



Predicting User Acceptance of Solar-Powered Vending Machines Based on Quality Dimensions

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Abstract: With the increasing demand for sustainable technologies in educational institutions, solar-powered vending machines have emerged as a promising solution to meet this need. This study assesses the perceived quality and user acceptance of solar-powered vending machines at North Eastern Mindanao State University (NEMSU) in Bislig City, Philippines. The research focuses on two key dimensions of perceived quality: attribute quality (performance, features, aesthetics) and reliability quality (reliability, serviceability, perceived quality), and evaluates how these factors influence user acceptance, based on the Technology Acceptance Model (TAM). A structured questionnaire was used to gather data from 200 participants, including students, faculty, and staff. The findings indicate that users generally have a positive perception of the vending machines, with high ratings for features and aesthetics, and satisfactory ratings for performance and reliability. Performance and aesthetics were identified as significant predictors of user acceptance, while serviceability emerged as the most important factor in reliability quality. The study concludes that solar-powered vending machines have strong potential for acceptance in educational settings. However, improvements in Wi-Fi stability and maintenance features could further enhance user satisfaction and long-term adoption. The results offer valuable insights for universities and policymakers seeking to implement sustainable technologies on their campuses.

Keywords: Perceived quality; user acceptance; solar-powered vending machine; renewable energy; educational technology

1. Introduction

The push for smart infrastructure and sustainable solutions within higher education has become increasingly urgent in the context of environmental responsibility and institutional modernization. Renewable energy systems are playing a central role in this transformation, enabling campuses to reduce carbon footprints while providing enhanced services to users [1, 2]. Technological innovations, such as solar-powered systems, smart vending machines, and integrated service outlets, reflect this dual focus on service convenience and environmental stewardship [3, 4]. The use of solar-powered vending machines offering amenities such as Wi-Fi access, mobile device charging, and clean drinking water aligns with this trend by enabling tertiary institutions to integrate green technology into everyday campus life.

Despite the growing adoption of sustainable technologies, several issues hinder their widespread and effective use in campus settings. User acceptance

remains a critical barrier: technologies deployed without adequate user engagement, perceived usefulness, or ease of use are less likely to deliver the intended benefits [5]. Research on renewable energy technology adoption reveals that, although many systems are technically feasible, user perceptions of quality, reliability, and design significantly influence actual uptake [6]. Some investigations into technology acceptance in green or energy-augmented contexts suggest that traditional models, such as the Technology Acceptance Model (TAM), may lack constructs specifically tailored to capture system quality or reliability in renewable technologies [7, 8].

In the Philippine context, particularly on island or regional campuses like North Eastern Mindanao State University (NEMSU) in Bislig City, innovations such as solar-powered vending machines are still emerging, and research on how users perceive these technologies remains limited. While some studies address renewable energy acceptance more broadly [8], few focus on user acceptance of solar-powered vending machines in higher education settings, especially in developing regions. Moreover, even fewer studies incorporate perceived quality dimensions, such as performance, aesthetics, and serviceability, which are crucial in understanding the factors that drive user adoption. "More importantly, existing studies predominantly examine single-function technologies (e.g., standalone charging stations or basic vending units) [9, 10], thereby overlooking the growing emergence of multi-functional systems that integrate services such as Wi-Fi access, device charging, and water dispensing into a single solar-powered unit." This lack of attention to how quality attributes and reliability influence acceptance in this specific and integrated context creates a significant gap. "Thus, the novelty of this study lies in its focus on a multi-functional solar-powered vending machine and in examining how distinct quality dimensions, specifically attribute-based and reliability-based factors, interact within the Technology Acceptance Model (TAM) to explain user adoption." As a result, institutions may implement solar-powered vending machines, but without a full understanding of how users evaluate quality and reliability, their long-term viability and user uptake may be compromised.

To address this gap, it is crucial to investigate the role of perceived quality dimensions in the adoption of solar-powered vending machines. [11] underscore the importance of integrating perceived quality with technology acceptance models to better understand user adoption of renewable energy technologies. Specifically, focusing on attributes such as performance, aesthetics, and serviceability provides deeper insight into how users evaluate and ultimately accept such technologies. "In contrast to prior studies, this research explicitly distinguishes between attribute quality (e.g., functionality and design) and reliability quality (e.g., consistency and dependability), and integrates these dimensions into the TAM framework." Incorporating both attribute and reliability quality dimensions, as suggested in [12], addresses the existing gap in the literature and provides valuable insights into the factors driving user acceptance in developing educational settings, such as NEMSU. "This approach advances existing models that typically treat quality as a single construct and instead proposes a more nuanced, multi-dimensional perspective tailored to complex, multi-functional systems." This approach ensures that solar-powered vending machines are not only technically feasible but also well-received, fostering long-term adoption and success.

This study, therefore, aims to investigate how perceived quality, encompassing both attribute quality (performance, features, aesthetics) and reliability quality (reliability, serviceability, perceived quality), predicts user acceptance of solar-powered vending machines at NEMSU. Integrating traditional Technology Acceptance Model (TAM) constructs, such as perceived usefulness and perceived ease of use, with quality dimensions tailored to renewable energy systems, this research contributes to both theory and practice. It addresses the gap in the literature on technology acceptance within sustainable campus infrastructure, offering actionable insights for university administrators, designers, and policymakers overseeing the deployment of green technologies in educational settings. Ultimately, this study enhances our understanding of how engineering and design factors, combined with user perception, drive the acceptance of renewable energy technologies in higher education.

2. Literature Review and Theoretical Framework

2.1 The Technology Acceptance Model (TAM) as a Framework for User Adoption

To understand the factors that drive the adoption of new technologies, researchers frequently turn to the Technology Acceptance Model (TAM). Initially developed by Davis, TAM provides a parsimonious yet powerful framework for explaining how users come to accept and utilize new systems, “and is widely recognized for its theoretical simplicity and robustness, as well as its consistent ability to explain user adoption behavior across various domains [13, 14]”. The model posits that a user's decision to adopt a technology is primarily determined by two core perceptual constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). [15], define Perceived Usefulness as the degree to which an individual believes that using a particular system will enhance their job performance or task effectiveness. Concurrently, they define Perceived Ease of Use as the degree to which an individual believes that using the system will be free of physical and mental effort [16].

Within the TAM framework, these two constructs have distinct but interrelated roles. Perceived Usefulness is consistently identified as the strongest and most direct predictor of a user's behavioral intention to adopt a technology [17, 18]. In contrast, Perceived Ease of Use exerts its influence both directly on a user's attitude and indirectly by positively affecting their perception of the technology's usefulness; a system that is easy to operate is more likely to be considered useful [16, 19]. Together, these beliefs shape a user's attitude and intention, which ultimately lead to the actual adoption and use of the technology.

