Design of a Cost-Effective Cookie Feeding and Delivery System on an Automated Robotic Packaging Manufacturing Line

by

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ABSTRACT

In order to transition to an efficient and automated cookie packaging line at the Gamesa-Quaker plant in Monterrey, Mexico, the goal of this project was to design an improved system to feed individual cookie packages to robots on an assortment packaging line and evaluate any resulting changes in plant operations. The project and analysis are specific to the Surtido Rico assortment product packaging lines at Gamesa-Quaker.

In order to accomplish this, three potential delivery methods and systems were evaluated, prototypes were designed and tested, and a recommendation for as improved design is presented. In addition to evaluation of the three delivery methods, this project required consideration of which criteria would be most relevant to determining efficiency in the line and cost-effectiveness. Further, each delivery method required different design and layout of the final product packaging. Sample customer surveys were conducted to ensure that any such product presentation changes did not negatively impact consumer perception of the product.

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Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Overview

Goals and Motivation

In order to transition to an efficient and automated cookie packaging line at the Gamesa-Quaker plant in Monterrey, Mexico, this project focuses on designing an efficient and cost-effective method of feeding and delivering individual cookie packages to the robots in the production line. Additionally, each delivery method requires different design and layout of the final product packaging. Sample customer surveys were conducted to ensure that any such product presentation changes would not negatively impact consumer perception of the product. Further, any relevant and necessary changes to plant operations required by the system are analyzed.

Based on research and discussion with Gamesa-Quaker engineers to identify the most preferred methods of delivery, three options were selected for inclusion in this research. The three potential delivery methods and systems were evaluated and prototypes were designed and tested.

1. *Traditional Manual Delivery*: this is the current method used on the line so data was collected to assess the feasibility of a similar process on an automated line
2. *Redesigned Magazine Feeder*: these are currently used on several other lines at Gamesa-Quaker so data was collected on several types of magazine feeders

3. *Innovative Box Delivery*: this is the newly proposed method identified in this thesis project, several designs were created, prototyped, and tested on individual lines

Requirements

Since full implementation within the timeline of this thesis was not possible, testing was done on current production lines in a simulated setting – on the actual production and packaging lines used today, but without the robots or automation equipment present. Testing was done in the packaging areas of individual cookie production lines as well as in the Surtido Rico packaging line. In each test, actual workers from the plants were asked to use the prototype of a new box design in packaging and sorting the products. Observations about ease of implementation, ease of learning the new packaging technique, and time to complete the step were noted.

In order to make a fair evaluation, this project investigated which criteria would be most relevant to determining efficiency in the line and cost-effectiveness. The project required collaboration among the student, faculty advisor, Gamesa-Quaker engineering project manager, and the third party company designing the robots for the production line. The total initiative, if implemented, will require an initial capital expenditure of $4.2 Million with an expected ROI of $4.5 Million in labor costs alone by the end of Year 1 (expenses incurred by Gamesa-Quaker).

Highlights of Results

The three potential methods for feeding individual cookie packages to robots on an automated packaging line were evaluated and an improved design was selected. The improved design consists of a double corrugated fiber box delivery method. The cookie packages should be packaged into the box in a flat orientation, manually delivered to the Surtido Rico packaging line, and then emptied systematically onto the feeder belt for the robots. The improved design successfully meets the project goals of improving efficiency and decreasing cost on the line while ensuring that the new design does not significantly alter plant operations, work culture, or physical layout of the plants. The improved design also performed well in the technical feasibility testing in the plant. Customer research indicated that the final display packaging that this solution requires is also agreeable to customers.

1.2 Background

History of the Project

The Gamesa-Quaker company of PepsiCo., based in Monterrey, Mexico is a consumer driven, manufacturing based cookie and snack company. Gamesa-Quaker's operation is comprised of nine plants and over 100 distribution centers across Mexico. They serve Mexico, several Latin American Region (LAR) countries, and selected cities in the United States. They have 560,000 clients, 3,400 routes, and 12, 756 employees (mostly working in the plants). Currently, the company plans to design and build the first fully

automated, dedicated line to package their high-end "Surtido Rico" ("delicious assortment") variety cookie trays.

Gamesa-Quaker currently produces its high-end product "Surtido Rico" or "Delicious Assortment" of gourmet cookie variety trays on seven lines across four plants in Mexico. This requires a total head count of 675 people. The current process is 100% manual and is therefore highly inefficient and not cost-effective. Because of these limitations, plans are in order to condense production operations to a single dedicated line by implementing the first fully automated packaging line for assortment trays in all of Gamesa-Quaker operations in Mexico, using robots to place individual cookie packages into assortment display trays. The company is working closely with an outside engineering firm designing the robots to ensure that all automated packaging systems meet the requirements and quality specifications of Gamesa-Quaker.

The Surtido Rico assortment contains the following cookie varieties:

Emperador – 4 individual packages

Cremax – 4 individual packages

Maravillas – 1 individual package

Barras de Coco – 2 individual packages

Chokis – 1 individual package

Only the Cremax product is currently wrapped individually in the package because this cookie is particularly fragile and must be wrapped before transport from its individual production line to the Surtido Rico packaging area.

An initial plan has been developed by engineering management at Gamesa-Quaker to install a dedicated Surtido Rico packaging line in the Vallejo Plant to replace the seven existing labor intensive Surtido Rico packaging lines throughout Gamesa-Quaker in Mexico. This line will have a capacity of 3,000 kg/hour and will have six robots. The only labor required on the proposed line would be for feeding individual cookie packages to the robots. The third party company is designing the robots and will be responsible for all manufacturing steps that take place after the individual cookies are fed to the robots. However, design and implementation of a cookie delivery system to feed individual cookies to the robots is left completely to the Gamesa-Quaker engineers (and this project). As a pilot research project between MIT and Gamesa-Quaker, this thesis project will seek to design an efficient and cost-effective way to feed the cookies to the robots and to analyze the resulting changes in plant operation.

My Role at Gamesa-Quaker

Separate from Gamesa-Quaker's efforts to automate the line, research was necessary to design and develop an efficient and cost-effective method of feeding individual cookie packages to the robots, before the fully automated phase of the production line begins. Additional analysis is necessary to understand any changes that such a system will require of plant operations. This includes creating plans for new plant layout if necessary to accommodate new automation equipment. Both tasks will require communication between myself, Gamesa-Quaker engineers, and the robot supplier. These topics will be the focus of this thesis project.

Partnership between MIT and PepsiCo.

After completion of an intense summer program at Gamesa-Quaker in Monterrey, Mexico, the President of Gamesa-Quaker, along with the engineering team, expressed an interest in creating a research initiative between MIT and Gamesa-Quaker to create opportunities for real-world hands on engineering study for MIT Mechanical Engineering students. The goal of the program for Gamesa-Quaker would be to develop a research initiative with MIT for innovation in the manufacturing cycle and improvement of production processes. This thesis is the first project in the initiative.

2 Problem

2.1 Detailed Discussion of Problem

In-depth Goals and Requirements

In this thesis project, the primary task is as follows: make a recommendation for an efficient and cost-effective method of delivering individual cookie packages to robots on the automated packaging line. The secondary task is to consider whether the design of this cookie delivery system will require any significant changes in plant operations and if so, to outline such changes for the company.

There are two very critical requirements that emerged as metrics were being designed and considered. They are:

(1) The design solution must not significantly alter plant operations, work culture, or physical layout of the plants.

(2) The solution must be cost-effective.

All subsequent analysis and evaluation using the metrics discussed below, were subject to these two considerations.

After careful consideration of various types of metrics that could have been used to compare each delivery system, the metrics shown in Table 1 were chosen. The primary goal was to ensure that any delivery system could deliver a final product that met customer requirements. In trying to gauge which customer requirements were most important, several discussions were help with the Gamesa-Quaker Marketing Team as well as with the Surtido Rico brand manager. They provided insight into the key customer needs and product attributes currently monitored by customer research today. The process continued with a brainstorming session of the most important metrics that would be relevant in assessing the relative value of a redesigned package in a customer's purchasing decision. Once these customer needs had to be identified, they were translated into product attributes and then converted into measurable and quantifiable engineering specifications.

Table 1-1: Translating Customer Needs into Engineering Specifications

Customer Need	**Product Attribute(s)**	**Engineering Specification(s)**
Affordable Product	- Low Cost to Manufacture - Competitive Price	- Cost: Under 10Pesos per unit - Price: Under 30Pesos per unit
Elegant Visual Appeal (good presentation)	- Layout of product in tray is pleasing compared to current	- 6:4 product preference ratio
Minimal Effort Required to Serve	- Easy to open - Easy to unwrap	- Less than four steps to serve - Further research in this area would be useful
Durable Package for Customer Storage Needs	- Packaging is durable through transport, shelf storage, and home storage - Inner tray is sturdy	- Does not fold if full of cookies (new design for robots solves this already)

In addition to the final set of metrics in Table 1, other options for types of metrics were considered in the evaluation. It was important to ensure that decisions considered the engineering perspective in the context of Gamesa-Quaker's manufacturing operations. Further research in this area allowed for the identification of further standards for evaluation. These are shown in Table 2.

