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Development and acceptability of vendo-sealant and tire inflator machine

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Abstract

Aim: This study aimed to design, develop, and evaluate the acceptability of a vendo-sealant and tire inflator machine intended to improve accessibility, convenience, and efficiency in tire maintenance for motorists. The system integrates a coin-operated air compressor and tire sealant dispenser to provide an immediate solution for tire inflation and minor puncture repair.

Methodology: The study employed a product development research design with developmental and evaluative phases. A functional prototype of the vendo-sealant and tire inflator machine was designed and developed, followed by usability testing and field evaluation. Data were collected through user feedback surveys assessing functionality, effectiveness, safety, environmental friendliness, user-friendliness, and general acceptability. Descriptive statistical analysis was used to interpret the results.

Results: Findings revealed that the developed vendo-sealant and tire inflator machine was highly acceptable to users, demonstrating strong performance in terms of functionality, effectiveness, and ease of use. Respondents reported high satisfaction with the system's convenience and accessibility, indicating its effectiveness in reducing downtime during tire-related emergencies and supporting safer driving conditions.

Conclusion: The vendo-sealant and tire inflator machine is a functional, user-friendly, and acceptable innovation for tire maintenance. Its integration of automated inflation and sealant dispensing offers a practical solution for motorists, with potential applications in public and commercial automotive service settings to enhance road safety and maintenance efficiency.

Keywords: vendo-sealant system, coin-operated tire inflator, product development, user acceptability, tire maintenance, road safety

Introduction

Proper tire maintenance plays a critical role in ensuring vehicle safety, performance, and fuel efficiency. Globally, underinflated tires have been shown to increase rolling resistance and fuel consumption, leading to economic losses and heightened environmental impacts (Das et al., 2023). Inadequate tire maintenance also compromises vehicle stability and braking efficiency, increasing the risk of road accidents (Johannessen et al., 2022).

In many developing countries, including the Philippines, these global concerns are amplified by local conditions. Roadside emergencies, uneven distribution of vulcanizing shops, and limited access to reliable tire maintenance services—particularly in rural areas and high-traffic public roads—often prevent drivers from maintaining recommended tire pressure levels. Motorcyclists and public utility vehicle operators are especially vulnerable, as immediate tire services are not always available when punctures or pressure loss occur.

Current technological trends in tire maintenance include AI-enhanced inflators, advanced Tire Pressure Monitoring Systems (TPMS), and portable or automated inflation devices. While these innovations improve accuracy and monitoring, most existing systems focus on single functions such as inflation or pressure detection and often require professional assistance, continuous power supply, or high initial costs. Similarly, commercially available tire sealants and portable pumps are typically offered as separate solutions, resulting in fragmented and less accessible tire maintenance options for ordinary drivers.

Despite advancements in automation and vending-machine-based service delivery models, there remains a clear research gap in the development of an integrated, user-acceptable, and accessible tire maintenance system that

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combines both tire inflation and sealant dispensing in a single automated unit. Existing studies rarely evaluate such systems in terms of not only technical performance but also user acceptability, safety, and practicality in community-level roadside settings.

To address this gap, the present study focused on the design, development, and acceptability evaluation of a vendo-sealant and tire inflator machine. The technical novelty of this study lies in the integration of automated tire inflation, sealant dispensing, and a coin-operated vending mechanism within one system. Academically, the study contributes to product development research by combining technical performance testing with user acceptability assessment grounded in the Technology Acceptance Model (TAM). At the community level, the system offers a practical roadside solution aimed at improving accessibility, reducing response time during tire-related emergencies, and supporting safer and more sustainable vehicle operation.

Review of Related Literature and Studies

This section synthesizes literature relevant to the development, sustainability, and technological innovations of tire inflation systems, including material engineering, artificial intelligence applications, vending-machine service models, and tire safety technologies. The review covers global and local contexts to establish the foundations of modern tire maintenance, sustainability practices, and user-centered service delivery.

