Development of automotive packaging by applying the QFD method

Desenvolvimento de embalagens para automóveis através da aplicação do método QFD

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ABSTRACT
The main operational functions of packaging are: containment, protection/conservation, promotion of the product and/or linking a message, i.e. packaging is almost a part of product marketing. In the automotive industry, the packaging developed serves as a means of packaging and transport ensuring the integrity of the product within the supply chain, at the best cost and within the established deadlines. This paper discusses how Quality Function Deployment (QFD) proves to be an effective methodology for ensuring success in automotive packaging development. The study is delimited to the development of packaging at a vehicle

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manufacturer in the southern region of the state of Rio de Janeiro. It is expected that the House of Quality, the first stage of the QFD method, presented in this article and used by the packaging development sector, can attract more teams and organizations to adopt QFD in the development of packaging, identifying, and meeting the needs of the company's internal customers and guiding external suppliers in the development of this packaging, aiming for better quality and lower cost packaging.

**Keywords:** Packaging Development. Quality Function Deployment (QFD). House of Quality (HoQ), Simultaneous Engineering.

**RESUMO**

As principais funções operacionais da embalagem são: contenção, proteção/conservação, promoção do produto e/ou ligação de uma mensagem, ou seja, a embalagem é quase uma parte do marketing do produto. Na indústria automóvel, a embalagem desenvolvida serve como meio de acondicionamento e transporte garantindo a integridade do produto dentro da cadeia de abastecimento, ao melhor custo e dentro dos prazos estabelecidos. Este artigo discute como o Quality Function Deployment (QFD) se revela uma metodologia eficaz para garantir o sucesso no desenvolvimento de embalagens para automóveis. O estudo é delimitado ao desenvolvimento de embalagens em uma montadora de veículos na região sul do estado do Rio de Janeiro. Espera-se que a Casa da Qualidade, primeira etapa do método QFD, apresentada neste artigo e utilizada pelo setor de desenvolvimento de embalagens, possa atrair mais equipes e organizações a adotarem o QFD no desenvolvimento de embalagens, identificando, e atendendo as necessidades dos clientes internos da empresa e orientando os fornecedores externos no desenvolvimento destas embalagens, visando uma embalagem de melhor qualidade e menor custo.

**Palavras-chave:** Desenvolvimento de Embalagens. Desdobramento da Função Qualidade (QFD). Casa da Qualidade (HoQ), Engenharia Simultânea.

**Introduction**

In Brazil, the Brazilian Packaging Association - ABRE (2009) considers that the process of import substitution, which occurred after the Second World War, significantly boosted the country's industrialization and, as a result, there was an increased demand for
packaging of various types and materials that ensure the quality of the parts along the supply chain and during its production cycle.

Packaging and transportation have assumed a primary and decisive role in the logistics process because they can be the cause of the success or failure of the entire logistics operation, making the packaging key to ensure product quality.

Thus, it became clear that companies should adopt initiatives in investments in packaging design (Meiri, 2008).

The design comprises the activity of designing for the industry according to a project methodology that takes into consideration the function that the product will perform, the technical characteristics of the raw material and the production system used in its confection, the characteristics and needs of the market and the consumer (Mestriner, 2002, p. 10).

Floriano do Amaral Gurgel in his book Packaging Management - 2007 (Thomson edition) defines packaging as wrappings, containers or any form of removable or non-removable packaging, intended to cover, pack, bottle, protect, maintain products, or facilitate their marketing.

These packaging means must contemplate the complete use that goes from the Inbound of the parts until the production line feeding, including storage in an adequate place, that is in compact mode (stacking of the packaging) or, in pallet rack and the transport from the suppliers to the production plant.

The Use Of Returnable Packaging And The Concurrent Engineering

The use of returnable packaging is increasing, driven by several factors, including greater standardization of freight carriers and more modular packaging concepts. As product complexity and the number of parts increases, and automotive production and distribution networks spread across the globe, packaging companies must keep pace by developing new products and services (Donato, 2008).

