error Protection (EP), and user Interface Aesthetics (IA)), and five factors affecting their importance (a strong Customer Focus (CF), a clear and concise Value Proposition (VP), well-defined Target Markets (TM), a strong Brand Identity (BI), and a sound Financial Foundation (FF)). The local and global priority weights of each item were also found.

However, this study addresses the shortcomings of previous research in several ways. Firstly, it considers 12 sub-criteria presented in the study, which is an improvement on previous studies that only covered some of them. Secondly, it takes into account essential business success factors that were previously overlooked. Thirdly, it integrates the business model with IoT platform evaluation, a new approach that previous studies did not explore. Lastly, it employs the Fuzzy Delphi method to deal with uncertainty problems during the evaluation, which is a more effective method than the traditional Delphi method used in previous studies. The proposed model can help organizations effectively compare and evaluate different platforms, ensuring that the chosen platform possesses relevant core capabilities that align with the organization's objectives to ensure success.

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