Table 1-2: Evaluation Metrics – Engineering and Manufacturing Perspective

	Definition	How to Measure	Quantifiable?
Labor Required	Number of person hours required on the line	Count	Yes
Quality	Number of misplaced cookie packages per 100	Count	Yes
Cost	1. Implementation Cost of new Delivery System (Fixed) 2. Cost of Delivery per 100 packages	1. Estimate based on analysis with Gamesa-Quaker plant manager 2. Material cost per 100	Yes
Ease of Implementation	Simple, intuitive methods for package delivery and loading with minimal changes to other plant operations	- Time to train workers - Time to install - Consideration of other plant operations affected	Yes Yes No
Efficiency	Process overall more efficient than current manual system	See notes from Process Maps	See notes from Process Maps
Fill Rate	Number of completed boxes per minute	Taken at line assembly	Yes
Damage Rate	- Number of individual packages damaged per 100 - Number of final products damages per 100	Count or Estimate	Yes

Table 1 outlined metrics that were relevant from a customer perspective and therefore were necessary considerations for the engineering team. In doing feasibility analysis of any new process on the lines, there are additional considerations from the engineering team. Table 2 identifies these.

Ease of Implementation and Labor Required were two metrics used to ensure that the proposed solution met the first criteria outlined in the project requirements – that the solution not significantly alter plant operations, work culture, or physical layout of the plants. Additionally, these two metrics were important to ensure that the proposed solution would not require substantial additional training of the plant workforce. The

other metrics shown in Table 2 were mainly used as indicators of cost-effectiveness of the proposed solutions also described in the project requirements.

Assumptions

In making decisions related to production regulations, labor laws, budget, and health and safety standards, all efforts were made to use existing standards upheld by Gamesa-Quaker. In areas where package redesign or packaging layout significantly alters the status quo in a way in which a new decision on standards was needed, there were a few courses of action.

First, discussion with engineering management and the plant manager at Gamesa-Quaker's Monterrey Plant. Second, a request for information regarding standards was sent to the plant health and safety manager as well as the brand managers to ensure that any packaging redesign does not violate health and safety rules. Third, consideration was given to Mexico's labor laws which ban part-time hiring of workers. Therefore, decisions for how to structure plant operations around changes in the packaging process needed to account for a non-seasonal workforce.

2.2 Current Situation

Overview of Current Surtido Rico Packaging Processes

As discussed previously, the Surtido Rico production process currently takes place on seven lines across four plants in Mexico – Monterrey, Vallejo, Obregon, and Celaya. The current labor intensive processes are costly, inefficient, and outdated. Before it would be possible to overhaul the Surtido Rico packaging process, it was necessary to map out the current packaging process and identify possible areas for improvement. The packaging processes and equipment for Surtido Rico are virtually identical at every Surtido Rico packaging line in all four plants.

Appedix A-1 shows a process map of the current packaging process. There are several non-value-added steps in the current packaging process. These are indicated on the diagram in Red. The intermediate steps that are necessary but do not add any value to the customer are indicated in Yellow. The value-added steps are indicated in Green. The left side of the figure indicated steps which take place on the main packaging line. Steps on the right side of the diagram are taking place in parallel to the main packaging line and involve interactions between the two. As the process map highlights, there are clearly several areas for improvement in this packaging process.

Damaged Products

There are two main steps in the current process in which cookie products are damaged most frequently – Transport and Tray Packing. In the Transport step, unwrapped cookies

Figure 2-1: Raw cookie product placed directly into transport trays

are placed directly into a plastic lined corrugated fiber (cardboard) box as shown in Figure 2-2. These boxes are then transported manually from the production line where the cookies were produced to the Surtido Rico packaging line in a different area of the plant. At the Surtido Rico packaging area, these transport boxes are stacked as shown in Figure 2-3. Products may remain in this waiting area for several hours before being sent to the

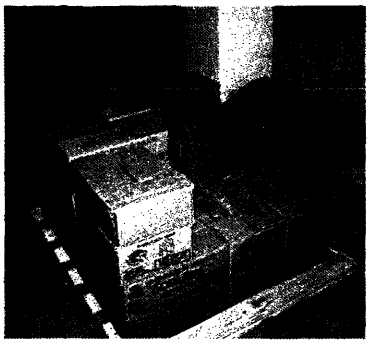


Figure 2-2: Transport boxes stacked in waiting area of Surtido Rico Packaging Line

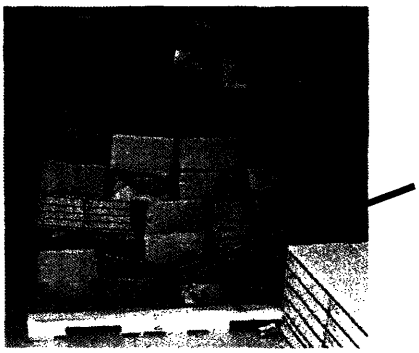


Figure 2-3: Transport boxes buckle during wait time, destroying product

Tray Feeding area. During this time, the boxes at the bottom of the stack often buckle and the products are destroyed (see arrow on Figure 2-4 indicating damaged product). Additionally, these transport boxes are reused several times in this process.

In an improved system, these steps would be modified or eliminated to reduce waste and increase efficiency. Therefore, solutions proposed for improving this process must provide a convenient method of transfer for the cookie products from their production lines to the Surtido Rico packaging line that would reduce the amount of wasted product and preferably also allow for reuse of the transport mechanism.

An important point to note here also is that in almost every type of packaging line at Gamesa-Quaker, when cookies are moving through the line and packaging areas without wrapping ("raw"), a substantial percentage of cookie product is damaged or completely destroyed. When cookies are individually wrapped before transport, this product damage is virtually reduced to zero.

Wait Time

Another major drawback of the current Surtido Rico packaging process is that several steps create bottle necks in the system. Since each step in the process is completed at a different rate, the slowest steps create bottlenecks that increase the overall packaging completion time. Wait time at individual steps often reflects inefficient use of labor or other backlog further down the process flow chart and results in higher production costs and decreased process efficiency. This is true for the following steps: Transport (to Surtido Rico waiting area) and Box Prep (for Tray Packers).

The rate limiting step in the packaging process is the manual Tray Packing step. This particular step in the packaging line can often require up to 15 workers at a time, just for placing the cookies into the trays. An additional 3-5 workers are continually prepping the boxes to ensure that the packers have a continual supply of unwrapped cookies to place in the display trays. Figures 2-5a, 2-5b, and 2-5c show different stages of the tray packing step at the Celaya Plant illustrating how labor intensive the process is.

Figure 2-4a: Stage 1 of Tray Packing Step. Worker is separating individual display trays and passing them onto the tray packers to be filled manually.

Figure 2-4c: Stage 2 of Tray Packing Step. 12 workers are in an assembly line to display trays.

Figure 2-4b: Stage 2 of Tray Packing Step. Each variety of cookie is individually placed into the display tray.

Because the Tray Packing step is slow, the individual boxes in which the cookies were transported from their production lines to the Surtido Rico packaging line remain in the waiting area for several hours at a time. Additionally, the workers who prep these boxes – by re-opening them and placing them onto the Tray Packing assembly line – must wait around constantly. These workers are monitoring the progress of the tray packers, and once a specific product is running low, the workers can prepare the next box.

Critical Areas for Improvement

Several areas for improvement in the process have been identified. In an ideal system, each step could be fully analyzed and optimized. In future tests, it would be valuable to collect data on the flow rate of product through each stage, the average amount of waste per step per hour, and the average amount of wait time experienced by an average final package over the entire line. These variables can help inform better evaluations of effectiveness on a line – assessing whether a stage is value-added or non-value-added.

Effectiveness can then be calculated using the following equation:

Effectiveness = (Total Value – Added Time) / (Total Elapsed Time)

In the scope of this project and with the available data, the transport boxes and wait time issues were identified as most critical areas for improvement.

