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OPTIMIZATION WITH A FOCUS ON DESIGN AND SIMULATION IN THE IDEALIZATION OF THE PACKAGING PROCESS

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Abstract-- The main objective of this research project, entitled "Optimization with a focus on design and simulation in the idealization of the packaging process," was to optimize the packaging system in a ceramics company. Accordingly, concurrent engineering methodology was applied to redesign cubing processes focused on improving the efficiency, safety, and sustainability of ceramic product transportation.

To this end, an initial phase was carried out involving a qualitative analysis with staff from various departments involved, and based on these findings, solutions were proposed that focused on the design of more resistant, modular, and adaptable packaging. Using SolidWorks 2024, digital and physical prototypes were developed and subjected to simulations and physical tests that validated their performance against the load and stability standards established by the company. At the same time, an automated tool was developed in Excel linked to SolidWorks 2024, which allows customized packaging to be generated from a base file. This automation has reduced errors, standardized processes, and decreased dependence on the engineering department, directly benefiting departments such as exports, purchasing, and production.
Keywords-- Design, Packaging, Concurrent Engineering, Optimization, Simulation.

Abstract-- This research project, entitled "Optimization with a Design and Simulation Approach in the Idealization of the Packaging Process," aimed to optimize the packaging system of a ceramics company. To this end, concurrent engineering methodology was applied to redesign cubing processes focused on improving the efficiency, safety, and sustainability of ceramic product transportation.

Additionally, an automated Excel tool linked to SolidWorks 2024 was also developed, which allows for the generation of customized packaging from a base file. This automation has reduced errors, standardized processes, and decreased dependence on the engineering department, directly benefiting departments such as export, purchasing, and production.
Keywords: Concurrent Engineering, Design, Optimization, Packaging, Simulation

INTRODUCTION

The cubing process can be complex if you want to obtain optimal results in each of its stages (Jiménez, 2015). Some of the new simulation technologies, such as SolidWorks, allow simulate and analyze loads that are subjected to both domestic and international transport, which is why it is essential to rely on digital tools that predict possible failures under real conditions. (Kruk, P, 2023)

For this reason, *SolidWorks software* is currently widely used in the industry for various processes (Sánchez, 2020), one of which is the simulation and creation of plans that provide instructions so that production or quality departments have a frame of reference that facilitates the creation and validation of pallet distribution for transport (Hernández J. A., 2018).

On the other hand, according to Bon, A. T. (2018), when there is no standardization, significant delays occur in activities. However, by applying a new method based on defined times, the cycle time is reduced by up to 11.1%, improving task synchronization. Nevertheless, there is a risk that, if activities are not identified when accommodating a product, the stability and integrity of the loads during transport may be compromised, resulting in the product arriving at the customer in poor condition.

For these reasons, it can be said that the use of automation technologies and methods within the process is favorable in an industrial environment where product shipping is required (Ferreira and Reis, 2023). In addition, minimizing dependence on human judgment and replacing it with pre-established standards can help reduce errors that arise from the operator's experience and knowledge.

To recognize the scope of the aforementioned technologies, as well as the influence they can have, a methodological route was used that integrates the approaches of concurrent engineering and *Design Thinking,* which allow the development of the project to be structured under the principles of simultaneity, technical analysis, and empathetic understanding of the end user. Concurrent engineering, as proposed by Winner et al. (1988), involves carrying out design, validation, and development activities in parallel, ensuring efficiency in terms of time and quality of results. *Design Thinking*, conceptualized by Brown (2009), offers an iterative sequence oriented towards people-centered innovation, favoring the identification of opportunities through direct observation and practical experimentation.

Applying both approaches has enabled us to design solutions focused on the packaging system, with special attention to the actual conditions of the working environment. The methodological process has been structured in progressive stages under a *SMART* (Specific, Measurable, Achievable, Relevant, Timely) approach, which allows the entire product packaging system to be documented, ensuring that each phase of the packaging system is clear, measurable, and results-oriented.

Thus, using a mixed research approach, i.e., both documentary research and direct observation of the operators, the specific problem of the company with regard to the cubing of ceramic pieces was identified, and it was found that the main cause of delays in the modeling of pallets in *SolidWorks 2024* is the lack of training of personnel in the advanced use of the software. This deficiency has a direct impact on the assertiveness of the process, as errors in tool handling, plan interpretation, and 3D model generation lead to rework and prolonged design times (Hmeshah, 2017). Reducing operator discretion optimizes workflow, reduces errors, and improves accuracy in model development.

This is due to a lack of automation in the processes within *SolidWorks 2024 and Excel*. In most cases, pallet modeling and cubing are done manually, which increases variability and execution time. The implementation of parametric tools or predefined configurations within the software could significantly speed up model generation and minimize dependence on repetitive processes, improving productivity in the documentation phase.

