

Development of A Wearable Mechanic Creeper Garment for Underbody Automotive Repairs

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ABSTRACT

This study focused on the development and evaluation of a Wearable Mechanic Creeper Garment for underbody automotive repairs, an innovative tool engineered to enhance comfort, safety, and operational efficiency during under-chassis and low-position maintenance tasks. Integrating the mobility of a traditional rolling creeper with the utility of a mechanic's work vest, the prototype allows users to maneuver freely while providing crucial ergonomic support during demanding tasks. Utilizing a descriptive-quantitative research design, the prototype was evaluated by sixty (60) automotive students, instructors, and experts at Cebu Technological University – Main Campus. Data gathered through standardized survey questionnaires and performance checklists assessed the garment's comfort, safety, mobility, and overall functional usefulness. The empirical results demonstrated that the wearable mechanic creeper achieved high user acceptability, receiving exceptionally strong ratings for mitigating physical fatigue, improving ergonomics, enhancing under-car mobility, and increasing task efficiency. Participants reported that the garment significantly minimized the physical strain of extended under-chassis operations. Although the evaluation was overwhelmingly positive, respondents noted minor recommendations for future iterations, specifically incorporating additional padding and reinforcing high-stress areas to optimize long-term durability. Overall, the study concludes that the Wearable Mechanic Creeper Garment serves as a highly practical and effective instructional and workshop tool, possessing strong viability for integration into both technical vocational training and commercial automotive industries.

Keywords

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Introduction

Automotive maintenance workers, commonly known as mechanics, are consistently exposed to numerous intense work stressors while performing their daily duties. Maintenance activities require technicians to operate within various types of demanding working postures, most of which are highly awkward configurations that place them at an elevated risk of developing work-related musculoskeletal disorders. Statistical data across industrial sectors disclose that the prevalence of musculoskeletal disorders among automotive maintenance workers is exceptionally high compared to other types of job fields. Therefore, thoroughly examining these problematic working postures based on active job activities is critical to establishing safer workshop practices [1].

This structural and physical toll is highly evident in localized automotive service environments within the Philippines. Empirical assessments of auto-mechanics in regional repair shops, such as those in San Jose, Occidental Mindoro, highlight critical issues with increasing body pains and severe headaches that directly impact worker efficiency and operational performance. Comprehensive evaluations tracking cognitive, temporal, emotional, and performance constraints indicate that an auto-mechanic's mental workload sits in a demanding medium range, which previous research directly links to poorer physical postures. Utilizing standardized ergonomic evaluation metrics like the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) reveals high risk indices during standard tire and engine repair operations, proving that immediate preventive measures and physical changes in posture are strictly required [2].

To alleviate these physical strains during maintenance and manufacturing, ensuring the proper and secure positioning of heavy vehicle components is crucial to maximizing safety. Industrial solutions frequently focus on the structural analysis, finite element modeling, and prototype production of heavy chassis positioning systems—such as automated scissor platforms engineered to rotate structures across three axes to optimize physical alignment. While these heavy mechanical systems effectively withstand high stress values and minimize worker displacement under load, such massive industrial machinery is rarely accessible or practical for underbody repairs in smaller, localized automotive shops or instructional environments [3].

Consequently, a distinct gap exists for a portable, direct-to-worker ergonomic interface that protects technicians during low-position maintenance. This paper addresses this challenge by evaluating the development and field acceptability of The Wearable Mechanic Creeper Garment for Underbody Automotive Repairs. Engineered as a localized safety solution, this prototype directly accommodates awkward postures, mitigates the physical and musculoskeletal workloads identified in regional shops, and offers an innovative, apparel-based alternative to heavy shop infrastructure.

Literature Review

A. Foundational Role of Ergonomics and User-Centric Design

This book is designed to allow the reader to develop a more comprehensive knowledge of issues facing the developers of automotive products and delivers methods to manage communication, coordination, and integration processes. Delivering a toolkit that will allow you to implement systems engineering to minimize the risks of delays and cost overruns, it also delivers a framework that will allow you to create the right product for your customers. The reader will therefore develop a knowledge of future in-vehicle devices that are easy to program and use, safe, cheap to manufacture and assemble, and eco-friendly. This title is an ideal read for students and practitioners of ergonomics, human factors, automotive design, civil engineering, product design, work design and mechanical engineering. This title is an ideal read for students and practitioners of ergonomics, human factors, automotive design, civil engineering, product design, work design and mechanical engineering [4].

The creation of effective innovation ecosystems (IES) at the national or sectoral level remains a difficult and not always feasible task. Based on evidence from the Brazilian automotive industry, a case of unused opportunities for building a strong IES is considered. This is due to the insensitivity of such ecosystems to new, complicated configurations and the formats of non-traditional interaction that suggest a “new ecology of competition”, etc.[5]

B. Safety, Performance, and Physiological Advantage

Lightweight design is one of the current key drivers to reduce the energy consumption of vehicles. Design methodologies for lightweight components, strategies utilizing materials with favorable specific properties, and hybrid materials are used to increase the performance of parts for automotive applications. In this paper, various forming processes to produce light parts are described. Material lightweight design is discussed, covering the manufacturing processes to produce hybrid components like fiber-metal, polymer-metal, and metal-metal composites, which can be used in subsequent deep drawing or combined forming processes [6].

In the past 20 years, the proportion of Mg alloy in the automotive industry has gradually expanded, whereas currently the design and development of Mg alloy parts for automobiles has rarely been reported. Thus, the application models and typical parts cases of Mg alloy are summarized mainly from the four systems of the whole vehicle (body system, chassis system, powertrain system, interior, and exterior system). Subsequently, two actual original equipment manufacturers (OEM) cases are used to introduce the development logic of reliable die-cast Mg alloy, including forward design, formability analysis, process design analysis, structural redesign, manufacturing, and testing, aiming to share the methods, processes, and focus of attention of automotive OEMs for developing Mg alloy parts to enhance the confidence and motivation of applying Mg alloy in automotive field [7].

