User-Centered Design for Urban Locksmiths: Integration of Design Thinking, TRIZ, NASA-TLX, and Kano-AHP Method

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Abstract*– This study presents a comprehensive methodological approach based on Design Thinking and TRIZ for the user-centered design of a portable workstation aimed at residential locksmiths in the district of Comas, Lima. The research addresses the issue of high perceived workload resulting from the use of conventional tool cases that lack ergonomic criteria. Multicriteria analysis tools such as NASA-TLX were applied to assess cognitive workload, and the Kano-AHP model was used to prioritize functional attributes valued by users. Based on functional analysis and the identification of technical and physical contradictions, an ergonomic and transformable tool-carrying backpack was developed and validated through finite element simulations (FEA) and physical prototyping. The testing phase with real users showed a 50% reduction in perceived workload, significantly improving physical effort, temporal demand, and subjective performance. The integration of design methods, ergonomic evaluations, and prioritization tools proved effective in generating an innovative, context-sensitive, and technically robust solution. This approach may be replicated in other sectors of informal technical work, promoting the design of tools focused on user well-being.

Keywords-- Design Thinking, TRIZ methodology, NASA-TLX , Kano-AHP Method, Urban locksmith.

I. Introduction

Workload, understood as the dynamic interaction between the physical requirements of a task and the cognitive and psychophysiological capacities of the worker, constitutes a critical factor in operational efficiency and occupational health [1][2]. From a cognitive ergonomics perspective, perceived workload is not only related to the required physical effort but also to mental demand, induced stress levels, and the individual's ability to make effective decisions under adverse conditions [3].

Numerous studies have shown that excessive workload can negatively impact job satisfaction, increase stress levels, and impair overall worker performance [4]. A recent study in the Canadian context during the COVID-19 pandemic demonstrated that an excessive workload significantly reduces the quality of work performance and deteriorates employees' psychological health [5].

In Latin America, studies conducted within the National Social Security Administration (ANSES) in Argentina reported high levels of mental exhaustion among personnel who directly interact with the public, especially under unfavorable organizational conditions [6].

In Peru, the situation worsens in informal and technical sectors where working conditions are unstable and poorly regulated. There is a pressing need to evaluate environmental and organizational conditions in advance to mitigate exposure to risks and safeguard worker health [7]. In particular, residential locksmiths—despite belonging to formal associations—face high situational variability, requiring constant mobility, handling of heavy tools, real-time problem-solving, and work in complex urban environments.

The traditional design of tool cases does not consider ergonomic criteria or functional adaptations for specific contexts such as that of urban locksmiths. This leads to physical overload, inefficiencies in accessing critical tools, and a decline in operational performance. To address this issue, the development of an ergonomic system for the transport and use of tools is proposed. This system is validated through standardized instruments such as NASA-TLX and the Kano-AHP model, which allow for systematic evaluation of perceived workload and user satisfaction levels.

The integration of user-centered innovation methodologies, such as Design Thinking and the Theory of Inventive Problem Solving (TRIZ), together with multicriteria analysis tools, constitutes a robust strategy for developing context-adapted, replicable, and socially impactful solutions. This methodological approach has already proven effective in improving processes and products across various industries. In this study, it is adapted to a relatively unexplored sector: residential locksmiths in the district of Comas, Lima.

II. Materials and Methods

A. Integrated Methodological Approach

This research adopts a comprehensive methodological approach that combines user-centered design techniques with advanced workload analysis and product attribute prioritization tools [8]. First, the Design Thinking model integrated with TRIZ is employed, articulating five phases (Empathize, Define, Ideate, Prototype, and Test) [9], and incorporating structural analysis tools through finite element simulations (FEA) to validate the mechanical strength of the design. Then, in parallel, evaluation instruments such as NASA-TLX (Task Load Index) and the Kano model combined with the Analytical Hierarchy Process (AHP) [10][11] are applied to conduct a comparative assessment between the users' perceived effort and their functional preferences regarding the design of mobile workstations.