This leads to another problem, the lack of standardization in technical documents, which generates inconsistencies in communication between the departments involved. This coincides with findings in other sectors, where non-standardized documentation is associated with problems in quality, information flow, and interdepartmental coordination (Ebbers, 2022).

In this context, this research proposes the following objective: to design and optimize a packaging system using concurrent engineering and the *SolidWorks* simulation tool, with the aim of ensuring safe and stable loads during transport, maximizing space utilization, and reducing logistics costs, thereby improving supply chain efficiency in companies in the ceramics sector.

Therefore, the work was justified by the impact that a cubing algorithm has on the arrangement of goods in the company and aims to ensure safe loads and volumetric use of pallets when cubing products and transporting them, minimizing the intervention of operators' judgment. The aim is to reduce logistics costs and minimize the risk of falls.

Based on this research, the aim is to optimize the packaging process within the industry, where it is essential to ensure protection, stability, and efficiency in product distribution. In this regard, Bernal-Carrillo et al. (2024) state that the redesign and standardization of packaging is a key factor in avoiding losses and maximizing logistics performance, especially in sectors with fragile products, such as ceramics, where it is essential to ensure protection, stability, and efficiency in product distribution, where there were significant limitations that affected operational efficiency, wasting the total space on pallets.

This is important because it can influence both social and technological aspects, considering that tools already exist that automate the cubing process. However, these techniques are limited to the public because they require payment to access them, and this protocol provides a different technique and tool.

Returning to the idea, this project has an impact on the social sphere, where, before developing the contribution proposal, a pilot project is carried out in a fragile goods company in the ceramics sector to test the contribution proposal, which consists of unifying simulation and documentation processes.

For this reason, from a technological point of view, the creation of an algorithm as a tool seeks to integrate different aspects of the goods to generate greater compatibility in their cubic capacity, maximize the volumetric occupancy of the load, and ensure the stability of the whole. In this way, the outcome of the algorithm represented a viable, accessible solution that can be adapted to different scenarios, such as the variety of box sizes available to the company for packaging its product, where the aim was to improve efficiency and the use of material and human resources. Therefore, mixed-method research is justified by the potential to generate a positive impact within companies in the ceramic sector and end customers.

METHODOLOGY

Consequently, the research work addresses concurrent engineering as a methodology for developing the study and achieving the goals. According to Taboada (2021), concurrent engineering integrates product design, manufacturing processes, and support throughout the life cycle from the early stages, through multidisciplinary approaches that work in parallel. These actions and ideas are condensed into several steps that are shown and explained below.

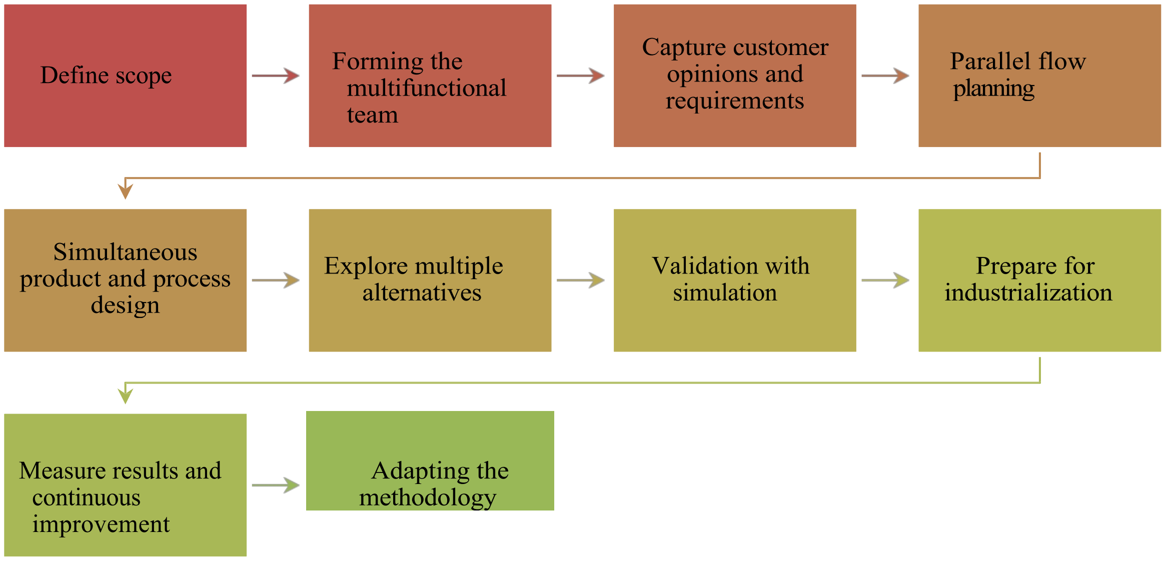

Figure 1. *Steps in the concurrent engineering methodology.*

Note: This methodology was applied to the field of ceramic product packaging. Own creation (2025).