C. Data-Driven Assessment and Digital Evaluation

This study aims to examine the effects of industrial clustering and manufacturing flexibility on innovation capability and operational performance. This study follows a survey method to collect data pertaining to the phenomena of industrial clustering, manufacturing flexibility, innovation capability, and operational performance by utilizing a single-respondent design. A total of 124 Indonesian manufacturing SMEs were selected to test the proposed theoretical model by utilizing a covariance-based structural equation modeling approach. It was found that both industrial clustering and manufacturing flexibility were positively associated with operational performance and innovation capability as well. In addition, innovation capability may account for the effects of industrial clustering and manufacturing flexibility on operational performance [8].

This study is concerned with the development of a consistency check for structural equation modeling on both the direct and indirect influences on research and development capabilities that affect the competitiveness of Thai automotive parts industry enterprises. Thailand's automotive sector in 2013 was the 3rd largest sector of the economy, contributing 12% of GDP [9].

The objectives of this paper, and the novelty brought to the topic of Industry 4.0 manufacturing systems, are related to the integration of computer vision algorithms, remote sensing data fusion techniques, and mapping and navigation tools in the Slovak automotive sector. We conducted a thorough examination of Industry 4.0-based value and supply chains, clarifying how cyber-physical production systems operate in relation to collision avoidance technologies, environment mapping algorithms, and mobility simulation tools in network connectivity systems through vehicle navigation data [10].

The automotive sector is one of the key branches of the global economy. The automotive industry is also a very important sector of the Polish economy, as it generates over 8% of GDP and accounts for over 20% of the annual export value. Industry 4.0 and the effective use of

modern technologies give a chance for its further dynamic development. The implementation of Industry 4.0 solutions in the business processes of automotive companies should not only take place in the area of production or logistics, as is usually indicated, but also in their other functional areas, such as quality management, human resources management, and innovation management [11].

Automotive perception involves understanding the external driving environment and the internal state of the vehicle cabin and occupants using sensor data. It is critical to achieving high levels of safety and autonomy in driving. This article provides an overview of different sensor modalities, such as cameras, radars, and light detection and ranging (LiDAR), commonly used for perception, along with the associated data processing techniques. Critical aspects of perception are considered, such as architectures for processing data from single or multiple sensor modalities, sensor data processing algorithms and the role of machine learning techniques, methodologies for validating the performance of perception systems, and safety [12].

D. Cognitive and Behavioral Integration in Usability

The automotive industry is undergoing dramatic transformation as a result of connectivity, software-defined vehicle technologies, and electrification. Software-defined vehicles (SDVs) are transforming the in-vehicle software environment, facilitating continuous innovation through software-driven updates and new feature enhancements without the need for hardware modifications. Cloud connectivity is revolutionizing vehicles into dynamic, software-centric platforms that facilitate over-the-air updates, real-time data exchange, and communication with cloud-based applications [13].

We discuss the motivation for centralized architectural schemes by carefully examining challenges and drawbacks of the traditional decentralized automotive E/E architectures, while contrasting with the corresponding benefits offered by centralization. Then, the technologies required to support new centralized architectures are discussed in detail. In particular, we present the state of the art in networking technologies, virtualization, electronic control unit (ECU) hardware and AUTOSAR, and discuss the state of adoption of these technologies in industry. Throughout, functional safety is considered and addressed as an overarching concern in the automotive industry [14].

E. Alignment with Modern Vocational Education

It is consistently perceived that the tool is a natural extension of the hand, appreciating its effectiveness, durability, and ergonomic design. However, a significant difference in perception was found among the three user groups ($F = 166.1522$, $p < .001$), highlighting varied views based on experience. The main challenges identified were a lack of sufficient torque, non-standard sizing, and tool slippage. In conclusion, the ICW is a viable and effective teaching tool

despite these limitations. It is recommended that the university formally adopt a standardized, redesigned version of the wrench, with enhancements to address the identified challenges, and implement a comprehensive training module to ensure its proper and safe use in the curriculum [15].

Promoting technology development co-operation is particularly relevant while addressing global climate change or regional pollution. Investors may contribute to increasing environmental-related patents, which may help to improve the quality of the environment as long as supported by proper regulations and policies. In the quest towards a cleaner environment via the mitigation of climate change, this study investigates the relationship between technological innovation, income level, renewable energy, and carbon emissions in both the United States and China. Applying the dynamic autoregressive distributed lag (DARDL) simulation method revealed varying impacts of regressors on CO₂ emissions in the short run and long run [16].

This study aims to investigate the nexus between green growth, technological innovation, energy policy stringency, renewable energy, and carbon net-zero emission targets with a special emphasis on the world's two largest pollution-emitting economies (i.e., the United States and China). For this reason, quarterly data on all relevant variables were collected from 2012Q1–2020Q4. Because of its various benefits, including displaying causation patterns based on shifting quantiles of variables like green growth, technological innovation, environmental policy stringency, and renewable energy, this study employed the quantile autoregressive distributed lag (QARDL) method [17].

This study aims to develop a theoretical circular economy model that examines the impact of eco-innovation practices on recycled product performance and competitiveness in the Malaysian automotive industry. The supply of recycled materials has been recognized as one of the critical components to produce brand new automotive products. This empirical study was conducted among automotive firms and groups consisting of first-, second-, and third-tier suppliers. The data were analysed using structural equation modeling. The results support the importance of innovation and cost efficiency from the perspective of the resource-based view and the ability of a firm to manage resources while practicing circular economy initiatives, which is instrumental to the success of recycled product performance and competitiveness [18].