Today, vehicle manufacturers tend to use returnable packaging throughout the supply chain, mainly for the national flow. For the imported parts flow, we see that most Brazilian vehicle manufacturers still use disposable cardboard for long distance shipments to avoid empty return transportation. Besides the cost that ends up being diluted in the car part price, disposable packaging made of cardboard or wood materials (pallets) has numerous disadvantages. In addition to being more susceptible to weather damage, companies also must spend more on disposal fees and waste time on repackaging before use. On the other hand,
companies that currently use reusable, stackable, small-load packaging, from the German Klein Lagerung und Transport (or KLT's) often have difficulty dealing with the issues of reverse logistics, maintenance, and loss management, especially for cross-continent shipments (Leite, 2009).

Within returnable packaging services, companies have been considering the needs of the industry in structuring KLT packaging as delivery systems to make them as flexible and cost-effective as possible. Thus, the goal of managing the entire reusable packaging process, from delivery to collection and maintenance, is becoming increasingly intensified (Leite, 2009).

KLT packaging suppliers have developed the boxes according to the German VDA (Verband Der Automobilindustrie) 4500 automotive standard. Originally created to meet the demand of the German automotive market and industry, these KLT bins have become a standard type of packaging for many purposes and are widely used in industries all over the world, including Brazil. They can be used in intensive handling, and the static load they can yield up to 20 kg, while the stacked load can reach 600 kg. All models of KLT bins are compatible with both the plastic pallets for KLT’s and the 1.00m x 1.20m Brazilian Standard Pallets PBR and can be stacked on top of each other.

Some suppliers also offer in their portfolio mobile GLT packaging that holds pieces with larger dimensions compatible with the PBR Brazilian Standard Pallets of 1.00m x 1.20m and can also be stacked on each other.

Identifying a custom packaging solution for each part would be a difficult and probably unnecessary task. Grouping parts by size or commodity and assigning packaging materials to each can reduce much of the complexity (Valle & Souza, 2014).

Proper packaging for less fragile automotive parts must take into consideration weight and multiple shipping cycles of potential returns.

Understandably, not all parts fit perfectly in a rectangular KLT box or a GLT box. For larger, irregularly shaped items KLT and/or GLT boxes are not the best solutions for accommodation and transportation.

A packaging, therefore, must create a custom mold for parts of any shape and provide cushioning to protect the parts from vibrations and shocks (Santos & Santos, 2016).

In this context, assemblers need to develop, make and deploy a metal “Stillage Cage” packaging, with the purpose of improving the internal and external industrial logistics system, accommodate the larger parts that do not fit in the KLTs and/or in the GLTs, and with the intention of reducing costs with handling and transport, also aiming to increase the safety and
quality of the process, contributing to a better occupation of packaging, eliminating waste, and streamlining the entire logistics system.

In certain cases, packages designed to protect may cause more damage to the parts by scratches or abrasion.

Effective reverse logistics, and packaging to accommodate this process, is a product of collaboration and communication. Helping customers and partners understand the role that consistent packaging plays and the basic steps they can take to stabilize packaged parts can make a significant difference in reducing shipping damage (Leite, 2009).

For this reason, simultaneous engineering, and quality tools such as QFD are of utmost importance when developing metal stillages cage or wire cages.

Simultaneous engineering can then be understood as a systematic approach that integrates the simultaneous development of products and associated processes, including manufacturing and logistical support. This approach considers, from the very beginning, the product life cycle from conception to industrialization, including quality, costs, planning, and user requirements.

Applied to the development of packaging in the automotive industry, this theory means that the person responsible for the means of packaging the parts should be a member of the team in charge of product development, within which he can propose evolutions that will allow reducing the packaging costs, simplifying it, and ensuring the integrity of the packaged part.

Many tools have been developed to meet the requirements of the product development process. In order to launch a product at the right price and at the right time, promoting the best customer satisfaction, it is necessary to apply many tools in project management for effective decision making. Efficiency and interaction are enhanced through information sharing, allowing numerous perspectives for working together. It also allows a multidisciplinary approach in product development, facilitating interaction at the design level, and tools to share product data (Badin, 2005).