Firstly, concurrent engineering involves, according to Mengual (2015), defining and delimiting the project in such a way that both the design development and related processes are involved, with the aim of addressing the entire life cycle of the product and the process. In other words, it encompasses research into the entire packaging process at the ceramic product production plant and the requirements involved in transporting fragile items.

This research has a multidisciplinary approach, since, according to Raudberget (2024), it must be addressed from various areas with the collaboration of all stakeholders in order to improve decision-making. At this point, McKenna (2021) points out that this approach must gather requirements internally and from the product life cycle, supported by tools such as empathy maps and the 5 Whys, among others. The aim is to gather the opinions and experiences of all employees involved in the packaging and packing process for ceramic products.

In accordance with the methodology to be used, parallel flows are defined where several research and design activities begin simultaneously, and integrated review milestones are established for design, process, and service. This approach reduces the total development time from early stages

According to Juárez (2015), this approach to work means that design decisions incorporate process constraints, avoiding conflicts between the design and manufacturing areas.

This leads to exploring multiple alternatives. Pellerin (2020) mentions that multiple design or process solutions are maintained at the beginning, and those that do not meet relevant criteria are subsequently discarded until converging on the best option to proceed with early validation with prototypes and resolution of functional conflicts. According to Sandoval (n.d.), using digital simulations, physical/logical prototypes, and reviewing assembly, maintenance, and production from the early stages allows problems to be detected before launch, which reduces costs and correction time. According to Bertrand (1998), planning production, logistics, and maintenance ensures that the entire system is ready for launch. Concurrent engineering considers the design of the product and its related processes, including manufacturing and support, as an integrated system from the initial stages.

In addition, measuring results, capturing lessons learned, and continuous improvement are fundamental parts of research. Ashaab (2019) indicates that it is a priority to define performance indicators (development time, cost, defects, rework) and conduct post-project reviews to document learnings.

Finally, the methodology must be adapted to the context of packaging and packing for the ceramic products industry. Juárez (2015) points out that concurrent engineering should be implemented gradually, taking into account the culture, size, and resources of the company. To this end, it is recommended to start with tools and pilot tests.

Table 1. *State of the art.*

Title	Objective	Limitations	Methodology	Results	Reference
1. Algorithm for search large neighborhoods for solve problems of loading containers (Solver spreadsheet CLP calculation)	- Improve filling and reduce empty spaces. - Develop a search algorithm (LNS) for the container loading problem and 3D packaging.	Excel limits the size of the instances and time computation in very complex problems large. Requires enabling macros and using to have a starting point	Algorithmic research: Algorithmic Research 1.Formulation of the mathematical problem CLP: The cubic capacity problem considering weight, volume, and orientation and stability. 2. Solution generation: Sorts items and inserts them initially to have a starting point. 3. Application of the LNS algorithm 4. Massive iteration of the 5. Practical implementation in Excel–VBA 6. Experimental validation	Achieves high percentages of use volume compared to other reported methods, in sets of standard CLP tests. Excel allows that logistics operators or SME planners can use the algorithm withoutknowledge of programming.	Şafak, Ö., & Erdoğan, G. (2023).
2. Model mathematical hybrid	-Propose a model mathematician with and techniques	The software does not frees as	Mathematical model Recurring Engineering	The model achieves Satisfactory Solutions in short times for	Rajadel Valdés, A., &

heuristic-combinatorial for cargo balanced containers in distribution of goods	combinatorial for the problem of cubic capacity/cargo of containers or trucks at la distribution of goods. -Ensuring load balance so that trucks are stable and mainly conceptual	open-source package source standard Not comparable experimentally e with tools international trade; the validation is mainly conceptual and based on specialized software internal.	1. Construction of a model formal mathematical with variables of weight, dimensions, rotation, and stacking and with volume restrictions volume, mass centering, and balance of cargo. 2. Design of a "wall-by-wall" heuristic: The container is divided into strips. 3. Recursive algorithm: The system generates positions and evaluates constraints. 4. Integration with software specialized software: The user uploads an Excel template. 5. Validation in real cases: Focused on technical feasibility	practical situations of logistics companies in Cuba. It explicitly considers balance of load, reducing the risk of accidents due to poor weight distribution.	Cortés Cortés, M. (2025).
PackageCargo: A support tool support for decision for the problem of container loading with stability	-Develop PackageCargo, an tool to support the decision for the problem of loading containers that is: modular, open source, capable of combining algorithms approximate optimization with modules simulation of dynamic stability	Unity and architecture modular tool the software be somewhat more complex deploy than a simple template Excel; can require IT support. Not discussed detailed cost/benefit study of implementation in a specific company in a specific	Applied Research 1. Conceptual review: Review of dynamic stability metrics in the literature. 2. Modular architecture design. 3. Integration of metaheuristics of optimization. 4. Stability simulation: Allows validate the quality of the load pattern more beyond the volume. 5. Comparative validation Results are compared with software commercial.	PackageCargo achieves patterns by packaging competitive in terms of occupancy and quality in the face of commercial solutions. Allows sess the load stability load dynamics, something that many programs basic cubic capacity does not include	Martínez-Franco, J., Céspedes-Sabogal, E., & Álvarez-Martínez, D. (2020).
SIC: A system packaging with characteristics level industrial	-Present a system of packaging with "application-based features industrial" that extends PackageCargo for make it practical for real companies. -Provides companies with tool with interface user-friendly, with extensive possibilities for definition of instances, saving/editing/exporting and algorithms packaging.	Requires deploy a application based in Unity, which can be more demanding technically.	Applied research 1. Detection of industrial needs. 2. Reuse and reconstruction of PackageCargo. 3. Integration of reactive heuristics: Adjust parameters according to performance observed 4. User-centered design 5. Functional validation: The usability and ability to solve real cases.	SIC provides a platform for use industrial, maintaining the possibility of adaptation and extension. Uses algorithms sophisticated but encapsulated in a user-friendly interface, the which brings these packaging. own	Pachón, J. C., Martínez-Franco, J., & Álvarez-Martínez, D. (2022).

