QUALITY IMPROVEMENT

AT PATIO PACIFIC, PETDOORS

by

TRI NGUYEN

KEVIN SUH

A Senior Project submitted

in partial fulfillment

of the requirements for the degree of

Bachelor of Science in Industrial Engineering

California Polytechnic State University

San Luis Obispo

Graded by:___________________ Date of Submission:___________________

Checked by:__________________ Approved by:________________________

TABLE OF CONTENTS

ABSTRACT

Quality is key in manufacturing any type of product. Customer expectations only rise with time, and it has become more crucial than ever for companies to produce quality products to survive. This project sets out to improve quality of flagship products at Patio Pacific. This report contains the background of the company, Patio Pacific, the process of finding critical problems, and the methodology to solve them.

Customer returns and inquiries have the ability to eat up cash flow in any type of company. This senior project sets out with introduction of the project that explains how the project came about, followed by background of the project, which explains in detail the steps it took to illuminate the core scope of the project. Below, there is evidence that magnets in the threshold of the pet doors are causing a huge volume of customer inquiries and returns. The design section of the project discusses an experiment that supports that 80% overlap between the magnet in the flap and the magnet in the threshold is optimal for minimum magnetic strength and a 100% threshold pop up rate. The report ends with recommendations of future work, as this project is only the beginning of quality and continuous improvement.

ACKNOWLEDGEMENTS

We would like to thank Nick Pullano, general manager of Patio Pacific, and Dr. Lizabeth Schlemer for giving us the opportunity to work on this project, and letting us collaborate with employees to go forward with the project. And a big thank you to Dr. Matt Moelter, professor of physics, for sharing expertise on magnet and testing matters, and for providing equipment necessary for carrying out the tasks.

LIST OF FIGURES

INTRODUCTION

To date, there are over 50 million dog owners in the U.S. With such volume, comes a huge market of pet products. Within the pet industry, there is a niche market for pet doors for the pets to easily access homes and backyards. The following project was introduced through the help of Dr. Liz Shlemer and Nick Pullano, general manager of Patio Pacific. Patio Pacific, founded in 1976, is a local company in San Luis Obispo that manufactures and sells high end pet doors. The company employs roughly 16 employees. Patio Pacific is also known by PetDoors.com, which is its domain name. The company has three distribution channels: its own website, amazon.com, and pet stores. Their leading product is the Endura Flap, which is the best insulated pet door on the market. Nick Pullano, general manager who oversees the company activities and operations, has been pivotal in providing necessary information to go forward with this project.

As it is in any type of manufacturing environment, there are always opportunities to improve quality of the final product and/or the processes used to make the product. Nick has noted that they want to improve quality of their products, and to reduce customer returns and inquiries. This senior project aims to provide a solution that will be a foundation for reducing customer returns and inquiries for Patio Pacific in the long run. The problem statement for this project is as follows: Nick Pullano, general manager of Patio Pacific, desires to improve quality of their products to reduce customer returns/inquiries and to increase customer satisfaction.

The problem statement is broad and open to various parts of the company operations. With this in mind, the project delves into a strategic method to find a specific problem to work on. After several sessions of brainstorming, the project positioned itself to identify critical quality issue(s) that causes inquiries and returns. One of the best approaches to identify the

product issues is to create a pareto chart that identifies the most recurring issues with the product; identifies the most popular products in terms of sale volume; and identifies the products with most issues. The pareto chart, which will be discussed later in the report, identified three major issues: 1) Magnets are too strong 2) Threshold does not pop up 3) Errors in installation. After some research, which will be discussed in detail in the next section, Nick has agreed to move forward with the idea of investigating the magnets within the pet doors. Nick provided a set of data that recorded all the customer inquiries and returns in the past two years, and after analysis, the above three issues proved to be the best opportunities for improvement.

This report includes methods that are used to solve the first two issues stated above: 1) Magnets are too strong 2) Threshold does not pop up. Some of the methods include the use of pareto charts, capturing product lines and the step-by-step build process, weighing alternatives, and design of experiments. The deliverables or objectives of this senior project are to find a method that will weaken the magnets' strength and also have the threshold pop up.

In order to complete the project, extensive research took place regarding quality engineering and process improvement. This senior project report begins with company/project background, and continues with literature review, followed by design, methodology, and results. The report will end with a conclusion and a brief recommendation of future work.

BACKGROUND

Patio Pacific is a small pet doors company that manufactures and sells high end pet doors and related products across the nation. The company is located in 202 Tank Farm Rd San Luis Obispo, CA 93401 with a facility that holds an office, a warehouse, and a manufacturing site. The company operates approximately eight hours a day from six in the morning to two in the afternoon with two full time builders/assemblers and several office personnel. This section of the report discusses the main product lines, detailed build process, economics/cost of materials for the products, how the project came about (research), pareto chart, and why it's an important problem to address.

Patio Pacific, as mentioned above, has a leading product named Endura Flap (See Figure 1). This is the name of the flap that insulates the frame of the pet doors very well. Here is an example of the flaps in use.

Figure 1: Example of Pet Doors (Rotation)

Within this category, there are three flagship pet doors (See Figure 2, starting from left): 1) Pet doors for doors 2) Pet doors for walls 3) Sliding glass panel doors.

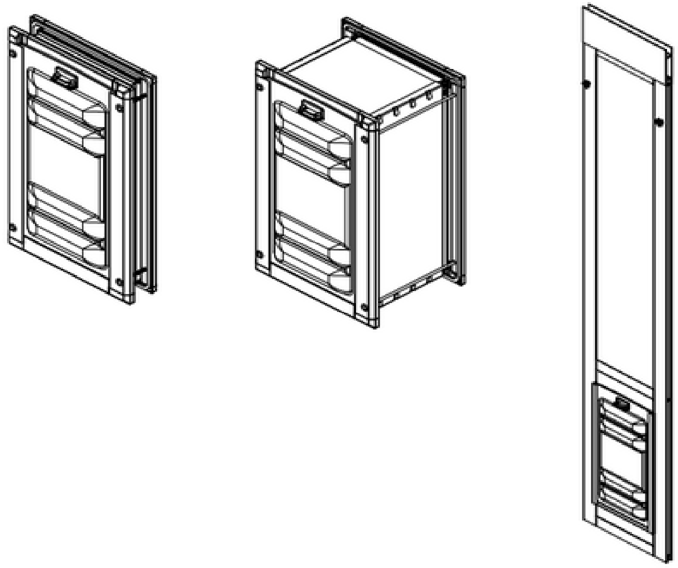


Figure 2: Pet doors for door, wall, and panel

These three products come in different sizes: small (6), medium (8), large (10), extra-large (12). The size numbers indicate the width of the flaps in inches. For the first two products, for the door and wall, they also have the option of having a single flap or a double flap. The double flap is mainly used for better insulation in a more extreme environment. The sliding glass door comes only in single flap, but comes with a height adjustment: 74 ¾" – 77 ¾" (P), 77 ¼" – 80 ¼" (Q), 93 ¼" – 96 ¼" (R). These products also come in three colors: bronze, white, and silver. The retail prices for the pet doors for doors, for walls, and sliding glass doors start from $219, $269, $399, respectively. (See Figure 3)

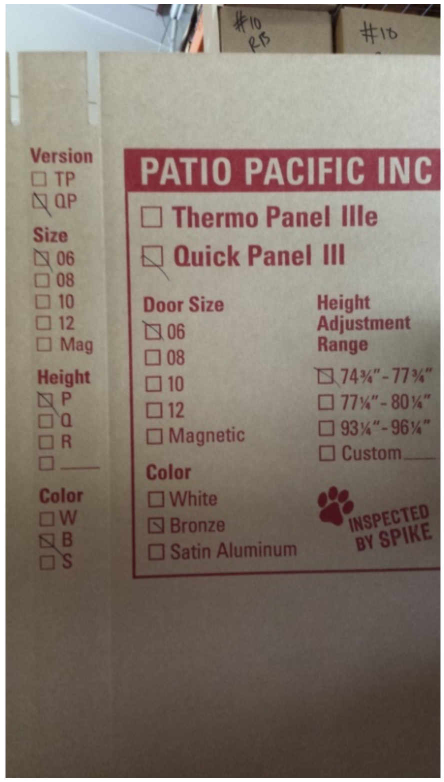


Figure 3: Example of packaging with product information

In order to capture potential issues with the product, the entire build process was recorded for a sliding glass door. The build process is very similar across all the three main products, and therefore, only the sliding glass door build process was recorded. There are two experienced builders that build the pet doors throughout the day. The build process for the sliding glass door pet door is as follows:

Assembly area:

Step 1: Cut strip magnets to length, and plastic covers to length.

Step 2: Insert strip magnets into plastic covers, with North Pole of the magnets facing outward.

Step 3: Insert rod into spring that goes on the toppers.

Step 4: Insert rod to assemble flap and attach strip magnets onto the sides of the flap.

Step 5: Insert magnet piece into the metal strip that clinches bottom of the flap.

Step 6: Insert washers on both ends of the rod to secure the rod in place.

Step 7: Drill screws onto panel lock cover.

Step 8: Cut rubber tubes and wrap around panel glass.