Some tools can be used to capture these demands of the product development process, such as: DFA (Design for Assembly), DFMA (Design for Manufacture and Assembly), 3D CAD (Computer Aided Design), virtual prototyping and PDM (system that updates and makes available the information for all the teams involved in the product development), technologies that directly support the product design (Badin, 2005).

However, relatively few new technologies support collaborative design processes, ensuring better quality products. Among the main methods, the following can be mentioned:
the Quality Function Deployment (QFD), the FMEA (Failure Mode and Effect Analysis), which are used to transfer and satisfy the desires and requirements of the consumer in all phases of development (Badin, 2005).

The QFD is one of the most used methods in Simultaneous Engineering, because in a systemic way, it translates the needs and expectations of the consumers. Matrices are used to integrate and unfold the technical information translated from customer needs to product delivery; values are established to these needs, which are transformed into quality characteristics in the project, production, and manufacturing process (Wheelwright & Clark, 1992).

In this context, this paper aims to develop, make and deploy a metal packaging stillage cages, with the purpose of improving the internal and external industrial logistics system of a company in the automotive industry located in the southern region of the state of Rio de Janeiro, through technical solutions aimed at the area of logistics and production, applying the QFD method, in order to reduce costs with handling and transport, also aiming to increase the safety and quality of the process, contributing to a better use of packaging, eliminating waste, and streamlining the entire logistics system.

The QFD method is widely used by the automotive industry in product development, however, it is not common to observe the use of QFD in the development of production support devices and equipment, such as packaging and handling equipment.

**Applying The Quality Function Deployment From General Perspective**

QFD involves building a set of interrelated matrix diagrams, and this set may have one or more matrices, called quality tables, that ensure customer satisfaction and better-quality services at all levels of the product development process.

The first matrix of the QFD method is called the House of Quality, because of its roof-like structure resembling a house. The House of Quality consists of several "rooms", each containing information about the product. The main goal is to convert customer demands into technical product requirements that must be met throughout the supply chain.

According to Hauser & Clausing (1988), the House of Quality is a type of conceptual map that provides the means for planning and its cross-functional communications.

The basic structure of the House of Quality is shown in Figure 1.
3.1 Building the House of Quality (HoQ)

The House of Quality, one of the most used matrices in the QFD methodology, is a toolbox of decision matrices. Customer requirements and competitive benchmarks are used for decision making (Andronikidis et al., 2009).

Building the House of Quality begins with determining customer demands/needs.

After analyzing the customer needs, the next step in building the HoQ is the development of the technical requirements.

The Technical Product Requirements are the design specifications that meet the customer's needs. These technical requirements are at the top of the HoQ. They describe "how" to meet customer needs and improve a product or service (Gomes et al., 2022; Sales et al., 2022; Silva et al., 2021).
The relationship between customer needs and technical requirements constitutes the main "body" of the House of Quality, called the Relationship Matrix. This matrix helps identify certain technical requirements that should be given priority when addressing various customer needs. Once the Relationship Matrix is complete, the focus of the analysis shifts to the construction of the Planning Matrix.

The Planning Matrix defines how each customer consequence has been addressed by the competition. It provides market data, facilitates the establishment of strategic goals for the new product, and allows comparison of customer wants and needs. For the competitive analysis, research should be conducted on similar products.

After the relationship and planning matrices are completed, the Technical Correlations are determined. These correlations are represented in the HoQ roof. The roof maps the relationships and interdependencies among the technical requirements, the analysis of which informs the development process by revealing the existence and nature of product or service design bottlenecks.

The Correlation Matrix, placed on the roof of the House of Quality shows where trade-off decisions should be made.

The last step in forming the HoQ is the foundation or base of the house. This foundation is called the Technical Matrix and determines priorities and directions for improvements and provides an objective meaning of ensuring that requirements are met. In addition, they provide targets for more detailed development (Gomes et al., 2022; Sales et al., 2022; Silva et al., 2021).

Other "rooms" at the bottom of the House of Quality are the Competitive Technical Assessment, showing the technical benchmarking of the product.