Note: A documentary study was conducted to identify the tools currently available for similar industries. Own creation (2025).

DEVELOPMENT

Through documentary research and observation, the operations involved in the design of new packaging until its arrival in production in the relevant departments for ceramic products were identified, and the following line of operations was determined.

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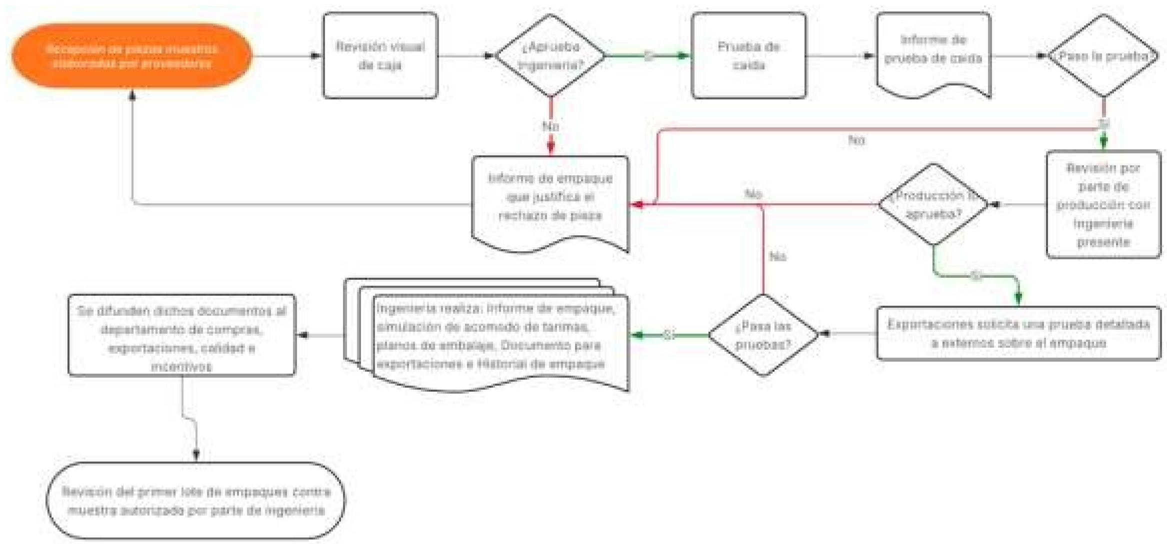

Figure 2. *Flow chart for packaging samples.*

Note: Current status of the company. Own creation (2025).

Based on the above, it was determined that this research covers the packaging process from its conception, i.e., from the search for new packaging, starting with a fragile ceramic product, to international shipping under standards imposed by the customer. This delimits the research to improving and automating the packaging process in these stages.

On the other hand, the requirements of both users and customers were also identified directly through participatory and non-participatory observation of employees from various departments involved, during continuous 8-hour workdays and at different times of the day, taking into account variable performance. Descriptive research was used through surveys and empathy maps, tools aimed at exploring the user's perception of the current packaging system, frequent difficulties, the level of understanding of the instructions, and suggestions for improving the workflow.

This revealed that this procedure is carried out empirically and without automation tools, coupled with the fact that there is little standardization between projects. Several employees are not completely familiar with the established process, which leads them to consult previous notes, tutorials, or even request external technical support, significantly delaying delivery times and generating possible inconsistencies.

The lack of a fluid communication system between departments, such as quality, purchasing, production, and sales, exacerbates this problem, as information about new pallet configurations or packaging adjustments does not always arrive clearly and in a timely manner. This can lead to operational errors, logistical delays, or even complaints from customers who demand strict standards of presentation and protection.

This in-depth understanding of the human and technical environment made it possible to identify opportunities for improvement with greater precision. It also facilitates the development of innovative proposals for both the creation of new packaging and the implementation of a more efficient, automated, and standardized cubing system that can be integrated into the company's workflow without creating friction between departments.