Cut and Drill area:

Step 9: Cut threshold, frame pieces, and topper to length.

Step 10: Drill necessary holes in various location of the frame pieces.

Assembly area:

Step 11: Sand off edges of frame pieces.

Step 12: Assemble frame pieces and flap together.

Step 13: Use blow dryer to expand flap.

Step 14: Place the lock cover on the frame.

Step 15: Assemble the panel glass with rest of the frame pieces and insert flap on the bottom.

*Step 16: Wrap bar magnet with duct tape and insert into the threshold.

Step 17: Place threshold on the bottom of the frame.

Step 18: Place topper into the frame with spring and rod.

Step 19: Place the final product with manuals/instruction into packaging for shipping.

*This step will prove to be crucial in the senior project design.

Note that this is the general build process for all of the three products. Here is part of an exploded view of the sliding glass door (See Figure 4):

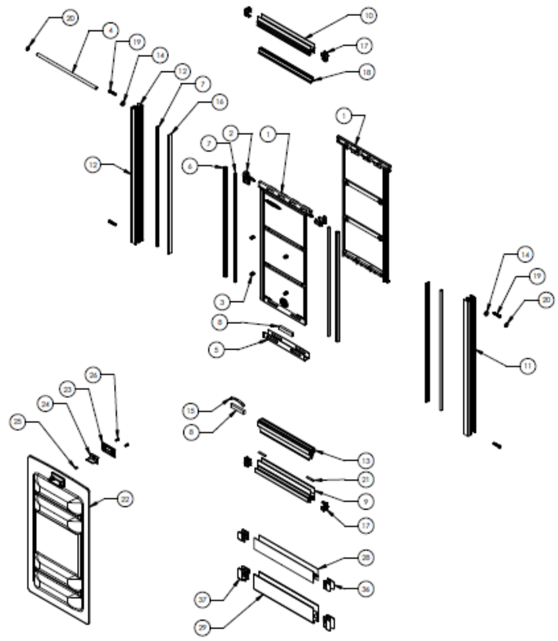
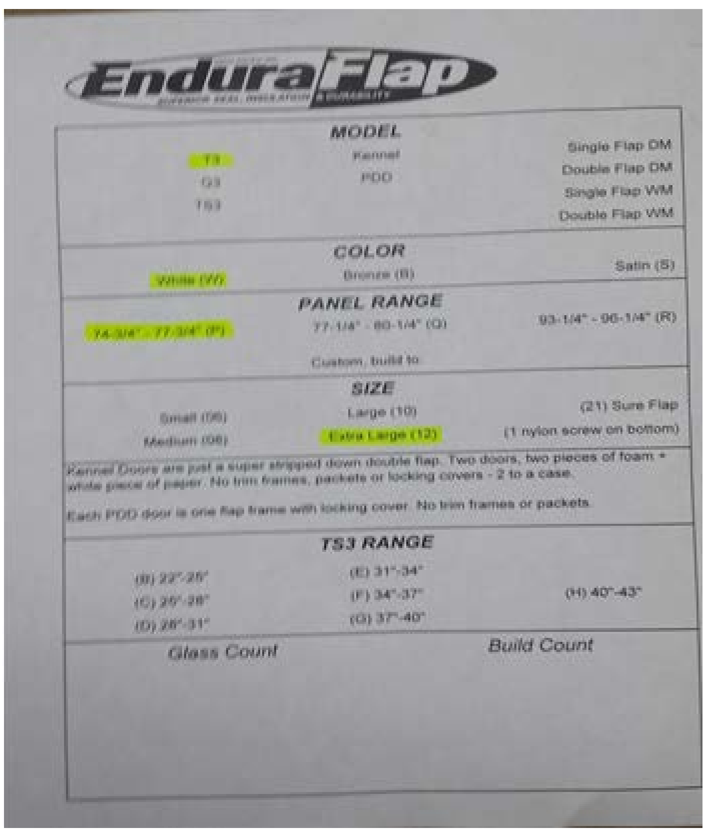


Figure 4: Exploded view of panel frame

And here is a picture of an order sheet (See Figure 5):



EnduraFlap

MODEL

T3
G3
TS3

Kennel
POD

Single Flap DM
Double Flap DM
Single Flap WM
Double Flap WM

COLOR

White (W)
Bronze (B)
Satin (S)

PANEL RANGE

74-3/4" - 77-3/4" (P)
77-1/4" - 80-1/4" (Q)
93-1/4" - 96-1/4" (R)
Custom, build to

SIZE

Small (06)
Medium (08)
Large (10)
Extra Large (12)
(21) Sure Flap
(1 nylon screw on bottom)

Kennel Doors are just a super stripped down double flap. Two doors, two pieces of foam + white piece of paper. No trim frames, packets or locking covers - 2 to a case.

Each POD door is one flap frame with locking cover. No trim frames or packets.

TS3 RANGE

(B) 22"-25"
(C) 25"-28"
(D) 28"-31"
(E) 31"-34"
(F) 34"-37"
(G) 37"-40"
(H) 40"-43"

Glass Count

Build Count

Figure 5: Order Sheet

On the back of the order sheet, there is a spreadsheet of time studies of each build. As the results will show, the process time will not be affected in the design of the senior project (See Figure 6).


* Senior Project students coming at 17:30. Please save this build for them to watch.

Piece rate

Hourly

Builder: J

Build amount	Product	Points	Optimum build amount	Target speed per unit (minutes)	Target time per build
	T3 or Q3 -6	1.62	6	29.2	2hr 55min
	T3 or Q3 -8	1.58	6	28.4	2hr 50min
	T3 or Q3 -10	1.55	6	27.9	2hr 47min
5	T3 or Q3 -12	1.81	5	32.6	2hr 42min
	T3 or Q3 -21	1.54	6	27.7	2hr 46min
	T3 or Q3 -8 Sectional	2.28	4	41.1	2hr 44min
	T3 or Q3 -10 Sectional	2.58	3	46.5	2hr 19min
	T3 or Q3 -12 Sectional	2.58	3	46.4	2hr 19min
	T3 or Q3 -21 Sectional	2.57	4	46.3	3hr 5min
	SF -6	0.85	6	15.3	1hr 31min
	SF -8	0.80	6	14.3	1hr 26min
	SF -10	0.82	6	14.8	1hr 28min
	SF -12	0.91	5	16.3	1hr 21min
	DF -6	1.00	6	18.1	1hr 48min
	DF -8	0.98	6	17.6	1hr 45min
	DF -10	1.07	6	19.3	1hr 56min
	DF -12	1.20	5	21.6	1hr 47min
	PDD -6	0.45	12	8.1	1hr 36min
	PDD -8	0.46	12	8.4	1hr 40min
	PDD -10	0.48	12	8.7	1hr 44min
	PDD -12	0.60	10	10.8	1hr 47min
	K -6	1.04	6	18.7	1hr 52min
	K -8	1.01	6	18.2	1hr 49min
	K -10	1.09	6	19.6	1hr 57min
	K -12	1.12	5	20.2	1hr 41min
	TS3 -6	1.87	4	33.7	2hr 14min
	TS3 -8	1.84	4	33.2	2hr 12min
	TS3 -10	2.11	3	38.0	1hr 53min
	TS3 -12	4.11	2	74.0	2hr 27min

Figure 6: Build times spreadsheet

Patio Pacific manages to try to meet demand on a daily basis. The economics/cost of the materials with order cycles are as follows: The company buys 25,000 bar magnets every 9 months at 13 cents per bar magnet and buys 8000 feet of strip magnets every couple months at 43 cents per foot. Dimension of the bar magnet is 0.25 inches in width, 0.39 inches in height, and 2 inches in length. Strip is 0.188 inches by 0.188 inches and the length depends on the size of the frame. Builders cost the company $30/hour with worker's compensation and insurance. The rough estimate for product returns is $11,000/year.

