Designing a Pizza Box That, When Recycled, Does Not Contaminate Paper Pulp

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Element A: Presentation and Justification of the Problem

Abstract

When pizzas are transported in carryout boxes, oil seeps into the cardboard and makes the box unrecyclable. In the recycling process, paper and cardboard are mixed with water to make a slurry. When contaminants such as oil are introduced, the whole batch of slurry becomes landfill because contaminated slurry makes for poor-quality paper that is not worth using ("Because You Asked: Why Can't I Recycle Stuff with Food n It?", 2014). Even small amounts of contaminants can ruin products made from recycled material. In fact, if contaminated materials are used to produce food packaging, the contaminants can migrate into food and become safety hazards (Triantafyllou, Akrida-Demertzi, & Demertzis, 2006). Food waste is one of the top five recycling contaminants, and if dirty materials go through recycling machinery, they can clog the system, leading to significant downtime at recycling centers (Marshall & Bandhauer, 2017). With the ever-growing threat of climate change and resource depletion, humans need to be more aware of how they use resources. In the city of Denver, only 12% of the waste was recycled, but if recycling contamination were to be eliminated, the recycling rate could be 16%, which represents a difference of over nine thousand tons of waste (McMillin, 2019; Cotton, 2017). Being able to recycle pizza boxes would decrease the amount of waste sent to landfills, so more work needs to be done to stop oil from ruining batches of recycling.

Problem Statement

Recycling plant employees and environmental analysts who currently process recycled material in the United States report that greasy pizza boxes are a constant issue that can ruin entire batches of recycling (wm_editor, 2018). The threat of contamination is from the oil that drips off the pizza while it is in the box. During the recycling process, the recycled paper is all soaked in a tub and mashed into a pulp. If oil is present in the mixture, it causes the paper fibers

to have trouble sticking together and ruins the entire batch of paper. There has been little innovation in the pizza box industry in recent years and there are currently no completely recyclable pizza boxes (Heil, 2019). Therefore, there is a need for a better way to dispose of pizza boxes and educate the public on how to properly dispose of them.

Areas of Focus

Economic Considerations

One of the most important areas of focus would be the impact that recycling contamination has on the economy. China, one of the biggest importers of recycled materials, instituted a policy where any materials above 0.5% contamination will have to be thrown away (wm_editor, 2018). After the ban was instituted, over 2,000 tons of paper has been sent to landfills in the Pacific Northwest alone because it did not meet China's strict contamination guidelines. If oil is introduced during the recycling process, the whole batch of paper will be ruined and has to be sent to a landfill. If recycling companies cannot reliably filter out contaminants, then large amounts of contaminated paper will still be sent to landfills. The Chinese recycling guidelines have also led to an increase in costs to consumers. Since China now accepts less recycled material, some recycling companies have needed to charge consumers more to make up for lost income (Albeck-Ripka, 2018).

Health and Safety Considerations

A big part of recycling contamination has to do with health and safety. Food waste left on recyclables can rot and become a hazard to the workers tasked with handling the recycling (Adminssm, 2017). Furthermore, mold that has grown on food containers can be released into the air, which is a danger to the workers who are dealing with the recycling. Also, in the case of oil contamination in recycling, the floors of the recycling center may become covered in oil,

which makes the floors slippery and more dangerous for workers to walk on (*"Worker Safety in Recycling Facilities",* 2013). According to the State of Oregon, when compacted in a trash truck with other paper, pizza boxes soiled with grease can leak and ruin the whole truckload, contaminating the whole load (*"Recycling"*).