Tire Sealants, Material Innovation, and Environmental Sustainability

Several studies highlight innovation in tire materials and sealants as a means to enhance vehicle safety and environmental performance. Li et al. (2023) introduced a crumb rubber/polyurethane compound for asphalt sealant, emphasizing durability under long-term stress. Complementing this, Araujo-Morera et al. (2022) examined the self-healing properties of styrene–butadiene rubber (SBR), revealing how curing agents influence mechanical recovery. Research by Grammelis et al. (2021) further stressed sustainable solutions by showing that more than 90% of Europe's End-of-Life Tires (ELTs) are already being repurposed, supporting circular-economy practices. Studies on tire wear particles, such as Johannessen et al. (2022), added environmental urgency by highlighting the limited understanding of their toxicity and behavior in urban atmospheres.

Technological Advancements and AI Applications in Tire Inflation

Recent literature shows the increasing role of artificial intelligence and digital technologies in improving tire inflation systems. Singh et al. (2019) demonstrated how machine learning models can optimize automation in mechanical processes, including tire pressure systems. Choudhury et al. (2017) applied an Extreme Learning Machine (ELM) algorithm to enhance the speed and accuracy of tire inflators, showing AI's potential in precision maintenance. Complementing this, Ojariafe and Bashir (2023) developed a DC-operated compressor made from recycled materials, illustrating both technological innovation and sustainability in portable tire inflation devices.

Tire Maintenance, Road Safety, and Fleet Operations

A substantial body of literature confirms the direct relationship between proper tire inflation and road safety. Foundational studies, such as Lutsey et al. (2006), emphasized tire management strategies in fleet operations, noting the role of correct inflation in reducing waste and improving energy efficiency. Although earlier, this work remains relevant as a baseline reference for tire maintenance practices.

Local studies further reinforce these findings within the Philippine context. Gumasing and Magbitang (2020) and Gunadhi and Nugruho (2020) identified tire condition and maintenance as critical factors in motorcycle safety. Similarly, Dela Cruz and Padilla (2015), serving as a foundational local reference, reported that inadequate tire pressure significantly increases accident risk. These studies highlight the continuing need for accessible and reliable tire inflation systems, particularly in developing and high-risk road environments.

Vending Machines as Service Models for Tire Inflation

Emerging literature supports the integration of automated vending systems into technical services, including tire inflation. Alburo and Tindugan (2020) demonstrated the success of vendo machines as business models through their J2KLC Wi-Fi Vendo, showing how automated systems can increase accessibility and affordability. Dėdelė et al. (2022) expanded this perspective by presenting a self-service water vending machine designed to promote healthy consumption behavior. Burmester et al. (2020), through the Snackomat project, explored the social and experiential impact of vending machines, showing their potential for enhancing user engagement and convenience. These concepts align with recent vehicle-service innovations such as V-Locate (Melendres et al., 2022) and VulcaLoc (Sunico et al., 2020), which use digital platforms to improve accessibility of vulcanizing shops.

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Advancements in Tire Pressure Monitoring Systems (TPMS)

Innovation in TPMS has been widely documented in recent studies. Silalahi et al. (2019) improved TPMS technology by incorporating automatic inflation features for better driver comfort and safety. Mpindi (2023) proposed a real-time monitoring and alert system that supports proactive maintenance, prolonging tire lifespan and reducing accident risk. These advancements reflect the global movement toward intelligent transport systems and real-time safety technologies.

Synthesis and Justification for the Study

The reviewed literature demonstrates a strong research foundation in material innovation, AI-enhanced tire systems, and automated service delivery models. However, there remains a gap in accessible, sustainable, and user-friendly tire inflation technologies that can serve local communities, especially in areas with limited resources. The development of an automated tire inflation system—whether coin-operated, solar-powered, or digitally integrated—responds to this need by combining technological innovation with practical service delivery. This study contributes to ongoing efforts to improve road safety, environmental sustainability, and service accessibility by integrating modern engineering solutions into everyday tire maintenance practices.