B. *Project Methodology*

Design Thinking Integrated with TRIZ The methodology used in this study integrates the Design Thinking approach with the TRIZ methodology, generating a systematic and creative process that addresses complex problems from a user-centered perspective [12]. This methodology is structured into five phases:

1) Empathize: Information was gathered through direct observation of residential locksmiths' work, semi-structured interviews, and the ISQ (Innovative Situation Questionnaire) [9]. User requirements, system constraints, and norms were identified, employing TRIZ's Ideal Final Result concept to guide conceptual improvement.

2) Define: The data were analyzed to identify technical and physical contradictions within the current system. Functional Analysis and the TRIZ Contradiction Matrix were used to clearly define the user's and the system's priority problems [13].

3) Ideate: Inventive Principles and the TRIZ Contradiction Matrix were applied to generate technical solutions. The ideas, represented in sketches, were prioritized based on functionality, safety, and contextual efficiency. Subsequently, three-dimensional digital models of the product were developed using Autodesk Inventor Professional 2025 with an educational license. These models allowed exploration of multiple geometric configurations, folding and unfolding mechanisms, and functional compartments. Additionally, structural simulations were conducted using the finite element analysis (FEA) method to evaluate the product's behavior under expected maximum loads. Safety factors were obtained, validating the structural resistance of the design and ensuring that it does not compromise the user's physical integrity during use. The digital simulation results in Autodesk Inventor supported this validation, reinforcing the structural feasibility and compliance with safety requirements.

4) Prototype: Based on available resources and the guidelines of the simulated design, prototypes were developed first in corrugated cardboard and later in MDF (Medium-Density Fiberboard).

5) Test: The prototypes were evaluated with real users through field tests, measuring their performance in real operational contexts.

C. *Instruments: NASA-TLX and Kano-AHP Model*

Following the design process, two evaluation methodologies were implemented to quantify, compare, and validate the functional and cognitive impact of two portable tool configurations: (1) the use of a conventional case, defined as the current equipment used by residential locksmiths, characterized by limited ergonomics and manual carrying load; and (2) the use of an ergonomically designed tool-carrying backpack, representing the innovation proposed in this study, aimed at improving functionality, portability, weight distribution, and reducing perceived cognitive load during operation.

1) NASA-TLX: The NASA-TLX (Task Load Index), developed by NASA, is a widely validated subjective evaluation instrument that measures perceived workload during task execution [14]. It assesses six key dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration level [15]. Participants assign ratings to each dimension using visual analog scales and then weight the relative importance of each, generating a composite index that reflects overall cognitive load. This tool has demonstrated high sensitivity and utility in cognitive ergonomics research, allowing the identification of overload or inefficiency factors in product or system design [16].

2) Kano-AHP Model: The Kano model, developed by Noriaki Kano, classifies product attributes based on their impact on user satisfaction [17], using a categorization system that includes Must-be, One-dimensional, Attractive, Indifferent, and Reverse attributes. To this end, paired functional and dysfunctional questions are used to accurately map user perception of each product feature [10]. Complementarily, the Analytic Hierarchy Process (AHP) was applied as a multicriteria decision-making method to rank these attributes [18]. Through pairwise comparisons and the development of judgment matrices, priority vectors were calculated and consistency verified using the Relative Consistency Index (RCI), ensuring the reliability of the analysis.

The combination of NASA-TLX and the Kano-AHP Model offers a relevant analytical synergy for user-centered product redesign. While NASA-TLX captures the subjective experience of cognitive effort during tool use, the Kano-AHP model provides a structured and hierarchical view of user preferences regarding specific product functionalities. This dual methodological perspective not only empirically validates the functional benefits of the new design but also aligns its attributes with the latent expectations and needs of end users.