In view of the above and in order to determine the parallel workflow, the main lines of research were identified as follows:

- Need for standardization in packaging design to facilitate the learning curve for operators and improve their productivity.
- Need to develop a faster, more accessible, and easier-to-understand cubing system for members of the engineering department.
- Need to improve technical communication between engineering, quality, production, and purchasing through clearer documentation of packaging and its configurations.
- Need for digital integration of modeling and documentation systems to streamline transfer and consultation.

This led to the creation of a table of preliminary requirements and design criteria, based on the findings, representing the simultaneous lines of work to be addressed:

Table 2. *Preliminary design criteria.*

Identified requirement	Related area	Preliminary design criterion design
Familiarity with packaging	Packers	Redesign inserts and boxes with recognizable shapes and repetitive processes.
Reduction of time in cubic measurement	Engineering	Create an automated automated tool for volume calculation

		using Excel or other accessible *software*.
Transfer configurations between departments	Production, Quality, Purchasing	Generate packaging technical data sheets with clear and standardized visual language standardized visual language.
Minimization of packaging errors	Packaging, Engineering	Include graphic assembly and placement instructions, as well as colors or packaging codes. packaging.

Note: The key design points for each person involved in the packaging process were gathered. Own creation (2025).

As a result of the preliminary research, a digital document in *Excel* format was developed during a simulation and validation stage. Its purpose is to optimize the document workflow, particularly with regard to the verification of packaging requested for different products. This file represents a comprehensive solution that automates the collection and organization of technical data essential for the evaluation and simulation of packaging boxes. On the first sheet of the document, the user can enter the key data for each request, starting with the product identification (name, code, design line), its physical dimensions (height, length, and width), weight, and type of material. Subsequently, specific information about inserts or internal structural elements—such as dividers, adjusters, or reinforcements—is included, detailing their quantity, measurements, layout, and materiality, which allows for a complete profile of the packaging characteristics to be obtained.

One of the biggest advantages of this tool is its ability to automatically generate a second sheet with a technical data sheet that serves as a direct guide for performing the simulation in *SolidWorks 2024* software. This sheet contains the parameters required to build the digital model of the packaging, ensuring standardization and speed in the computer-aided design process. Based on ten predetermined configurations designed to offer a variety of structural schemes that can be adapted to different product geometries and box dimensions, each configuration represents a strategic internal distribution alternative, considering both product orientation and stacking.

The implemented algorithm can select the most appropriate option or suggest the most feasible one depending on the case, either prioritizing space efficiency or the precise fit of the product inside the container. This analysis also considers the maximum dimensions allowed on pallets, the type of product contained, and the logistical restrictions defined by company standards, which allows us to provide a technically sound recommendation tailored to actual transportation and storage needs.

On the other hand, in order to carry out the preliminary validation of the proposals developed to verify the functional, operational, and structural feasibility of the packaging redesign, both digital and physical prototypes were developed. This phase was understood as a stage of tangible experimentation within the design process focused on the user and the specific needs of the product, which suggests generating physical representations of the design to identify potential improvements, evaluate its interaction with the user, and detect opportunities for optimization before the final implementation phase (Arastehfar, S., & Liu, Y., 2013).

First, digital prototypes were developed using the SolidWorks 2024 computer-aided design platform, a resource that allowed for the accurate modeling of the actual dimensions of the products and the configuration of the packaging elements, supporting the principle of simulation and early validation promoted by Concurrent Engineering (Prasad, 1996), whose methodological integration has made it possible to optimize technical decisions from a multidisciplinary and cross-cutting perspective throughout the entire process. The digital models generated provided accurate information regarding the geometry, tolerances, and assemblies planned for the packaging system, allowing for the validation of its perfect fit with ceramic products of various dimensions.

At the same time, physical prototypes were developed using 32 ECT cardboard equivalent to that planned for final production, which made it possible to corroborate not only the technical feasibility of the design, but also its ease of assembly, direct interaction by packers during pilot testing, and effectiveness under real handling conditions. This physical prototyping phase was based on the principles of iteration and empirical testing proposed by Kelley and Littman (2001), who highlight the importance of validating tangible ideas in a real context in order to accurately detect their strengths, limitations, and possibilities for improvement before reaching the production scaling phases.