The efficacy of TAM as a predictive tool is firmly established in the literature. Numerous systematic reviews and meta-analyses confirm that TAM is a robust, highly validated framework for predicting user adoption across a wide range of contexts, including education, healthcare, and e-commerce [3, 12, 20]. For instance, [21] found, in a systematic review of telemedicine, that TAM consistently outperformed many alternative models in explaining user acceptance. While the core model is powerful on its own, researchers also note that its predictive accuracy can be further enhanced by integrating relevant external variables such as social influence, trust, or system quality, “which [13] and [22] have shown to significantly influence behavioral intention and actual usage, and improve the model's explanatory power across different technological contexts,” making it a versatile and adaptable foundation for technology adoption research [20, 23, 24].

While the DeLone & McLean Information Systems Success Model is widely used in technology adoption studies, its reliance on constructs such as 'System Quality' and 'Information Quality' is primarily tailored to software-based or digital information environments. In contrast, the solar-powered vending machine evaluated in this study is predominantly a physical, multi-functional hardware unit. Consequently, software-centric dimensions do not fully capture the physical user experience. Therefore, employing 'Attribute Quality'—which evaluates physical aesthetics and hardware functionality—and 'Reliability Quality'—which measures mechanical serviceability and consistent power output—provides a more robust, context-specific framework for this technology than the traditional DeLone & McLean dimensions.

2.1.1 The Role of Perceived Quality in Influencing Consumer Behavior

While technology acceptance models provide a strong foundation for understanding user adoption, they are often enhanced by considering external variables that shape a user's core perceptions. Among the most critical of these variables is perceived quality. In marketing and consumer behavior literature, researchers define perceived quality not as an objective or technical attribute of a product, but as the consumer's subjective judgment of its overall excellence or superiority [25, 26]. [27] and [28] characterize this as a holistic evaluation based on an individual's unique expectations and experiences. This subjectivity means that a consumer's perception of quality can be influenced by a range of tangible and intangible cues, such as brand reputation, price, and product design, particularly when product knowledge is limited [29, 30]. The relationship between this subjective perception and a consumer's ultimate decision-making is direct and powerful. A substantial body of research has firmly established that a higher level of perceived product quality is a significant driver of consumer purchase intention [31, 32]. [30] explain that this effect is particularly strong in e-commerce, where consumers rely heavily on quality cues to reduce perceived risk and build trust [33]. This principle extends directly into the domain of technology adoption. Within the context of the Technology Acceptance Model (TAM), perceived quality is considered a key antecedent to its core constructs. [34] and [35] demonstrate that

when users perceive a technology as high quality, they are significantly more likely to also perceive it as useful and easy to use. [36] found that the perceived quality of service robots in the food industry had a strong positive influence on their acceptance, mediated by perceived usefulness and ease of use. Therefore, perceived quality does not operate in isolation; it is a foundational belief that directly shapes user perceptions, which ultimately determine whether a new technology will be accepted or rejected.

2.2 Key Dimensions of Perceived Product Quality

The concept of perceived quality is best understood through its core dimensions, commonly categorized into attribute-based and reliability-based factors. These dimensions serve as key cues that shape users' quality judgments and adoption intentions, as supported in consumer behavior literature [37, 38]. This study adopts these dimensions because they align closely with user-centered evaluation of tangible, multifunctional technologies such as solar-powered vending machines. Research grounded in the Technology Acceptance Model shows that users rely on direct interaction with system features and performance outcomes in forming acceptance decisions [22, 39]. Attribute-based factors capture immediate functional and experiential evaluation, whereas reliability-based factors reflect sustained performance and trust. In contrast, System Quality and Information Quality from the DeLone and McLean Information Systems Success Model are more suited to information systems focused on data and processing, as cited by [40] and [41]. Solar-powered vending machines, as physical service systems, are better evaluated through observable features and operational dependability, making attribute and reliability dimensions more appropriate for this study.

2.2.1 Attribute-Based Quality: Performance, Features, and Aesthetics

The most immediate drivers of quality perception are a product's tangible attributes. [42] and [43] assert that high product performance is a fundamental determinant of perceived quality and purchase intention, as consumers expect a product to function effectively and reliably. Beyond basic performance, the product's features also play a critical role. However, [44] cautions that the sheer quantity of features can be detrimental if it reduces usability. Their research reveals that the interrelatedness of features—how well they work together to create a seamless experience—is a more significant driver of positive quality perception than the total number of features alone [45]. Complementing function and features is the powerful influence of aesthetics. Product design has a significant impact on first impressions and can create a "beauty premium" that directly enhances perceived quality and willingness to adopt [46, 47]. [48] confirm in a meta-analysis that visual aesthetics are strongly linked to consumer preference. This effect is significant for innovative products, where [49] argue that strong aesthetics can help buffer consumer uncertainty about performance. While an attractive design is a powerful initial draw, long-term satisfaction ultimately depends on the product's functional performance living up to its aesthetic promise. In this context, attribute-based dimensions were selected because they capture users' immediate functional and sensory evaluation of the system, as highlighted by [50], which is critical for public-facing technologies that rely on direct interaction rather than purely digital outputs.

2.2.2 Reliability-Based Quality: Reliability, Durability, and Serviceability

Beyond immediate attributes, a user's perception of quality is profoundly shaped by factors related to a product's long-term dependability. Reliability, which is the ability to function consistently without failure, is a cornerstone of user trust [51]. [25] and [52] demonstrate that when users experience reliable performance, their dependence on and confidence in the technology grow, directly influencing long-term acceptance. This is closely linked to durability, which refers to a product's ability to maintain its performance over time. A durable product signals quality, reduces the perceived risk of a poor investment, and can foster stronger trust and even emotional attachment [53, 54].

Finally, serviceability, which is the perceived ease of maintenance and repair, plays a crucial role in building and maintaining trust. The assurance that potential issues can be resolved efficiently and effectively protects users against the risk of failure, thereby supporting long-term retention and positive word of mouth [55, 56]. [29] argue that for emerging technologies, strong reliability and clear serviceability are essential for overcoming brand barriers and establishing a foothold in the market. Together, these reliability-based

reliability-based dimensions were included because they reflect sustained operational performance and maintainability as noted by [57], which are essential for ensuring continuous service delivery and long-term usability of solar-powered vending machines in real-world institutional environments.

2.2.3 Consumer Adoption of Sustainable and Solar-Powered Technologies

The successful introduction of a solar-powered vending machine depends not only on its inherent quality and usability but also on the broader context of consumer attitudes toward sustainable technologies. The literature identifies a complex interplay of factors that drive or hinder public adoption of "green" innovations. A primary driver identified by [58] and [28] is the consumer's perceived benefits, which include not only potential cost savings but also a sense of contributing to environmental well-being [59, 60]. Social influence also plays a critical role [61, 62], and [62] notes that social norms and peer recommendations significantly increase adoption intentions. Furthermore, government support in the form of financial incentives and clear policies is consistently found to be a powerful catalyst for adoption, reducing the primary barrier: high initial costs [63, 64, 65]. Conversely, significant barriers can impede the adoption of solar-powered products. The most frequently cited obstacle is the high upfront financial investment, which can be prohibitive for many consumers [4, 62]. [58]. Also highlight that perceived risks related to the technology's long-term performance, reliability, and value can create significant consumer hesitation. This uncertainty is often compounded by a lack of awareness or technical knowledge, underscoring the importance of clear information and marketing campaigns in building consumer confidence [66, 67, 68]. These dynamics are directly relevant to the acceptance of solar-powered vending machines, which exist at the intersection of sustainable technology and automated retail. Public perception of automated retail is generally positive, driven largely by its convenience, 24/7 accessibility, and speed [69, 70]. [71] and [72] found that modern technological features, such as contactless payment and a user-friendly interface, further enhance acceptance. However, just as with sustainable technologies, barriers related to trust and risk are prevalent. [73] notes that consumer concerns about payment security, data privacy, and machine reliability can hinder adoption, particularly among those unfamiliar with such systems [74]. Therefore, the acceptance of a solar-powered vending machine will likely depend on its ability to deliver the convenience expected of automated retail while simultaneously overcoming the perceived risks associated with a novel, sustainable technology.