As shown in Figure 1, the evaluation process began with defining the operational scenario (door unlocking during an actual service), followed by the application of the NASA-TLX instrument in both usage contexts, gathering individual perceptions regarding experienced workload. In parallel, the Kano-AHP model was applied to identify and prioritize functional attributes valued by users through structured surveys. The integration of both approaches facilitated a comprehensive understanding of the effect of ergonomic redesign, considering both subjective workload parameters and objective dimensions of satisfaction and functional utility.

D. *Participants*

The study was conducted in the district of Comas, Lima (Peru), with participants consisting of active residential locksmiths from the "Asociación Comerciantes Unidos por el Progreso de Comas," who perform lock opening, installation, and repair services in private homes. A purposive sample of 17 participants with at least two years of experience in the field was selected. These participants were involved both in the empathy phase of the design process and in the comparative functional tests. This group represented a spectrum of users with diverse ages, operational contexts, and work methods, allowing for a more robust evaluation of the proposed redesign's impact.

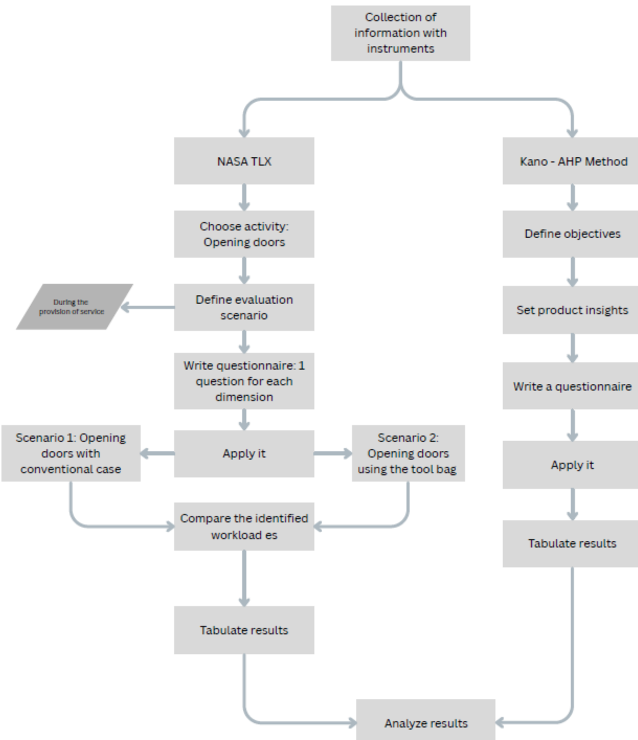

Fig. 1 Combined methodological flow for evaluation using NASA-TLX and Kano-AHP model. Source: Authors

E. *Ethical Considerations*

This study was conducted in accordance with fundamental ethical principles governing research involving human participants. Prior to fieldwork, informed consent was obtained from all participants, who were informed about the study's objectives, procedures, benefits, and potential risks. Anonymity of personal data and confidentiality of collected information were ensured, complying with national ethical research regulations [19]. Additionally, during the data collection process, participants were given the option to withdraw from the study at any time without consequence. The interaction with residential locksmiths was carried out respectfully, ensuring safe conditions throughout the experimental trials.

III. RESULTS

A. *Results of the Design Thinking Process Integrated with TRIZ*

The implementation of the Design Thinking approach integrated with TRIZ enabled the generation of a conceptual and functional design that addresses the latent needs of residential locksmiths in the district of Comas, Lima. Through the articulation of five methodological phases, key findings were identified at each stage, as detailed below:

1) Empathize. During this phase, direct information was collected using qualitative methods such as contextual observation and semi-structured interviews with 17 locksmiths. Recurrent ergonomic limitations were identified in the use of conventional tool cases for transporting equipment, along with problems related to organization, accessibility, equipment weight, and exposure to hostile environments (heat, dust, humidity).

A Functional System Analysis was applied to tool organizer drawers, revealing useful functions such as general containment and immediate access, but also harmful functions such as the lack of drawer braking mechanisms and disorganized internal distribution. Additionally, insufficient functions were identified, including insecurity during drawer movement and the absence of classification based on frequency of use.