Overview of Gamesa-Quaker Proposed Solution

Gamesa-Quaker is currently working with a third-party company to install six robots with two arms each onto the Surtido Rico Packaging line in Monterrey. Target production on this line will be 3,000kg/hour (representing 4,225 Surtido Rico displays per hour) with a $4.2 Million investment. The company working with Gamesa-Quaker will be responsible for all steps in the packaging process after cookie products are fed to the robots – this includes separating individual display trays (will be done with a tray de-nester utilizing a suction), placing each type of cookie in the appropriate section of the display tray, sealing trays and placing them into display boxes, and then packaging the individual display boxes for transport out of the plant. The outside firm will not, however, be responsible for designing a system to deliver individual cookie products to the robots from the lines where they were produced. They will build a conveyor belt system to allow products to flow to the robots for feeding, but it is up to Gamesa-Quaker to determine how cookie products are delivered to and placed upon the conveyor belt system.

Individual Wrapping of Cookies

Gamesa-Quaker engineering management have made the decision to invest capital for only six robots – each robot has two arms. Current designs of the robot arms allow for them to pick up only one item per arm stroke (e.g. one raw cookie or one individual package). Since the robot arms can operate at 100 strokes per minute, in order to achieve the target output rates, cookies must be fed to the robots in individual packaging – meaning, cookies of the same type need to be pre-wrapped in the "individual serving" packaging. If the robots were to pick up raw, unwrapped cookies, they would need more strokes per minute to reach the target output goals, requiring 18-20 robots on the line. Individual packaging is not much more expensive since equipment is already in place at the individual packaging lines to perform this type of packaging for each of the products in the Surtido Rico assortment.

The project will require a redesign of the final display tray for the Surtido Rico presentation in addition to redesign of the packaging processes required to feed individual cookie packages to the robots on the line. A pending question is whether another layer of plastic seal is required over the box if cookies are individually wrapped. This decision has not yet been made by the health standards committee. If this is required, the machine that covers the display box with a plastic film wrap operates at 50 trays per minute and will need to be accounted for in designing the final solution.

Error Correction by Robots: The robots use a vacuum suction arm to pick up individual cookies from a feed line. They can then rotate the cookie or package horizontally to

adjust it into the correct slot in the display tray. However, the robot arms are not able to flip the packages over, in the case that a product is on the feed line in an overturned or up-side-down position. If a product is fed to the robot in this way, it will be placed into the display incorrectly, causing a decrease in presentation quality. The Chokis and Barras de Coco products are most sensitive to this error as they are flat cookies with a clear top side so they need to be presented "top side up" in the display.

3 Design Solutions and Testing

3.1 Design Solutions

Three Options Considered

Traditional Manual Delivery

(Illustrated in Figure 3-1)

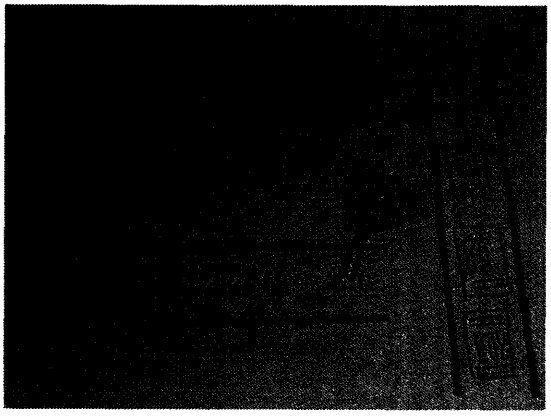


Figure 3-1: Traditional Manual Delivery on Automated Line

The current Surtido Rico packaging process is 100% manual, utilizing current Gamesa-Quaker practices of traditional manual delivery and packaging for the product. Using this conventional feeding method in conjunction with the robots would require an operator at

the plant to manually transport boxes of cookies to the packing line. Another worker would then manually empty the contents of the box onto the conveyor belt feeding the robots, but the individual cookie packages will fall in random order and position onto the belt. Since the robots can not compensate for overturned packages, there would be a high percent error in the final display, decreasing the final product quality. Alternatively, additional workers would be needed to correct these errors and adjust individual packages into the correct orientation before feeding to the robot.

As discussed previously, it is this very labor intensive process that is contributing to high production costs and lower margins on the Surtido Rico high end product. The goal of the project is to reduce the amount of labor needed on the line in order to transition to a more efficient and cost-effective packaging process.

Redesigned Magazine Feeders

(Illustrated in Figure 3-2)

Figure 3-2: Redesigned Magazine Feeders for Automated Line

Gamesa-Quaker currently uses a variety of types of magazine feeders in their individual cookie packaging lines. However, none of the designs (shown in Figures 3-3, 3-4, and 3-5 below) are designed for feeding individually wrapped cookies. Rather, they are designed for feeding raw unwrapped cookies. In order to be used in the Surtido Rico automated lines, they would need to be redesigned. Before going further with a magazine feeder redesign, other aspects of this delivery option were considered.

In the set up required for the automated line, if redesigned magazine feeders were used, an operator would be required at each magazine to load the individual cookie packages into the magazine. The magazine feeder would then align the packages into rows onto the conveyor belt feeding to the robot. Here, quality is much improved over the manual delivery method though labor is still required to load the magazine feeders properly. If the feeder is loaded incorrectly, overturned packages will still make it onto the conveyor belt and into the final presentation. Additionally, if the magazines were redesigned but still used unwrapped cookies to feed to the robots, there would be increased product damage as raw cookies are more likely to be crushed and destroyed in the feeder cycle.

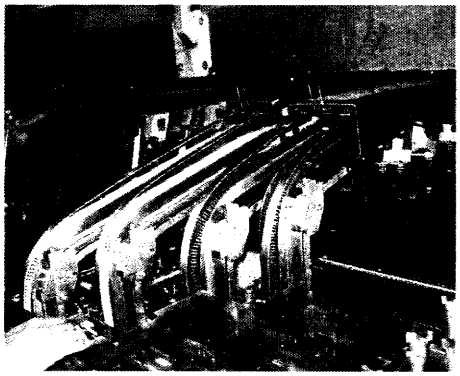


Figure 3-4: Vertical Magazine Feeds

Figure 3-3: Horizontal Magazine Feeds in parallel

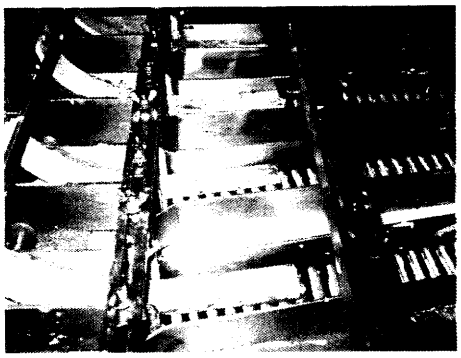


Figure 3-5: Horizontal Feeds
Note: damaged product collecting in sides of rows

Innovative Box Delivery (B)

(Illustrated in Figure 3-6)

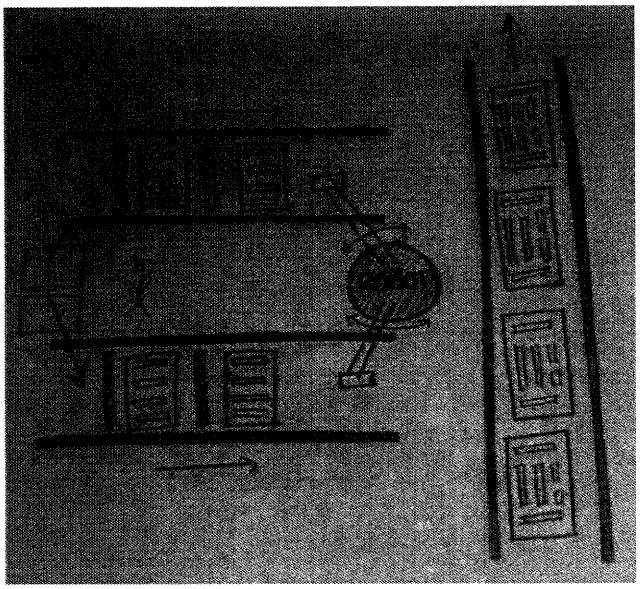


Figure 3-6: Innovative Box Design for Automated Line

This is an entirely new system and method for package delivery in the assortment line at Gamesa-Quaker. The goal with an innovative box system was to design a system that preserved some of the advantages of the manual and magazine delivery methods while at

the same time reducing cost and improving efficiency. Additionally, any new design would have to be compatible at two main stages in the packaging process.

Stage 1: End of Individual Cookie Production Line

- The design must be easy to implement at this stage
- The design can not alter plant layout here
- The design can not significantly change plant processes here (training, equipment, space)

Stage 2: Start of Surtido Rico Packaging Line

- The design must provide for a simple way to load or empty box contents onto line
- The design must meet requirements of robot feed

In a system like this, the operators and the end of the individual cookie production lines' packaging stage would place the packages directly into the box. This is a step already performed with different types of boxes and cookie orientations depending on the line, so as long as the box was not significantly different from current designs, very little training would be required. Ideally, the new box design should facilitate allowing the individual packages to be placed in the box in the correct orientation necessary later when the robot would extract the individual cookie packages from the box. Next, another operator would transport these boxes to the Surtido Rico packaging area and load the boxes onto the feeder belt (which will be designed specifically for this box).