Technical Considerations

There are also technical issues with recycling contamination that must be addressed. One of the biggest technical issues is the risk of damage to recycling machinery. Recycling contamination can cause costly damage to recycling equipment that leads to downtime and wasted money used to pay repairmen, according to the Environmental Protection Agency *"Frequent Questions on Recycling",* 2019). Furthermore, jammed recycling machinery can even catch fire, causing even more damage to the facility *"NJDEP- Recycling Information"*). In fact, the main cause of recycling contamination, or at least in the case of the pizza box, has to do with the properties of paper. Paper fibers get shorter and shorter each time they are recycled. To make paper, the paper fibers have to be able to stick together, but when oil is introduced, the paper fibers cannot be separated from the oil, so they cannot bond nearly as well together (*"Frequently Asked Questions: Contamination").* Finally, there is no easy way to separate contaminated recyclables in single-stream recycling. According to the Associated Press, while single-stream recycling is cheaper because it only requires one recycling bin, it requires all of the waste to be sorted later, usually by hand (Roth, 2019). In the Washington D.C. area at the Prince George Recycling Plant, the recycling contamination rate is 13%. Put another way, for every ten truckloads of recycling, one of those trucks will be full of nothing but trash (Fenston, 2019).

Conclusion

Contaminated pizza boxes are a threat to paper recycling that must be addressed. Recycling contamination's impact on the economy, health and safety, and the functioning of recycling centers are just too great to be ignored, and something needs to be done to tackle the issue. A solution to the problem must be developed to curb recycling contamination and make the pizza industry more sustainable.

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Element B: Researching Existing Products and Solutions

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Introduction

Products and patents that attempt to reduce recycling contamination from greasy pizza boxes were researched and analyzed on how effectively they solve the problem. Products available on the market have both benefits and drawbacks. There are no products on the market that are recyclable after being used except for the DaVinci Pizza Box, which is very expensive and still must be washed after each use. Furthermore, current solutions do not use space efficiently when stored before use and are too expensive to be implemented in large-scale pizza delivery operations, such as the PizzaRound, World Centric pizza box, and the TreeSaver pizza box. Current products on the market are innovative in the different types of material used in their construction, such as the tree-free material used in the TreeSaver, and some have multiple functions to reduce the need for additional containers or dishes, such as the GreenBox. However, there are simply too many drawbacks to products available on the market and there is a market opening for a recyclable pizza box.

Current Products on the Market

Comparison Chart

Products available on the market were researched and documented in a chart to make it easy to compare them.

Product	$	Pros	Cons	Patent (Y/N)
DaVinci Pizza Box	$14.25 per box	• Reusable • Recyclable • Washable	• Very expensive price per unit	No

 (DaVinci Pizza)			• Not very convenient to the customer	
ARRRC Pizza Box  (*Archie Stack Black,* ARRRC Pizza)	$16.95 per box	• Reusable • Recyclable • Washable • Durable	• High price per unit • Takes up a lot of space in storage	No
PizzaRound  (Jimenez & Marinozzi, 2018)	$1.37 per box	• Tree-free • Compostable • Oven safe • No assembly required	• High price per unit • Not recyclable	No
GreenBox	$0.48 per box	• Made of recycled material • Multiple uses	• Not compostable or recyclable • Does not prevent oil from	Yes. 7,051,919

 ("GreenBox ", 2016)			contaminating cardboard	
TreeSaver Pizza Box  (Davidson)	$0.61 per box	• Compostable • No assembly required • Built using sustainable materials • Oven safe.	• Not recyclable	No
World Pizza Reusable Pizza Box  (Crosleycone & Madigan, 2018)	$5 per box	• Can be used multiple times • Dishwasher safe	• Hard to get access to because only sold in Seattle	No

World Centric Compostable Pizza Box  ("Fiber Flat Bread/Pizza Box")	$0.53 per box	• Compostable • Relatively cheap price per unit • Made from sustainable materials	• Can be ruined by pizza oil • Only can transport single slices of pizza	No
Zume Pizza "Pizza Pod"  (Heil, 2019)	Unknown	• Made from sustainable materials • Biodegradable • Compostable • No assembly needed	• Not recyclable	Yes D806575
White Paper Pizza Clamshells	$0.522 per box	• Made from recycled material. • Easily portable • Cheap price per unit	• Cannot hold a whole pizza • Still cannot be recycled if greasy	No

 ("White Paper Pizza Clamshells")				
Pi Pan  (Davies & Good News Reuse, 2011)	Unknown	• Reusable • Not wasteful • Doesn't take up space • Easy to clean	• Only used in schools and restaurants but not home deliveries	No

Benefits of Current Solutions:

1. Compostable products help decrease the amount of trash moved to landfills.
2. Reusable solutions help decrease the number of pizza boxes that are thrown away.
3. Containers made of sustainable, tree-free materials are more environmentally friendly and have less of an impact on the environment than boxes made from trees.
4. Containers are oven-safe eliminate the need for pizza pans and are more convenient to the customer.