This review aims to evaluate steps that could be taken by automotive manufacturers to further reduce energy consumed during manufacturing processes, particularly focusing on thermal management of low-temperature heat sources that are extensively present in the whole plant and in the paint shop. Through an extensive literature review on the subject, this article presents vehicle production processes, the past and future drivers, and strategies towards

sustainability. Firstly, the whole vehicle manufacturing process is explained, focusing on the energy sources and their use in the plant [19].

This paper reviews the challenges faced by the global automotive industry as it transitions towards decarbonization. The article presents a comprehensive survey of hybrid, battery electric, and fuel cell electric vehicles, offering insights into their merits, drawbacks, and the potential implications they might have on consumers. It also highlights advancements in electrochemical storage devices, improvements needed to make them competitive with conventional fuels, and the role of government policies in driving adoption. Factors that influence the adoption of low- and ultra-low carbon technologies are also examined from a market perspective [20].

The automotive industry is experiencing a monumental shift from internal combustion engine cars to electric vehicles and embracing Industry 4.0 technologies. This is a response to the high anthropogenic impacts of the automotive industry at 14% of all direct and indirect emissions worldwide. However, the shift occurring is not holistic and is only focused on addressing the direct emissions of the vehicles at their point of use, commonly referred to as tailpipe emissions. A more holistic solution for the industry to ensure future-proof and impactful change would be to change from a linear flow of materials to a circular one, for a linear flow of materials and energy is not feasible to maintain if industries are meant to be sustainable. The framework of the circular economy provides a solution for change across the lifecycle of a vehicle, providing the automotive industry a path towards a robust sustainable transportation solution [21].

The automotive industry remains one of the most significant contributors to total global emissions worldwide. This growing challenge is primarily attributed to the high dependency on fossil fuels as its primary source of energy. This review highlights the current state of the application of fuel cells in the automotive industry, as well as the technological advances made in comparison to the early years of the automotive sector. Prospects of these technologies are also thoroughly reviewed. Factors impeding the advancement of these technologies while also impeding their commercialization are presented, with possible solutions to this problem also suggested [22].

Methods

A. Rationale of Innovation

The Development of a Wearable Mechanic Creeper Garment for Underbody Automotive Repairs addresses a critical ergonomic and operational limitation within the automotive technology and industrial education sectors. Traditionally, the reliance on rigid, wheeled rolling creepers imposes significant spatial constraints, physical strain, and safety hazards, particularly in tight workshop environments, low-clearance vehicle bays, or field-repair scenarios with

uneven floor infrastructure. This traditional mobility constraint often causes severe musculoskeletal fatigue in the technician's spine, neck, and shoulders, directly affecting their focus, precision, and efficiency during prolonged under-chassis tasks. The project is therefore driven by the necessity to create an apparel-based, protective, and mobile ergonomics solution that mitigates these physiological barriers while maintaining the structural support required for professional-grade mechanical maintenance.

The innovation involves the strategic integration of lightweight structural reinforcement and shock-absorbing textile technology into a wearable, highly ergonomic protective garment. This approach goes beyond mere apparel design; it challenges the student or researcher to master complex principles of human kinematics, user-centric ergonomics, and advanced material performance under physical stress. By transitioning from an external, rolling shop accessory to a personal, wearable mobile interface, the project fosters a deeper understanding of human-centered engineering and functional safety. This is particularly vital in modern vocational curricula where the ability to innovate within physical and spatial workplace constraints is a paramount skill for future automotive technicians and industrial teachers.

Furthermore, the development of a comprehensive fabrication process and usability framework ensures that the innovation is not only physically functional but also pedagogically sound. It serves to standardize the safety and protective protocols associated with underbody mechanical operations, directly addressing the inherent occupational risks of creeping friction, debris exposure, and spinal compression. The primary objective of this work is to formally validate the mechanical performance, ergonomic safety, and user acceptability of the garment, ultimately recommending its integration as a versatile, sustainable, and professional-standard component within the existing automotive technology curriculum and industrial workshop safety practices.

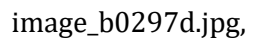
B. Materials

The fabrication, structural welding, and assembly of the Wearable Mechanic Creeper Garment required a strategic combination of structural metal elements, specialized fastening hardware, and high-density cushioning materials. The selection of these components was predicated on achieving an optimal balance between rigid spinal support, mechanical rolling mobility, and user comfort during supine under-body automotive repairs. The primary structural backbone of the innovation relies on a heavy-duty carbon steel angle bar, which forms the main load-bearing rigid chassis frame designed to protect the technician's spine from compressive forces. To achieve smooth, multi-directional rolling mobility and fluid translation along the workshop floor surface, eight low-profile rubber wheel caster assemblies are integrated directly into the structural frame.

Ergonomic support and comfort are achieved through a specialized upholstery layout consisting of a high-density polyurethane cushioning foam set wrapped in a heavy-duty protective industrial leather sheet. This material combination serves as the primary impact-absorption layer to minimize physical fatigue on pressure-sensitive body landmarks while acting as a resilient outer skin that effectively resists oil, grease, punctures, and abrasive workshop debris. To ensure the rigid frame bends naturally with the technician's posture adjustments during operation, the structural chassis utilizes an articulated joint system consisting of two large and two small stainless-steel hinges.

Securing the entire multi-jointed assembly ergonomically to the technician's torso relies on a high-tensile nylon webbing strap set paired with a heavy-duty quick-release polymer locking buckle system, which guarantees zero garment slippage during active locomotion under a vehicle chassis. The production and integration of these components required specialized workshop tools, including a leased shielded metal arc welding machine utilized alongside seven pieces of welding rods to execute robust, high-strength structural fillet and butt welds across the steel joints. Furthermore, a mechanical bar bender service was employed to contour the steel angle bar profiles to match the natural curvature of the human back, while a specialized dormer tool and heavy-duty stitching elements were utilized to bind the leather-foam upholstery seamlessly to the flexible metal-strapped framework.