The advantages of this system are that it reduces the amount of labor necessary at the Surtido Rico packaging line and does not require and increased amount of labor at the end of the individual product lines. Additionally, it reduces error to nearly 0%, increasing final product presentation quality. Several designs were created and evaluated by engineering management at Gamesa-Quaker before selections were made for prototyping and testing on the lines.

In designing a new box delivery system, there were several options and ways to implement it. One goal was to ensure that the newly designed box be reusable between Stages 1 and 2 of the packaging process. Beyond that, there were two major ways of designing a new box delivery system.

In the first option, the box would be versatile enough to be used for packing and transport from Stage 1 and then loaded onto the conveyor at Stage 2 directly, meaning the entire box and its contents would be fed to the robots. Two designs were explored in this option. The Box Slider Method would use a box that gets locked into the feeder conveyor belt or rollers at Stage 2 and moves down the line with the individual cookie packages inside it. This would require a complex box design to enable it to be locked and loaded onto the conveyer and then removed afterward. This would also require dividers or fins inside the box to both maintain order of the packages inside as well as connect to the conveyor. The Box Carrier Method is simpler and would involve designing bars on the feeder conveyor belt that moved at the appropriate rate for feeding the robot. In this model (the one

pictured in the Figure), an operator need only slide boxes onto the belt into the slots one at a time.

Both of these (Box Slider and Box Carrier) would require some design to ensure that the robot arm could reach cookie packages deeper in the box as the stacks of packages diminished when the arm picked up the top layer. Either the robot arm would have to be designed to reach down to variable lengths on the conveyor or the base of the box would need to be spring-loaded to allow packages to move up to the surface of the box opening as the robot removed the upper packages from the stack.

In the second option, the box used at Stage 1 would be used for temporary packing and transport from the individual production line to the Surtido Rico packaging area and then would be emptied at the Surtido Rico line for feeding during Stage 2. This option was found to require the same amount of labor as the first option but at a substantially lower cost in the areas of redesign, ease of implementation and training. Therefore, the engineering management at Gamesa-Quaker requested this path be pursued.

Comparing the Three Options

In order to make a decision about which method to pursue, all three delivery methods were compared across the Engineering and Manufacturing Evaluation metrics discussed previously. The goal of this comparison was to understand the relative benefits and disadvantages of the three options. Table 3-1 shows the results of this comparison.

Table 3-1: Comparison of Three Delivery Options

	Traditional Manual Delivery	Innovative Box Delivery	Redesigned Magazine Feeder Delivery
Labor Required	High	Low	Medium
Quality	High	High (potential for less flexibility)	High (potential for less flexibility)
Cost	Low - Medium	Medium	Medium
Ease of Implementation	High	Medium – Low	Medium
Efficiency	Low	High	Medium – Low
Damage (waste)	High	Low	Medium

The innovative box delivery method quickly emerged as the most promising option to pursue because of its advantages in cost-savings, efficiency, and reduced labor requirements.

Testing of Innovative Box Delivery Methods

Once the box delivery methods were identified as promising to pursue, two types of testing were necessary to ensure that a new design was feasible. First, testing needed to be done in the plants to ensure that the design was technically sound. Second, testing was necessary with sample consumers to ensure that changes in product presentation as required by the design did not negatively change consumer perceptions of the product.

As previously discussed, full testing in the plants was not possible as the robots were not installed on the lines in the timeframe of this project. Instead, testing had to be done in a

simulated setting – on the actual production and packaging lines used today, but without the robots or automation equipment present. Testing was done in the Stage 1 areas (packaging areas of individual cookie production lines) as well as in the Stage 2 areas (Surtido Rico packaging line) to ensure that the design was effective in both of the required stages. In each test, actual workers from the plants were asked to use the prototype of a new box design in packaging and sorting the products. Observations about ease of implementation, ease of learning the new packaging technique, and time to complete the step were noted.

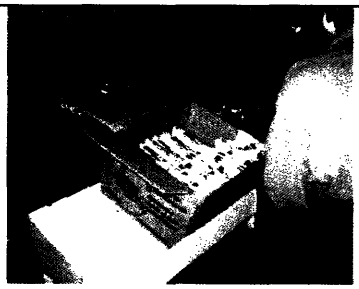
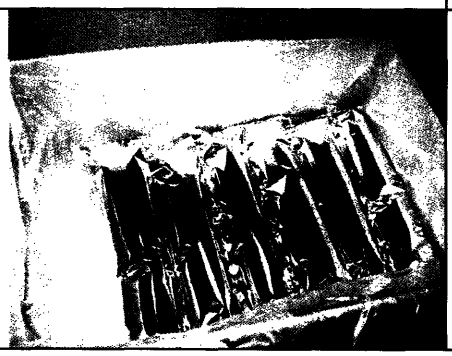
Tests in Plant: Technical Feasibility

There were five designs for various stages of the packaging process that were ultimately selected for testing on the line. The primary goals of testing were to ensure compatibility with Stages 1 and 2 of the packaging process as well as confirming that the designs represented an improvement over current packaging processes. As discussed, testing was possible only in a limited setting and in accordance with the wishes of Gamesa-Quaker's engineering team. They asked that only those designs which were selected in the initial screening process be tested.

The first round of testing in the plant focused on learning in what positions the workers could easily place individual cookie packages into transport boxes. Different types of transport boxes were also used in the testing: deep boxes (similar to the current boxes used for transport between Stages 1 and 2), shallow lined boxes, and shallow unlined boxes. In the course of the project, the health and safety committee concluded that a

lining is not required when transporting individually wrapped cookies – so in future testing this lining would not be required. Several positions of cookie placement were attempted: horizontal (flat) face display into a deep box, vertical display into a deep box, and flat display into a shallow box. Selected pictures from this testing and the results are shown in Table 3-2 below.

Table 3-2: Technical Feasibility Testing – Round 1

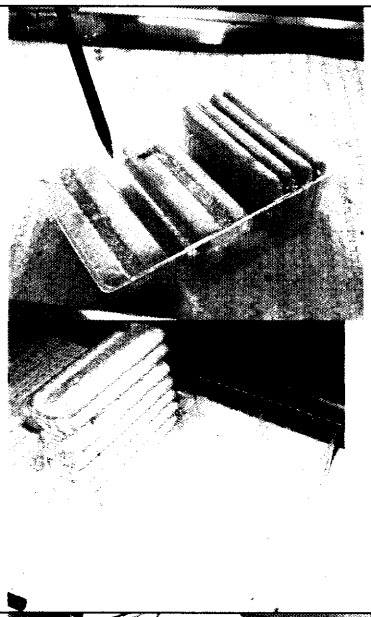
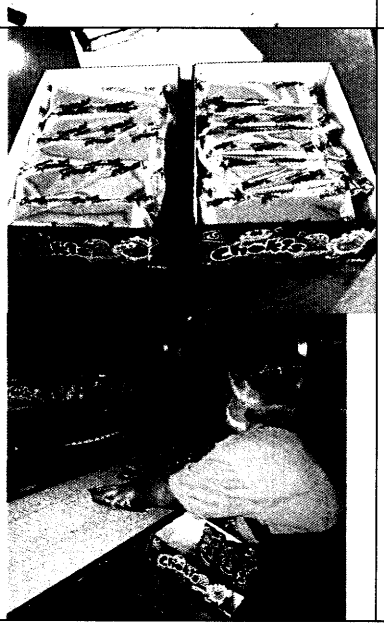
Test Description	Picture	Results
Deep Box Placement (Emperador Packaging Line)		- Workers found it difficult to place packages in purely flat or vertical display style with deep box - Combination shown here was successful
Shallow Box Placement (Marravillas Packaging Line)		- Workers easily placed individual packages in the flat orientation with this style box - Indicates that wide shallow boxes facilitate faster packing in flat display orientation

There were several problems identified with the Deep Box options. Workers had trouble ordering the packages in a manner that would make the packages easy to unload at Stage 2. In order to easily be unloaded at Stage 2, all cookie packages in the transport box need to be placed in the same orientation in the transport box. After several iterations, a simple way to load and unload cookie packages with this constraint in a deep transport box was not found. The results of the Shallow Box testing were more promising. Here the tests

demonstrated that workers could easily place individual cookie packages into the wider box opening. Additionally, the flat orientation in a shallow box was the easiest to unload in a systematic way. In order to unload the packages and ensure that they emerge from the transport box in a consistent orientation, the lightweight box can be overturned and placed directly on a conveyor belt and the aligned cookie packages proceed on the line to be fed to the robots.