Figure 7 shows an example of a bar magnet (wrapped in duct tape) and a strip magnet:

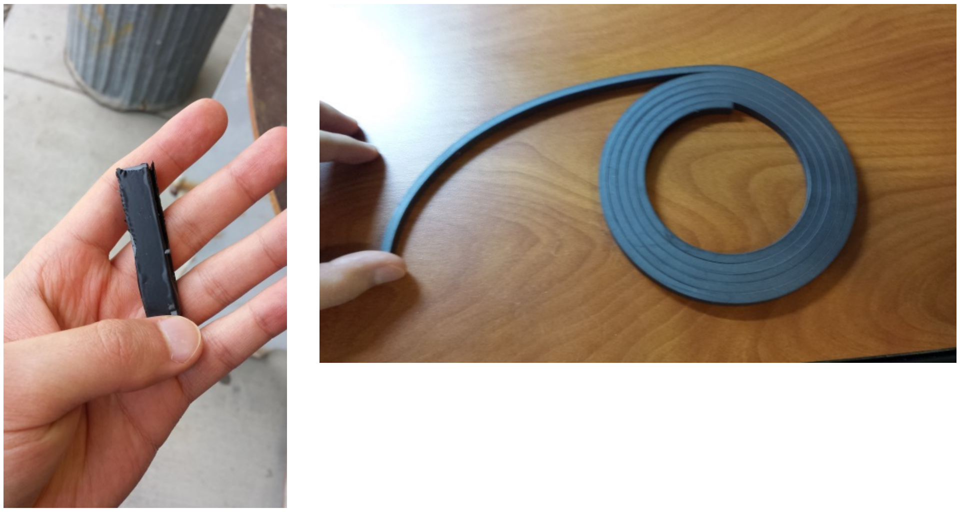


Figure 7: Bar magnet and strip magnet

At first, the project's intent was to add an additional step in the build process that would improve the quality and process to reduce customer inquiries and returns, but as it will be shown, the project's results show an adjustment of a step in the entire build process. The customer returns data that Nick provided, which can be found in the appendix, plays a huge role in the research portion of identifying the critical issues that affect the quality of the products. Before diving into the data, other form of research, such as acquiring builders' opinions took place. Afterwards, the data was analyzed to create several pareto charts. The following charts show the critical issues that cause customer inquiries and returns (See Figure 8, 9, and 10):

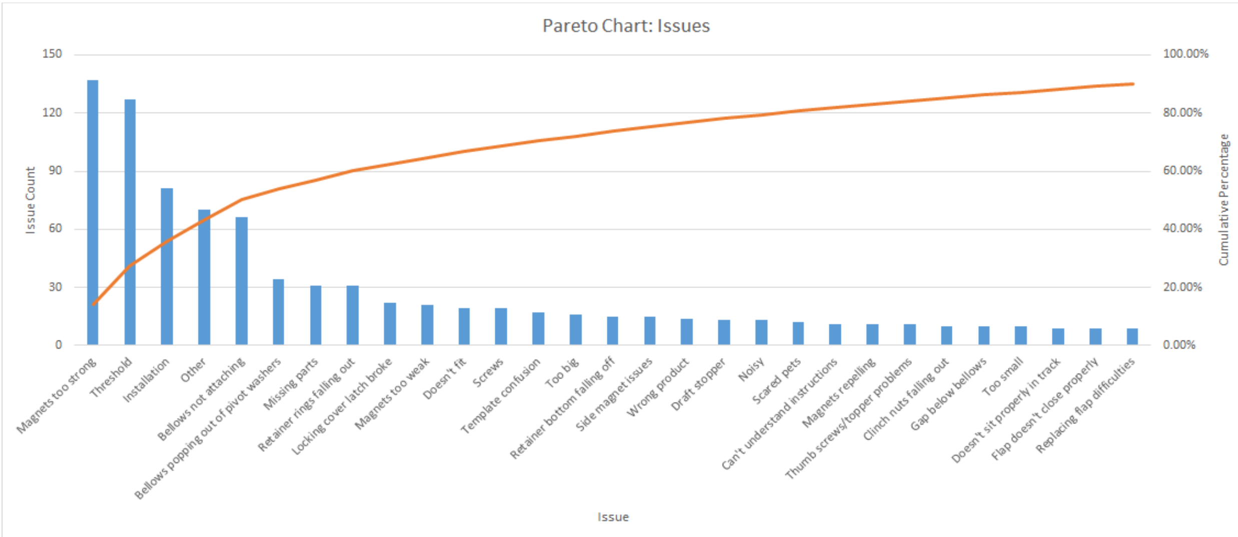


Figure 8: Pareto chart of product issues

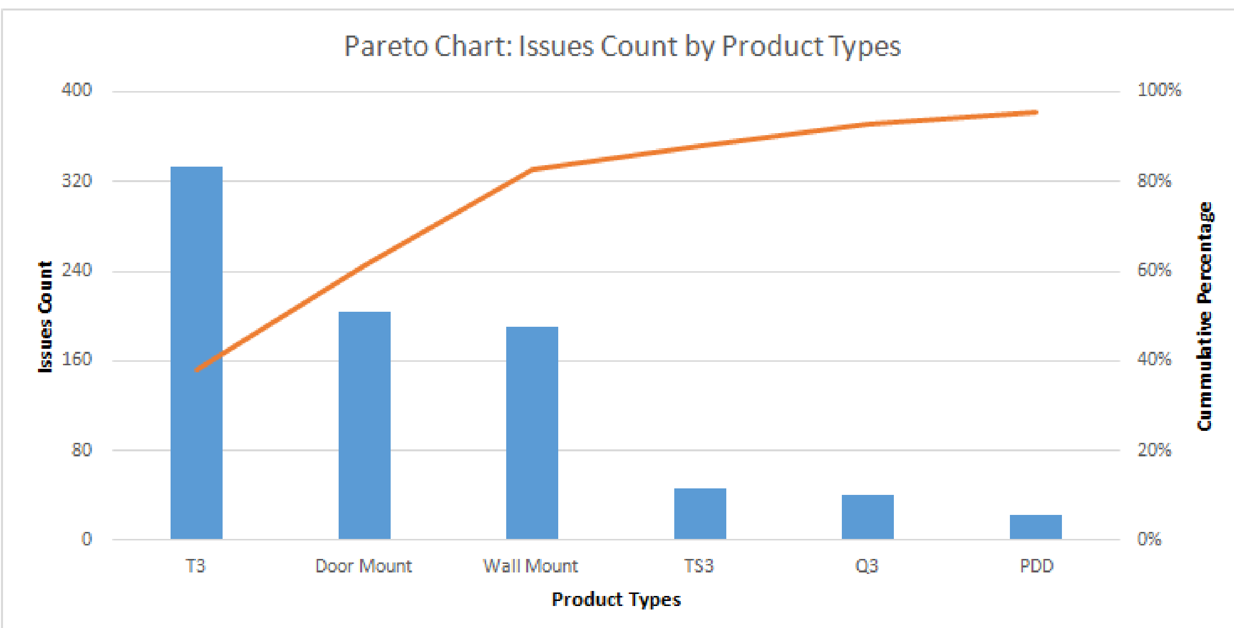


Figure 9: Pareto chart of product

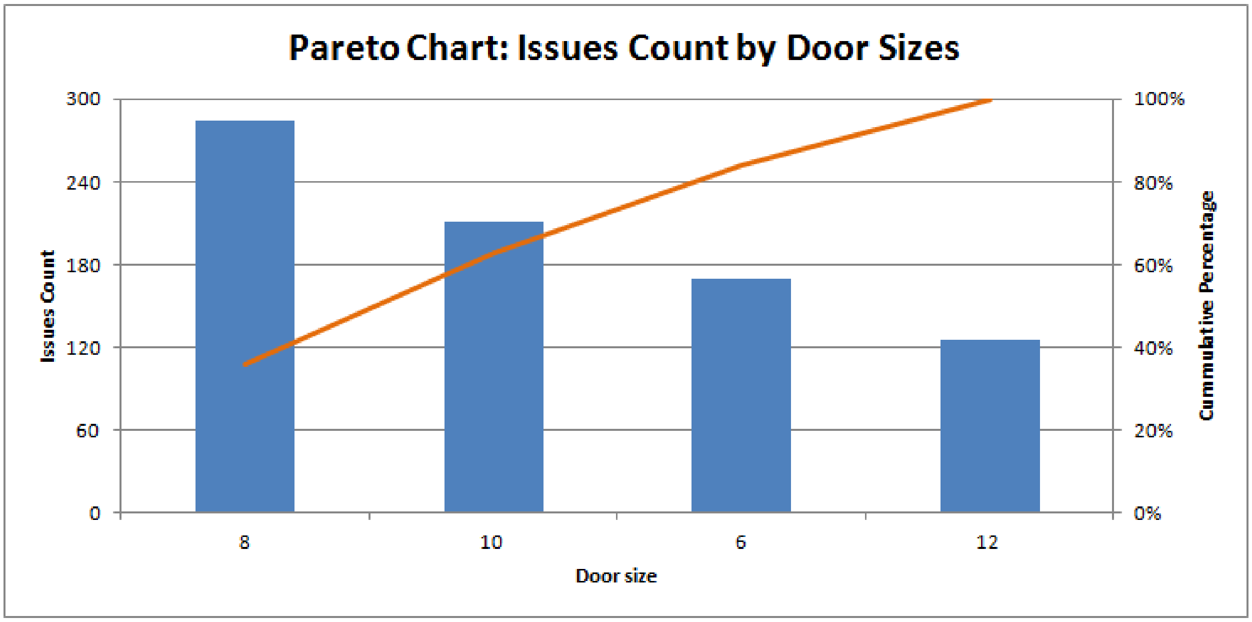


Figure 10: Pareto chart of size

As the chart shows, the most frequently occurring issue is that the bar magnets are too strong. The second issue, which is the exact opposite of the first issue, is that the threshold is not popping up due to the magnet being too weak. Nick noted that he would like to reduce the magnet strength, but not so that it would cause more issues with the threshold. Also as the chart shows, the most popular product with issues is the thermo panels. The specification of the actual product tested will be discussed further in the design section of the report.