The information gathered from the above methods enables strategic decisions to be developed, one of which is resource allocation.

Once the House of Quality has been built, additional matrices can be made to further guide the decisions that the development team needs to make.

In practice many development teams do not use the matrices after the House of Quality, but by not doing so they miss a lot of information (Cohen, 1995).

The House of Quality only provides the company with the goals they should try to achieve in the intended product, but it does not tell what part, process, or production plan the company needs to achieve those goals (Hauser & Clausing, 1988).

According to Cohen (1995), most organizations stop after developing their customized version of the House of Quality, even in Japan. Cohen (1995) explains that this is because
there is a lack of specificity in the literature on how to go beyond the first matrix. Real case studies are hard to find because companies are reluctant to share their experiences.

For this reason, the most widely used and described QFD model for going beyond the House of Quality is the Four Phase Model, also known as the ASI Model.

### 3.2 The Four-Phased Model of QFD

The Four Phase Model, as the name implies, consists of four phases: (I) the Product Planning Matrix (House of Quality); (II) the Project Deployment Matrix (Partial Deployment); (III) the Manufacturing Planning Matrix (Process Planning); (IV) the Production Planning Matrix (Production Operations Planning) (Cohen, 1995; Hauser & Clausing, 1988; Sullivan, 1986).

In the Four Phase Model the total product is divided into subsystems, and these are divided into parts to build the Project Deployment Matrix. Then, for each part, the important characteristics are listed. These product characteristics are the essential product descriptions for the project and are therefore the factors that drive customer satisfaction.

The product characteristics are placed in the matrix and the matrix is completed in the same way as the House of Quality (Cohen, 1995).

Subsequently, the main process flow is broken down into sub-assembly processes and operations to build the Manufacturing Process Planning Matrix. Next, the design team identifies the main operational process parameters related to the execution of the sub-assemblies. The process parameters are placed in the matrix and are prioritized according to their influence on product characteristics (Cohen, 1995).

In the fourth phase, production planning, the main operations are the input and the production requirements, such as: controls, operator training and maintenance, become the output (Hauser & Clausing, 1988). According to Cohen (1995), the fourth phase is, instead of a matrix, a table containing a checklist of topics or issues that should be considered when planning production steps. Examples of these steps are machine setup, control methods, sample size and frequency, control documents, operator training, and maintenance tasks.

Then, after the customer requirements are identified, the preparation of the Product Planning Matrix or "House of Quality" is done and after it is finished the construction of the next matrix is started by placing all the most important requirements from the House of Quality on the left side of the second matrix and their priorities on the right side of the next
matrix to facilitate communication, ensuring that goals are not missed (Figure 2). Every matrix along the cascade process contains more and more detailed information about the product.

**Figure 2. Interrelated matrices because of the Four Phases Model to the QFD method**

Source: Benner et al. (2003, p.330)

It should be noted, however, that there is a "hierarchy" between the four phases. It is the product deployment that "pulls" the rhythm of product development. The other phases are complementary to it, being executed only when "requested" by the product phase. It is important to emphasize that due to this "hierarchy", the analytical steps have a different execution sequence than the one described in AKAO (1990), AKAO (1996) and CHENG et al. (1995).

Another way to go beyond the House of Quality and the Four Phase Model is to use the Matrix of Matrices model, also known as the Akao QFD Model. This model consists of a system of 30 matrices, charts, tables or other diagrams. The whole system contains various phases of product development, with a strong emphasis on continuous improvement. This QFD model is intended to open up possibilities for a product development team. The team is expected to create its own QFD model, because every organization is different, and there are not two development projects alike. Compared to the Four Phase Model, the Matrix of Matrices Model creates explicit activities that are implicit or optional in the first model (Cohen, 1995).
However, little is published about the use of this model and the effort to complete so many houses prevent companies from applying the Akao QFD Model.

For this reason, the QFD approach used in the paper was building only the House of Quality.

First, the representation of the 4-phase model is not always useful, and one might infer that QFD is only about building a House of Quality (HoQ), which is not true.