The second round of testing focused on flat display orientations with shallow box types. The goal of testing was to understand if further design of dividers or fins within the box could help workers align the cookie packages at either Stage 1 or 2 of the process without compromising the speed of packing achieved in the first round of testing with shallow boxes. The rate achieved was approximately 1.2 times as fast as the current deep box packing methods used at the end of individual packaging lines for transport to warehouses. An additional goal was to see if smaller, tray-style boxes would be feasible as such boxes are easier to manipulate and overturn during the Stage 2 unloading steps than larger boxes. The summary of round two designs and testing are presented in Table 3-3 below.

Table 3-3: Technical Feasibility Testing - Round 2

Test Description	Picture	Results
Thermoformed Shallow Tray with Fins (see pen indicating fin) - Flat display - Vertical display		Stage 1: very difficult for workers to maneuver individual packages into tray slots quickly (much slower packaging rate) for flat display, even more difficult for vertical display (see right slot in top picture) Stage 2: most preferred design for unloading individual packages in orderly fashion onto conveyor belt for robot feed
Corrugated Fiberboard Box (Chokis and Emperador lines) - Flat display only		Stage 1: simple for workers to fill box with single or double layer of individual cookie products Stage 2: simple to manipulate box for unloading and product alignment is satisfactory

Round 2 of testing showed interesting results relating to the differences in packaging needs at Stage 1 and Stage 2. In Stage 1, workers had difficulty placing individual packages into the divided tray with fins. This was because with flat display orientations, workers were trained to pick up a set of packages together and place them into the

shallow box together. The fins made this more difficult and slowed the process by required additional steps for the workers to readjust the packages fully into the slots or place the cookies for each slot in separately requiring two extra arm strokes per tray.

In Stage 2, the important factor in ensuring that cookie packages were oriented correctly for robot feeding was the ease with which workers could manipulate and overturn the fully filled box in order to empty the contents properly onto the feed conveyor. The fins, while useful, were not so critical to the process. As a result, the corrugated fiber shallow box was chosen as the preferred design of an improved box delivery option. Later in testing, it was found that a double-box transport method (pictured third in the table) could increase the rate at which packages are emptied at Stage 2 without slowing the packing rate at Stage 1. Before implementation, further testing of this option would be valuable.

Tests with Consumers: Customer Response

During customer testing, four presentations of the Surtido Rico product were tested. These included the current two-tray Aluminum wrap display as well as options for new layout designs. Among the new designs, Presentation 4 is not actually feasible as it involves feeding raw cookies to the robots, but was included in testing for market research purposes. The presentation display options are outlined in detail in Appendix B, but the four options are listed below.

Presentation #1: Individually Wrapped, Vertical Display, Single Tray

Presentation #2: Individually Wrapped, Flat Display, Single Tray

Presentation #3: Unwrapped, Sealed Aluminum Display, Double Tray

Presentation #4: Unwrapped, No Cover, Single Tray (infeasible for production)

The results of consumer testing were quite interesting. The majority of people surveyed preferred the individual wrapping of the product as opposed to the aluminum wrapping of the full tray. Most commented that they preferred the clear individual wrapping which allowed them to view the cookie inside as well as choose to open a single product at a time. When asked which presentation was their top choice overall, the majority of respondents chose Presentation 1, though Presentation 2 came in a close second choice. Interestingly, the current presentation, Presentation 3 ranked very poorly both overall and across several other categories such as aesthetic characteristics and suitability to customer lifestyle. Figure 3-7 shows the results of the top choice question. Further details of the customer survey results are available in Appendix B.

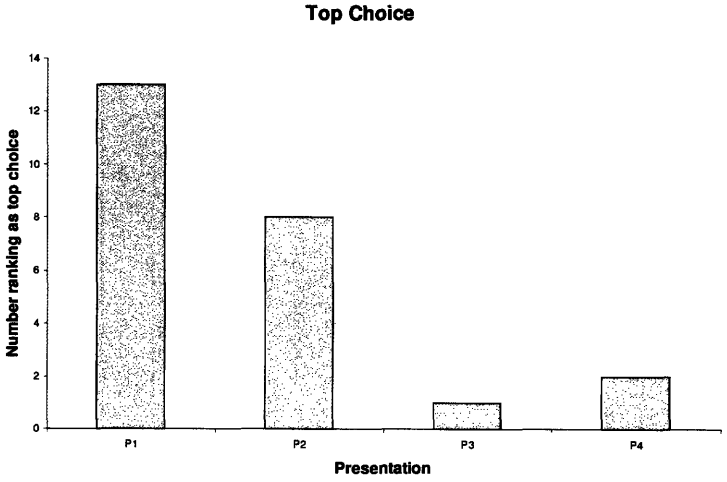


Figure 3-7: Results of Customer Surveys

The research results indicate that shifting to the individually wrapped packaging for the final display should not negatively impact customer perception of the product or their

willingness to purchase the product. In fact, based on the results, customers may prefer the new design layout. Gamesa-Quaker uses a 6:4 preference ratio as a target to compare its products to the leading competitor. The results show that Presentation 2 certainly meets (actually, exceeds) this target when compared to the current display, Presentation 3.

Before implementing a new tray design, further customer research is recommended. The surveys done in the scope of this project were with a limited sample consisting of only MIT Students living in the United States. Since the target market for this product is females in Mexico, further testing with this group would be helpful.

3.2 Preferred Design

Based on the technical feasibility testing and the results of the customer research, the recommended design for an improved cookie package feeding and delivery system on the Surtido Rico automate line is the double corrugate fiber shallow box method. Not only does this method rank highest in the two critical requirements from the Gamesa-Quaker team (of low cost and ease of implementation, training, and minimal effects on plant operations), but it also allows for a final packaging display which is preferred by customers. This design also allows for significant improvements in the efficiency of the packaging process over the current methods used. The total number of steps decreases by three and all non-value added steps are eliminated. The complete improved process map is in Appendix A.

4 Conclusions

Outcomes

In this project three potential methods for feeding individual cookie packages to robots on an automated packaging line were evaluated and an improved design proposed. This design meets the project goals of improving efficiency and decreasing cost on the line while ensuring that the new design does not significantly alter plant operations, work culture, or physical layout of the plants. Additionally, in the course of the project, careful consideration was given to the types of metrics that should have been used in evaluating the effectiveness and feasibility of each proposed solution. These metrics were necessary to ensure that both customer needs and engineering requirements were adequately accounted for in new designs.

Finally, two types of testing were used to evaluate the final design solutions. First, technical feasibility of the solutions was tested with prototypes in the plants in a simulated setting. Second, customer satisfaction with the new product display was tested with prototype displays in a limited sample. Both series of testing showed that the final proposed design solution of a redesigned box delivery method is a much preferred alternative to the current manual processes employed at Gamesa-Quaker on the Surtido Rico line.

Future Steps

Testing within the scope of this project was somewhat limited. Technical feasibility testing in the plants had to be done with out the robots installed on the line, and therefore only presented a picture of how well workers on the line would be able to implement and execute the Stage 1 (individual line packaging) steps. Further testing of the technical feasibility of this solution in Stage 2 (at the Surtido Rico line – feeding the robots) would be useful before full implementation of the proposed solution. Customer testing was also limited in this project to a small sample of college students living at MIT. Before approval of a redesigned display presentation of the Surtido Rico product, further customer research with Gamesa-Quaker's target market segment should be completed to ensure that the packaging redesign does not negatively impact customer preference for the product.

Acknowledgements

I would like to thank my thesis advisor, Prof. Dave Wallace, for his support and guidance while working on this project and for teaching me the fundamentals of designing for the customer. I would also like to thank the following people from Gamesa-Quaker for making this project possible and teaching me about the manufacturing and engineering operations at Gamesa-Quaker, especially over the summer of 2006: Jose Luis Prado, Jesus Villanueva, Victor Elizalde, Miguel Acosta, and Sarene Lopez. Finally, I would like to thank Dr. Gauri Srivastava, Piyush Srivastava, Tina Srivastava, and Andrew Greenhut for their support throughout this project.