Furthermore, through direct observation, three main activities were analyzed: (1) residential door unlocking (see Fig. 2) using tools such as manual lock picks, bumping sets, drills, and portable grinders; (2) system change operations at the workstation, which involve the use of a latch hook tool (Fig. 3) and a calibrated stainless steel bar; and (3) key duplication. For each activity, the tools used, the sequence of actions, and the required time were recorded, thus achieving a deep understanding of the usage context and the functional requirements of the new design.

Fig. 2 Repetitive sequential movements of locksmiths during a door unlocking service

Fig. 3 Repetitive sequential movements of locksmiths during a lock system replacement service.

However, the locksmiths noted that lock system replacement and key duplication services, although among the most common in their daily work, require less effort due to the use of vices and specialized instruments. In contrast, they emphasized door unlocking services as the most demanding in their work routine. Therefore, the developed product proposed in this research is focused on door unlocking services performed at home.

Finally, the users completed the Innovative Situation Questionnaire (ISQ), consisting of 30 questions or items adapted for this research. The responses allowed for the establishment of cause-effect relationships between the characteristics of the work environment and the required technical solutions, serving as a key input for the definition stage.

2) Define. Based on the findings from the previous phase, the data were analyzed to identify the main issues in the user experience of the current system. This stage allowed for the structuring and delineation of problems from a functional perspective, facilitating their approach using TRIZ methodology principles.

Technical and physical contradictions limiting the efficiency and safety of the current system were identified:

- *Technical contradictions*: These include situations such as Safety vs. Operability, Detailed Organization vs. Quick Access, and Easy Cleaning vs. Oil Resistance. These contradictions highlight the need for systems that uphold high standards of protection and organization without compromising usability speed or durability against external agents.

- *Physical contradictions*: Conflicts were found such as Rigidity vs. Structural Flexibility, Aesthetics vs. Functionality, and Portability vs. Security. These contradictions underscore the challenge of creating solutions that are simultaneously durable, visually appealing, and functional, without compromising portability or protection.

From this analysis, specific contradictions were formulated under the TRIZ framework, considering not only the parameters to be improved but also the structural elements involved and the undesired side effects that might arise from implementing solutions. This rigorous formulation enabled a comprehensive understanding of the system's complexity, revealing technical and physical tensions specific to locksmiths' working environments. Recognizing these contradictions not only guided the creative phase toward viable and innovative solutions but also ensured that each design decision precisely addressed the previously identified operational, ergonomic, and safety needs from the empathy phase. In this way, a solid and contextualized foundation for the final product development was established.

In addition, insights guiding product development were synthesized and presented in Table I. These attributes were compared with the state-of-the-art existing products, revealing the absence of specific solutions tailored to the working conditions of residential locksmiths operating in urban environments such as those in the Comas district.

The integration of these findings constitutes the technical and contextual foundation upon which the innovative concept of an ergonomic tool-carrying backpack for locksmiths was designed, distinguishing it from conventional tool cases through its capacity to address real, unmet user needs.

TABLE I
DEFINITION OF INSIGHTS

Insights	Definition
Portability	Incorporate adjustable and padded handles to facilitate easy transportation.
Accessibility	Ensure immediate access to tools during task execution.
Internal Organization	Design the product to double as a seating surface for the user
Dual Functionality	Enable the product to also function as a portable workbench.

3) Ideation. Based on the detailed formulation of technical and physical contradictions, the ideation phase involved the generation of creative solution alternatives that incorporated the desired attributes while avoiding or resolving the identified trade-offs. This phase was characterized by the synergistic application of TRIZ principles—such as separation in space, dynamism, and adaptability—alongside an empathic sensitivity to the usage context.