C. Shop Drawings

The technical design of the Wearable Mechanic Creeper Garment is characterized by an articulated, modular configuration designed to optimize both user mobility and physiological support during supine underbody automotive repairs. As illustrated in the shop drawings in , the device is structured into distinct, interconnected segments including a headrest, backrest, and seat section, with the main body segments maintaining a uniform width of 30 cm (300 mm). The backrest segment features a vertical profile length of 50 cm (500 mm), while the corresponding lower seat section extends to a length of 40 cm (400 mm), and the independent headrest section is defined by a length of 30 cm (300 mm). This specific dimensionality ensures a low-profile, contoured alignment with the technician's anatomy, providing a stable, force-distributing foundation that prevents physical strain and localized pressure points during prolonged under-chassis maintenance operations.

The orthographic layout highlights a centralized, integrated harness system featuring heavy-duty adjustable strapping engineered to secure the multi-segmented chassis directly to the user's torso. The main horizontal waist strap features a total length of 90 cm (900 mm) and is bisected by a heavy-duty quick-release polymer locking buckle for rapid donning and removal. The perspective and vertical alignments delineate the ergonomic integration of the vertical shoulder

and headrest straps, which utilize standard 3 cm (30 mm) wide high-tensile webbing to facilitate multi-point adjustments along the backrest boundaries. This strategic spatial arrangement allows for fluid anatomical articulation across the hinged metal intersections while maintaining secure contact parameters between the internal foam-upholstered padding and the technician's back. By adhering to the designated orthographic projection parameters outlined in image_b0297d.jpg, the blueprint provides a comprehensive guide for the precise cutting, welding, and assembly phases of the fabrication process.

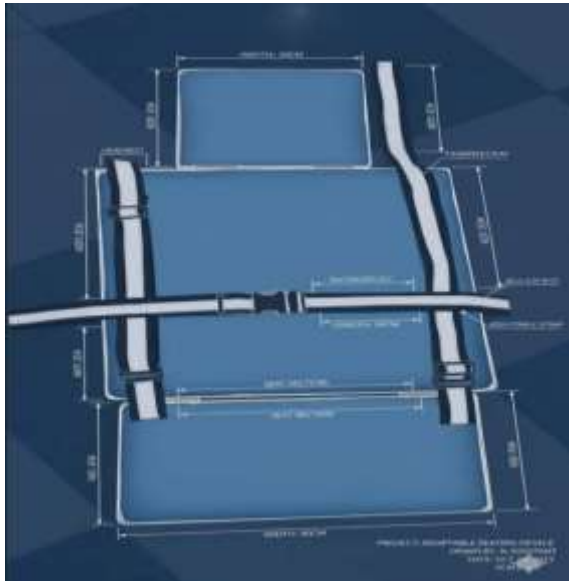


Fig. 1. Dimensional blueprint and structural component layout of the adaptable seating/creeper device.



Fig. 2. Cutting and preparation of the metal frame members using an angle grinder.

D. Fabrication Process

The fabrication of the Wearable Mechanic Creeper Garment which serves as the critical phase where the conceptual design is transformed into a functional, tangible product. The goal of fabrication was to ensure the prototype met all structural requirements, provided adequate fastener security, and possessed the necessary sturdiness to perform reliably and safely during the subsequent real-world performance testing in the demanding automotive environment.

1. Laying out
 - a) All materials and tools needed for fabrication of the Wearable Mechanic Creeper.
 - b) The materials were laid out on the workplace.
2. Measuring, drilling, cutting, and riveting of the materials.
 - a) Tailoring fabrics



Fig. 3. Fully assembled padded deck, headrest, and adjustable restraint harness system of the mechanics creeper.



Fig. 4. Bottom view showing the structural frame layout and caster wheel placement of the improvised mechanics creeper.

3. Assembly

The assembly and the design of the Wearable Mechanic Creeper Garment. Installing the Mechanic Creeper.

- a) Fixing of all parts
- b) Final checking and testing

E. Research Design

The study structural framework adopts a mixed-methods research and development (R&D) design, specifically utilizing a hardware fabrication phase paired with an empirical, descriptive-survey methodology to evaluate technological acceptability. This approach mimics the systematic development lifecycle required for industrial engineering innovations, moving sequentially from conceptualization and materials sourcing to physical fabrication, structural welding, and multi-point prototyping. The initial engineering phase focuses on the design layout, metallurgical bending, and assembly of the articulated steel-and-leather garment chassis to satisfy strict ergonomic and structural load requirements.

Following successful prototyping, the descriptive-survey phase is deployed to quantify the functional performance and practical acceptability of the wearable innovation. This empirical evaluation relies on a standardized assessment instrument, typically structured around a modified Liker scale, to capture objective feedback from a purposively selected cohort of technical experts, automotive instructors, and hands-on vocational students. By synthesizing qualitative engineering development with quantitative user metrics, this design provides a robust validation framework. It ensures the wearable creeper garment is rigorously analyzed for

ergonomic safety, structural durability, and operational viability before its proposed integration into the automotive maintenance curriculum and industrial workshop safety practices.

F. Research Environment

The study was strategically conducted within the technical workshop facilities and specialized instructional laboratories of Cebu Technological University (CTU) Main Campus. Specifically, the primary setting for both the physical innovation testing and the empirical evaluation was the Bachelor of Technical and Vocational Teacher Education (BTVTED) Automotive Shop. This environment provided the authentic, industrial-grade infrastructure necessary to execute and evaluate the project, featuring standardized automotive service bays, low-clearance vehicle work areas, and concrete workshop floors.