Theoretical Framework

This study is anchored on the Technology Acceptance Model (TAM) developed by Davis (1989) and the Diffusion of Innovations Theory proposed by Rogers (2003). TAM explains that the acceptance of a new technological system is shaped primarily by users' perceptions of its usefulness and ease of use. In the context of this study, the vendo-sealant and tire inflator machine is expected to gain user acceptance if drivers perceive it as beneficial for tire maintenance and convenient to operate. These two constructs guide the evaluation of the system's usability, functionality, and overall acceptability.

Complementing TAM, Rogers' Diffusion of Innovations Theory provides a broader lens for understanding how new technologies spread within a community or industry. The theory outlines key attributes influencing adoption: relative advantage, compatibility, complexity, trialability, and observability. The vendo-sealant and tire inflator machine offers a relative advantage over conventional tire maintenance methods by delivering faster, more accessible, and cost-efficient services. Its compatibility with existing tire care practices and its user-friendly operation further support its potential for widespread adoption.

Together, these theoretical perspectives frame the study's examination of both system development and user acceptability. By integrating TAM and Diffusion of Innovations, the study conceptualizes the adoption of the vendo-sealant and tire inflator machine as a function of technical performance, perceived efficiency, and user experience, offering insights into how innovative tire maintenance technologies can enhance road safety, convenience, and automotive reliability.

Conceptual Framework

The conceptual framework illustrates the relationship between the system components of the vendo-sealant and tire inflator machine and the expected improvement in tire maintenance accessibility, convenience, and efficiency for vehicle users. It consists of three major components:

1. Input

Refers to the essential requirements and resources needed to develop the system, including:

- The identified problems in traditional tire maintenance (time delays, limited access to services, and manual processes).
- Technical components such as the air pressure vendo unit, tire sealant vendo unit, air compressor, and sealant refilling mechanism.
- Electrical power input (220V supply) and mechanical materials necessary for system assembly.

2. Process/Development

Refers to the systematic procedures involved in designing and developing the vendo-sealant and tire inflator machine. This includes:

- Conceptualization and analysis of user needs.
- System design, integration of components, and prototype fabrication.
- Testing of functionality, usability, efficiency, and safety.
- Refinement of the system based on evaluation results and user feedback.

3. Output/Outcome

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Refers to the final product and its demonstrated performance, including:

- A fully functional vendo-sealant and tire inflator machine that offers automated sealant dispensing and tire inflation.
- Improved accessibility and convenience for drivers, particularly in locations with limited vulcanizing services.
- Enhanced user satisfaction, perceived usefulness, and ease of use—aligned with Technology Acceptance Model (TAM) constructs.

Conceptual Model Flow

[Input: Identified Tire Maintenance Problems & Required System Components]

▼

[Process: System Design, Prototype Development, and Testing]

▼

[Output: Functional Vendo-Sealant and Tire Inflator Machine & Improved Maintenance Accessibility]

This framework demonstrates the logical progression from identifying the limitations of traditional tire maintenance practices to developing an automated, user-friendly system that enhances convenience, efficiency, and road safety.

Statement of the Problem

Tire maintenance remains a persistent challenge for many drivers, particularly in areas where vulcanizing shops are limited, inaccessible, or unavailable during roadside emergencies. Conventional tire inflation and puncture repair methods are often time-consuming, require manual assistance, and depend heavily on the availability of service personnel. As a result, drivers experience delays, increased safety risks, and additional expenses when immediate tire solutions are needed. Although portable air pumps and tire sealants are commercially available, these options are not always accessible, affordable, or user-friendly for the general public.

The growing number of motorcycle and vehicle users in both urban and rural communities further intensifies the demand for convenient, automated, and reliable tire maintenance solutions. Existing technologies rarely integrate tire inflation and sealant dispensing within a single automated system, limiting drivers' ability to independently address punctures and maintain proper tire pressure. This gap in accessible and integrated tire maintenance solutions directly affects road safety, fuel efficiency, and tire longevity.

Given these challenges, there is a clear need to develop and evaluate an innovative, cost-efficient, and automated tire maintenance system. This study addressed this need by developing and assessing the functionality, usability, and general acceptability of a vendo-sealant and tire inflator machine designed to provide motorists with immediate and convenient tire care services.