Figure 11 shows the threshold (main product) that this project focuses on:

Figure 11: Threshold

Figure 12 shows the layout of the magnet positions for every size of the products:

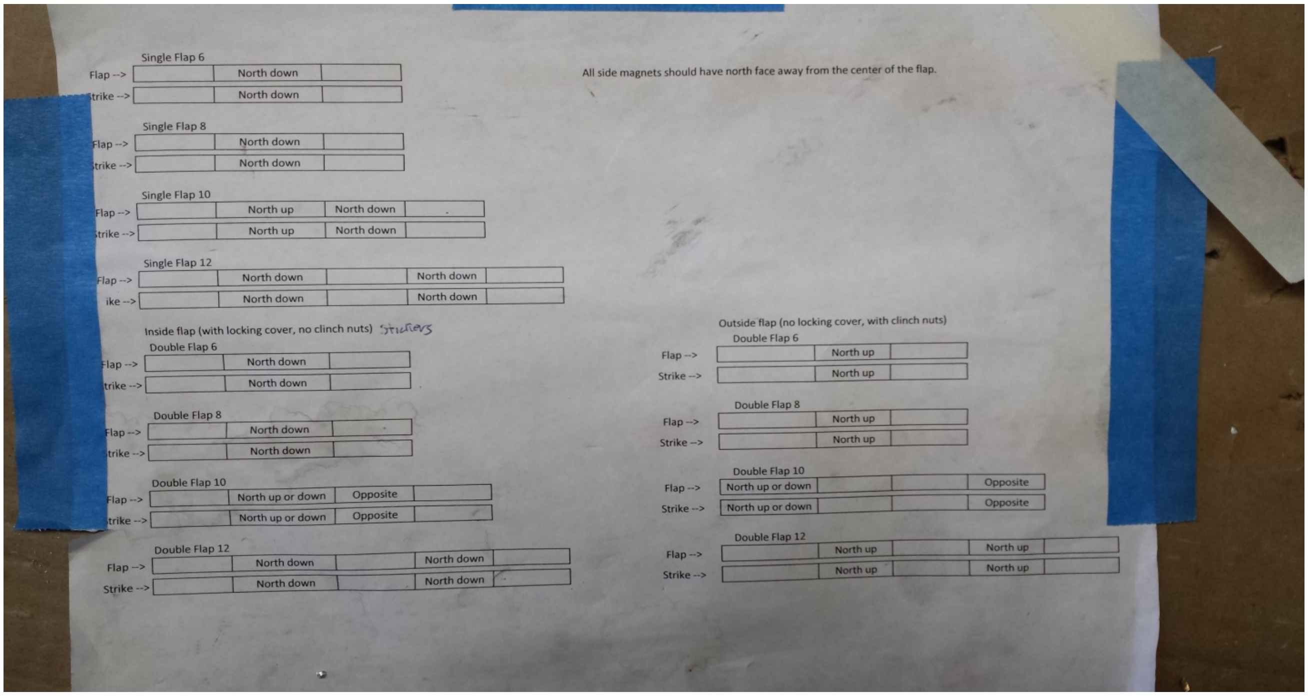


Figure 12: Magnet positions

Patio Pacific does have a current process of handling quality issues with the magnets. They currently deal with the magnet issue by linking them to a YouTube video on how to take out the magnet to reduce magnet strength.

It’s important that pet owners are able to install pet doors properly to ensure safety of their pets and also households in general. Purchasing, installation process, and more importantly, maintenance should be easy and hassle free to reduce customer product returns and inquiries. For the company to thrive, it’s pivotal for the quality of the products to shine. The next section provides an extensive literature review that enhances the knowledge within the fields to conduct this senior project.

LITERATURE REVIEW

Every manufacturing facility has a process that leads materials to a final product, but not every process carries a definite way of checking quality and a fully implemented philosophy of continuous improvement. The following literature review for quality improvement in pet supply manufacturing company focuses on three main topics. The first topic will discuss quality engineering in manufacturing and assembly. The second topic will address process improvement also in manufacturing and assembly. And lastly, the third topic will briefly discuss the pet supply industry/business.

Quality Engineering

On BusinessDictionary.com, quality engineering is defined as follows: “Discipline that deals with the analysis of manufacturing system at all stages, to improve the quality of the production process and of its output.” A different definition of quality engineering provided by Wikipedia.org that may be well suited for the following project is as follows: “A way of preventing mistakes or defects in manufactured products and avoiding problems when delivering solutions or services to customers. Quality is a discipline that has been around for centuries, however, “The genesis of modern methods of quality and reliability will be found in a simple memo date May 16, 1924, in which Walter A. Shewhart proposed the control chart for the analysis of inspection data” (Pyzdek, 1992). Many enterprises and executives view quality as a criteria that places value into customers’ hands, but Taguchi mentions that “Quality is the loss a product causes to society after being shipped, other than any losses caused by its intrinsic functions”(Taguchi, 1986). The following is a brief review of Taguchi’s quality philosophy and his dedicated work in furthering the field of quality.

Taguchi uses an analogy when it comes to quality. He believes that quality depends on variability, just like natural resources. “The trouble with natural sources of energy is their variability. The same problem occurs to a greater or lesser degree in products and services provided by man. The reason specifications are set is to prevent many of these problems” (Taguchi, 1986). Unlike the intuitive view of quality as adding value to the customers, Taguchi states that reducing loss is vital in quality control. “If cost control is concerned with reducing the various losses that may occur before the product is shipped, quality control is concerned with reducing the two types of losses that it may cause to society after it is shipped” (Taguchi, 1986). In quality, there are extrinsic and intrinsic functions. And “Quality control is not, however, concerned with reducing the loss the product may inflict on society through its intrinsic functions” (Taguchi, 1986).

There is a debate over what quality exactly means, and how to approach it in the view of customers, but as Taguchi states, “Better quality means providing the same utility (function) with less loss to the consumer: with fewer failures, less power dissipation, and a longer service life” (Taguchi, 1986). In order to capture quality, one must view not only the production process, but also the design process. Taguchi mentions that “Quality design in the product design stage is particularly important because, although variability can be reduced in the production stage, deterioration of the product or unsuitability for its environment cannot” (Taguchi, 1986). As obvious as it may seem, a precise and carefully crafted product will contribute to great quality. With so much focus on quality and improvements however, one may ask, “where do you stop?” Taguchi answers this with “…improving the quality of its product to the point where the product never failed, so retail sales of replacements fell to zero. If improved quality causes our sales to

drop in the future, we intend to develop other products that consumers want. We put quality first" (Taguchi, 1986).

Taguchi introduces three types of noise (variability): external noise, internal noise, and unit-to-unit noise. External noise deals with the environment a product is placed in such as humidity, temperature, dust and so on. Internal noise deals with the parts of the product that may wear down over the years. Unit-to-unit noise deals with differences between each manufactured units. It is vital that all products improve quality by making the noise as quiet as possible. As Taguchi says, "Assuring functional quality means finding means to reduce the effect of these three types of noise" (Taguchi, 1986). As mentioned above, variation is existent in any type of manufacturing and assembly environment. It is inevitable. So in order for the customers to value a product, the manufacturer must do its best to reduce variation. "Good functional quality means little functional variation from any of the above types of noise – a product which functions as intended under a wide range of conditions for the duration of its design life" (Taguchi, 1986).

In the book, Taguchi Techniques for Quality Engineering, Ross mentions that "The Taguchi philosophy provides two tenets: 1) the reduction in variation (improved quality) of a product or process represents a lower loss to society, and 2) the proper development strategy can intentionally reduce variation" (Ross, 1996). Variation can be reduced in various ways, however, one of the definite ways of reducing variation is by setting up a control system that rejects or accepts a product in the process. The second philosophy mentions development strategy, and as with any product, initial proper design will quiet the noise that causes loss to society. And as a final note on loss, Ross mentions that "The loss function is a mathematical way of quantifying the cost as a function of product variation, which answers the question of whether further reduction of variation will reduce costs" (Ross, 1996).

As with many aspects of engineering, improvement in quality can be brought to the surface by design of experiment (DOE). Ross names three phases for DOE: “The DOE process is made up of three main phases: the planning phase, the conducting phase, and the analysis/interpretation phase” (Ross, 1996). These phases are simple, yet crucial in finding out the truth behind improving a product’s quality.

In another book, A Systems Approach to Quality Improvement, Roth states that “Systemic quality improvement process (QIPs) must include five over-lapping integrated phases. They are familiarization, vehicle emplacement, training, implementation of measurement techniques, and long-range or strategic planning” (Roth, 1992). Familiarization begins with the upper-level management and it always comes first in improving quality in an organization. It is about defining quality and explaining the need for it downward. The next three phases provide the ways to improve quality in a systematic approach, and the last phase sustains the idea and philosophy within an organization. And history has proven that long term sustainability is crucial in gaining market share and thriving in any economic circumstances. Roth mentions that “While many quality improvement processes in business have enjoyed initial success, most have eventually failed – not producing the desired long-term results. Though our learning curve is good, we still lack the sophistication requisite to generate the necessary comprehensive whole” (Roth, 1992).