The engineering fabrication, structural welding, and initial material assembly phases were carried out using the specialized equipment and layout spaces within the campus's industrial arts and fabrication sectors. Once the prototype was fully assembled, it was transitioned directly into the BTVTED Automotive Shop for operational testing. This environment served as a rigorous, real-world proving ground, allowing researchers to evaluate the wearable mechanic creeper garment under actual underbody vehicle repair scenarios. Conducting the study within this specialized vocational training facility ensured that both the physical maneuvering tests and the user-acceptability assessments were performed under standardized, professional-grade institutional workshop conditions.

G. Respondents

The study participants comprised subject-matter experts and a group of student end-users. The experts included instructors from automotive and industrial technology, as well as technical personnel with professional experience in the automotive industry. These experts provided critical insight into the wearable garment's design and operational functionality. Additionally, a sample of fifty (50) automotive students from Cebu Technological University – Main Campus participated in an experimental task. These students were instructed to use the newly fabricated Wearable Mechanic Creeper Garment during underbody and under-chassis automotive repair operations. The data collected from the students' usage was subjected to appropriate statistical analysis to evaluate the tool's usability, comfort, and overall effectiveness. In total, the study involved 5 expert instructors, 5 industry technical experts, and 50 student users.

H. Research Instrument

To achieve the research objectives, a custom-developed survey instrument served as the principal method for data acquisition. The instrument's development was grounded in a comprehensive review of relevant literature, particularly the Technology Acceptance Model

(TAM), and an analysis of information concerning wearable ergonomic systems and technical apparel design. This rigorous approach ensured the instrument's theoretical relevance and empirical soundness for systematically collecting data on the wearable mechanic creeper garment's design specifications, aesthetic values, operational functionality, safety features, and user acceptance.

The survey was structured into multiple sections, each designed to address a specific research inquiry. Initial sections focused on the tool's foundational attributes, such as technical requirements, constituent structural materials, fabrication and assembly processes, and aesthetic properties (e.g., structural balance, proportionality, and handling efficiency). The core of the questionnaire utilized the TAM framework to quantify user perceptions, assessing perceived usefulness, ease of use, attitude toward use, and intention for continued use during underbody maintenance operations. Moreover, the instrument included specialized sections dedicated to evaluating user-perceived operational risks, mechanical reliability, and physiological ergonomic comfort, along with open-ended questions concerning specific structural challenges encountered and user-applied coping mechanisms. This multi-faceted structure facilitated a holistic evaluation of the wearable mechanic creeper garment's overall acceptability.

I. Data Gathering

The data collection process commenced with the submission of a formal request letter to the head administrator of Cebu Technological University (CTU) Main Campus, seeking institutional permission to conduct the study within the facility. The request package included a copy of the research-developed evaluation instrument and structural specifications pertaining directly to the Wearable Mechanic Creeper Garment. Following formal administrative approval, the principal investigator personally managed the data gathering process involving the selected automotive technology students and automotive experts at the Bachelor of Technical and Vocational Teacher Education (BTVTED) Automotive Shop. Prior to the completion of the evaluation instrument, the investigator provided a detailed briefing on the study's purpose and executed a live operational demonstration of the wearable garment framework under actual low-clearance vehicle chassis configurations. This instructional overview ensured that all participants possessed a clear understanding of the research context, mechanical articulation joints, structural steel design, and ergonomic metrics under evaluation.

Upon completion of the practical workshop trials and testing phases, the survey forms were immediately gathered by the investigator to ensure data integrity and prevent response alteration. The accumulated empirical feedback from both the automotive student and expert cohorts was systematized for subsequent statistical analysis to assess the wearable creeper's ergonomic performance metrics, rolling translation, and safety utility within the institution's

automotive training workshop. This structured data collection phase, conducted entirely within the specialized university automotive facility, provided valuable empirical feedback essential for validating user comfort, refining underbody mechanical mobility, and ensuring the successful pedagogical integration of the wearable protective innovation into the practical technology curriculum.

J. Data Treatment and Analysis

The empirical data collected via the survey instrument underwent standard preparatory procedures, including tallying, collation, and tabulation. Subsequently, the data was subjected to various statistical treatments, which included frequency counts, simple percentage calculations, weighted mean determination, ranking procedures, and analysis of variance (ANOVA).

Simple percentage calculations and frequency counts were used to determine the distribution of responses across the evaluation categories. The weighted mean determination was utilized to assess the overall acceptability of the Wearable Mechanic Creeper Garment in terms of its functional performance, ergonomic safety, and usability. The resulting mean scores were interpreted using a standard five-point scale: 4.21 – 5.00 as Strongly Agree; 3.41 – 4.20 as Agree; 2.61 – 3.40 as Neutral; 1.81 – 2.60 as Disagree; and 1.00 – 1.80 as Strongly Disagree. Furthermore, ranking procedures were applied to prioritize which design features achieved the highest levels of user satisfaction. Finally, the Analysis of Variance (ANOVA) was executed at a 0.05 level of significance to determine if there was a significant difference between the perceptions of the automotive experts and the BTVTED automotive technology students regarding the performance and utility of the wearable garment innovation.

K. Ethical Standards

The study adhered to rigorous ethical standards throughout all phases of the research. Prior to any data collection, formal permission was secured from the relevant institutional administrative bodies. All participants were provided with a comprehensive consent form detailing the study's purpose, the nature of their involvement, the expected duration of their participation, and the assurance that their involvement was entirely voluntary. Participants were explicitly informed of their right to withdraw at any point without penalty. Data handling procedures were designed to ensure confidentiality and security, with all collected information being used solely for research purposes and stored in locked or password-protected environments accessible only to the research team.