2.2.4 Technological Advancements Supporting Solar-Powered Vending Adoption

Recent advancements in renewable energy and smart retail technologies strongly suggest that the adoption of solar-powered vending machines is no longer constrained by the limitations identified in earlier studies but is instead supported by a rapidly evolving technological landscape. Improvements in photovoltaic efficiency, battery storage, and IoT-enabled system monitoring have significantly enhanced the reliability and operational stability of solar-powered devices, directly addressing prior concerns related to performance and maintenance. As argued by [75], the continuous decline in solar technology costs, combined with increasing environmental awareness, has shifted consumer perception from skepticism to acceptance, making sustainable technologies more accessible and desirable. At the same time, the transformation of traditional vending machines into smart retail systems further strengthens this adoption argument. The integration of features such as cashless payment, real-time inventory management, and data-driven personalization has redefined vending machines as efficient, user-centered platforms rather than mere automated dispensers. According to [76], these technological enhancements not only improve operational efficiency but also increase user trust and perceived value, which are critical determinants of technology acceptance. Taken together, these developments indicate that solar-powered vending machines are uniquely positioned at the convergence of sustainability and intelligent retail innovation. This convergence supports the argument that their adoption is not only feasible but increasingly inevitable, as they align with both environmental priorities and modern consumer expectations for convenience, efficiency, and technological sophistication.

2.3 Conceptual Framework

The conceptual framework in Figure 1 highlights the relationship between Perceived Quality and User Acceptance of solar-powered vending machines. It posits that users' perceptions of quality, specifically Attribute Quality and Reliability Quality, are crucial factors in determining whether they will accept and

engage with the technology. Attribute Quality, which includes performance, features, and aesthetics, plays a significant role in shaping user satisfaction. A well-performing vending machine, with useful features such as mobile charging and Wi-Fi access, alongside an aesthetically pleasing design, is more likely to attract users. These elements contribute to the perceived functionality and visual appeal of the machine, which can strongly influence user acceptance [8]. On the other hand, Reliability Quality, encompassing factors like reliability, serviceability, and perceived quality, ensures that users feel confident in the machine's ability to function consistently and be easily maintained, which also affects their willingness to adopt it [51]. The framework further integrates these quality dimensions with User Acceptance, which is primarily influenced by Usefulness and Ease of Use—key components of the Technology Acceptance Model (TAM). According to TAM, a system's usefulness and ease of use directly determine whether users will embrace it. In the case of solar-powered vending machines, their usefulness in providing convenient services and ease of operation are critical for fostering widespread use. The framework suggests that both Attribute Quality (H1) and Reliability Quality (H2) significantly predict User Acceptance, with each dimension influencing users' overall willingness to engage with the technology. Recognizing the importance of both functional attributes and reliability, the model provides valuable insights into the design and deployment of renewable energy technologies in educational settings, ensuring they meet users' expectations and support sustainable, long-term adoption.

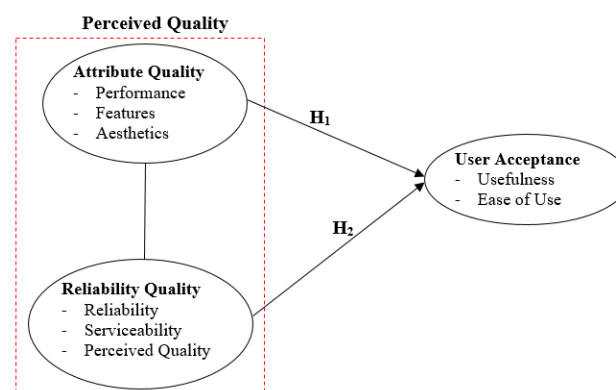


Figure 1. Conceptual Framework of Perceived Quality and User Acceptance of Solar-Powered Vending Machines

3. Methodology

3.1 Research Design

This study employed a quantitative research design to evaluate the perceived quality and user acceptance of solar-powered vending machines, with a focus on the relationships among quality dimensions and technology adoption. A non-experimental, descriptive-correlational design was employed to collect data on users' perceptions of attribute and reliability quality, as well as their acceptance of the technology. A structured survey gathered data on key quality attributes (performance, aesthetics, features, reliability, serviceability) and perceptions of the vending machines' usefulness and ease of use. This design was ideal as it allowed for the collection of objective, measurable data, offering insights into user perceptions. [77] and [78] demonstrated the effectiveness of survey-based quantitative designs in capturing attitudes and behaviors related to technology acceptance, particularly in the context of renewable energy systems. Data were collected through online and on-site surveys to ensure wide representation.

3.2 Participants and Sampling

The participants in this study were users of solar-powered vending machines at North Eastern Mindanao State University (NEMSU) in Bislig City, Philippines, including students, faculty, and staff who regularly interacted with the machines. As shown in Table 1, 200 participants were selected using convenience sampling, which was ideal for accessing users on the NEMSU campus. The survey was administered both on-site and through online platforms to ensure accessibility for all potential users. Participants were required to be at least 18 years old, have used the solar-powered vending machines at least once, and agree to participate voluntarily. The sample aimed to include a diverse range of users, balancing students, faculty, and staff to

provide a comprehensive understanding of user acceptance across different demographic groups. This approach ensured that the study gathered relevant insights into how various groups perceive and engage with solar-powered technology on campus.

Table 1. Profile of the Respondents (n=200)

Profile	Category	Frequency	Percentage
Age	20-22	99	49.35%
	23-25	67	33.52%
	25 and older	34	17.13%
Gender	Male	117	58.44%
	Female	83	41.56%
Academic Affiliation	BSEE Students	122	61.04%
	BTVTEd Students	52	25.97%
	Faculty	13	6.49%
	Industry Practitioners	13	6.49%

Regarding demographics as shown in Table 1 and Figure 1, most respondents were young, with 80.52% aged 25 or younger, and the largest group was those aged 20–22 (49.35%). Males comprised the majority of respondents (58.44%), while females accounted for 41.56%. In terms of academic affiliation, the sample was predominantly composed of Bachelor of Science in Electrical Engineering (BSEE) students (61.04%), with a significant percentage from Bachelor of Technical Vocational Teacher Education (BTVTEd) students (25.97%), and smaller proportions from faculty (6.49%) and industry practitioners (6.49%). This demographic distribution aligns with the perspectives of a younger, more technically-minded audience, making them ideal evaluators of renewable energy technologies in educational settings.