With long term goals, Roth “suggests 14 ground rules that will be imperative to quality improvement through teamwork. The first rule is as follows: Teams must meet, at least initially, on a regular basis, and members must attend” (Roth, 1992). Rules make clear the commitment an organization has and Roth mentions that “Ground rules are the glue that binds employee teams and the rest of the organization together, encouraging the generation of thoroughly thought out,

well-integrated improvements. They help systematize the quality improvement process and make possible the development of a strong sense of commitment through the realization of beneficial changes in products, manufacturing processes, management systems, and the work environment" (Roth, 1992). Based off of this, it is imperative to note that quality is not just a matter of quantitative process, but that it is also a team effort with long term goals.

Co-written by Taguchi, Elsayed, and Hsiang, the book Quality Engineering in Production Systems states that "The trade-off between quality and price is an important subject. Product quality is affected by its tolerance design…" (Taguchi, 1988). Pricing may be detrimental or favorable in the success of a product and its quality. It is important to consider pricing when designing the quality of a product as quality may mean nothing in the face of success if pricing is not just right in the eyes of customers. In this book, the authors bring few activities to the table to improve quality: "It is important to note that company-wide activities are needed to improve quality and productivity. These activities are 1. Product planning 2. Product design 3. Process design 4. Production 5. Service after purchase" (Taguchi, 1988). And as mentioned above, "Product design has the greatest impact on product quality" (Taguchi, 1988). Now, with the above activities, the authors introduce methods that will fulfill the activities: "Production process improvement methods include: 1. Introduction of preventive maintenance measures such as tool changes 2. Use of tools with long lives 3. Improvement in the production process itself to achieve longer time between successive adjustments 4. Improvement of scrap and disposition methods for defective products" (Taguchi, 1988). These methods must be executed carefully to be fully effective to the quality of a product.

When mentioning quality, one cannot dismiss the experimental design associated with quality. In the book Quality by Experimental Design, Barker states the truth of the 20th century,

“Quality products that perform as advertised and do so without variation are now part of the informed customer’s expectation” (Barker, 1985). In order to meet customer’s expectation, organizations must give it their best in testing the products to its boundaries. Barker mentions that “In many cases, only testing can give us the information necessary to determine the quality of a product or service” (Barker, 1985). But how do you exactly know if an experiment is good or not? Barker answers this by stating that “A good experiment must be efficient. Efficient: An experiment that derives the required information at the least expenditure of resources” (Barker, 1985).

To wrap up this brief overview of quality engineering, the statistical portion of experimental design will be briefly discussed. Barker claims that “By using statistical methods, we will obtain the required information to do the job in a systematic and controlled manner” (Barker, 1985). Control is a key word in the world of statistics. Statistics provide a story behind numbers that may explain the solution to a problem. With control, one may be certain that the method will prove to be effective anywhere else in the world. In the Quality Engineering handbook, Berger and Pyzdek define SPC as follows: “Statistical Process Control (SPC) is a collection of techniques for use in the improvement of any process. It involves the systematic collection of data related to a process and graphical summaries of that date for visibility” (Pyzdek, 1992). SPC will be important in capturing the picture of the numbers behind quality control. As the authors mention, “The use of SPC will show that a process is: 1. In control, that is, the process variation appears to be random 2. Out of control, that is, the process exhibits non-random variation, or 3. Improving as a result of planned reductions in process variation” (Pyzdek, 1992). In the bigger picture, statistics will be an essential tool that will unlock doors to quality control problems that exist in any manufacturing process.

Process Improvement

Continuous process improvement, or continuous quality improvement techniques have been a major approach employed to improve manufacturing operations. Six Sigma methodologies from Motorola and Lean Manufacturing practices from Toyota Production System are the most popular approaches in use to improve the said operations. This section will offer some insight into these two main approaches to process improvement.

Toyota Production System's Lean Manufacturing practices contains the following main tools:

- Single piece flow: refers to the ideal manufacturing system in which, when customer places an order, this triggers the process of obtaining raw materials, manufacturing, assembling and completing the customer's order in immediate sequence without materials waiting in storage and queue. By having the ideal single piece flow, multiple sources of wastes are removed from the manufacturing process: overproduction, waiting, excess inventory, etc. (Liker, 2004)
- Kanban: Japanese word for sign. It is a manufacturing system in which "every manufacturing process has the equivalent of a gas gauge built in, to signal to the previous step when its parts need to be replenished. This creates pull which continues cascading backwards to the beginning of the manufacturing cycle." This is an example of the pull system where supply is only replenished when low in stocks. (Liker, 2004)

● The 5'S:

Figure 13: The 5Ss (Liker, 2004)

Visual control system is about improving value added flow, and "is also a tool to help make problems visible". The 5Ss are "not to neatly organize and label materials, tools, and waste to maintain a clean and shiny environment." (Liker, 2004)

● Poka-yoke: refers to mistake-proofing, fool-proofing, or error-proofing. "These are creative devices that make it nearly impossible for an operator to make an error." An example of a poka-yoke device would be a car's trunk lock, the trunk would not be locked if the car key is inside the trunk, thus preventing the mistake of losing the car key in a locked trunk. In addition, for manufacturing purposes of ensuring Toyota's level of quality, "each poka-yoke device also had its own standard form that summarizes the problem addressed, the emergency alarm that will sound, the action to be taken in an emergency, the method and frequency of confirming the error-proof method is operating

correctly, and the method for performing a quality check in the event the fool-proof method breaks down." (Liker, 2004)

All of the above tools should be implemented in order to optimize the system, as best described by Fujio Cho, the president of Toyota Motor Corporation. "Many good American companies have respect for individuals, and practice kaizen and other TPS tools. But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner - not in spurs - but in a concrete way on the shop floor." (Liker, 2004) The successful implementation of Toyota Production System's Lean Manufacturing practices "requires more than just use of these tools. It requires a cultural change of the organization." (Downing, 2010)

Another tool often used for production process improvement is the Six Sigma methodology introduced by Motorola. Six Sigma uses DMAIC approach to implement the process improvement and control. (Downing, 2010) The following will provide an overview of the DMAIC process.

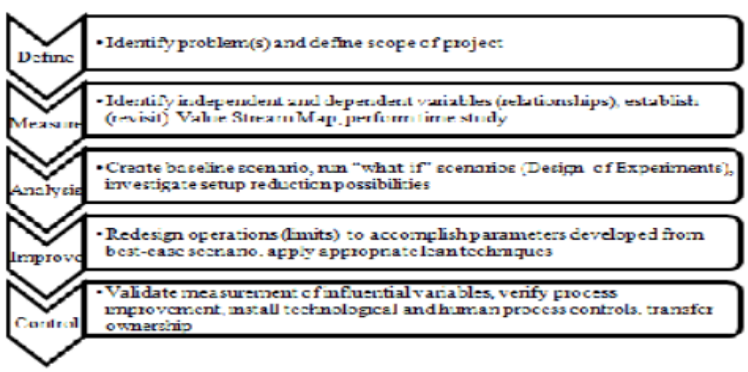


Figure 14: Six Sigma DMAIC Process (Pyzdek, 1999)

The DMAIC approach is often used to "expose and increase an understanding of the elements of the current manufacturing processes that contributed to unacceptable throughput and cycle times." (Downing, 2010) There are five phases in the process:

- Define phase: the scope of the project is defined, and then the following can be identified: problems, stakeholders, critical process, timelines, and deliverables. (Pyzdek, 1999)
- Measure phase: Establish the current baseline for improvement. Performance metrics of the baseline then can be compared with the performance metrics at the conclusion of the project. By using the Value Stream Maps to identify the critical inputs that affect the throughputs, a function Y = f(X) then can be defined with the throughputs being a function of multiple inputs. Data for the performance metrics would be recorded and complied.
- Analyze phase: Identify the root causes for elimination, a fishbone diagram is often used for this analysis. The relationship between inputs (root causes) and outputs (performance metrics) can be defined afterwards. Lastly, statistical tests need to be performed to validate the relationship between inputs and outputs. Statistical tests with p-values are often used in the process.
- Improve phase: identify, test, and implement solutions to the problems in order to eliminate the root causes. Analysis tools like Design of Experiment are often used in this phase to validate the solutions.
- Control phase: Control plan with control charts is created to monitor and sustain the improvements of the process.

Pet Industry

For many years, dogs, cats, and other pets have been viewed as a family member in many families in the United States. According to the American Pet Product Association (APPA), in the 2014-2015 national pet owners survey, 62% of U.S. households own a pet. The historical data in previous surveys also shows that there are increasing trends in pet ownership, as well as pet

owner spending in pet foods, supplies, and healthcare. In addition to the essential pet goods and services, pet owners have been spending increasingly more on premium products, as they preferred best products for their pets, even if it is more expensive. (APPA, 2014)

Pet industry has grown tremendously over the past decades. It has grown from a $17 billion industry in 1994 to a $61 billion industry today. This market can be broken down into five parts: food, supplies/otc medicine, vet care, live animal purchases, and pet services: groom and board. Over 50 million U.S. households own a dog as of 2015. There is definitely a huge market out there for pet supply manufacturers. Brough states that "The majority of pet businesses are independently owned and operated, and being small heightens their sensitivity to external market pressures" ("Pet Businesses," n.d.). In the past several years, the pet industry, just like any other retail industry, took a huge hit with the recession. The growth since then has been slow; however, "Going forward, growth in the pet industry is projected to be 4 percent annually through 2018. In the next five years, pet operations are projected to maintain strong growth. The number of households owning pets is expected to continue to increase along with an increase in discretionary income as the economic recovery takes hold" ("Pet Businesses," n.d.). With this in mind, it is only obvious that there will be increase in demand for pet doors. The pet door industry has been around for decades, and it is claimed that the idea has existed since the ages of Isaac Newton. The demand is growing, and the demand to produce quality pet doors is imperative to keep up with the market demand. Customer satisfaction and easy usage of pet doors will increase the pet door market.