We do not develop the product for a House of Quality (HoQ), but the House of Quality (HoQ) sets the priority plan for the development work that follows. However, the 4-phase model is represented to resemble distinct stages of the process one where the packaging design is completed and corrected, before we start thinking about the design process. Of course, this is not how real projects flow. Finally, the models and international standard for QFD lack clarity about its interface with the broader design management system.

It is important to remember that QFD is still evolving, practitioners are still learners, and experts should be doubted.

Methods

Research can be classified by its nature, its form of approach, its objective and its technical procedures (Araujo et al., 2021; Cardoso et al., 2023; Fonseca et al., 2023). Regarding its nature, this is an article applied to a practical problem. Regarding its form of approach, this article can be classified as qualitative. Regarding its objective, it can be classified as exploratory, because, due to, the bibliographical survey of the QFD method and the construction of the House of Quality allowed a better understanding of the problems faced by the company with the development of new packaging for new projects.

Regarding the technical procedures, this is an action article, because the investigated problem is conducted by the author, who works in the logistics/transportation area and is responsible for managing the packaging flow, having direct contact with the packaging development sector and other sectors involved, such as: costs, product engineering, quality, process engineering, etc.

A survey of the internal customers’ requirements was carried out, so that the areas that approve the packaging could assign scores to these quality requirements according to the degree of importance judged by them. The quality requirements are presented in Table 01 and the scores were used on the House of Quality (HoQ).
<table>
<thead>
<tr>
<th>CR: CUSTOMER REQUIREMENTS</th>
<th>DEFINITION OF CUSTOMER REQUIREMENTS (REQUIRED QUALITY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESERVE THE INTEGRITY OF THE PARTS</td>
<td>MAINTAIN THE DIMENSIONAL AND FUNCTIONAL CHARACTERISTICS OF THE PACKAGED PRODUCT.</td>
</tr>
<tr>
<td>AVOID HAND INJURIES WHEN HANDLING THE PACKAGING</td>
<td>AVOID INJURY TO THE OPERATOR'S HANDS DURING HANDLING OF THE PACKAGE, WHICH CAN BE CAUSED BY SHARP EDGES.</td>
</tr>
<tr>
<td>AVOID PHYSICAL INJURIES AT THE END OF THE SHIFT (ARM, BACK, ETC.)</td>
<td>ATTEND THE ERGONOMIC CONDITIONS (PACKAGING IN THE ADEQUATE WEIGHT, WITH A HANDLE TO MAKE IT EASIER FOR THE OPERATOR TO PICK UP THE PACKAGE, ETC.)</td>
</tr>
<tr>
<td>PACK AS MANY PARTS AS POSSIBLE</td>
<td>THE PACKAGING NEEDS TO HOLD AS MANY PARTS AS POSSIBLE TO REDUCE THE NUMBER OF TIMES PER SHIFT THAT THE OPERATOR NEEDS TO REFILL THE LINE EDGE.</td>
</tr>
<tr>
<td>DO NOT INTERFERE WITH THE PROFITABILITY OF THE SUPPLIER'S AUTO PART</td>
<td>MINIMIZE THE PACKAGING COST SO AS NOT TO MAKE THE NEW SUPPLIER'S DEVELOPMENT UNPROFITABLE, AS THE PACKAGING PRICE IS CONSIDERED IN THE INITIAL PROFITABILITY STUDY.</td>
</tr>
<tr>
<td>LOW MAINTENANCE COST</td>
<td>AVOID MAINTENANCE ITEMS, SUCH AS: BEARING, SPRING, ETC. THIS IS A SPECIFIC REQUIREMENT FOR RETURNABLE PACKAGING.</td>
</tr>
<tr>
<td>BE COLLAPSIBLE OR FOLDABLE</td>
<td>TRY TO DEVELOP PACKAGING THAT CAN BE FOLDABLE OR COLLAPSIBLE TO MINIMIZE THE COST WITH TRANSPORTATION, BECAUSE IT IS NECESSARY TO MINIMIZE THE SPACE IN THE TRUCK.</td>
</tr>
<tr>
<td>STACKABLE</td>
<td>THE PACKAGING NEEDS TO BE SUSTAINABLE IN TRANSPORT AND GIVE STACKABLE AND ARCHED (STABLE) CONFIGURATION FOR FORKLIFT HANDLING AND STORAGE.</td>
</tr>
<tr>
<td>EASY AND FAST LOADING / UNLOADING</td>
<td>THE PACKAGING NEEDS TO FACILITATE THE REMOVAL OF THE PARTS AT THE LINE EDGE AND FACILITATE UNLOADING AND LOADING ONTO THE TRUCK.</td>
</tr>
<tr>
<td>CORRECT IDENTIFICATION</td>
<td>IT IS IMPORTANT TO CHECK THE LOCATION OF THE IDENTIFICATION AND WHETHER THE IDENTIFICATION IS LEGIBLE.</td>
</tr>
<tr>
<td>DO NOT ACCUMULATE WATER OR WASTE</td>
<td>EVERY PACKAGE, BEFORE LOADING, MUST BE EMPTY AND FREE OF ANY RESIDUE.</td>
</tr>
</tbody>
</table>