Research Objectives

The study aimed to develop and evaluate a vendo-sealant and tire inflator system to assist drivers in efficiently maintaining their tires. Specifically, the study sought:

1. To design and develop a cost-effective and user-friendly vendo-sealant and tire inflator machine that addresses the tire maintenance needs of drivers.
2. To evaluate the developed system as an accessible and affordable alternative to traditional vulcanizing services.
3. To assess the performance and acceptability of the vendo-sealant and tire inflator machine in terms of:
   3.1 Functionality
   3.2 Effectiveness
   3.3 Environmental friendliness
   3.4 Safety
   3.5 User-friendliness
   3.6 General acceptability

Research Questions

1. What features characterize a cost-effective and user-friendly vendo-sealant and tire inflator machine that meets the tire maintenance needs of drivers?

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2. How can the developed vendo-sealant and tire inflator machine serve as an accessible and affordable alternative to traditional vulcanizing services?
3. How do drivers assess the developed system in terms of:
   3.1 Functionality
   3.2 Effectiveness
   3.3 Environmental friendliness
   3.4 Safety
   3.5 User-friendliness
   3.6 General acceptability

Methodology

Research Design

This study adopted a mixed-methods developmental–experimental research design, supported by a survey method, to design, develop, and evaluate the vendo-sealant and tire inflator system. The developmental–experimental component involved the systematic construction and technical testing of the prototype to determine its functionality, reliability, and effectiveness using measurable performance indicators.

The quantitative aspect of the design focused on objective system testing results and structured survey ratings, while the qualitative component captured users' perceptions, experiences, and feedback regarding usability, convenience, and overall performance. The integration of these methods enabled a more comprehensive evaluation by combining technical performance data with user-centered insights.

This research design was deemed most appropriate because the study aimed not only to verify the operational effectiveness of the developed system but also to assess its acceptability and practicality in real-world applications. By employing both experimental testing and user evaluation, the mixed-methods approach ensured a holistic assessment of the product's technical validity and user suitability.

Population and Sampling

The study utilized a purposive sampling technique to select respondents who possessed direct experience and relevant knowledge related to tire maintenance and roadside vehicle services. A total of 50 respondents were involved in the study, composed of two distinct groups.

The quantitative respondents included vehicle owners and operators in Borongan City, particularly those frequently operating in high-traffic areas such as public markets, transport terminals, and major roadways. These participants were selected based on the criteria that they regularly operate vehicles, have prior experience with tire-related issues, and are potential users of automated tire inflation services.

The qualitative and technical respondents consisted of local automotive repair and vulcanizing shop personnel who have hands-on experience in tire maintenance and repair. Their inclusion aimed to assess the system's practicality, operational feasibility, and potential impact on existing maintenance practices.

This sampling approach ensured the collection of relevant, informed, and diverse perspectives, allowing for a more accurate evaluation of the vendo-sealant and tire inflator system's usability, efficiency, and overall acceptability.

Instruments

The primary research instrument for this study was a structured questionnaire designed to evaluate the vendo-sealant and tire inflator system. The questionnaire aimed to collect data on key dimensions, including Functionality, Effectiveness, Environmental Friendliness, Safety, User-Friendliness, and General Acceptability. Respondents rated each item using a five-point Likert scale ranging from Excellent to Poor.

To ensure a comprehensive assessment, the instrument also included qualitative components, allowing participants to provide open-ended feedback, observations, and suggestions for system improvement. This combination of quantitative ratings and qualitative responses provided a holistic understanding of user perceptions and the overall performance of the developed system.

The questionnaire was researcher-made and subjected to content validation by a panel of faculty members experienced in research design, quantitative, and mixed-methods studies. These evaluators assessed the instrument for clarity, relevance, completeness, and alignment with the study objectives, ensuring its validity and appropriateness for both technical and user-based evaluation.

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Data Collection

Data collection for this study, conducted in Borongan City over a four-week period, followed a structured, multi-phase approach to gather both quantitative and qualitative data on the usability, effectiveness, and overall acceptability of the vendo-sealant and tire inflator system.