DESIGN

The design on this project was carried out using the DMAIC (Define, Measure, Analyze, Improve, Control) approach, often used in the Six Sigma methodology. The DMAIC approach was selected, because it was the ideal tool to "expose and increase an understanding of the elements of the current manufacturing processes that contributed to unacceptable throughput and cycle times"(Downing, 2010). It was also to implement the process improvement and control, which was the requirement of the project.

During the Define phase, the scope of the project was determined. In order to increase customer satisfaction, and reduce returns and inquiries, the General Manager Nick Pullano desired to improve quality of the company's most popular products in term of sell volumes and number of inquiries about the product. After analyzing the customer service's product issue tracker, the main problems existing in the current process were identified in the Figure 15 below. The most recurring issues with the pet doors were magnets being too strong (pet cannot open door), threshold not popping up (door will not close), and other installation issues. According to the Nick Pullano, the threshold not popping up issue was mostly due to the flap of pet doors thermally contracts in low temperature environment, thus created a gap between the flap and threshold parts. The gap increased the distance between the magnets in flap and magnets in threshold, and decreased the magnetic field strength between the magnets; this was categorized as another magnets issue. Therefore, the magnet issues were determined to be the main problems in this project (See Figure 15).

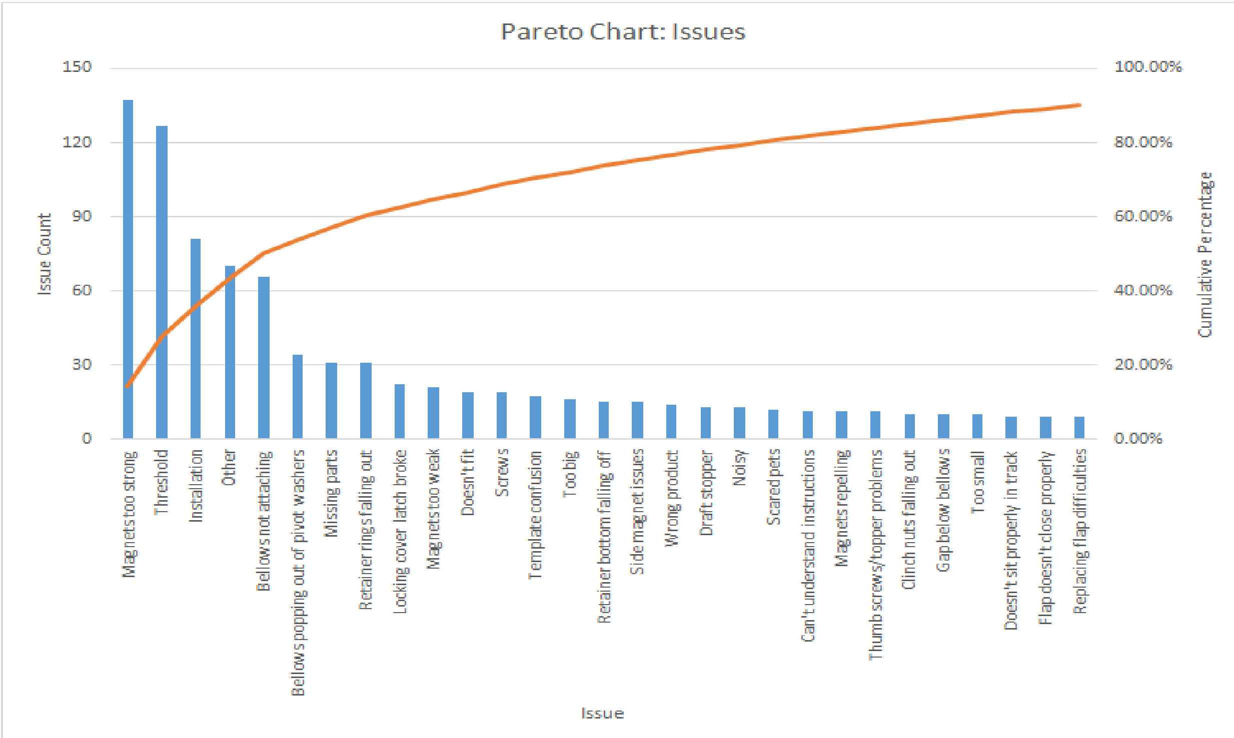


Figure 15: Pareto Chart - Pet Doors Issues

The types of pet doors with the most sales were sliding glass thermal panel III (abbreviated as T3), door mount, and wall mount, which also had the most issues (Figure 9). Since the main frame of those three types were the same, those three types were determined to be dealt with in this project (Figure 4). The door size with the most issues were size 8 (Figure 10). Thus the scope of the project was the magnet strength issues in size 8 of sliding glass thermal panel III (abbreviated as T3), door mount, and wall mount.

After our research was done on magnet field strength, alternative solutions for the main problem were:

- Offset magnets positions in flap and threshold, thus varying the magnetic field strength.
- Select and purchase different types of magnets for different door sizes. This approach was very costly as order costs, inventory costs, and transportation costs for different types of magnets were higher when ordered separately.

- Reduce the strength of the magnet by additional processes: heating, hammering, etc. However, the magnets were ceramic, thus they were very brittle and easily shattered if hammered. Additionally, heating the magnets produced unpredictable magnetic field strength.
- Produce a new design for the pet door frame. This approach was very time and resources consuming, and it was not within the scope of the project.

The selected solution was to offset magnets position in flap and threshold, and determine the offset/overlap positions, so that doors will close at minimum magnetic field strength required.

METHODOLOGY

In order to simulate the worst-case scenario for the pet doors being used in low temperature environment, a customized 8-inch pet door's frame was provided for the project by the company. The customized frame was approximately 1 inch larger in height and ½ inch larger in width; the added size was to simulate the gap between the flap and threshold, created by the flap thermally contracting in low temperature environment. By using this customized frame for the worst-case scenario, the ideal offset/overlap positions of magnets in flap and threshold can be determined, so that doors would be able to close at minimum magnetic field strength.

The tools used in the design testing were a vise, Force Probe w/Mount, circular rod with a diameter of approximately ¼ inch, collars, and a calibre.

<u>Percent Overlap Calculation</u>

Threshold length: 8.2 inches

Magnet length: 2 inches

When the magnets in flaps and threshold were 100% overlapped, the magnet was also aligned to the center of the threshold length-wise. The distance to insert the magnet into the center of threshold was (8.2 inches / 2) + (2 inches / 2) = 3.1 inches.

The % overlap and corresponding distance magnet inserted into threshold were shown in the table below:

Percent Overlap	Distance Inserted (inches)
100	3.1
80	3.5
60	3.9
40	4.3
20	4.7
0	5.1

Figure 16: Table - % Overlap and corresponding Distance Inserted

<u>Procedure</u>

1. Secure the frame with a vise (Figure 17)
2. Measure with caliber the Distance Inserted on the rod and mark on the rod with marker/pencil
3. Secure the collar on the rod at the mark without cutting into the Distance Inserted
4. Mark a point in the center of the flap width-wise with marker/pencil
5. Using the Force Probe, pressed against the point on the flap until the flap leave the

threshold, record the force needed to open the door (Figure 17)

6. Measure and record the force needed to open the door, using the Force Probe.
7. Replicate the measurement 30 times.
8. Open the door to a bearing of approximately 45°, let go and record if the flap and threshold close.
9. Replicate the step 8 100 times.
10. Repeat the procedure with different Percent Overlap and Distance Inserted.