Fig. 4 presents functional sketches emphasizing aspects such as portability, ergonomics, durability, internal organization, and safety. One of the most relevant concepts was the design of a transformable ergonomic tool-carrying backpack, featuring a robust base that can be used as a work seat, and allowing immediate access to tools through dedicated compartments differentiated by function (e.g., drill, grinder, batteries, etc.). The incorporation of external magnetic zones enhances field operations by enabling temporary fixation of metal parts or small tools, improving efficiency and preventing loss.

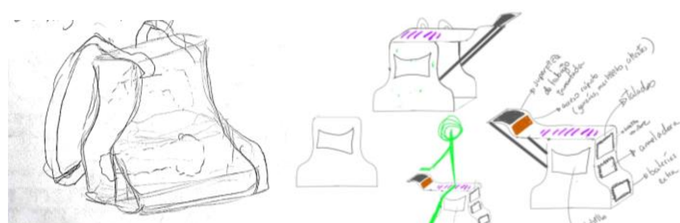

Fig. 4 Sketches of the form and functions of the transformable ergonomic tool backpack.

The sketches depict vertically organized modules designed to reduce the equipment's footprint during transport by distributing weight evenly across the user's back. This configuration also allows the backpack to unfold into a functional workstation once on-site, raising the tools to an operationally ergonomic height (approximately 1.20 meters) without the need for auxiliary surfaces.

Additionally, elements such as resistance to industrial oils—achieved through the use of low-adhesion materials—were considered. Adjustable belts or handles were integrated to ensure stabilization during transport, and the exterior design was conceived to be sober, professional, and visually low-profile to minimize the risk of theft. The concept also includes the option to attach external batteries and supports for rechargeable electric tools.

Once the most promising ideas were validated using multicriteria selection techniques, digital development of the model was undertaken. Autodesk Inventor® software was used to generate the 3D model of the tool backpack, enabling validation of dimensions, assemblies, functional principles, and internal structural reinforcements required for high mechanical resistance. Subsequently, structural simulations using finite element analysis (FEA) were conducted, evaluating mechanical stresses, deformations, and critical points under realistic load and usage conditions. This allowed for geometry optimization and ensured the structural integrity of the design.

According to the Peruvian government, 62% of Peruvians are overweight or obese, with a minimum BMI of 39.9 for level III obesity [20]. Considering an average height of 1.653 meters for Peruvian males [21], the following parameters were established:

$$IMC = \frac{Wieght\ [kg]}{size^2 [m]} \tag{1}$$

The minimum weight considered is 110 kg. A safety factor of 4 is adopted [22], which is consistent with the standard load resistance requirements for metallic ladders and scaffolding. Consequently, the total load considered in the structural analysis is 4,400 N, uniformly distributed over the external upper surface.

As illustrated in Fig. 5, the left panel displays the final 3D model of the prototype, while the right panel presents the results of the finite element structural analysis. The analysis revealed a minimum safety factor of 2.41 under a static load of 440 kg applied to the top surface. This area is intended to function as a seat during locksmith operations at residential locations, particularly while performing door unlocking services. The structural performance confirms that the design can support the expected operational loads without compromising user safety or product integrity.

The results of this stage reflect a comprehensive understanding of the environment and the functional tensions of the current system, evidencing a deliberate pursuit of innovation guided by technical, ergonomic, and operational criteria. The continuous iteration between TRIZ principles, obtained insights, functional sketches, three-dimensional modeling, and structural analyses led to the development of a differentiated, feasible solution aligned with the users' real context.

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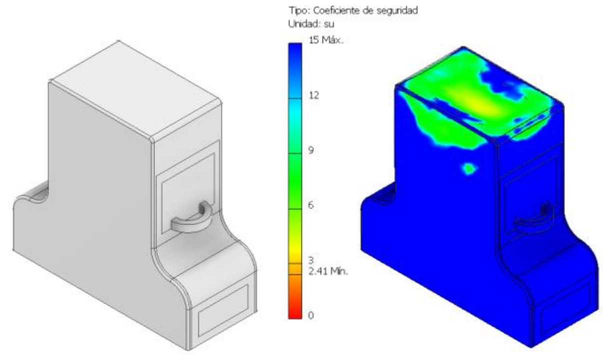