L. Anonymity Clause

To protect the privacy and identity of all individuals involved, strict anonymity protocols were implemented. No personally identifiable information (e.g., names, specific employee IDs, or departmental locations) was collected or recorded alongside the survey responses or

experimental data. Responses from instructors, technical experts, and students were aggregated and reported only in statistical summaries (e.g., means, frequencies), ensuring that no single response could be traced back to an individual person or specific educational unit. The institution's name and its specific campus locations were similarly generalized in the final reporting (as evident in the "Environment" section) to prevent any deductive identification of the setting and its staff or students, thereby safeguarding participant privacy and the institutional context.

Results

The following tables present a comprehensive analysis of a Wearable Mechanic Creeper Garment developed for educational training. Table 1 outlines the tool's design and technical specifications, while Tables 2 and 3 examine its acceptability and usability through the Technology Acceptance Model and user feedback. Table 4 identifies key challenges students encountered during practical application, and Table 5 documents the coping strategies they employed to address these difficulties, providing insights into the tool's real-world effectiveness and limitations.

Table 1. Product Assessment of a Wearable Mechanic Creeper

Item	Indicators	$\bar{x}$	Description
1	Technical requirements as to tool design; materials & cost; and fabrication and assembly processes.	4.58	Strongly Agree
2	Aesthetic Values in terms of balance; color, shape & proportionality; movement & handling efficiency.	4.62	Strongly Agree
3	Functionality in performing Automotive tasks; durability; and ease of use.	4.60	Strongly Agree
Overall		4.60	Strongly Agree
Legend: 4.21 – 5.00 Strongly Agree, 3.41 – 4.20 Agree, 2.61 – 3.40 Neutral, 1.81 – 2.60 Disagree, 1.00 – 1.80 Strongly Disagree			

Table 1 presents the technical requirements on tool and innovation design for the Wearable Mechanic Creeper Garment. The empirical data gathered evaluates the core engineering and design specifications of the prototype across several operational domains.

Regarding the technical requirements on innovation design, the evaluation covers indicators checking how precision-machined support tracks prevent slippage, how the ergonomic torso backing ensures comfort, and how the multi-jointed articulation framework offers mobility and structural stability alongside a stress-distributed internal layout and versatile secure-strapping features. For materials and costs, the instrument measures how high-grade structural alloys ensure durability, how a protective rust-resistant coating prevents corrosion, how the frame construction balances chassis hardness with flexibility, how an abrasion-resistant finish

preserves the protective skin, and how the bulk purchasing of fabrication components effectively reduces total development costs.

In terms of the fabrication and assembly process, the indicators address how precision component mounting strengthens the backing frame, how a multi-stage stress treatment balances articulation properties, how precision machining ensures an accurate fit for the multi-directional wheels, how grinding effectively removes structural burrs, and how rigorous quality control standards are maintained.

Table 2. Wearable Mechanic Creeper Garment as to TAM model

Item	Indicators	$\bar{x}$	Description
1	Functionality in terms of usefulness; ease of use; attitude towards using the tool; and intention to continue using the tool in future tasks.	4.58	Strongly Agree
2	Safety component regarding risks, reliability, and comfort during use of the tool.	4.60	Strongly Agree
Overall		4.59	Strongly Agree

Table 2 presents the empirical findings regarding the extent of acceptability of the Wearable Mechanic Creeper Garment, specifically structured around its functional utility and the core dimensions of the Technology Acceptance Model (TAM).

Regarding the functionality and usefulness component of the TAM framework, the evaluation measures how the wearable tool assists mechanics in completing underbody automotive tasks efficiently, provides high-quality repair results, and enhances overall workshop productivity. As to the ease of use, the instrument covers how the intuitive wearable layout simplifies the rolling and maneuvering process, how clear structural lines provide real-time operational status, and how the lightweight, low-profile design reduces mechanical complexity during use. Additionally, regarding the users' attitude towards using the tool, the indicators cover how technicians and students feel confident during active shop operations, appreciate the modern wearable interface, and value the exceptional convenience of a completely cordless, strap-on mobility setup. As to the intention to continue using the tool in future tasks, the indicators look into the likelihood of adopting the garment for regular workshop fabrication and repair, its distinct preference over traditional wooden or plastic wheeled rolling models, and its long-term role as a permanent part of the institution's technical toolkit.

On the other hand, with regards to the safety component, such technical requirements cover the indicators for operational risks, focusing on how the integrated steel protection frame prevents physical impacts, how the secure quick-release layout reduces entanglement hazards, and how the heavy-duty, heat-insulated leather casing protects the user from accidental shop

burns or abrasions. As to the garment's reliability, these indicators point out how the structural chassis maintains stable load performance under heavy mechanical strain, how wheel bearing consistency ensures steady translation across the floor, and how the durable build withstands rugged laboratory and workshop environments. Finally, part of the evaluation digs directly into the component on comfort during use of such a tool, where specific indicators cover how the ergonomic torso backing prevents physical strain, vibration-free rolling translation ensures mechanical precision, the smooth surface finish of the interior lining prevents skin irritation, and a perfectly balanced weight distribution promotes long-term body comfort and maximum tool control during intricate underbody automotive assemblies.

Table 3. Perceived performance of a Wearable Mechanic Creeper

Variables under Statistical Inference	F-statistics	p-value	Decision	Interpretation
Comparative analysis of the reliability and comfort of the Wearable Mechanic Creeper Garment as evaluated by automotive industry experts, instructors, and students.	166.1522	7.75×10^{-45}	Reject the null hypothesis	Significant

As regards this table, it ranks ten challenges of using a Wearable Mechanic Creeper Garment. Top concerns include rigid spine articulation causing movement restrictions, inconsistent wheel alignment leading to uneven rolling, and slow maneuverability times compared to traditional models. Other issues involve a bottom-heavy imbalance affecting precision, a bulkier chassis that reduces ergonomic comfort, and the lack of precise clearance control for low-clearance vehicles. Furthermore, challenges include proprietary strap limitations, internal heat retention of the backing, leather degradation over time, and the vulnerability of fragile caster bearings to physical damage.