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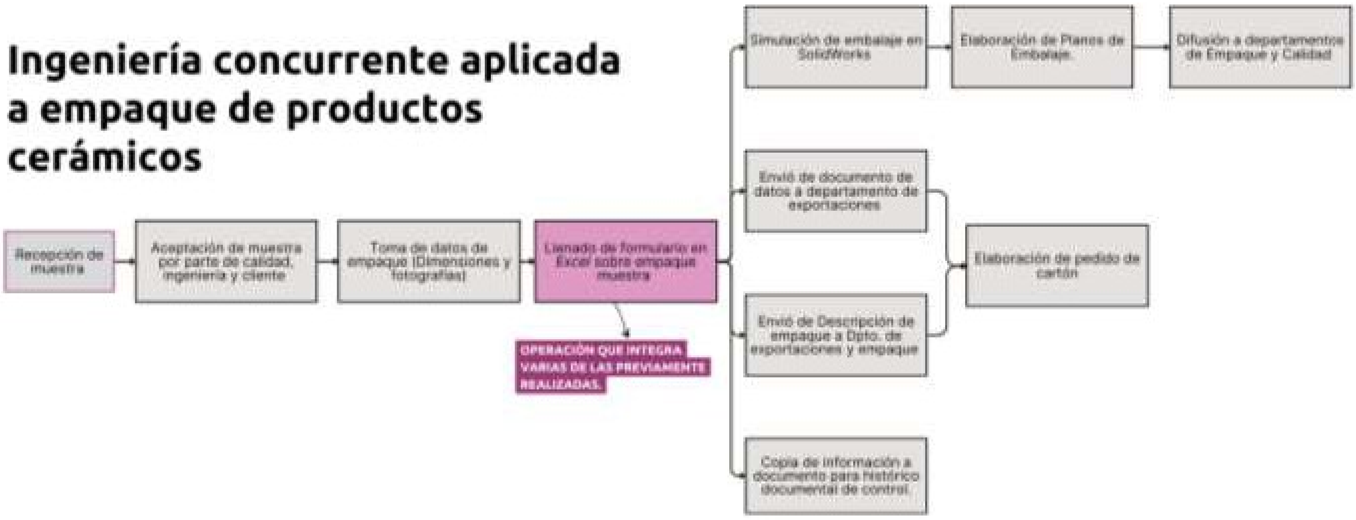

Figure 3. *Concurrent engineering applied to the packaging of ceramic products.*

Note: This is presented in diagram form to visualize simultaneous operations with the changes implemented. Own creation (2025).

DISCUSSION AND ANALYSIS OF RESULTS

In order to proceed with a correctly grounded analysis and given that the sample will be related to convenience tracking, it was necessary to specify the type of pilot test used and the sampling method applied in the methodology. First, a pilot test was implemented, which, according to Díaz and Muñoz (2020), corresponds to a "small or short feasibility or viability study, conducted to test methodological aspects of a larger-scale study." This allowed us to verify the clarity of the instruments, evaluate the operational logistics, and verify the feasibility of the proposed design before proceeding with the full implementation of the study.

Likewise, non-probabilistic convenience sampling was used. As Otzen and Manterola (2017) point out, in this type of sampling, "the selection of the subjects to be studied will depend on certain characteristics, criteria, etc. that the researcher considers at that time; therefore, no random selection is used, and not all members of the population have the same probability of being chosen." This approach was relevant since the research required direct observation of employees who actively participate in packaging operations during their working hours, selecting only those who were available in the specific processes analyzed, which ensured the relevance of the information collected for the development of the study.

The objective of this analysis was to compare the working times in *SolidWorks 2024*, from assembly to drawings, and it was applied to two subjects, first to one with no experience in the *software* and then to another with experience, as this was a critical point in this project, using two different working methods: the new method proposed in this protocol and the traditional method. To this end, a single-factor analysis of variance (*ANOVA*) was applied to determine whether there were statistically significant differences in the average times between the two methods. The significance level used was 5% (α = 0.05).

The results of the analysis of variance show a very high F value of 3833.91, with a corresponding p value of 0.000. This p value is considerably lower than the specified significance level, therefore, the null hypothesis that there are no differences between the methods is rejected. This implies that there is a statistically significant difference in the average times between the new method and the traditional method, and this information is supported in Table 3.

Table 3. *Analysis of variance on work in SolidWorks for subject No. 1.*

Analysis of variance					
Source	**GL**	**SC Adjusted**	**MC Adjusted**	**F value**	**p value**
Method	1	132205	132205	3833.91	0.00
Error	18	621	34		
Total	19	132,826			

Note: Data obtained using Minitab 2019. Own creation (2025).

The group averages reinforce this conclusion. The new method has an average time of
103.76 minutes, while the traditional method averages 266.37 minutes. This difference is substantial in both statistical and practical terms, as it represents a significant reduction in the time required when using the new method, as shown in Table 4.

Table 4. *Evaluation of averages for subject No. 1's lift times.*

Averages				
Method	**N**	**Mean**	**Std. Dev.**	**95% CI**
New	10	103.76	4.43	(99.86, 107.67)
Traditional	10	266.37	7.03	(262.47, 270.27)

State Dev. grouped	5.87223

Note: Data obtained using Minitab 2019. Own creation (2025).

In summary, this analysis provides compelling evidence that the new method is significantly more efficient than the traditional method, allowing for an average reduction of more than 160 minutes in the time required to complete the task. This difference is not only statistically significant but also highly relevant in operational terms, so it is recommended that serious consideration be given to implementing the new method in the processes evaluated. However, it should be noted that this stage was also evaluated with a second subject to assess the difference between a person who is familiar with the *software* and one who is not.