Figure 17: Picture - Secure frame on a vise, and Measure the force with force probe

RESULTS

Below is the chart of the average force needed to open the pet doors out of 30 replications for each increment of the percentage overlap:

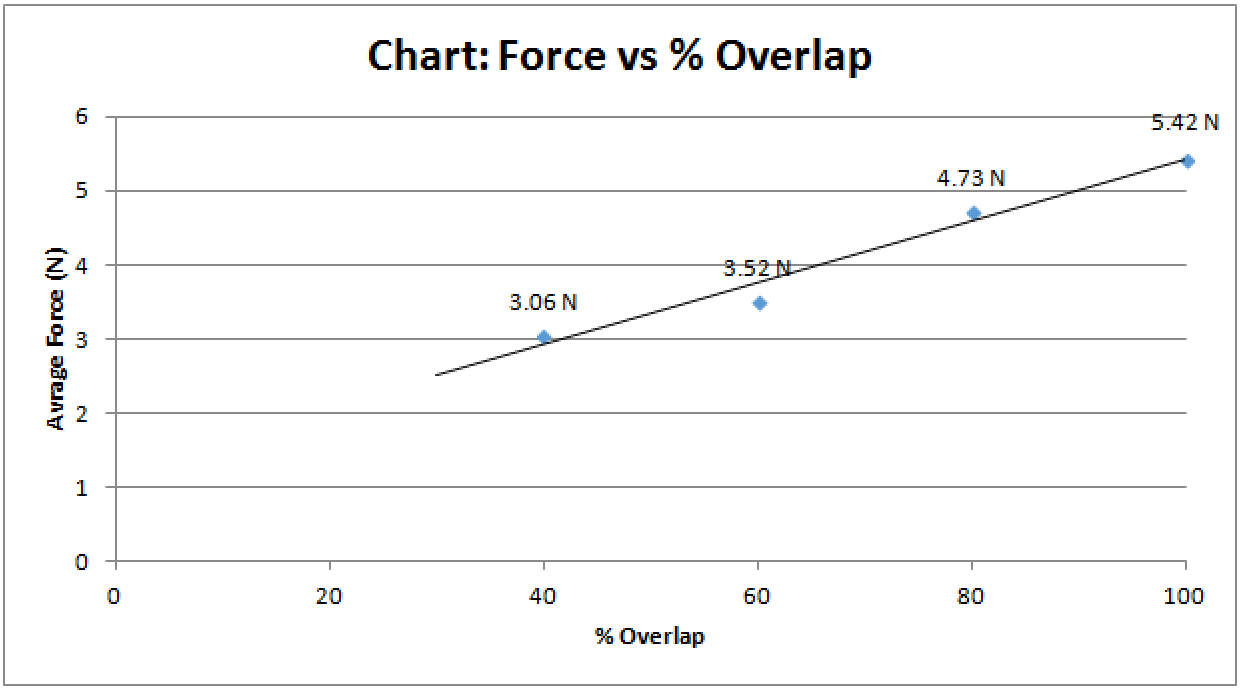


Figure 18: Chart - Force vs % Overlap

There were values for the forces measured when the magnets in flap and threshold were 40% or more overlapped. However, when the magnets were 20% overlapped, the threshold did not pop up and close the flap even in closing position; thus there was not any measurement below the 40% overlap.

Below is the chart of the number of times the flap closed after opening the flap approximately 45° from the frame, the number is out of 100 replications for each increment of the percentage overlap:

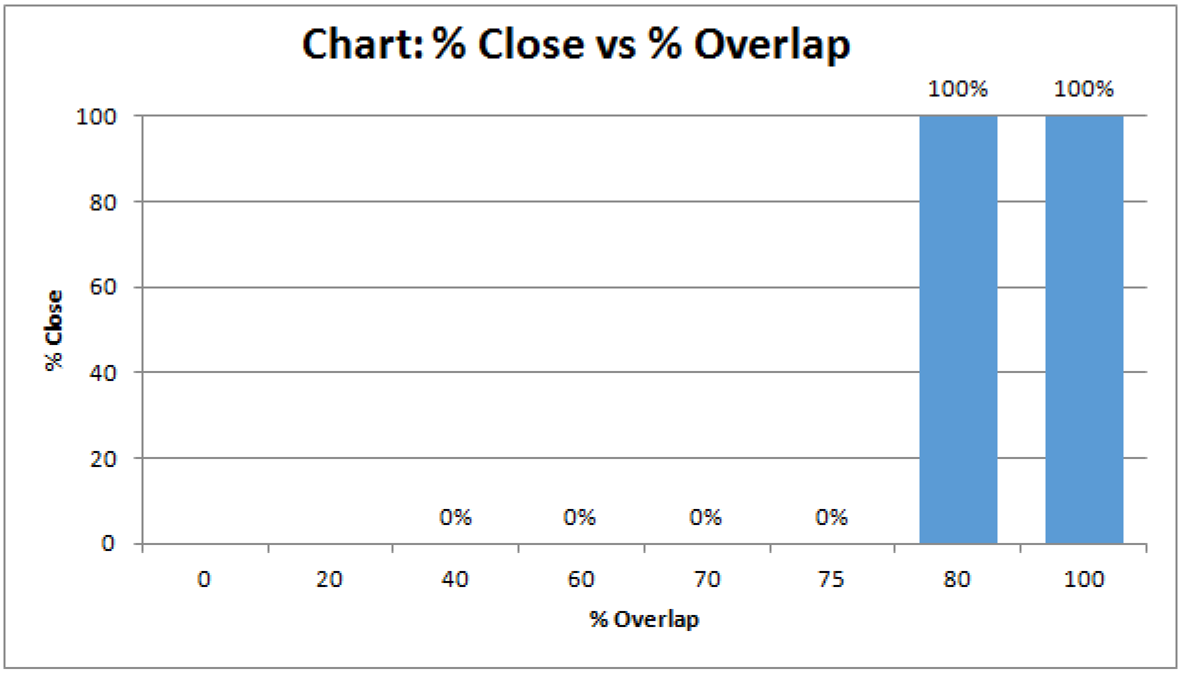


Figure 19: Chart - Percent Close vs. Percent Overlap

As shown above, the flap and threshold only closed with 100% certainty when the magnets in flap and threshold were 80% or more overlapped. Below 80% overlap, the threshold did not close up with the flap at all. With this result it was shown that at 80% overlap, the magnetic field produced the minimum force required to close the flap and threshold.

Result Summary

% Overlap	Flap and Threshold % Close	Average Force (N)
100	100	5.42
80	**100**	**4.73**
75	0	-
70	0	-
60	0	3.52
40	0	3.06

Figure 20: Table - Result Summary

At 80% overlap between magnets in flap and threshold, which is 3.5 inches into the threshold (2.7 inches from opposite side), the magnetic field produced the minimum force required to close the flap and threshold. The minimum force required was 4.73N for this customized 8-inch pet door frame.

CONCLUSION

From the results above, it is clear to state that 80% overlap between the magnet in the threshold and the magnet in the flap will provide the minimum magnet strength, yet still provide a 100% pop up. It is important to note that this is the case for a single flap size 8 frame. The senior project recommends that the builders use the same process and tool to insert the magnet, but to adjust the tool to insert at 80% overlap. Accompanying this solution is the idea of inserting cheap and light material to secure the magnet in place within the threshold. Such materials may be plastic straws or foams. This senior project used pareto charts to tackle one of the key factors in product quality: from a broad question of "how do we improve quality," to "solving the magnet issues." The report went through an extensive background of the company product lines, and build process to explain the necessary information needed for the execution of the project. It then covered literature review for breadth of knowledge, followed by design, methodology, and results. As mentioned in the introduction of the report, it is important to note that the results here are only foundations of improving the quality of the products at Patio Pacific.

There are several alternative solutions mentioned in the report, and one of them leads to future works of this project (buy different magnets). The objective of this project was to improve the quality of Patio Pacific products. Common sense says that a 100% overlap would be economically effective in purchasing the magnets. Future work with numerous tests will be required to achieve this concept. Here are several ideas of possible future works: 1) Replicate the experiment multiple times on multiple doors (size 10, 12, and single, double flap, etc. 2) Search for exact (minimum) magnetic strength to purchase ideal magnets (i.e. 100% overlap) 3) Measure returns/customer satisfaction and adjust solutions as needed from future customer feedback.

BIBLIOGRAPHY

Barker, Thomas B. *Quality by Experimental Design*. New York: M. Dekker, 1985. Print.

Downing C. and Bryan A., 2010, “Optimization of Operational Techniques Using Six-Sigma Principles”, Proceedings of the 2010 Industrial Engineering Research Conference

Liker, J., 2004, The Toyota Way, McGraw-Hill, New York, NY, USA.

Melton, T., 2005, “The Benefits of Lean Manufacturing: What Lean has to Offer the Process Thinking Industries,” Chemical Engineering Research and Design, 83(6), 662-673.

"Pet Businesses Will Prosper: Industry Trends for 2014 and beyond." *Pet Businesses Will Prosper: Industry Trends for 2014 and beyond*. N.p., n.d. Web. 03 May 2015.

Pet Industry Market Size & Ownership Statistics. (n.d.). Retrieved May 8, 2015, from http://www.americanpetproducts.org/press_industrytrends.asp

"Pet Industry Market Size & Ownership Statistics." *Pet Industry Market Size & Ownership Statistics*. N.p., n.d. Web. 03 May 2015.

Pyzdek T., 1999, The Complete Guide to Six Sigma. Quality Press, Milwaukee, WI, USA.

Pyzdek, Thomas, and Roger W. Berger. *Quality Engineering Handbook*. New York: M. Dekker, 1992. Print.

Ross, Phillip J. *Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design*. New York: McGraw-Hill, 1996. Print.

Roth, William F. *A Systems Approach to Quality Improvement*. New York: Praeger, 1992. Print.

Taguchi, Gen'ichi. *Introduction to Quality Engineering: Designing Quality into Products and Processes*. Tokyo: Organization, 1986. Print.

Taguchi, Gen'ichi, Elsayed A. Elsayed, and Thomas C. Hsiang. *Quality Engineering in Production Systems*. New York: McGraw-Hill, 1988. Print.