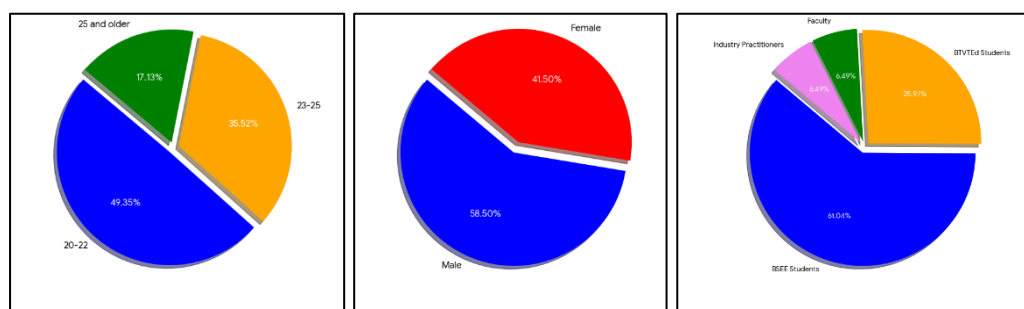


Figure 1. Profile of the Respondents

However, while this technically minded demographic provided valuable insights into the system's performance, the heavy reliance on engineering students through convenience sampling introduces a potential technical bias. Specifically, their inherent familiarity with complex mechanical and electrical systems may have positively skewed the ratings for 'Perceived Ease of Use.' Therefore, this demographic concentration is acknowledged as a limitation of the current study. Future research should employ a more randomized sampling approach to include a larger proportion of non-technical staff, students from other disciplines, and general campus visitors to further validate these findings.

3.3 Instrument

In this study, a structured questionnaire consisting of a three-part instrument was used. The first part included Informed Consent, where participants were provided with information about the study's purpose, the voluntary nature of participation, and their rights, ensuring ethical transparency and compliance. Following the informed consent, participants completed the survey questionnaires. The second part of the instrument was the Perceived Quality Scale, which consisted of two dimensions: (1) Attribute Quality, assessing performance, functionality, and aesthetics, and (2) Reliability Quality, which included reliability,

serviceability, and perceived quality. A pilot test was conducted to assess the instrument's internal consistency, yielding excellent results. Cronbach's alpha for this scale was 0.92, and the Composite Reliability (CR) was 0.91, both exceeding the recommended threshold, indicating strong internal consistency and reliability. The third part of the instrument was the User Acceptance Scale, based on the Technology Acceptance Model (TAM) dimensions of Perceived Usefulness and Perceived Ease of Use. Similar to the Perceived Quality Scale, a pilot test was conducted for this section, yielding a Cronbach's alpha of 0.94 and a Composite Reliability (CR) of 0.92, both exceeding the recommended threshold and confirming the scale's excellent reliability. All respondents were asked to rate their agreement with statements on a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Pilot testing confirmed the instrument's robustness, ensuring it could reliably measure the constructs of perceived quality and user acceptance.

3.4 Data Collection and Analysis

The data-gathering procedure followed a systematic, ethical approach. Formal permission to conduct the study was first secured from North Eastern Mindanao State University (NEMSU), including approval from the Research Ethics Committee. The study's purpose, methods, and requirements were presented, and all necessary documents, such as the ethical review, were submitted. Once approved, participants were informed through an Informed Consent Form outlining the study's objectives, the voluntary nature of participation, anonymity of responses, and their right to withdraw at any time. Only those who provided consent were included in the study. Participants were recruited both online and on-site to ensure accessibility. The survey link was distributed through NEMSU's official communication channels, such as social media groups and email lists, while on-site recruitment targeted users of the solar-powered vending machines. After consenting, respondents completed a structured Likert-type questionnaire comprising three parts: Perceived Quality (performance, functionality, aesthetics, reliability, serviceability, and perceived quality), User Acceptance based on the Technology Acceptance Model (TAM), and demographic information. Items were rated on a 5-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree). All responses were anonymized and stored in password-protected files accessible only to authorized researchers. Data were analyzed using IBM SPSS 26. Descriptive statistics (mean and standard deviation) were used to summarize responses. Pearson correlation tested the relationships between perceived quality dimensions and user acceptance, while multiple regression identified significant predictors of acceptance. All analyses used a 0.05 significance level. Reliability tests, including Cronbach's alpha and Composite Reliability (CR), confirmed strong internal consistency of the scales. Final results were presented using tables and graphs for clarity.

3.5 Ethical Considerations

Ethical standards were strictly followed throughout the data collection process. Participants were given full disclosure about the study's objectives, the voluntary nature of their participation, and their right to withdraw at any point. The Research Ethics Committee at NEMSU reviewed and approved the research design, ensuring compliance with ethical guidelines for research involving human subjects. All participants provided informed consent before their participation. Moreover, the study adhered to the principles of respect, beneficence, and justice, ensuring that participants were not harmed and promoting the fair distribution of research benefits. After completing the survey, participants were debriefed on the study's aims and were allowed to ask questions. Participants were informed of how the results would be used, and their contact information was kept confidential. A follow-up was conducted to ensure all data were collected and any concerns regarding the process were addressed.

4. Results and Discussion

4.1 Aesthetics

The design of the solar-powered vending machine is not only functional but also thoughtfully aesthetic, as demonstrated in the provided figures.

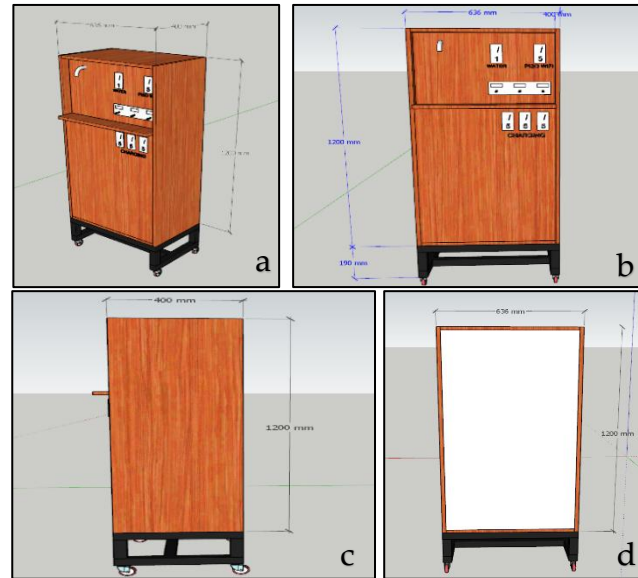


Figure 2. Dimensions of Solar-Powered Vendo Machine

As shown in Figure 2, the solar-powered vending machine features a compact, ergonomic design measuring 1,700 mm in height, 600 mm in width, and 400 mm in depth. This size ensures space efficiency while maintaining user accessibility. Its design combines functionality and aesthetics through a wood finish and a black base, creating a balance between eco-friendly and modern industrial appeal. The natural texture enhances visual attractiveness and reflects sustainability, making it suitable for public spaces. The solar panel positioned on top highlights its environmental purpose while contributing to its overall design. Rounded edges soften the machine's appearance, making it more approachable and less bulky compared to traditional vending machines. The front interface features a large touchscreen with a clean, user-friendly layout. Clear labels and interactive icons improve usability, while the modern design enhances both functionality and visual appeal.