Appendix A: Process Maps

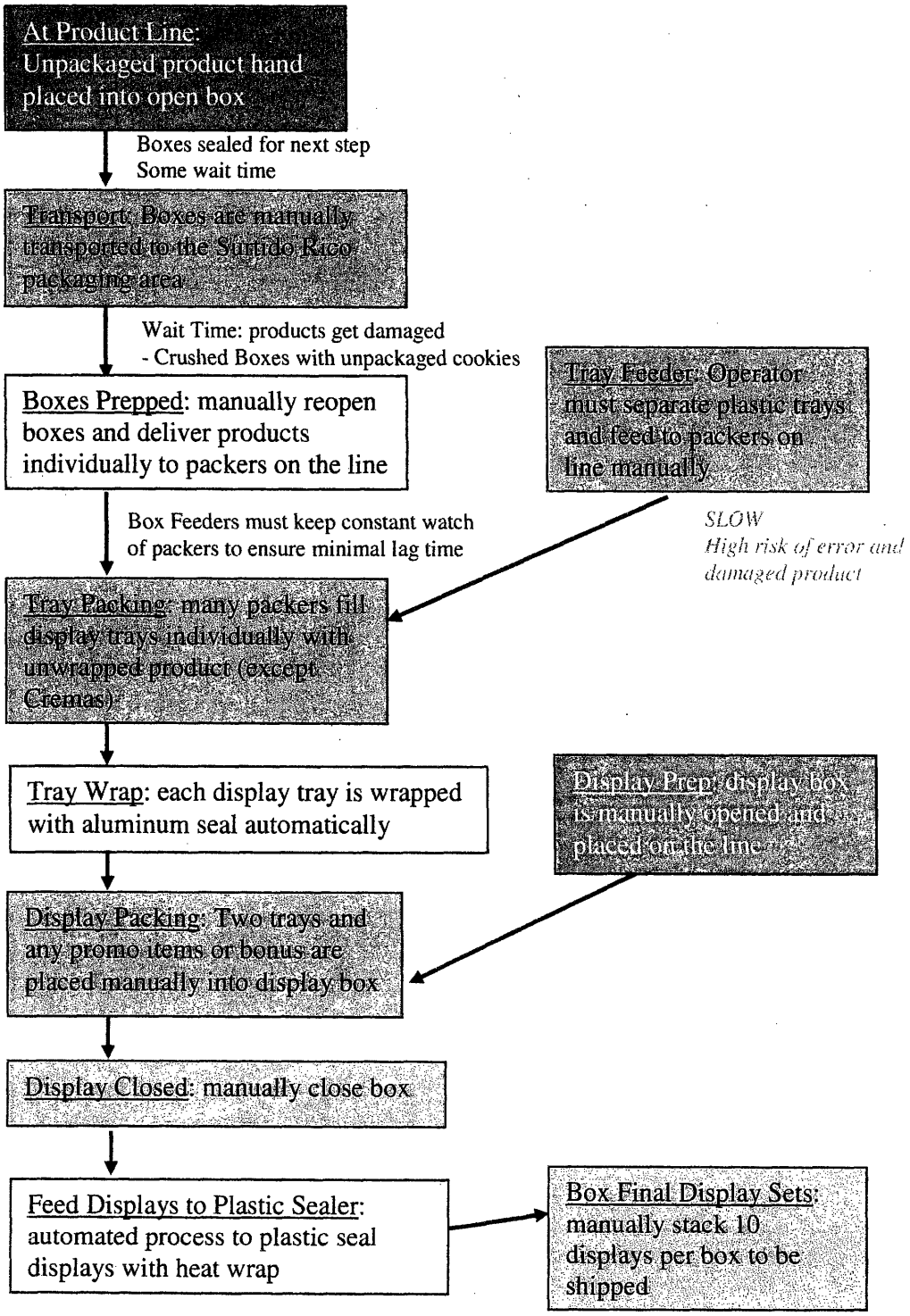


Figure A-1: Current Surtido Rico Packaging Process Map

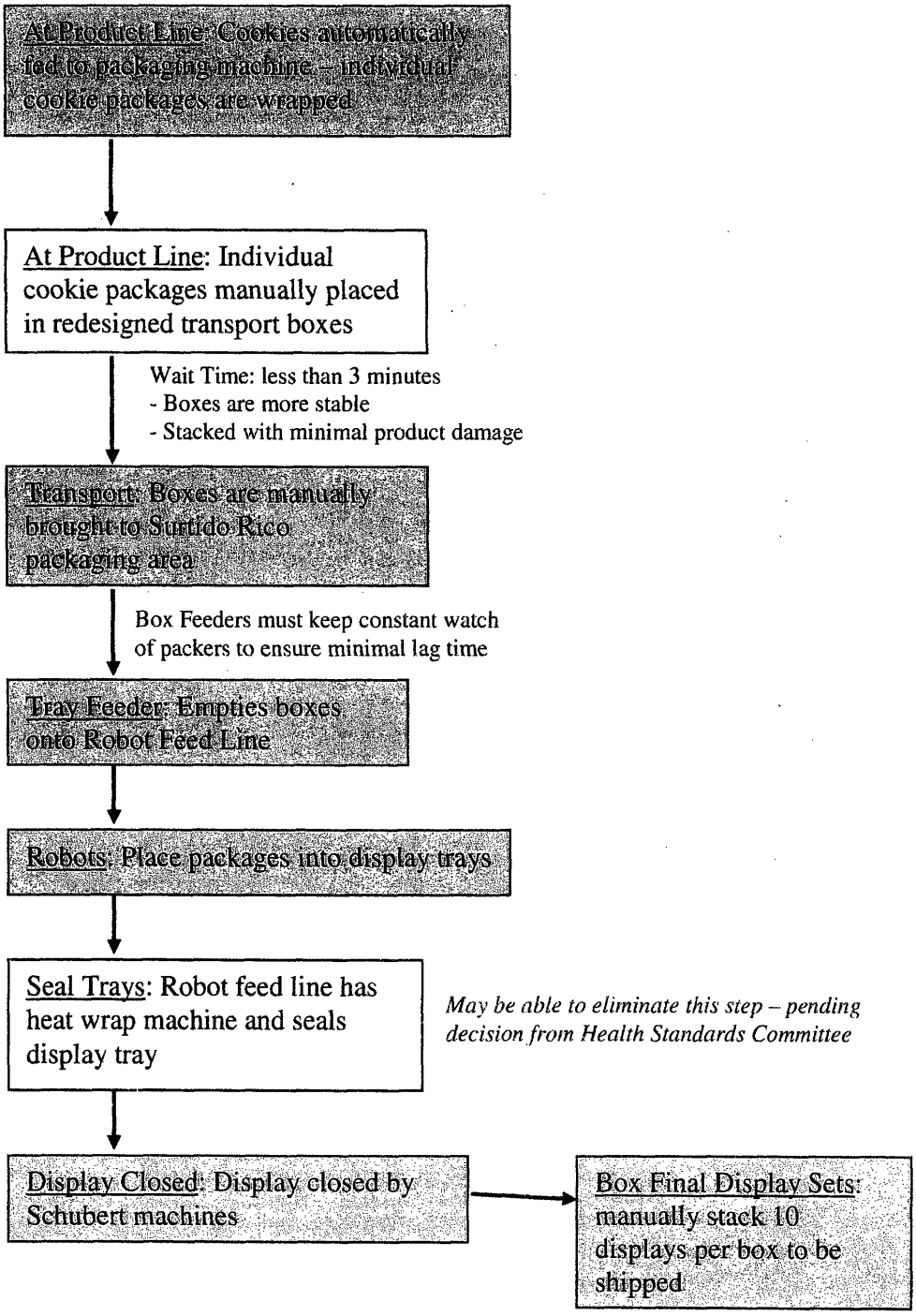


Figure A-2: Improved Surtido Rico Packaging Process Map for Proposed Solution

Appendix B: Presentations for Customer Surveys

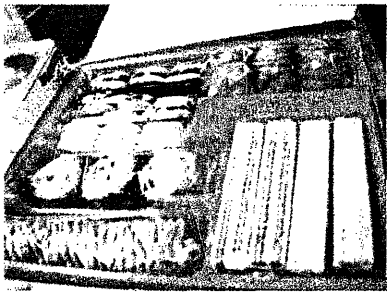


Figure B-1: Full size tray, vertical individually wrapped packages

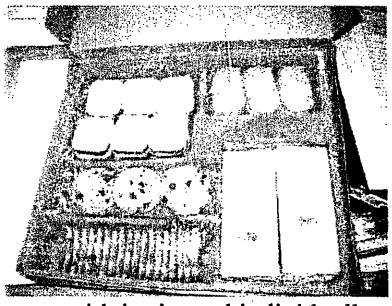


Figure B-2: Full size tray with horizontal individually wrapped packages

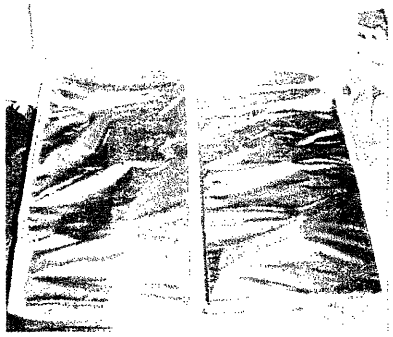


Figure B-3: Double trays with horizontal individually wrapped packages

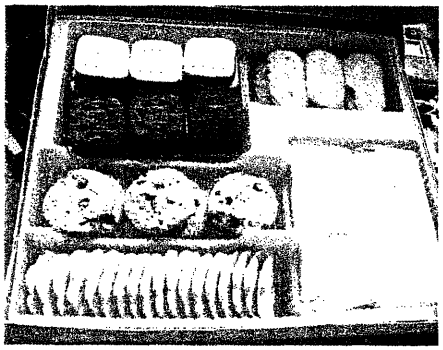


Figure B-4: Full size tray with no wrapping of product

Appendix C: Survey for Customer Research

Are you a: FEMALE MALE How old are you? _____

Please rank the presentations in order of your preference. Note: Each presentation costs $2.50USD (based on range of prices 18-25 Pesos)