Table 1. Customer Requirements / Customer Needs

The House of Quality (Figure 3) was elaborated following the steps described in Section 3 of the article.

The construction of the House of Quality started with an open questionnaire to obtain the quality requirements or demanded quality from the internal customers of the packaging development sector.
The research was conducted in a vehicle manufacturer, of French origin, located in the southern region of the state of Rio de Janeiro. Established in Brazil since 2000, the vehicle manufacturer still has some parts imported from Europe, and the development of national suppliers is still a reality for the company. The vehicle manufacturer has approximately three thousand employees, producing about four hundred and eighty cars per day, whose auto parts are handled by almost fifteen thousand packaging references.

During the process of defining national suppliers, the development of packaging is directly related to ensuring the integrity of the part's quality, from the manufacturing process to assembly on the vehicles' production line.

At the vehicle manufacturer studied, the development of packaging is carried out conjointly with the auto parts suppliers. The packaging, once developed, goes through an approval circuit in some areas that is represented by a flowchart of the packaging development process, from the study to the approval of the packaging by the involved areas.
Due to the constant delays in the application of parts, and the need for improvements in the packaging, after submitting it for approval, the opportunity arose to apply the QFD method with the objective of raising the needs of internal customers and avoiding rework, delays in the delivery of the developed product, noise in customer-supplier communication, and enabling the approval of the packaging in the first approval circuit.

<table>
<thead>
<tr>
<th>Product Requirements</th>
<th>%</th>
<th>% Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-effective compared to disposable packaging</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>Decrease the number of accessories</td>
<td>11%</td>
<td>24%</td>
</tr>
<tr>
<td>Certified Quality Material</td>
<td>10%</td>
<td>34%</td>
</tr>
<tr>
<td>Packaging (Good assembly/Welding)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase the number of parts per package</td>
<td>10%</td>
<td>43%</td>
</tr>
<tr>
<td>(minimizing labor, transportation, warehouse and lineside stock)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing free of burrs, sharp edges or any element that may cause an accident during handling</td>
<td>8%</td>
<td>61%</td>
</tr>
<tr>
<td>Dimensions as per drawing</td>
<td>8%</td>
<td>69%</td>
</tr>
<tr>
<td>Ergonomic Design</td>
<td>8%</td>
<td>76%</td>
</tr>
<tr>
<td>Avoid contact between parts</td>
<td>5%</td>
<td>82%</td>
</tr>
<tr>
<td>The machined and sensitive parts of the pieces should not be supported on the packaging</td>
<td>5%</td>
<td>87%</td>
</tr>
<tr>
<td>Clear and legible identification</td>
<td>5%</td>
<td>92%</td>
</tr>
<tr>
<td>(Identification code and serial number)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add holes on the packaging to prevent water or residue accumulation</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Painting in specified color</td>
<td>4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2. Product Requirements Prioritization Table
Source: Author (2023).