Fig. 5 Modeling of the ergonomic transformable tool backpack (left), Safety factor results under seated user load (right)

It is important to highlight that this innovative design is currently undergoing intellectual property protection. It has been submitted as a utility model application to the National Institute for the Defense of Competition and Protection of Intellectual Property (INDECOPI) of Peru. The patenting process is in progress in accordance with the prevailing provisions of the national intellectual property system

4) Prototyping. As part of the iterative process of verification and validation, two physical versions of the prototype were developed. The first was constructed from corrugated cardboard (Fig. 6), enabling initial validation of form, dimensions, spatial distribution, and preliminary ergonomic testing. This version facilitated early adjustments related to user mobility, tool handling, and structural balance.

Subsequently, a version was built using MDF (Medium Density Fiberboard) (Fig. 7), a medium-density wood fiberboard that allowed for a more accurate approximation of real-world usage conditions, particularly concerning structural rigidity and weight support. This version enabled validation of the constructive feasibility of the design, as well as the evaluation of the integration of functional compartments and quick-access areas.

5) Test. Finally, the testing phase was conducted with end users. The tests were carried out in real work contexts, evaluating both the portability of the system and its functionality and structural robustness. The images show locksmiths using the prototype as a backpack and as a workstation, verifying the functional deployment of the design and ease of use.

B. Results from the NASA TLX Questionnaire and the KANO-AHP Model

During this phase, validation instruments such as the NASA TLX (Task Load Index) questionnaire were applied, allowing for the assessment of perceived workload across dimensions including physical effort, mental load, performance, and frustration level. Additionally, the KANO-AHP model was implemented to prioritize functional requirements and establish the degree of user satisfaction regarding the attributes of the developed product.

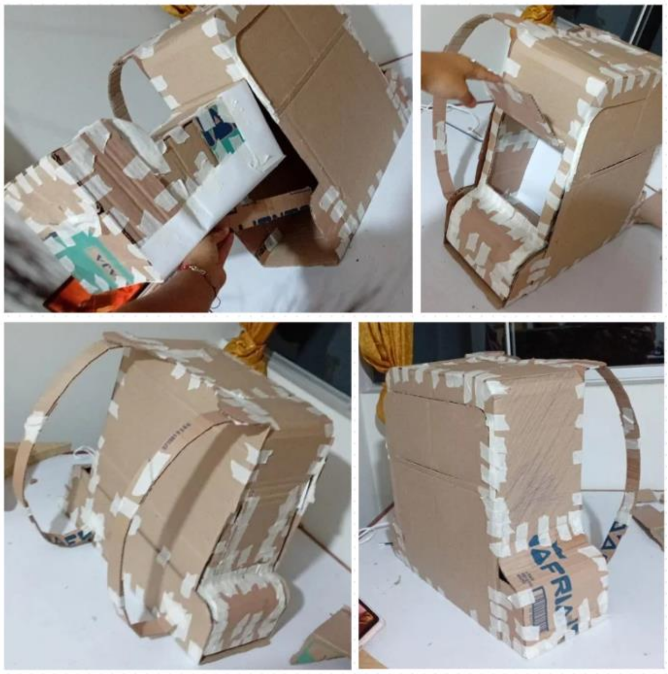

Fig. 6 First prototype made of corrugated cardboard depicting the general design of the ergonomic module, including straps, internal compartments, and the backrest for the verification of preliminary ergonomic dimensions.

Fig. 7 MDF version demonstrates structural improvements, integration of removable trays, and a more robust construction that simulates the behavior of the final product, allowing for more demanding tests in a simulated context.

1) NASA TLX Questionnaire Results: Two scenarios were considered for applying the instrument: (1) door unlocking service while the locksmith uses their conventional tool case, and (2) door unlocking service while the locksmith uses the proposed backpack tool case.