In the quantitative phase, a purposive sample of vehicle owners and operators, as well as local automotive repair and vulcanizing shop personnel, was surveyed using a structured questionnaire. The instrument measured key performance variables, including Functionality, Effectiveness, Efficiency, Safety, and User-Friendliness, and included open-ended items for capturing user observations and suggestions. Participants were oriented on the system's operation at designated locations before completing the questionnaire to ensure informed responses.

The qualitative phase involved observations and informal interviews with selected users while interacting with the system. Observations focused on real-world use, noting user behavior, challenges encountered, and operational ease. Interviews provided deeper insights into user perceptions, satisfaction, and recommendations for improvement.

This multi-method approach ensured a comprehensive understanding of both the technical performance and practical user experience, allowing the integration of quantitative results with contextual qualitative insights.

Treatment of Data

Quantitative Data: Survey responses were encoded and analyzed using SPSS version 22. Descriptive statistics, including mean scores, standard deviations, and frequency distributions, were calculated to determine user satisfaction and system performance based on the following numerical rating and descriptive interpretation:

Numerical Rating	Descriptive Interpretation
4.21 – 5.00	Excellent
3.41 – 4.20	Very Satisfactory
2.61 – 3.40	Satisfactory
1.81 – 2.60	Good
1.00 – 1.80	Poor

Qualitative Data: Observational notes and interview responses were analyzed using thematic analysis. Recurring patterns and themes were identified, including ease of use, perceived effectiveness, safety concerns, environmental considerations, and overall acceptability. These themes were interpreted to provide insights into user experiences and to validate quantitative findings.

Integration of Data: Quantitative and qualitative results were triangulated to produce a holistic understanding of the vendo-sealant and tire inflator's performance and user acceptance. This integrated approach ensured that statistical findings were supported by real-world experiences, guiding recommendations for system improvements and broader implementation.

Ethical Considerations

The study adhered to strict ethical standards to ensure the protection of participants and the integrity of the research:

- Approval and Consent: Authorization was obtained from vehicle owners, operators, and relevant local authorities in Borongan City before data collection.
- Informed Consent: Participants were fully briefed on the purpose, procedures, and potential risks and benefits of the study prior to their involvement.
- Confidentiality: Personal identifiers were omitted from all survey responses and observation notes. Data were securely stored and accessed solely by the researcher.
- Academic Integrity: All instruments, references, and materials were properly cited to maintain academic honesty and avoid plagiarism.

These measures ensured that participants' rights were respected and that the study maintained credibility, transparency, and ethical integrity.

RESULTS AND DISCUSSION

This section presents the findings and interpretations derived from the testing and evaluation of the Vendo-Sealant and Tire Inflator System. The discussion is organized according to the two main phases of testing—Initial

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Testing and Pilot Testing—to ensure alignment with the study's objectives and problem statement. Findings are analyzed in relation to both technical performance and user perceptions, with contextualization from relevant literature.

1. Initial Testing

The initial testing phase evaluated the system under controlled conditions, focusing on Functionality, Effectiveness, Environmental Friendliness, User-Friendliness, and General Acceptability. The system successfully inflated 100% of tires and sealed 96% of punctures, maintaining pressure above 92% over 24 hours.

Mean scores and interpretations:

- Functionality (4.78) – The system reliably performed intended functions, consistent with Singh et al. (2019), who highlighted the role of precise automation in enhancing operational efficiency.
- Effectiveness (4.78) – Adaptability to different tire types and ease of troubleshooting mirrored findings by Choudhury et al. (2017) on AI-assisted maintenance systems.
- Environmental Friendliness (4.70) – Use of recyclable and biodegradable components aligns with Grammelis et al. (2021) on sustainable tire material practices.
- User-Friendliness (4.75) – Participants reported intuitive operation and affordability, supporting the concept of user-centered design (Dėdelė et al., 2022).
- General Acceptability (5.00) – High acceptability indicates readiness for implementation, demonstrating potential for accessibility improvements in local contexts (Gumasing & Magbitang, 2020).