The *ANOVA* results for the second subject indicate an F value of 5743.76 with a corresponding p value of 0.000, which is clearly below the defined significance level. This result allows us to reject the null hypothesis, which means that there is statistically significant evidence to affirm that the average times differ between the two methods analyzed, as shown in Fig. 5.

Table 5. *Analysis of variance on work in SolidWorks for subject No. 2.*

Analysis of variance					
Source	**GL**	**SC Adjusted**	**MC Adjust.**	**F value**	**p value**
Method	1	73658.2	73658.2	5743.76	0.00
Error	18	230.8	12.8		
Total	19	73889.1			

Note: Data obtained using Minitab 2019. Own creation (2025).

Looking at the descriptive statistics in Table 6, we can see that the new method has an average time of 143.74 minutes, while the traditional method has a considerably higher average: 265.11 minutes. The clear separation between these intervals suggests that the observed difference is significant and not the result of chance.

Table 6. *Averages for work in SolidWorks for subject No. 2.*

Average				
Method	**N**	**Average**	**Std. Dev.**	**95% CI**
New	10	143.74	4.02	(141.36, 146.12)
Traditional	10	265,113	3,075	(262,734, 267,492)

State Dev. grouped	3.58107

Note: Data obtained using Minitab 2019. Own creation (2025).

The graphical representations in Table 7 reinforce this conclusion. The box plot shows a marked difference between the methods, demonstrating that the traditional method consistently requires more time, in addition to having less dispersion. In contrast, the new method is not only more efficient, but also maintains a more compact distribution around its mean.

Table 7. *Table of times.*

Time Table (Minutes)		
	New	**Traditional**
Minutes (Range)	10	250

Graph 7. *Box plot of SolidWorks usage by subject No. 2.*

Note: The data was obtained using Minitab 2019. Own creation (2025).

In summary, this analysis clearly demonstrates that the new method is significantly more efficient than the traditional one, with an average reduction in time of more than 120 minutes. This difference is statistically significant and operationally relevant, so it is recommended that the new method be adopted as an improvement to current processes.

In this fourth analysis, a one-factor *ANOVA* test was performed to compare the times, measured in minutes, between two different methods: the new method and the traditional method.

during the preparation of volume documentation. The null hypothesis states that there are no differences between the means of both methods, while the alternative hypothesis states that at least one of the means differs. A significance level of 5 percent was used to evaluate this hypothesis. Table 8 shows the result of the analysis, which has a p-value of 0.000, indicating that the difference between the methods is statistically significant. This p-value is lower than the established significance level, so the null hypothesis is rejected. Consequently, it is concluded that the execution times between the new and traditional methods are not equal.

Table 8. *Analysis of variance on work Documentation*

Analysis of variance					
Source	**GL**	**SC Adjusted**	**Adjusted MC**	**F value**	**p value**
Method	1	12005.5	12005.5	1921.96	0.00
Error	18	112.4	6.2	6.2	
Total	19	12117.9			

Note: Data obtained using Minitab 2019. Own creation (2025).

In terms of averages, the new method shows an average of 6,267 minutes, while the traditional method shows a substantially higher average of 55,533 minutes. The 95 percent confidence intervals for each group do not overlap, reinforcing the evidence of a significant difference. The new method has an interval between 4,637 and 7,897 minutes, and the traditional method between 53,437 and 56,897 minutes, as shown in Table 9.

Table 9. *Means for subject documentation work.*

Averages				
Method	**N**	**Mean**	**SD**	**95% CI**
New	10	6,227	0.853	(4,567, 7,887)
Traditional	10	55.23	3.43	(53.57, 56.89)
Standard Deviation grouped	2.49930			

Note: The data was obtained using Minitab 2019. Own creation (2025).

The box plot in Table 10 provides a clear visual representation of this difference. It can be seen that the times associated with the new method are considerably more concentrated and show less dispersion compared to those of the traditional method, which tend to be clustered toward much higher values.

Table 10. *Box plot for documentation work.*

Table 10. *Table of times.*

Table of Times (Minutes)		
	New	**Traditional**
Minutes (Range)	0 – 10	50

Note: Data obtained using Minitab 2019. Own creation (2025).

In summary, the results obtained allow us to conclude that the new method is significantly more efficient than the traditional one, since it considerably reduces the average execution times for both users who are familiar with the program and those who are not, with a saving of between 169 and 209 minutes depending on their experience. It should be noted that, although there is a difference between them, it is not significant and is understandable given their prior knowledge. This statistical evidence strongly supports the adoption of the new method as an effective alternative for improving efficiency in the processes analyzed, demonstrating that in terms of time, the proposed method is effective. However, the cost factor involved in its development must also be evaluated to identify its profitability, an aspect that is addressed in the following sections.