Table 4. Challenges encountered during the Use of Wearable Mechanic Creeper in Training

Item	Indicators	$\bar{x}$	Rank
1	Spine Articulation Conflict- The rigid framework restricts natural body bending, making it difficult for the mechanic to walk, stand, or kneel comfortably between rolling tasks.	2.21	1
2	Low Ground Clearance- The ultra-low wheel profile causes the heavy-duty backing to drag, scrape, and catch on uneven concrete workshop floors.	2.61	2
3	Sluggish Rolling Maneuverability - Navigating tightly confined spaces beneath vehicle chassis takes more physical effort compared to using traditional, free-wheeling traditional creepers.	3.11	3
4	Poor balance Imbalance- An uneven weight layout in the backing frame shifts the center of gravity, causing the garment to tilt or slide awkwardly during high-torque wrenching tasks.	3.97	4

Item	Indicators	$\bar{x}$	Rank
5	Bulky chassis Restriction- The thick protective frame reduces overall ergonomic comfort and limits the user's upper-body squeezing space under low-clearance vehicle bellies	4.91	5
6	Zero Vertical Clearance Adjustment - The fixed wheel height lacks structural adjustment, preventing mechanics from altering their working distance relative to different vehicle undercarriages	6.00	6
7	Proprietary Strap Limitations - The rigid, non-standard chest strap boundaries fail to adapt dynamically when the mechanic shifts into complex, angled side-lying repair positions	6.97	7
8	High Heat Retention - The protective industrial shell traps body sweat and heat, causing heavy user discomfort and fatigue in non-airconditioned automotive shops.	7.70	8
9	Fabric Degradation Vulnerability- Continuous exposure to spilled motor oil, brake fluid, and harsh degreasers breaks down the garment's outer textile boundaries over time	8.70	9
10	Caster Bearing Jamming- Fragile multi-directional wheel bearings easily absorb shop dust, metal shavings, and debris, causing the rollers to lock up and suffer physical damage	8.75	10

As can be gleaned, the table ranks ten challenges of using a Wearable Mechanic Creeper Garment. Top concerns include a spine articulation conflict causing posture restrictions, low ground clearance leading to floor dragging, and sluggish rolling maneuverability compared to traditional creepers. Other issues involve a poor balance imbalance affecting precision, a bulkier chassis that reduces ergonomic comfort, and the lack of vertical clearance adjustment for different vehicle undercarriages. Furthermore, challenges include proprietary strap limitations, high heat retention of the industrial leather shell, fabric degradation vulnerability over time, and the vulnerability of fragile caster bearings to physical damage

Table 5. Coping Strategies applied by Student-Respondents to address the Challenges

Item	Indicators	$\bar{x}$	Rank
1	Students unbuckled the chest straps and partially slipped out of the garment when transitioning from rolling undercarriages to standing tasks.	2.42	1
2	Mechanics laid down smooth plywood boards over rough, cracked concrete to prevent the ultra-low backing from catching and dragging	3.30	2
3	Users utilized rhythmic shoulder swings and leg thrusts to generate extra momentum when navigating tight, high-friction workshop spaces.	3.58	3
4	Technics wore heavy tool pouches toward their front to offset the uneven backing weight and maintain stable body balance	4.07	4
5	Students extended their arms fully outward to maximize torque and compensate for the squeezing limitations caused by the bulky chassis	5.10	5
6	Mechanics raised vehicle chassis extra inches using hydraulic floor jacks to manually compensate for the garment's fixed wheel height	5.18	6
7	Users cross-fastened the chest straps diagonally to allow more torso flexibility when twisting into complex side-lying repair angles	6.92	7

Item	Indicators	$\bar{x}$	Rank
8	Students scheduled frequent resting intervals outside the vehicle bay to cool down from the intense heat trapped by the leather	7.43	8
9	Mechanics taped disposable shop towels over vulnerable fabric seams to absorb oil spills before they could degrade the textile boundaries	8.38	9
10	Users regularly sprayed the wheel assemblies with brake cleaner and WD-40 to flush out metal shavings and prevent caster jamming	8.62	10

As can be gleaned, the table ranks ten coping strategies users employ to address Wearable Mechanic Creeper Garment challenges. Top strategies include using intermittent doffing routines by unbuckling chest straps during upright transitions to optimize work runtime, laying down smooth plywood floor matting to minimize low-clearance scraping on uneven concrete shop floors, and utilizing kinetic body rocking through rhythmic shoulder swings and leg thrusts to overcome sluggish rolling maneuverability in tight automotive spaces. These practical adaptations demonstrate that technicians can actively modify both their clothing configurations and physical workspace environments to maintain seamless workflow momentum. By combining these environmental adjustments with targeted postural shifts, users effectively minimize physical fatigue and overcome localized structural friction without compromising the ergonomic and protective advantages of the garment chassis.

Discussion

A. Design & technical specifications for the Wearable Mechanic Creeper Garment

The wearable mechanic creeper garment received consistently high ratings across all three technical requirement categories, with mean scores ranging from 4.58 to 4.62 on a 5-point scale, yielding an overall mean of 4.60 (Strongly Agree). Aesthetic values including balance, color/shape, and movement and handling efficiency scored 4.62, functionality encompassing task effectiveness, durability, and ease of use achieved 4.60, and technical requirements regarding tool design, materials/cost, and fabrication and assembly processes obtained 4.58. All indicators fell within the 4.21–5.00 range, indicating strong agreement from respondents regarding the tool's technical adequacy.