5. Containers that require minimal construction are better because they require less time and labor to prepare for use.
6. Most of the containers are designed to be more heat-efficient than traditional pizza boxes.
7. Some of the solutions are designed to be more space-efficient and easier to store prior to use.
8. Many of the products are more durable than current pizza boxes.
9. The containers have been designed to waste less material during manufacturing.
10. Many of the containers are designed to eliminate the need for additional containers to store leftovers.

Drawbacks of Current Solutions:

1. None of the boxes can be recycled if they are contaminated with oil from pizza.
2. The solutions with the fewest drawbacks have the highest prices per unit.
3. Current solutions are inconvenient to use because they require the customer to do extra work to dispose of them properly.
4. There are no products designed to prevent oil from ruining the container.
5. Some of the products are not space efficient and are difficult to store.
6. None of the current products have been adopted by major pizza chains for widespread long-term use.
7. Members of the public believe that recycled materials are not food safe.
8. Products designed to be recycled are still thrown in the trash due to insufficient public awareness of the problem.
9. Reusable products need to adhere to strict food safety regulations.
10. The products are expensive and have very minimal benefits.

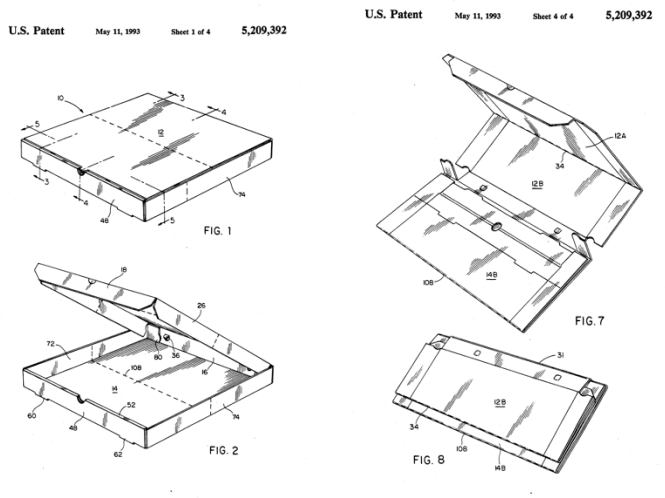
Patents

Patent Sketches and Critiques

Patents relevant to the problem are listed below with a critique on each one.

US5209392A: Recyclable Pizza Box

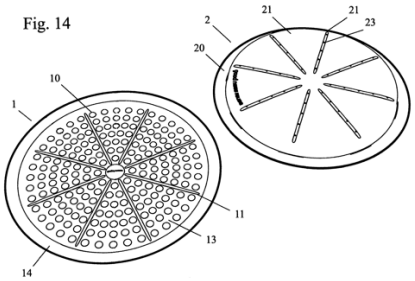
A patent for a pizza box with score lines make the box easier to collapse and place in the recycling bin. The collapsed box requires less space to be stored until the waste is collected. The score lines make the box easier to break down into fourths. The patent is clever in its usage of score lines to make it easier to break down and store. However, the patent does not attempt to tackle the issue of recycling contamination, and there is no method to prevent grease contamination in the patent. While an effort is made to make the box more convenient to recycle, there is no tangible effort made to make the pizza box recyclable and the box can still be affected by oil from the pizza.