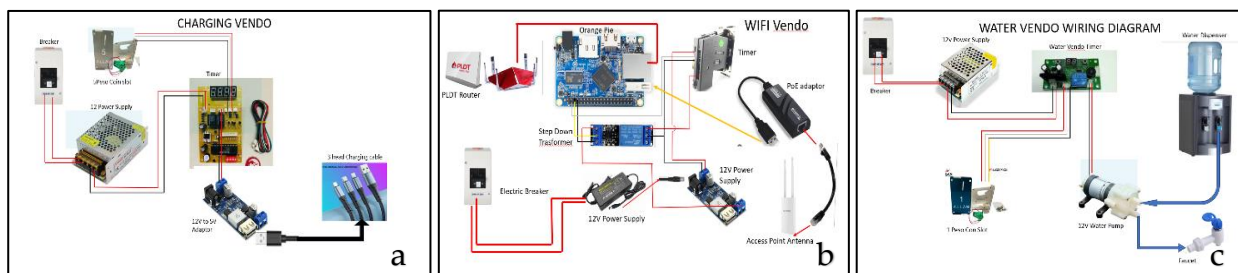


Figure 3. Wiring Diagram of Solar-Powered Vendo Machine

The three diagrams in Figure 2 show the internal wiring and system architecture for three models of the solar-powered vending machine, each serving a unique function and utilizing solar energy. The Charging Vendo Diagram illustrates (see figure 2.a) how the machine functions as a charging station, using a solar power supply, transformers, and timer control to manage the charging of devices. This setup ensures that the machine can operate in locations without a direct power supply, making it eco-friendly and energy-efficient. The Wi-Fi Vendo Wiring Diagram (see figure 2.b), demonstrates how the machine connects to a Wi-Fi network using an access point antenna and Wi-Fi module. The diagram also highlights the inclusion of step-down transformers for voltage regulation, enabling the machine to function in areas requiring internet connectivity for remote control or data monitoring. Lastly, the Water Vendo Wiring Diagram (see figure 2.c) outlines the integration of a water pump and UV filter system, ensuring the machine dispenses clean water efficiently and is powered entirely by solar energy. These wiring configurations underscore the versatility and sustainability

of the solar-powered vending machine, demonstrating its ability to support a range of needs, including device charging, internet connectivity, and clean water dispensing.



Figure 4. Actual Campus Set-up of Solar-Powered Vendo Machine

Figure 4 shows four units strategically deployed across different areas of the campus, including hallways and waiting areas. These placements ensure high visibility and easy access for students and staff. Positioning the units in high-traffic locations, such as common spaces, ensures they are readily available for use, enhancing convenience and accessibility. The setup optimizes functionality, enabling users to quickly engage with units where they are most needed, thereby contributing to efficient campus operations.

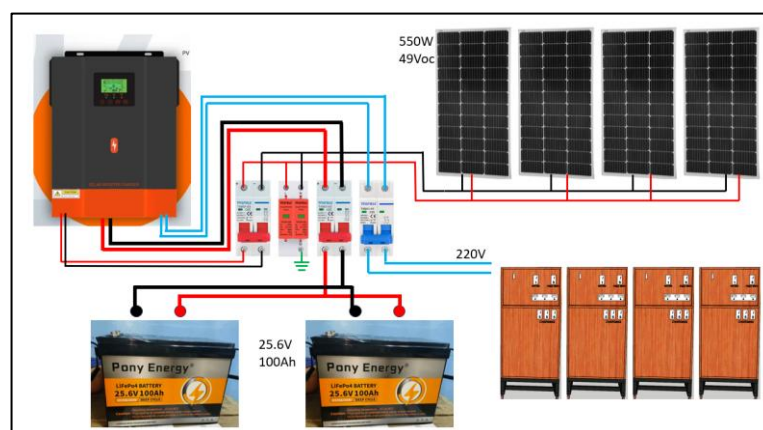


Figure 5. Wiring Set-up of Solar-Powered Vendo Machine

Figure 5 illustrates the wiring setup for a solar-powered vending machine, showing the connections between the various components. The system consists of four solar panels (550W each) connected to a charge controller that regulates power flow to the battery bank. The batteries (25.6V, 100Ah) store the energy generated by the panels for use. The charge controller is connected to an inverter that converts the DC power

into AC (220V) to operate the vending machine. The wiring includes safety features, such as fuses and breakers, to protect the system from overcurrent and ensure safe, efficient operation. This setup highlights a sustainable, off-grid power solution for the vending machine that uses solar energy and energy storage for continuous operation.

4.2 Perceived Quality of Solar-Powered Vending Machines in terms of Attribute Quality

The data in Table 2 shows a strongly positive perception of the solar-powered vending machines, reflected in the high overall mean of 4.39 ("Agree") and a standard deviation of 0.81. This favorable baseline is important because perceived quality heavily shapes user attitudes and their willingness to adopt new technologies [79, 80]. A closer look at the dimensions reveals what users value most. The features dimension earned the highest rating (4.56, "Strongly Agree"), showing that multi-functionality, portability, and convenient payment options are strongly appreciated. The integrated functions—Wi-Fi, cold drinking water, and smartphone charging—received the highest individual score, suggesting strong user preference for systems that offer multiple services in one unit. However, the regression analysis indicates that features alone do not drive acceptance as strongly as performance and aesthetics. This aligns with findings that multi-functionality may initially attract users, but long-term adoption depends more on how consistently and effectively core functions operate [44]. The performance dimension supports this pattern, with a mean of 4.17 ("Agree") and strong approval of the cold-water feature, yet a notable weakness in Wi-Fi stability. Since performance reliability is central to perceived usefulness, disruptions—particularly in Wi-Fi—pose a real threat to continued use and acceptance [52, 71]. This lower rating may be attributed to technical constraints in solar-powered systems, where energy intermittency affects continuous power delivery to network components such as routers and signal amplifiers [81]. During periods of low solar irradiance or nighttime operation, limited battery storage capacity can result in unstable voltage supply, leading to intermittent connectivity or reduced router performance. To address this, engineering solutions such as optimizing battery storage capacity, integrating power management systems with load prioritization for communication modules, and implementing energy-efficient routers with low-power standby modes may enhance Wi-Fi stability and overall system reliability. Hybrid charging support or auxiliary backup power systems may also be considered to ensure uninterrupted connectivity [82]. Meanwhile, the aesthetics dimension (4.42, "Agree") demonstrates that users view the machines as visually appealing and well-suited to the campus environment, a factor known to enhance perceived value and promote willingness to engage with technology in shared public spaces [47, 72, 83].