For data collection, a six-question survey was applied in both previously identified scenarios. Each question was related to a specific dimension of workload, aiming to determine the total perceived load. The instrument was administered via a mobile version (App), meaning that locksmiths responded through a digital application, facilitating data collection and processing. Responses were recorded using an application that utilized a 0 to 100 scale. Finally, the scores obtained were classified into three workload levels: 39 points or less is considered low, scores between 40 and 69 are considered medium, and scores from 70 to 100 are considered high.

These results are tabulated by averaging the responses of all participating users (Fig. 8), yielding an average score of 55.5 points with the conventional tool case, considered a medium workload, and an average score of 24.5 points with the ergonomic tool backpack, considered a low workload.

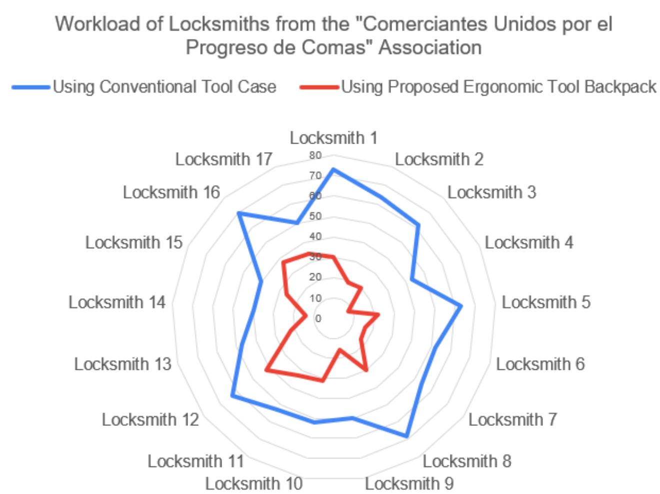

Fig.8 Results of the NASA TLX workload instrument applied to users in two scenarios: using the conventional tool case and using the ergonomic tool backpack proposed in this research.

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2) Results of the Kano Model: The analysis of data collected using the Kano model allowed for the classification of product attributes into various categories, such as basic requirements, one-dimensional attributes, and excitement factors. Among the basic requirements identified are material resistance, structural stability, and the safety of compartments.

The attributes align with those selected as insights during the Define stage of the Design Thinking integrated with TRIZ methodology.

TABLE II
CLASSIFICATION OF ATTRIBUTES FROM THE KANO MODEL ANALYSIS

Attribute	A	O	M	R	Q	I	Total	Category
Portability	0	0	12	0	0	5	17	M
Accessibility	0	10	7	0	0	0	17	O
Internal Organization	12	1	2	0	0	2	17	A
Dual Functionality	13	0	0	1	0	3	17	A

3) Analytic Hierarchy Process (AHP): This methodology allows assigning weights to criteria through pairwise comparisons among the evaluated attributes. In this study, the comparison matrix was developed with the participation of a product design specialist and an experienced user, who assessed the relative importance between the design attributes (see table III). This approach enabled a hierarchical structuring of the product requirements (see table IV), incorporating both the technical perspective and the practical experience of the end user.

TABLE III
RESULT OF PRIORITY WEIGHTS ASSIGNED TO THE ATTRIBUTES OF THE PROPOSED ERGONOMIC TOOL BACKPACK USING THE AHP METHOD

Attribute	Portability	Accessibility	Internal Organization	Dual Functionality
Portability	1.00	5.00	5.00	5.00
Accessibility	0.20	1.00	0.50	0.50
Internal Organization	0.20	2.00	1.00	0.50
Dual Functionality	0.20	2.00	2.00	1.00

TABLE IV
RESULT OF NORMALIZED PRIORITY VECTOR

Attribute	Normalized priority vector
Portability	0.6069
Accessibility	0.0888
Internal Organization	0.1285
Dual Functionality	0.1758