With the data from the Quality House it is possible to observe that the greatest challenge for the packaging development team would be to create a package that was more profitable than disposable packaging (cardboard); that had few accessories (no bearings, springs, locks), in other words, that was easy to use and move; of certified quality and resistant, in other words, that did not present many problems or rework that impacted the delivery of parts.

It is worth mentioning that, after prioritizing in descending order of importance, the requirements for the development of a packaging solution, the economic feasibility of developing packaging instead of using disposable packaging was verified. In the process of developing national suppliers, during the quotation process of the auto part, the national supplier sends its commercial proposal with the estimated packaging price included in the part price. In this way, the price of the packaging to be developed cannot exceed the estimate made at the beginning of the development.
The economic conditions that made the automotive market jump from 1.4 million vehicles in 2003 to 3.8 million in 2012, are no longer present in our economy and are not likely to be repeated in this decade (Merluzzi, 2022).

As the chart above (Figure 4) shows, the automotive market grew from 2004 to 2012 as a result of a combination of several factors:

- Predictability, employability, and credit;
- Low inflation (despite fluctuations);
- Availability of financing and attractive interest rates;
- Appreciation of the Real and purchasing power;
- Retail competition and product supply;
- Consistent predictable demand, not one-off repressed demand;
- Government programs that encourage vehicle manufacturers to produce and invest in the country.

Today, these elements are misaligned, and future projections are not encouraging. In addition to this, new car prices have skyrocketed, purchasing power has fallen, inflation has accelerated, the consumer has changed his behavior, intelligent mobility has taken over from the desire for a car in the garage, financing is no longer possible as before, the exchange rate
parity has inverted and current cars have, on average, 42% imported components; with the current exchange rate the variable cost of the operation knocks down any "business case" (Merluzzi, 2022).

Automotive manufacturers have asked for and received help from the governments on which they depend, but they are still affected and still looking for a clear way out of this difficult period.

Within this context, and even if it was a known practice, but not much applied, the Carry-Over, or reuse, becomes a useful financial weapon if it is well evaluated and applied.

To this end, it is paramount to follow a relatively simple Carry-Over analysis methodology, but eliminating throughout the analysis process in order to focus on what will really bring true financial gains for the company without compromising the prerogatives of quality and deadline.

First, it was necessary to survey which packages are available for Carry-Over, information that should be guaranteed by the owner of the packages. From this information, a physical quantitative analysis was made. In fact, the information provided by the owner of the packages in most cases was based on the theory of what was officially delivered, and this value will not necessarily contemplate the losses over the useful life of the vehicle due to hits, reduction of assets, etc.

Thus, possibly reusable packaging is affected to be developed for new projects. This is the moment to evaluate the economic viability of the Carry-Over.

At the evaluated manufacturer, for the nationalization of auto parts for the new model year, after the QFD analysis, it was observed that reuse or Carry-Over would be the best solution to develop packages that would be more profitable than disposable packages (cardboard); since it would not be necessary to invest in making a new metal stillage cage from scratch and the metal stillage cage that had already been made and purchased for previous projects and that were unused at the company would be reused.
To solve the problem of the quantity of accessories, in other words, to develop a certified quality and resistant packaging, without bearings, springs, locks, easy to use and carry, thermoformed trays that would fit the stillage cage and accommodate the parts without them coming into contact with each other and without moving were developed, which means that it would not present many problems or rework or impact the quality of the parts delivery.

A new code was defined for packages with this configuration (stillage cage previously acquired for old projects with the new trays acquired by the company). The new code was engraved on the stillage cages and the stillage cage was reconditioned with the color defined in the project for the packaging referring to the car model.
Economically each metal stillage cage costed the company R$ 896.00 when they were purchased.

Each set of thermoformed trays costed the company about R$ 3604.00. Developing a specific metal stillage cage to accommodate the parts would cost the manufacturer about $4954.98. Therefore, for each set of stillage cage with trays the company saved R$ 1350.98. That is, a savings of 27% for each reconditioned metal stillage cage.

In addition to the savings in the development of the packaging solution, the company also obtained improvements in transportation, since it used the stillage cages that were already part of the logistics process for other auto parts suppliers and that optimized the cubage of the vehicle during transportation.