The consistently high ratings across all attributes signal strong acceptance potential within educational settings, yet targeted improvements are needed to sustain long-term user loyalty. Strengthening performance, especially Wi-Fi stability, should be the top priority because performance was identified as the strongest predictor of acceptance. Enhancing this single area would significantly improve perceived quality and usefulness. The strong aesthetic appeal of the machines should continue to be leveraged, as the design contributes to positive first impressions and helps attract new users. At the same time, expectations around features must be carefully managed. While the multi-functionality is well-received, the priority should be to refine the reliability of existing services—water dispensing, phone charging, and Wi-Fi connectivity—rather than adding new functions. Focusing on consistent performance for these core features will build trust and repeat use more effectively than expanding the feature set. Overall, the machines have established a solid perception of quality, and addressing the identified performance gap will allow the institution to convert this positive perception into long-term adoption, user satisfaction, and sustainability of the service.

Table 2. Mean Distribution of the Respondents' Ratings on the Perceived Quality of Solar-Powered Vending Machines in terms of Attribute Quality

Attribute Quality	Mean	SD	Description
Performance			
1. The Wi-Fi vending feature provides a stable and fast internet connection.	3.92	1.02	Agree
2. The cold-water feature consistently dispenses water at the desired temperature.	4.39	0.67	Agree
3. The smartphone charging feature charges devices quickly and reliably.	4.00	1.06	Agree
4. The solar-powered vending machines exhibit strong performance and cost-effectiveness.	4.36	0.67	Agree
Mean	4.17	0.71	Agree
Features			
5. The 3-in-1 vending machine's multi-functionality addresses diverse user needs by offering Wi-Fi vending, cold drinking water, and smartphone charging in a single unit.	4.63	0.63	Strongly Agree
6. The machine's wheels make it portable and easy to move to different locations.	4.46	0.74	Agree
7. The machine's compact size makes it suitable for small spaces without being obtrusive.	4.53	0.64	Strongly Agree
8. The machine's coin slot payment option is convenient and easy to use.	4.62	0.61	Strongly Agree
9. The smartphone charging feature supports multiple device types, ensuring compatibility and convenience for a wide range of users.	4.57	0.52	Strongly Agree
Mean	4.56	0.50	Strongly Agree
Aesthetics			
10. The overall design of the 3-in-1 vending machine is visually appealing.	4.36	0.81	Agree
11. The machine's appearance complements its surroundings well (e.g., a campus environment).	4.47	0.77	Agree
12. I find the machine's design to be modern, elegant, attractive, and aesthetically pleasing.	4.42	0.80	Agree
Mean	4.42	0.72	Agree
Weighted Mean	4.39	0.81	Agree

Legend: 4.50 – 5.00 – Strongly Agree; 3.50 – 4.49 – Agree; 2.50 – 3.49 – Neutral; 1.50 – 2.49 – Disagree; 1.00 – 1.49 – Strongly Disagree

4.3 Perceived Quality of Solar-Powered Vending Machines in terms of Reliability Quality

The results in Table 3 show that respondents generally perceive the solar-powered vending machines as reliable, reflected in the high overall mean rating of 4.24. This positive perception is important because reliability consistently emerges in research as a major driver of technology adoption, shaping user trust, purchase intentions, and long-term satisfaction [29, 52]. When users believe a system performs dependably, they are more likely to embrace it and continue using it. The results reveal that serviceability received the highest rating at 4.29. This means users believe the machines are easy to maintain, repair, and install, which is a strong indicator of perceived durability and long-term value. Studies emphasize that products designed for easy maintenance tend to be perceived as higher in quality and more dependable, thereby increasing acceptance of technological innovations [53, 54]. Strong serviceability also enhances user confidence because it signals that any potential issues can be resolved quickly, supporting uninterrupted use and reducing concerns about risk or inconvenience. The reliability dimension had a mean of 4.13, supported by a high overall dependability rating of 4.34. This aligns with technology acceptance research, which recognizes

dependability as a major factor in the Technology Acceptance Model, strengthening perceived usefulness and reducing hesitation to adopt new tools [52, 77]. However, the feature-level results reveal an important concern. Although the cold drinking water feature scored well at 4.25, the Wi-Fi vending feature received the lowest rating at 3.79, suggesting occasional disruptions. Research on self-service technologies shows that even minor interruptions in heavily used features can lower user satisfaction and weaken behavioral intentions [51, 71]. This highlights that the reliability of each core feature is essential to shaping the overall user experience. The lower Wi-Fi rating may be associated with unstable energy supply during periods of low solar input, which can affect the continuous operation of network components supported by the system's storage capacity [84]. Enhancing battery efficiency, prioritizing energy allocation for communication modules, and using low-consumption networking devices may help stabilize connectivity and improve overall system reliability.

The perceived quality dimension also scored high at 4.30, with strong ratings for the cold-drinking-water feature at 4.39 and for overall machine quality at 4.35. These findings suggest that users believe the machines offer stable performance and solid construction. Consumer behavior studies consistently show that high perceived quality strengthens trust, encourages positive attitudes, and predicts stronger loyalty and likelihood of continued use [33, 85, 86]. Positive judgments of quality serve as a strong precursor to adoption in technology acceptance research [3].

In summary, the results indicate that the vending machines are viewed favorably for reliability, serviceability, and overall quality. The high ratings in both serviceability and water dispensing demonstrate a strong foundation for user acceptance. The lower Wi-Fi stability rating presents a clear area for improvement. Enhancing the reliability of this feature could significantly strengthen overall acceptance, as consistent performance across all functions reinforces perceptions of quality and usefulness [44], ultimately supporting long-term adoption.

4.4 User Acceptance of Solar-Powered Vending Machines

The results in Table 4 show very high acceptability of the solar-powered vending machines, with an overall mean of 4.52 and a standard deviation of 0.69. This strong response aligns with the core principles of the Technology Acceptance Model, as both Perceived Usefulness (mean = 4.53, standard deviation = 0.55) and Perceived Ease of Use (mean = 4.52, standard deviation = 0.70) fell within the "Strongly Agree" range. These findings demonstrate that users recognize the machines as both highly beneficial and convenient to operate, a combination supported in technology adoption research [3, 77].

Usefulness indicators highlight a clear driver of acceptance. The highest rating was given to the machine's environmental contribution, with a mean of 4.65 and a standard deviation of 0.56, showing strong user appreciation for its eco-friendly design. This quantitative finding is supported by open-ended survey responses, which indicate strong appreciation for the machine's green integration. For instance, one student noted, "*Seeing the solar panel on top makes me feel good about using it. It shows our campus is actually doing something real for the environment.*" Another participant highlighted, "*It's great that we can charge our phones using clean energy right in the hallway.*" These sentiments confirm that environmental advantages significantly boost the adoption. Studies confirm that environmental advantages significantly boost the adoption of sustainable technologies by increasing perceived usefulness and adding moral or social value to the user experience [87, 88]. High ratings for the cold drinking water feature (mean 4.58, standard deviation 0.57) and overall comfort and convenience (mean 4.57, standard deviation 0.68) also suggest that users see the technology as both practical and aligned with sustainable values. Research notes that green innovations succeed most when ecological benefits are paired with personal convenience, reinforcing this pattern [28].