1st Choice_____ 2nd Choice_____ 3rd Choice_____ 4th Choice_____

Do you find the presentation visually pleasing? (1 = not pleasing, 5 = very pleasing)

Presentation 1:	1	2	3	4	5
Presentation 2:	1	2	3	4	5
Presentation 3:	1	2	3	4	5
Presentation 4:	1	2	3	4	5

Does the packaging make this product easy to serve to guests? (1 = difficult, 5 = very easy)

Presentation 1:	1	2	3	4	5
Presentation 2:	1	2	3	4	5
Presentation 3:	1	2	3	4	5
Presentation 4:	1	2	3	4	5

Is the packaging practically suitable to your lifestyle? (1 = not practical, 5 = very practical)

Presentation 1:	1	2	3	4	5
Presentation 2:	1	2	3	4	5
Presentation 3:	1	2	3	4	5
Presentation 4:	1	2	3	4	5

Does the packaging seem durable enough for your storage needs? (1 = not durable, 5 = very durable)

Presentation 1:	1	2	3	4	5
Presentation 2:	1	2	3	4	5
Presentation 3:	1	2	3	4	5
Presentation 4:	1	2	3	4	5

Is the product simple to open and consume? (1 = not simple, 5 = simple)

Presentation 1:	1	2	3	4	5
Presentation 2:	1	2	3	4	5
Presentation 3:	1	2	3	4	5
Presentation 4:	1	2	3	4	5

Appendix D: Customer Survey Data

Table D-1: Summary of Customer Survey Data

Overview of Data Collected

	Total Males	15
	Total Females	11
	Total Overall	26

Top Choice	P1	13	Last Choice	P1	0
	P2	8		P2	2
	P3	1		P3	9
	P4	2		P4	13

Average Scores for each Presentation:

Do you find the presentation visually pleasing? (1 = not pleasing, 5 = very pleasing)	
P1	4.27
P2	4.31
P3	2.00
P4	3.08

Does the packaging make this product easy to serve to guests? (1 = difficult, 5 = very easy)	
P1	2.88
P2	3.12
P3	2.96
P4	4.62

Is the packaging practically suitable to your lifestyle? (1 = not practical, 5 = very practical)	
P1	4.35
P2	4.35
P3	2.85
P4	3.04

Does the packaging seem durable enough for your storage needs? (1 = not durable, 5 = very durable)	
P1	4.08
P2	4.19
P3	3.73
P4	2.19

Is the product simple to open and consume? (1 = not simple, 5 = simple)	
P1	3.31
P2	3.35
P3	3.23
P4	4.58