These results suggest that the system is technically reliable, environmentally responsible, and user-oriented, bridging the gap between conventional tire maintenance practices and automated, accessible solutions.

2. Pilot Testing

The pilot testing phase assessed real-world performance in an automotive shop and school parking area. Fifty participants interacted with the system, and their feedback was collected.

User ratings:

- Excellent – 50% (25 participants)
- Very Satisfactory – 30% (15 participants)
- Satisfactory – 14% (7 participants)
- Good/Poor – 6%

Mean scores across criteria:

- Functionality (4.87) – Fast inflation and consistent sealant distribution confirm practical efficiency. These findings support Silalahi et al. (2019), who emphasized the importance of real-time system responsiveness in TPMS and inflation devices.
- Effectiveness (4.72) – System troubleshooting remained straightforward under variable conditions. This mirrors Ojariafe & Bashir (2023), who demonstrated ease of operation as key for portable, sustainable tire maintenance devices.
- Environmental Friendliness (4.70) – Non-toxic and recyclable materials were maintained, reinforcing circular-economy principles (Grammelis et al., 2021).
- User-Friendliness (4.91) – Clear labeling and intuitive operation enhanced accessibility, aligning with Alburo & Tindugan (2020) on automated service models.
- General Acceptability (5.00) – Participants highlighted cost-effectiveness and easy installation, reflecting community-level relevance.

The overall grand mean of 4.84 (Excellent) indicates that the system performs exceptionally well in practical applications. Interpretation of feedback highlights that the automated, coin-operated design increases convenience, promotes efficient maintenance, and supports sustainable practices. Minor suggestions focused on routine maintenance, indicating strong readiness for larger-scale implementation.

Integration with Literature

The findings align with global and local studies emphasizing technological innovation, sustainability, and user-centered design in tire maintenance systems. While existing literature (Lutsey et al., 2006; Dela Cruz & Padilla, 2015) underscores the need for proper tire management, this study contributes an accessible, automated solution that addresses both environmental and operational challenges in the Philippine context.

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Summary of Findings

Both the initial and pilot testing phases validate the vendo-sealant and tire inflator's high functionality, effectiveness, and user satisfaction. The consistently excellent ratings across criteria demonstrate its technical reliability and practical usability. Moreover, the system's environmentally conscious design and affordability enhance its appeal for broader implementation in automotive maintenance.

Overall, the findings indicate that the vendo-sealant and tire inflator system is a highly functional, user-friendly, and eco-sustainable innovation that effectively meets the needs of vehicle owners and service providers, contributing to more efficient and sustainable tire care practices.

Conclusion

The findings of this study demonstrate that the vendo-sealant and tire inflator system is a highly effective, user-friendly, and environmentally responsible solution for modern tire maintenance. Initial and pilot testing confirmed its functionality, with successful tire inflation and puncture sealing, and high user acceptability, as reflected in mean ratings ranging from 4.70 to 5.00 across key evaluation criteria. The system's design enhances road safety, provides convenient and cost-effective tire maintenance, and supports sustainable practices through the use of recyclable and non-toxic materials. Overall, this study highlights the practical value of integrating technological innovation and user-centered design in creating accessible automotive solutions that improve both efficiency and safety in everyday vehicle care.

Recommendations

Based on the results of this study, it is recommended that the vendo-sealant and tire inflator system be deployed in strategic locations such as gas stations, highways, and parking areas to improve accessibility and convenience for motorists. Emphasis on regular maintenance and inspection is important to sustain system functionality and reliability. Providing clear user instructions and educational materials may enhance proper operation and user safety. Establishing a feedback mechanism could facilitate ongoing evaluation and support system improvements. Future enhancements might incorporate smart features, including tire pressure monitoring and mobile app integration, to increase efficiency and user engagement. Finally, continuing to adopt sustainable materials and practices in production and operation will strengthen the system's environmental responsibility. Collectively, these measures can improve road safety, user satisfaction, and the overall effectiveness of the system.

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