As a complement to this research, an economic evaluation was carried out with the aim of determining the financial viability of implementing the developed protocol, analyzing in detail the expected economic benefits in the medium and long term. First, the costs per man-hour were evaluated, since labor represents one of the most important items in any project. This takes into account the hours dedicated by the work team, which are valued according to their specialty and the estimated time invested. This calculation allows the human effort to be quantified in economic terms. Table 11 shows the weekly salary of each team member, which amounts to $2,100.00 MXN, giving an hourly cost of $43.80 MXN.

Table 11. *Total investment costs.*

WEEKLY SALARY	$2,100.00
HOURS PER WEEK	48
COST PER HOUR	$43.80
WORKING DAYS PER YEAR	288

Note: The data was obtained using the salaries of the employees' current positions. Own creation (2025).

Table 12 shows the hours per day worked by team members, with a time saving of 50.86%. This percentage is obtained because the old method took a total of 365.52 minutes to complete the entire packaging process, while with the new technique it takes a total of approximately 179.62 minutes, corresponding to 49.14% of the total time previously required. Therefore, the savings correspond to this percentage, which benefits the company by saving a total of $153,800.64 MXN annually due to the time reduction provided by this project.

Table 12. *Savings in man-hours.*

MAN-HOURS	
HOURS PER DAY	24
SHIFTS	1
HOURS PER SHIFT	8
PERCENTAGE TO BE SAVED	50.86
HOURS IN PERCENTAGE	4.0688
PEOPLE PER AREA	3
HOURS TO BE SAVED	12.2064

COST PER WORKER HOUR	$43.8
MONEY TO SAVE DAILY	$534.03
ANNUAL SAVINGS	$153,800.64

Note: Data was obtained using salaries from employees' current positions. Own creation (2025).

Costs of error

Every project is exposed to failures, unforeseen events, or repetitions of activities due to human or technical errors. Likewise, Table 13 shows the reduction in errors in the development of activities in the ceramic company, with a saving of 1%, representing a monetary saving of $2,756.25 MXN annually, all of which is a favorable result in the development of this research protocol. **Table 13.** *Cost of error.*

COST OF ERROR	
ERRORS PER WORKDAY	7
% OF HOURS PER ERROR TO BE RESOLVED	1
COST PER WORKER HOUR	$43.8
COST PER ERROR	$0.46
COST OF ERROR PER SHIFT	$3.20
ANNUAL SAVINGS PER PERSON	$918.75
TOTAL ANNUAL SAVINGS	$2,756.25

Note: The data was obtained using averages from the company on which the research was conducted. Own creation (2025).

CONCLUSIONS

This research project was developed in the ceramics industry with the aim of optimizing the packaging system in industries with a wide and changing variety of products that require specific care for fragile items. From its inception, the methodological approach was based on the application of concurrent engineering and the use of advanced computer simulation tools, with the aim of designing functional, safe, and economically viable solutions for the transport and storage of ceramic products. The partial implementation of the project and the quantitative results obtained through statistical analyses, such as *ANOVA*, show improvements.

substantial improvements in processing times and logistical efficiency, which supports the technical and economic relevance of the initiative.

In relation to the overall objective set, it can be said that it was largely achieved. A new packaging system was designed and optimized that not only meets product protection and space utilization requirements, but also considers rigorous technical criteria derived from simulation and simultaneous work. The proposed solution guarantees load stability during transport, while representing a 50.86% time saving compared to the time taken with the previous method.

In conclusion, the project not only met most of its technical and methodological goals, but also proved to be economically and operationally viable, representing a significant contribution to continuous improvement with monetary savings of $153,800.64 MXN annually representing man-hour savings and $2,756.25 MXN annually representing the cost of error.

On the other hand, based on the results obtained and the limitations identified during the development of this research, future research should focus on developing an advanced system based on intelligent algorithms such as heuristics or metaheuristics, as these have proven to be effective for solving problems in the area of container cubing and loading in industrial environments (Şafak & Erdoğan, 2023), as they are capable of automatically generating packaging configurations based on product constraints (dimensions and weight), pallet constraints (volume, stability, and weight), logistics regulations, and customer requirements, allowing different configurations to be evaluated and compared in terms of cost and/or time to suggest the best option without the need for human intervention. This enables the system to automatically generate, evaluate, and optimize packaging configurations in a matter of minutes, significantly reducing time.

Similarly, it is proposed to carry out an environmental impact assessment of the packaging system, since redesigning packaging has a positive impact on reducing material consumption, logistics costs, and environmental footprint (Bernal-Carrillo et al., 2024), which will allow for a comparison between the current system and the optimized system in terms of the amount of resources used, total weights, volumetric utilization, transport efficiency, reprocessing (repackaging), waste from damaged products, and conduct a life cycle assessment of the packaging to measure the impact from the production of the cardboard, its use during packaging, and its recycling, achieving more sustainable packaging management and better environmental performance for the company.

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