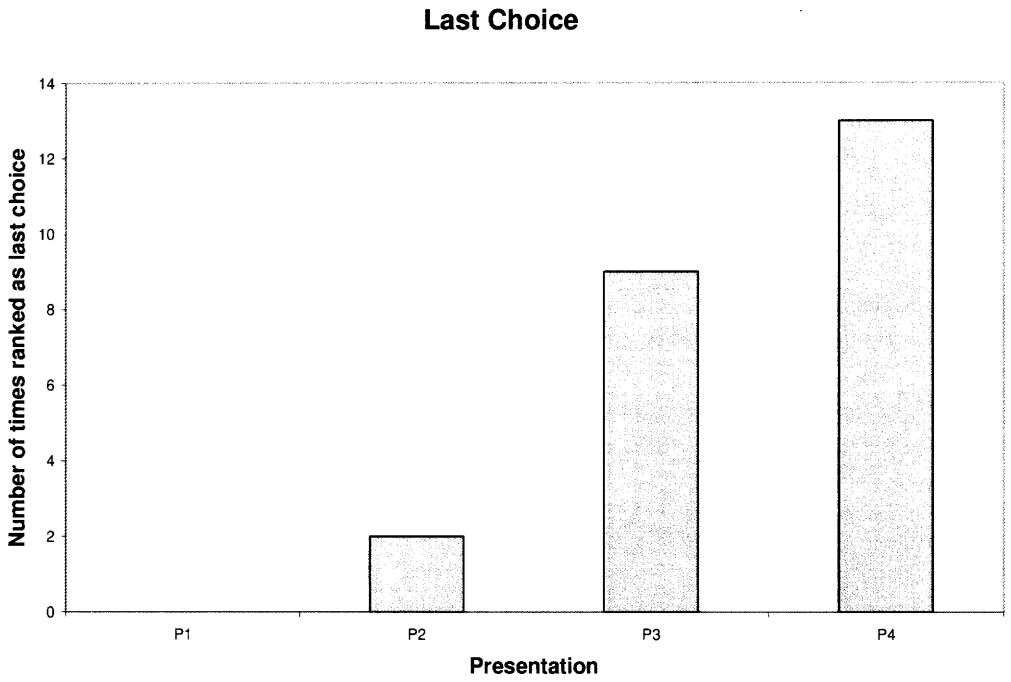


Figure D-1: Number of times a presentation was ranked last choice

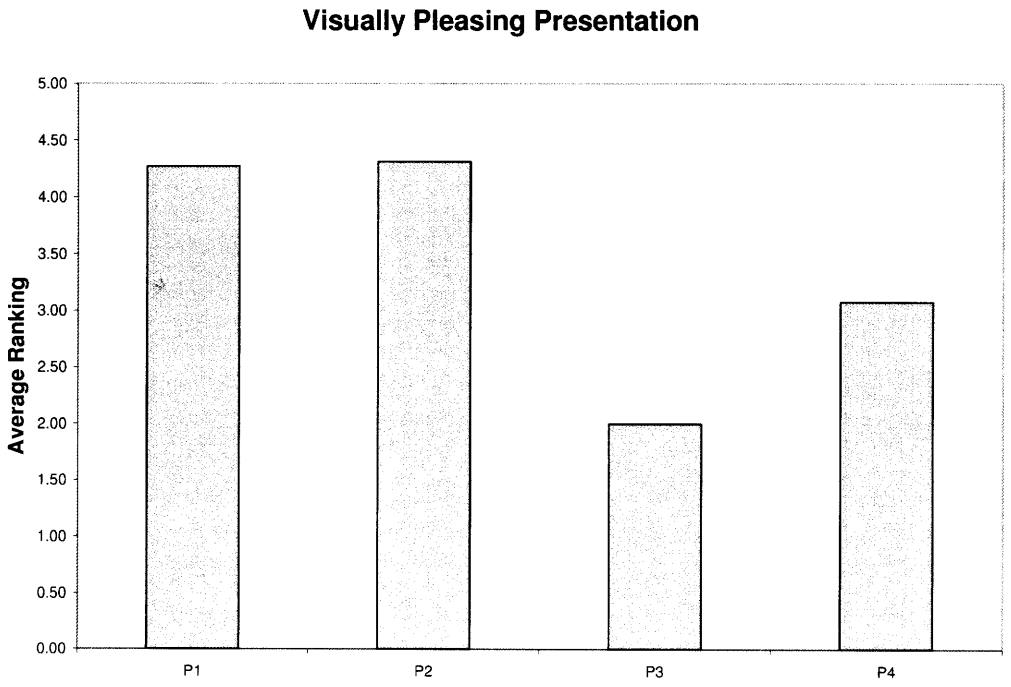


Figure D-2: Average ranking: "visually pleasing" per presentation

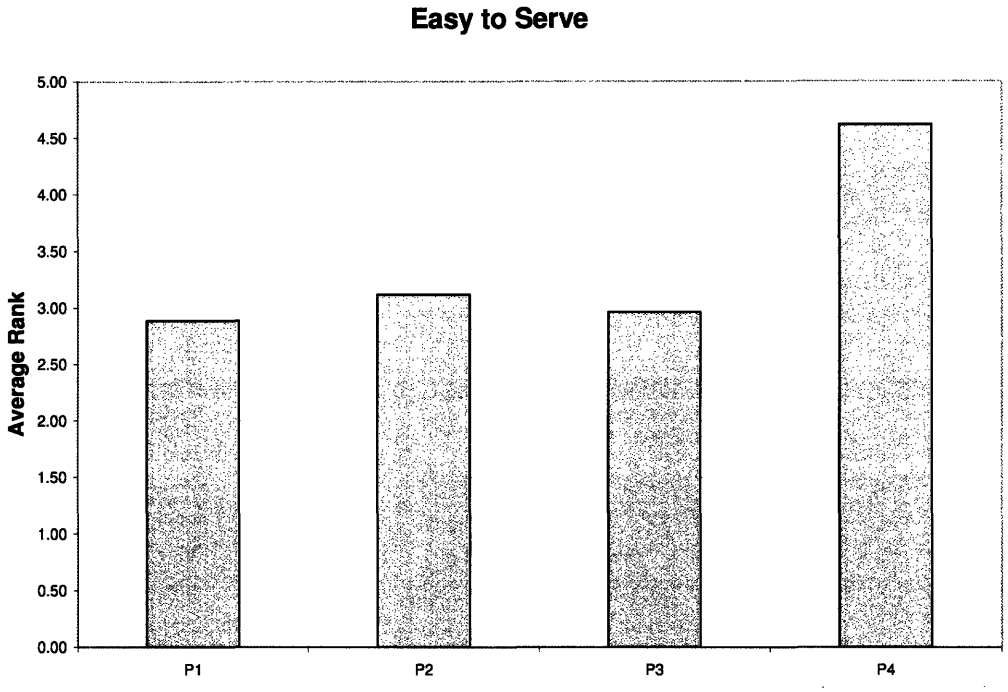


Figure D-3: Average ranking: "easy to serve" per presentation

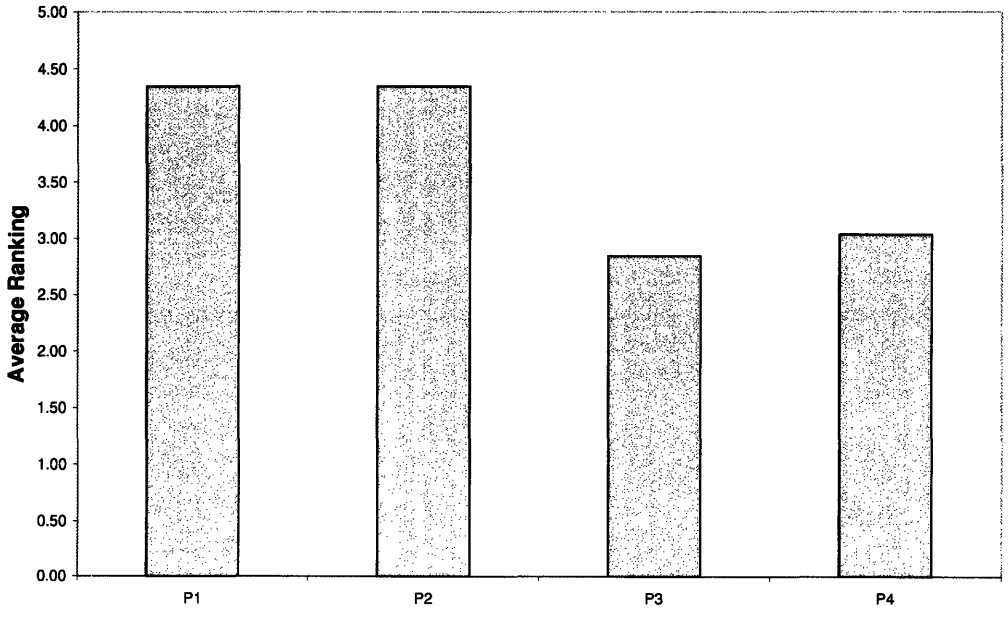


Figure D-4: Average ranking: "suits lifestyle" per presentation

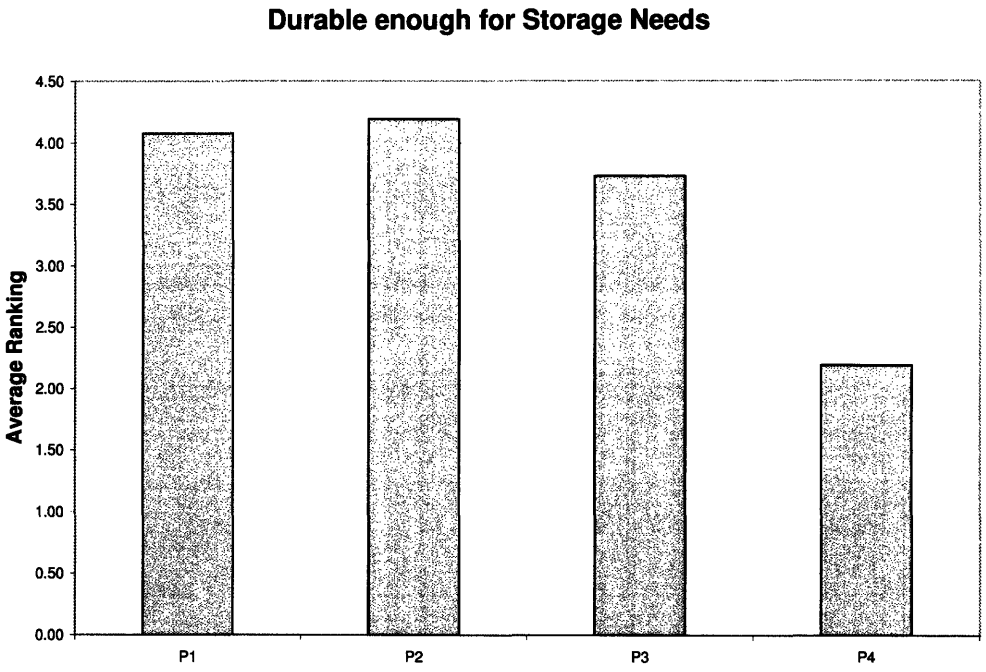


Figure D-5: Average ranking: "durable enough for storage needs" per presentation

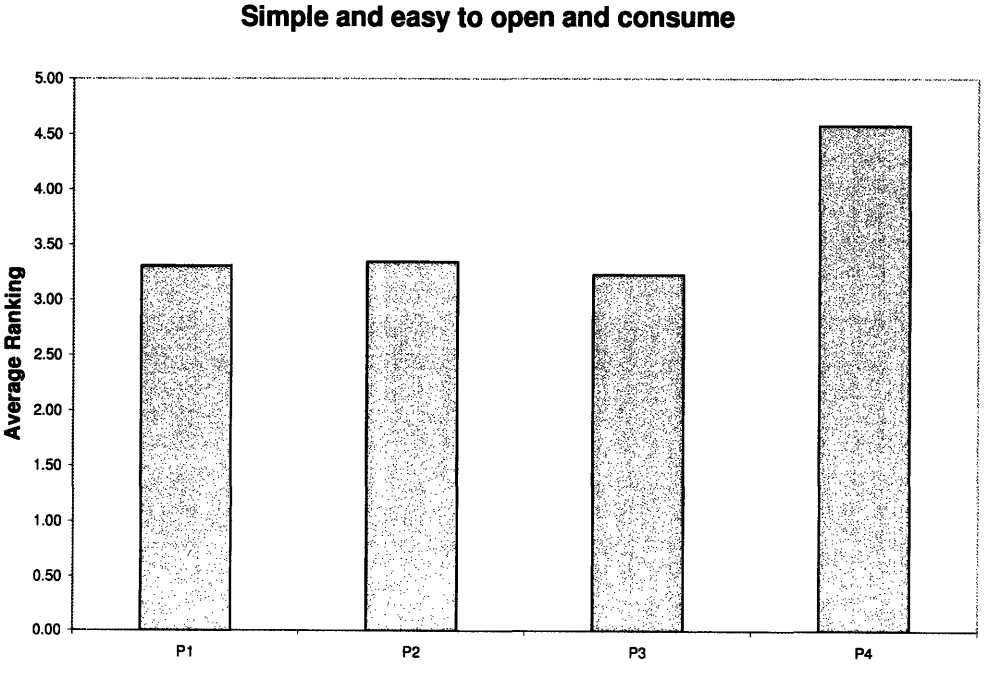


Figure D-6: Average ranking: "simple and easy to open and consume" per presentation

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