B. Acceptability of The Wearable Mechanic Creeper Garment Table

The Technology Acceptance Model (TAM) evaluation of the wearable mechanic creeper garment yielded exceptionally high acceptability ratings, with an overall mean of 4.59 (Strongly Agree). Safety component addressing aspects on risks, reliability, and comfort during use of such tool scored 4.60, while functionality (encompassing usefulness, ease of use, attitude towards using the tool, and intention to continue using the tool in future tasks) achieved a rating of 4.58. Both dimensions exceeded the 4.21 threshold for "Strongly Agree," with minimal variance

between the two primary acceptance factors, suggesting balanced user perception across practical and safety-related concerns.

C. Probe on Acceptability & Usability of Wearable Mechanic Creeper Garment Table

The one-way ANOVA comparing reliability and comfort perceptions across industry experts, instructors, and students yielded an F-statistic of 166.1522 with an extremely low p-value of 7.75×10^{-45} ($p < 0.05$), leading to rejection of the null hypothesis. This statistical outcome indicates highly significant differences exist among the three evaluator groups in their assessments of the wearable mechanic creeper garment's reliability and comfort during practical application and testing scenarios.

D. Challenges encountered during the Use of Wearable Mechanic Creeper Garment Table

Students encountered ten distinct challenges when utilizing the wearable mechanic creeper garment, with clear severity patterns emerging from the ranking data. The most severe challenge (rank 1) is a spine articulation conflict where the rigid framework restricts natural body bending during upright transitions (mean 2.21), followed by low ground clearance where the ultra-low wheel profile causes the heavy-duty backing to drag and scrape on uneven concrete workshop floors (rank 2, mean 2.61), and sluggish rolling maneuverability which requires extra physical effort to navigate tightly confined spaces beneath vehicle chassis (rank 3, mean 3.11). Mid-tier challenges include poor balance imbalance caused by an uneven weight layout that shifts the center of gravity during high-torque wrenching tasks (rank 4, mean 3.97), bulky chassis restrictions that reduce ergonomic comfort and limit upper-body squeezing space under low vehicle bellies (rank 5, mean 4.91), and zero vertical clearance adjustment due to a fixed wheel height that prevents mechanics from altering their working distance relative to different undercarriages (rank 6, mean 6.00). Less critical but prominent issues involve proprietary strap limitations that fail to adapt dynamically when shifting into angled side-lying repair positions (rank 7, mean 6.97), high heat retention from the industrial shell trapping body sweat and heat in non-airconditioned shops (rank 8, mean 7.70), fabric degradation vulnerability from continuous exposure to spilled motor oil, brake fluid, and harsh degreasers (rank 9, mean 8.70), and caster bearing jamming caused by shop dust and metal shavings locking up the multi-directional wheel bearings (rank 10, mean 8.75).

E. Coping Strategies applied by Student-Respondents to address the Challenges

The ranking of ten coping strategies reveals a clear hierarchy of approaches students use to address the challenges of using the Wearable Mechanic Creeper Garment. The most preferred strategy (rank 1) is using intermittent doffing routines by unbuckling chest straps when transitioning to standing tasks (mean rank 2.42), followed by laying down smooth plywood

boards to prevent the ultra-low backing from dragging (rank 2, mean 3.30) and utilizing rhythmic shoulder swings and leg thrusts to generate rolling momentum (rank 3, mean 3.58). Mid-tier strategies include wearing heavy tool pouches toward the front for better balance (rank 4, mean 4.07), extending arms fully outward to maximize torque against bulky chassis restrictions (rank 5, mean 5.10), and raising the vehicle chassis using hydraulic floor jacks to compensate for fixed wheel height (rank 6, mean 5.18). Lower-priority approaches involve cross-fastening chest straps diagonally for better torso flexibility (rank 7, mean 6.92), scheduling frequent resting intervals to cool down from trapped heat (rank 8, mean 7.43), taping disposable shop towels over seams to prevent fabric degradation (rank 9, mean 8.38), and regularly spraying wheel assemblies with cleaners to prevent caster jamming (rank 10, mean 8.62).

Conclusion

The Wearable Mechanic Creeper Garment is a highly acceptable instructional and practical tool for technical education, achieving an overall mean of 4.60 (Strongly Agree) across technical design, aesthetic, and functional dimensions. The high ratings in aesthetics (4.62) and functionality (4.60) confirm that the transition from traditional rolling creepers to purpose-built wearable devices successfully addresses previous issues of movement efficiency and structural utility. While technical requirements scored slightly lower (4.58), it still represents a strong professional endorsement of the tool's effectiveness in performing intricate automotive tasks.

Furthermore, the Technology Acceptance Model (TAM) evaluation confirms a robust user acceptance with an overall mean of 4.59. The high safety and functionality scores (4.60 and 4.58, respectively) indicate that users perceive the tool as both a productive and reliable solution for workshop operations. The rejection of the null hypothesis in the ANOVA ($p < 0.05$) reveals that while all groups agree on the garment's utility, their specific perceptions are significantly influenced by their level of expertise, with industry experts applying the most stringent standards regarding reliability and comfort.

Finally, the hierarchy of challenges and coping strategies identifies spine articulation conflict and low ground clearance as the primary operational barriers. However, the study concludes that users are highly adaptive, prioritizing pragmatic strategies—such as using intermittent doffing routines and plywood floor matting—to maintain workflow momentum. Ultimately, the redesigned creeper garment proves to be a viable, user-centered innovation that meets the rigorous demands of modern vocational training and automotive maintenance.

Conflict of Interest

The authors declare no conflict of interest.

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