To verify whether the result of the normalized priority vector is correct, the sum of all attribute weights must equal 1.0. Additionally, the consistency ratio (CR) must be calculated. This calculation is performed using the maximum eigenvalue ($\lambda max = 4.12$), a consistency index (CI), and a random consistency index (RI).

$$IC=(\lambda\_max-n)/(n-1) \quad (2)$$

Where n is the number of attributes (n = 4), a consistency index (CI) of 0.041 is obtained. According to the theory, for a 4x4 matrix, the random consistency index (RI) is 0.89. Therefore, the consistency ratio (CR) is calculated as follows:

$$CR=IC/IA \quad (3)$$

Obtaining a result:

CR= 0.046

IV. CONCLUSIONS

This research aimed to develop, through an integrated methodological approach, an ergonomic and portable workstation tailored to the needs of residential locksmiths in the district of Comas, Lima. To achieve this, user-centered design tools (Design Thinking), systematic contradiction resolution (TRIZ), structural simulation (FEA), and cognitive load and satisfaction assessments (NASA-TLX and Kano-AHP Method) were applied, resulting in a rigorous design process validated both technically and empirically.

From a design perspective, the integration of Design Thinking with TRIZ enabled an in-depth contextual understanding through observation, interviews, and the application of the ISQ questionnaire. These methods revealed the functional, ergonomic, and operational deficiencies of the traditional tool case used by locksmiths. The incorporation of TRIZ was instrumental in resolving technical contradictions, such as the simultaneous need for portability and stability, as well as physical contradictions related to weight versus structural strength.

The proposed design (a transformable ergonomic tool backpack) was modeled in 3D using Autodesk Inventor Professional 2025 and subjected to structural analysis via the Finite Element Method (FEA). The simulation, conducted underestimated maximum load scenarios, yielded a minimum safety factor of 2.41, demonstrating adequate structural resistance and ensuring a wide safety margin against failure criteria, thereby safeguarding user integrity under real operating conditions.

In terms of cognitive evaluation, results from the NASA-TLX instrument indicated a significant reduction in perceived workload with the new design, particularly in the dimensions of physical demand, effort, and frustration level. This decrease translates into tangible improvements in operational efficiency, reduced fatigue, and enhanced comfort during tool transport and task execution. The new design not only facilitates better access to tools but also mitigates stress from poor organization or weight distribution while improving temporal organization with the inclusion of a provisional worktable.

Regarding user satisfaction, the Kano model classified product attributes based on their impact on user perception.

Attributes such as portability, internal arrangement, structural resistance, and ease of access were identified as attractive and one-dimensional qualities, while cosmetic or non-functional elements were perceived as indifferent. This enabled design decisions to focus on components critical to product acceptance and effective use.

The AHP method complemented the Kano analysis by prioritizing key attributes through pairwise comparisons. Portability and internal organization received the highest relative weights, followed by structural resistance and multifunctionality. The consistency index of judgments was below 0.10, ensuring the validity of the preferences obtained. This mixed approach allowed for technically validated design priorities from the end-user perspective, integrating subjective criteria with a mathematical decision-making framework.

Overall, this study demonstrates that the methodological integration of user-centered approaches, technical problem-solving, structural analysis, and performance and satisfaction assessment tools provides an effective and replicable pathway for developing technical solutions in informal labor contexts. Beyond addressing a specific need, the developed product offers evidence of how ergonomic innovation can directly enhance occupational health, productivity, and user experience.

It is recommended to replicate this interdisciplinary approach in other sectors with similar demands and to incorporate biomechanical metrics and longitudinal evaluations in future research to strengthen the impact of redesign efforts on physical health and the sustainability of urban technical work.

ACKNOWLEDGMENT

The authors express their gratitude to Universidad Privada del Norte (UPN) and the Research and Innovation Support Center (CATI - UPN) for their support in managing the patent application process. Special thanks also go to the Research Group on Applied Innovation in Product and Service Design (GIADIPS - UPN) for their dedication, and collective effort in the execution of this research and innovation project, as well as in the development of this article..

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