Ease-of-use indicators reveal equally positive results. Strong agreement was recorded across all items, with high ratings for the intuitiveness of the cold drinking water feature (mean = 4.62, standard deviation = 0.57) and the accessibility of the Wi-Fi function (mean = 4.51, standard deviation = 0.69). These findings show that the machines achieve a user-friendly interface that reduces effort and supports repeated use, consistent with studies on usability and self-service technologies [71, 80, 89]. However, it is important to note that these exceptionally high ease-of-use ratings may be partially influenced by the sample's technical bias, as the majority of respondents were engineering students who are naturally adept at navigating new interfaces. The slightly lower score for "requires little assistance," with a mean of 4.40 and a standard deviation of 0.96, signals

that some first-time users may still need brief guidance. Research in educational technology shows that concise instructions and simple onboarding strategies can meaningfully improve ease-of-use perceptions [17].

Thus, the strong results across both TAM dimensions indicate exceptional user acceptance and high potential for long-term use. The environmental appeal provides an added advantage in sustainability-focused environments. Enhancing support for new users through visual guides or simple onboarding approaches, as validated in previous technology adoption studies [74, 90], can further strengthen long-term user engagement and sustained adoption.

Table 3. Mean Distribution of the Respondents' Ratings on the Perceived Quality of Solar-Powered Vending Machines in terms of Reliability Quality

Reliability Quality	Mean	SD	Description
Reliability			
1. The Wi-Fi vending feature works without frequent disconnections or interruptions.	3.79	0.91	Agree
2. The cold drinking water feature operates without breakdowns or malfunctions.	4.25	0.75	Agree
3. The smartphone charging feature consistently charges devices without issues.	4.16	0.93	Agree
4. The solar-powered vending machines are dependable.	4.34	0.68	Agree
Mean	4.13	0.67	Agree
Serviceability			
5. The Wi-Fi vending feature is easy to troubleshoot and repair if issues arise.	4.23	0.79	Strongly Agree
6. The cold drinking water system can be serviced or maintained without significant downtime.	4.36	0.65	Agree
7. The smartphone charging feature is easy to repair or replace if damaged.	4.29	0.79	Strongly Agree
8. The solar-powered vending machines are easy to maintain, install, and repair.	4.29	0.79	Strongly Agree
Mean	4.29	0.64	Strongly Agree
Perceived Quality			
9. Overall, I believe the Wi-Fi vending feature is of high quality.	4.18	0.93	Agree
10. Overall, I believe the cold-water feature is of high quality.	4.39	0.73	Agree
11. Overall, I believe the smartphone charging feature is of high quality.	4.26	0.93	
12. The overall quality of the solar-powered vending machine meets or exceeds my expectations.	4.35	0.79	Agree
Mean	4.30	0.79	Agree
Weighted Mean	4.24	0.88	Agree

Legend: 4.50 – 5.00 – Strongly Agree; 3.50 – 4.49 – Agree; 2.50 – 3.49 – Neutral; 1.50 – 2.49 – Disagree; 1.00 – 1.49 – Strongly Disagree

Table 4. Mean Distribution of the User Acceptance of Solar-Powered Vending Machines

Indicators	Mean	SD	Description
<i>Perceived Usefulness</i>			
1. The Wi-Fi vending feature is useful for my internet needs	4.39	0.83	Agree
2. The cold-water feature is useful for staying hydrated.	4.58	0.57	Strongly Agree
3. The smartphone charging feature is useful for keeping my devices powered.	4.44	0.80	Agree
4. Overall, solar-powered vending machines help make the environment cleaner and safer.	4.65	0.56	Strongly Agree
5. Overall, I find solar-powered vending machines useful, as they offer comfort and convenience.	4.57	0.68	Strongly Agree
<i>Mean</i>	4.53	0.55	Strongly Agree
<i>Perceived Ease of Use</i>			
6. The Wi-Fi vending feature is easy to access and use.	4.51	0.69	Strongly Agree
7. The cold-water feature is easy to operate.	4.62	0.57	Strongly Agree
8. The smartphone charging feature is easy to use.	4.53	0.72	Strongly Agree
9. Overall, I require little assistance to use the 3-in-1 solar-powered vending machines.	4.40	0.96	Agree
10. Overall, I feel positive and comfortable using the 3-in-1 solar-powered vending machines because of their user-friendly, intuitive design.	4.55	0.70	Strongly Agree
<i>Mean</i>	4.52	0.70	Strongly Agree
Weighted Mean	4.52	0.69	Strongly Agree

Legend: 4.50 – 5.00 – Strongly Agree; 3.50 – 4.49 – Agree; 2.50 – 3.49 – Neutral; 1.50 – 2.49 – Disagree; 1.00 – 1.49 – Strongly Disagree

4.5 Attribute-Quality as a Predictor of User Acceptance

The regression analysis in Table 5 provides key insights into the factors driving user acceptance of solar-powered vending machines. Performance ($\beta = 0.201$, $p = 0.0005$) and aesthetics ($\beta = 0.265$, $p < 0.001$) significantly influence acceptance, while features ($\beta = 0.067$, $p = 0.4563$) do not. With 59.6 percent of the variance explained ($R^2 = 0.596$), users rely more on how well the machine functions and how visually appealing it is when forming acceptance decisions, showing that certain attributes carry more weight than others in shaping adoption intent.

Performance emerges as a strong driver, emphasizing that reliable operation, including stable Wi-Fi, consistent cold-water dispensing, and dependable charging, is central to acceptance. This aligns with the Technology Acceptance Model, where functional performance is a key antecedent of Perceived Usefulness [77]. Dependability strongly influences technology trust [52], and research on smart retail and self-service technologies confirms that performance reliability is essential for user satisfaction and sustained use [51, 73]. Users are more likely to adopt technologies that consistently deliver without interruptions, making reliability a foundational determinant of acceptance.

Aesthetics is the strongest predictor, highlighting the importance of visual appeal, modern design, and environmental fit in shaping positive user attitudes. Attractive design enhances perceived value and quality [47, 48], creates positive first impressions, reduces perceived complexity, and signals modernity and professionalism [72, 83]. Design aesthetics also function as a post-adoption buffer, helping sustain continued use even when minor issues arise [49], reinforcing the influence of visual appeal on overall acceptance.

The non-significance of features provides an important insight. While users appreciate multi-functionality and portability, these aspects do not substantially shape acceptance once performance and aesthetics are accounted for. This reflects the “Feature Fatigue” concept [44], which warns that too many features can overwhelm users or fail to add meaningful value. Users expect a baseline level of functionality,

but acceptance depends more on the reliability of core features and visual satisfaction than on the number of features offered.