**Conclusion**

This article has illustrated how Quality Function Deployment (QFD) can be successfully applied to automotive packaging development efforts.

It is evident that in many projects, the packaging development process is conducted in a systematic way and resources are wasted due to lack of communication between the different areas involved. Time is also a critical factor in the development of packaging, because companies need to develop or improve a product as quickly as possible, so that it can be put on the market as soon as possible and the company can ensure its competitiveness.

QFD proves to be an effective and necessary methodology to ensure the success of packaging development projects through a better understanding of customer needs and requirements, as well as procedures and processes to improve communication. QFD is effective because it integrates customer needs as early as the design phase, producing better packaging with high levels of customer satisfaction. QFD transforms customer requirements into technical design specifications that promote customer satisfaction while maintaining customer integrity and generating innovative strategies to achieve the organization's vision.

QFD differs from traditional quality systems that aim to minimize negative quality, such as poor service, and focuses on providing "value" by seeking spoken and unspoken customer requirements, translating them into actionable service features, and communicating them throughout the organization, so it helps companies address the gaps between specific and holistic components of customer expectations and the actual experience.

QFD focuses on designing quality rather than inspecting it, which reduces development time, startup costs, and promotes team integration.
While many companies do not make full use of the methodology, those that do use QFD and complete the House of Quality, which is the first phase of the model, do:

- Visualize what the main trade-offs will be between what the customer demands and what the company can produce;
- Divide the main activities among the company's areas, improving teamwork;
- Ensure that the customer's demands are brought into the packaging development process;
- Do not let important points of production control be forgotten;
- Gather all the necessary data for the development of good packaging;
- Identify quickly where additional information is required during the process;
- Use and document information better.

For this reason it is extremely important that companies: establish clear objectives and the scope of QFD use; avoid first using it on a large, complex project; define whether QFD will be used for the overall product or applied to a subsystem, module, assembly, package, or critical part; define whether the full QFD methodology will be used or only the product planning matrix will be completed; obtain commitment from a cross-functional team with adequate time; obtain training with hands-on exercises to learn the methodology with a facilitator to guide initial efforts; schedule regular meetings to maintain focus and avoid crushing the development schedule, overshadowing effective planning and decision making; avoid gathering perfect data, because often important customer information and data exist within the organization, but are in the form of hidden knowledge, not communicated to the people who need this information; spend more time gathering customer requirements before starting QFD; avoid technical arrogance and the belief that company personnel know more than the customer.

Although some experts understand QFD as a system and others as a methodology, it is relevant to associate QFD with the idea of transforming data obtained primarily from customers, subjecting them to a series of processes, and reflecting them successively in such a way that the final products translate the attributes established by the customers.

In this way, the QFD method can reduce packaging development time, the number of design changes, problems in the beginning of production, and costs; and consequently, can increase customer satisfaction, broaden the knowledge base of the design practitioners, and bring greater profitability to the company.

The results obtained through this project showed that it was possible to quantitatively raise improvements that were reflected in savings in the production process, logistics, and
packaging. Through the QFD approach it was possible to rethink the packaging design of some parts, the company focus of the study can increase productivity and consequently its profits, reusing the metal stillage cage packaging with a few changes to suit its needs for new nationalized parts. Only with the purchase of thermoformed trays that fit the existing metal stillage cages, the company had significant savings.

The application of QFD in the design of new solutions allowed the improvement of several aspects that touch the production process, logistics, and the product value chain.

The House of Quality allowed us to identify the general characteristics that need to be considered when developing packaging for an auto part.

With the use of the QFD method, one can contribute to the development of packaging, an area that generally receives less attention in organizations, seeking to identify the needs of the areas responsible for packaging approval and use this information in the definition of new packaging, improving the packaging development process.

The objective of the work was achieved, because the designed model, when compared to the current packaging concept, presents countless productive, logistical, occupational, environmental, and financial advantages, in which the gains with the reuse of the metal stillage cage impacted in a large economy for the company.

References


Gurgel F. Administração da Embalagem, Thomson Learning 2007


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