APPENDICES

APPENDIX A: Customer inquiry tracker (Part 1)

	A	B	C	D	E	F	G	H	I	
1	Date	CSR Fill this out (use the drop down menu's)	Product Type Fill this out (use the drop down menu's)	Size Fill this out (use the drop down menu's)	Issue Fill this out (use the drop down menu's)	Order Number	Customer Name	Date Purchased	State	Details
2	October 1, 2011	Rachel	Q3	6		372898	Per Johanson	7/19/2013	CA	First claimed the flap wa corner,
3	January 25, 2013	Kelsey	Single flap wall mount	6	Clinch nuts falling out	319311	Chevrat	1/7/2013	IL	clinch nuts fell out, sent
4	January 25, 2013	Traci	Double flap wall mount	10	Doesn't fit	318186	Thomas Clarke	12/26/2012	MD	Doesn't fit location
5	January 25, 2013	Traci	Double flap door mount	10	Threshold	Unknown	Bill	Unknown	PA	Flap getting stuck on wi
6	January 26, 2013	Traci	T3	8	Doesn't fit	315559	Shirley McKelvey	11/14/2012	NE	TPIIIe doesn't fit well
7	January 28, 2013	Traci	T3	6	Aesthetics	317912	Silvia Rose	12/18/2012	NC	Uncommon Dog Custon panel looked with her sl
8	January 28, 2013	Traci	Double flap wall mount	8	Bellows not attaching	317947	Jerry Holly	12/19/2012	AK	Claims to have have no flap or in the interior of t

APPENDIX B: Customer inquiry tracker (Part 2)

1025	May 20, 2015	Kelsey	T3	6	Magnets too strong	669680	Kay Lang	5/13/2015	wa	sent her a link to the ma
1026		Kelsey	Unknown	Unknown	Template confusion	unknown	unknown	unknown	unknown	he was confused, but wl he figured it ou
1027		Kelsey	Double flap wall mount	6	Bellows not attaching	617659	katherine sllivan	4/13/2015	tn	told customer about the
1028	May 22, 2015	Kelsey	Double flap door mount	10	Installation	596411	david kennedy	3/29/2015	ca	customer had questions thinner, so I let him kno it out a little since what thinner.
1029	May 22, 2015	Kelsey	TS3	8	Installation	257538	terry helmbrecht	3/13/2012	tx	customer was having a and the rod, so I had hir if he could get the rod o sounds like it was just s with it a bit

APPENDIX C: Customer inquiry tracker (Part 3)

1			6	8	10	12
2		1				
3	Bug Warden					
4	Current distributor					
5	Double flap door mount	1	4	15	30	24
6	Double flap wall mount	1	18	33	47	22
7	Double flap wall mount				1	
8	In the Glass					
9	Kennel	1	3		2	2
10	Not applicable		1		1	1
11	PDD			7	4	2
12	Q3		5	15	16	4
13	Single flap door mount		12	26	51	29
14	Single flap wall mount		15	15	19	10
15	T2					
16	T3	1	52	90	97	68
17	TS3		15	9	14	4
18	Unknown			1	2	4
19	Grand Total	5	125	211	284	170

APPENDIX D: Customer inquiry tracker (Part 4)

1			6	8	10	12
39	Magnets too weak		1	6	5	4
40	Measured wrong		1		4	1
41	Missing parts		3	4	5	5
42	Noisy		1		7	3
43	Not available in stores					
44	Not clear enough		1		3	
45	Not satisfied			2		2
46	Other	2	6	11	19	12
47	Pet got stuck			1		1
48	Replacing flap difficulties			2	3	3
49	Retainer bottom falling off		1	3	5	5
50	Retainer rings falling out			3	17	8
51	Scared pets		2		4	3
52	Screws			5	9	1
53	Side magnet issues		1	3	3	4
54	Template confusion		3	4	5	3
55	Thinner than their door track		1			3
56	Threshold			1		
57	Threshold	1	12	36	31	27
58	Thumb screws/topper					

APPENDIX E: Customer inquiry tracker (Part 5)

1		Q3	Single flap door mount	Single flap wall mount	T2	T3	TS3	Unknown	Grand Total
44	Not clear enough		1	1		2			4
45	Not satisfied					4			4
46	Other	1	7	2	1	30	3	2	63
47	Pet got stuck					1	1		2
48	Replacing flap difficulties	2	1	1		1		1	9
49	Retainer bottom falling off		4			7			14
50	Retainer rings falling out	6	4			18	1		30
51	Scared pets	1		2		4	2		9
52	Screws	3	2	1		11	1		18
53	Side magnet issues		4	1		4	1	2	13
54	Template confusion		6	4					15
55	Thinner than their door track					5			5
56	Threshold						1		1
57	Threshold	3	16	3		58	4	3	115
58	Thumb screws/topper problems					10			11
59	Too big		4	2		6	1		15
60	Too small		1	1		3			10
61	Tunnel								5
62	Wrong product		1	3		4			14
63	Grand Total	41	126	63	1	333	46	20	878

APPENDIX F: Experiment data results

Overlap: 100%			Overlap: 80%		
Inserted: 3.1"			Inserted: 3.5"		
Replication No.	Force (N)	Pop-up?	No.	Force (N)	Pop-up?
1	5.5	1	1	4.7	1
2	5.5	1	2	4.7	1
3	5.5	1	3	4.7	1
4	5.6	1	4	4.7	1
5	5.4	1	5	4.7	1
6	5.4	1	6	4.7	1
7	5.4	1	7	4.7	1
8	5.4	1	8	4.7	1
9	5.4	1	9	4.7	1
10	5.4	1	10	4.7	1
11	5.4	1	11	4.7	1
12	5.4	1	12	4.7	1
13	5.4	1	13	4.7	1
14	5.4	1	14	4.7	1
15	5.4	1	15	4.7	1
16	5.4	1	16	4.7	1

17	5.4	1	17	4.7	1
18	5.4	1	18	4.7	1
19	5.4	1	19	4.7	1
20	5.4	1	20	4.7	1
21	5.4	1	21	4.7	1
22	5.4	1	22	4.7	1
23	5.4	1	23	4.7	1
24	5.4	1	24	4.7	1
25	5.4	1	25	4.7	1
26	5.4	1	26	4.7	1
27	5.4	1	27	4.7	1
28	5.4	1	28	4.7	1
29	5.4	1	29	4.7	1
30	5.4	1	30	4.7	1
31		1	31		1
32		1	32		1
33		1	33		1
34		1	34		1
35		1	35		1
36		1	36		1

37		1	37		1
38		1	38		1
39		1	39		1
40		1	40		1
41		1	41		1
42		1	42		1
43		1	43		1
44		1	44		1
45		1	45		1
46		1	46		1
47		1	47		1
48		1	48		1
49		1	49		1
50		1	50		1
51		1	51		1
52		1	52		1
53		1	53		1
54		1	54		1
55		1	55		1
56		1	56		1

57		1	57		1
58		1	58		1
59		1	59		1
60		1	60		1
61		1	61		1
62		1	62		1
63		1	63		1
64		1	64		1
65		1	65		1
66		1	66		1
67		1	67		1
68		1	68		1
69		1	69		1
70		1	70		1
71		1	71		1
72		1	72		1
73		1	73		1
74		1	74		1
75		1	75		1
76		1	76		1

77		1	77		1
78		1	78		1
79		1	79		1
80		1	80		1
81		1	81		1
82		1	82		1
83		1	83		1
84		1	84		1
85		1	85		1
86		1	86		1
87		1	87		1
88		1	88		1
89		1	89		1
90		1	90		1
91		1	91		1
92		1	92		1
93		1	93		1
94		1	94		1
95		1	95		1
96		1	96		1

97		1	97		1
98		1	98		1
99		1	99		1
100		1	100		1
	Average	Sum (out of 100)		Average	Sum (out of 100)
	5.42	100		4.70	100

Overlap: 60%		
Inserted: 3.9"		
No.	Force (N)	Pop-up?
1	3.5	0
2	3.5	0
3	3.5	0
4	3.5	0
5	3.5	0
6	3.5	0
7	3.5	0
8	3.5	0
9	3.5	0

10	3.5	0
11	3.5	0
12	3.5	0
13	3.5	0
14	3.5	0
15	3.5	0
16	3.5	0
17	3.5	0
18	3.5	0
19	3.5	0
20	3.5	0
21	3.5	0
22	3.5	0
23	3.5	0
24	3.5	0
25	3.5	0
26	3.5	0
27	3.5	0
28	3.5	0
29	3.5	0

30	3.5	0
31		0
32		0
33		0
34		0
35		0
36		0
37		0
38		0
39		0
40		0
41		0
42		0
43		0
44		0
45		0
46		0
47		0
48		0
49		0

50		0
51		0
52		0
53		0
54		0
55		0
56		0
57		0
58		0
59		0
60		0
61		0
62		0
63		0
64		0
65		0
66		0
67		0
68		0
69		0

70		0
71		0
72		0
73		0
74		0
75		0
76		0
77		0
78		0
79		0
80		0
81		0
82		0
83		0
84		0
85		0
86		0
87		0
88		0
89		0

90		0
91		0
92		0
93		0
94		0
95		0
96		0
97		0
98		0
99		0
100		0
	Average	Sum (out of 100)
	3.50	0