These findings suggest clear practical implications. Prioritizing performance reliability is essential, ensuring stable Wi-Fi, consistent water dispensing, and dependable charging. Investing in superior aesthetics is equally critical, as visual appeal strongly influences perceptions of quality and value. Introducing new features should be secondary to perfecting existing ones, following a “features-second” approach. Maximizing user acceptance requires a disciplined focus on operational excellence and thoughtful design, ensuring interactions with the vending machine are both reliably functional and visually rewarding.

Table 5. Regression Analysis Attribute-Quality Dimensions Predicting User Acceptance

Predictor	Beta Coefficient	p-value	Interpretation
Performance	0.201	0.0005	Significant
Features	0.067	0.4563	Not Significant
Aesthetics	0.265	0.0000	Significant
$R^2 = 0.596; F = 35.475$			

Dependent variable: User Acceptance of Solar-Powered Vending Machines

4.6 Reliability-Quality as Predictor of User Acceptance

The regression analysis in Table 6 provides a clear understanding of how reliability-related dimensions shape user acceptance. Serviceability emerges as the only significant predictor ($\beta = 0.316$, $p = 0.0029$), while reliability ($\beta = 0.208$, $p = 0.102$) and perceived quality ($\beta = 0.091$, $p = 0.4903$) do not significantly influence acceptance when considered alongside it. The model explains 37.0 percent of the variance in user acceptance ($R^2 = 0.370$), highlighting that serviceability has unique explanatory power and serves as a distinct driver of adoption intent relative to other reliability-related attributes.

The significance of serviceability underscores that users place high value on how easily the machines can be maintained, repaired, and restored to full operation. This aligns with research showing that ease of maintenance is a core element of perceived durability and contributes to long-term consumer satisfaction [53, 54]. In public-facing technologies, rapid and effective recovery from service failures builds trust and strengthens user loyalty [51, 91]. Even if a machine is generally reliable, users are more willing to adopt it when they know issues can be resolved quickly and with minimal inconvenience, thereby lowering the perceived risk of adopting the technology.

The non-significance of reliability and perceived quality provides an important insight into user cognition. When serviceability is high, users may perceive a strong maintenance and support system as sufficient protection, reducing concerns about inherent reliability or product quality. This reflects a dynamic understanding of reliability, where the surrounding support system becomes as crucial as the technology’s initial performance. Research in other fields supports this, showing that robust operational support acts as a safety net that outweighs baseline reliability concerns in adoption decisions [55].

These findings have clear practical implications. Institutions should prioritize developing a responsive support ecosystem, ensuring spare parts availability, and establishing clear maintenance protocols. Communicating serviceability to users strengthens confidence and encourages adoption. Future iterations should incorporate design-for-serviceability principles, such as modular components, accessible parts, and diagnostic features to streamline repair processes [55].

In conclusion, while inherent reliability and perceived quality remain important, accessible and effective serviceability is the key factor that strengthens user confidence and drives acceptance of solar-powered vending machines. A technology that is not only well-built but also supported by a dependable maintenance system minimizes downtime, enhances user experience, and fosters long-term adoption.

Table 6. Regression Analysis of the Reliability-Quality Dimensions Predicting User Acceptance

Predictor	Beta Coefficient	p-value	Interpretation
Reliability	0.208	0.102	Not Significant
Serviceability	0.316	0.0029	Significant
Perceived Quality	0.091	0.4903	Not Significant
$R^2 = 0.370; F = 13.911$			

Dependent variable: User Acceptance of Solar-Powered Vending Machines

5. Conclusions

This study evaluated the perceived quality and user acceptance of solar-powered vending machines at North Eastern Mindanao State University, focusing on attribute quality (performance, features, aesthetics) and reliability quality (reliability, serviceability, perceived quality). Results showed generally positive perceptions, with users valuing multi-functionality, portability, ease of use, and environmental sustainability. In particular, performance and aesthetics emerged as significant predictors of acceptance, underscoring the importance of both functional efficiency and appealing design in shaping user approval. Serviceability also proved to be a key determinant, underscoring the need for easy maintenance and repair to sustain system use over time. However, areas such as Wi-Fi stability were identified as needing improvement, as connectivity issues can negatively affect user satisfaction and overall adoption experience. Overall, high ratings for perceived usefulness and ease of use suggest strong potential for widespread adoption of the technology in educational settings. These findings provide practical guidance for administrators and policymakers in deploying and maintaining such systems to ensure alignment with user needs and sustainability goals. Consequently, addressing technical challenges while strengthening serviceability remains essential in maximizing system impact and sustaining user trust and engagement.

Future development of this technology should extend beyond system enhancement toward more rigorous and comprehensive evaluation frameworks. Future studies may adopt longitudinal research designs to track actual usage behavior over time, shifting focus from behavioral intention to sustained, real-world utilization. This approach would provide stronger evidence on long-term adoption patterns and system effectiveness in operational settings. In addition, future research may include financial viability indicators such as return on investment (ROI), cost recovery period, and long-term operational sustainability to assess the economic feasibility of scaling solar-powered vending machines. Environmental performance measures, such as carbon offset reductions, energy savings, and greenhouse gas mitigation, may also be incorporated to quantify contributions to institutional sustainability and climate goals. Collectively, these directions support a more holistic evaluation of solar-powered vending machines as both technological innovations and sustainability solutions in educational environments. The university may also integrate these systems into a broader “Green Campus” initiative, using them as instructional tools in renewable energy-related courses to strengthen practical learning in solar technology and applications.

This study also acknowledges several limitations that should be considered in interpreting the findings. The sample was drawn from a single institution, North Eastern Mindanao State University, which may restrict the generalizability of the results to other contexts. The study used convenience sampling with 200 participants, mostly engineering students (61.04%), which may have introduced technical bias and inflated ease-of-use ratings due to greater technology familiarity. Future research should use randomized or stratified sampling that includes non-technical students and staff to achieve a more balanced perspective. Participation was also limited to individuals with prior experience with the solar-powered vending machines, thereby excluding potential users who had not yet interacted with the system. The reliance on self-reported survey data may introduce response biases such as social desirability and recall bias, despite efforts to ensure anonymity and objectivity. Moreover, the study did not capture long-term usage behavior or post-adoption patterns, limiting insights into sustained engagement. External influences, such as socio-cultural factors and environmental conditions, were also not fully examined. While technical concerns such as Wi-Fi stability were identified, they were not deeply analyzed in terms of system engineering solutions. Furthermore, it is important to clarify that this research serves as an initial, cross-sectional baseline evaluation of the newly

deployed solar-powered vending machines in their current state. Because no prior versions of the machine existed on campus, pre- and post-upgrade satisfaction surveys and comparative technical matrices were not applicable. Future iterations of the system should utilize this baseline data to measure the effectiveness of subsequent technical upgrades. Similarly, while evaluating the economic impact is valuable, conducting a break-even point analysis or detailed financial assessment fell outside the scope of this user-centric behavioral study. Therefore, as recommended, future researchers should pair this acceptance data with economic viability metrics to fully assess the project's institutional value. Accordingly, future research may expand across multiple institutions, integrate qualitative approaches, incorporate longitudinal tracking of actual usage, and explore technical refinements to provide a more comprehensive understanding of the adoption and sustained use of solar-powered vending machines.

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