Patent US5209392A

US9446889B2 - Reusable pizza pan set

A patent for a reusable container for pizza storage or transport. Designed to prevent moisture from getting into the container but allows vapor to escape to keep the pizza crust crispy. The pan is designed to be stacked to make transport easy and aims to reduce the amount of cardboard that is used to produce pizza boxes. The patent is designed to be durable to effectively protect pizzas during transport. However, the container still is more expensive than a traditional pizza box, and it would have to be washed after each use to adhere to food codes.

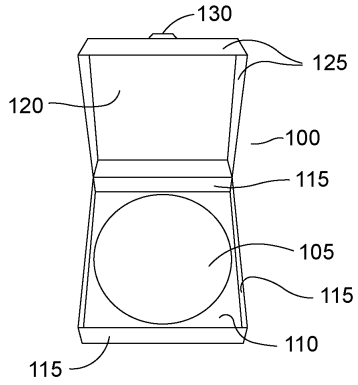


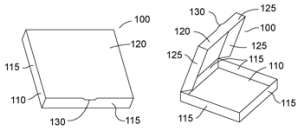
Patent US9446889B2

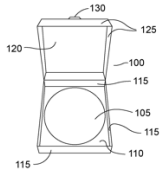
US20120305634A1 - Reusable Pizza Box

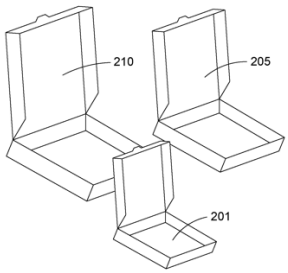
A patent for a pizza box that can be reused multiple times. The box can be washed and sanitized after each use. Part of the box is made from recycled plastic which prevents oil from seeping into the material. The pizza box was also designed to be versatile and can be used to transport a range of foods, including pies and cakes. The patent suggests that the pizzeria require customers to return the box after use or pay a fee. The fees would be used to purchase more pizza boxes. The pizza box is made of material that is better at heat retention than corrugated board, so the pizza would stay hot for longer. Since the box can be reused, it is less wasteful than current single-use pizza boxes. The better heat retention gives the box an advantage over other designs. However, customers may be irritated that they have to return the box after use. Since the pizza box is

expensive to purchase, it would be difficult to incorporate into operations and the return on investment would likely be low.





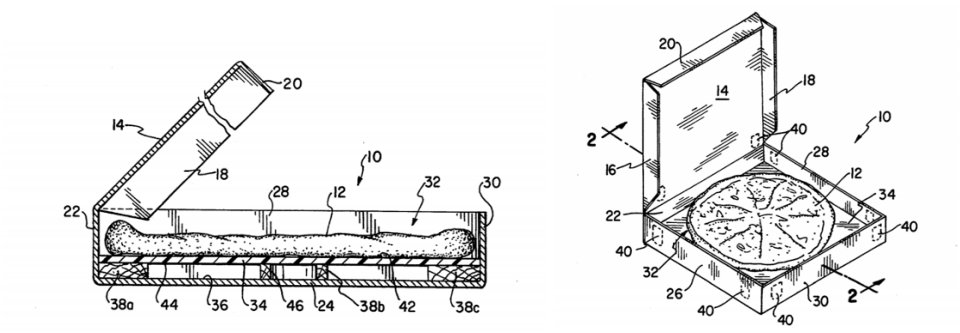




US20120305634A1

US5385292A - Pizza box having moisture absorbent material

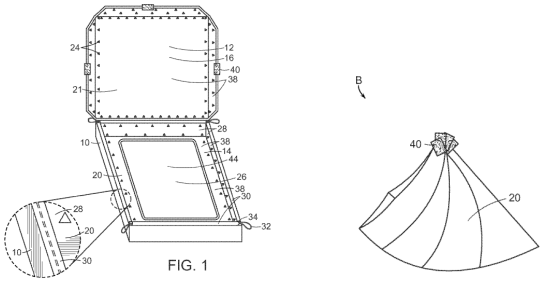
A patent for a pizza delivery package that can keep the pizza crust crispy. The design is similar to a traditional pizza box, except there is a sheet of balsa wood that increases the heat retention of the box. There are multiple vents on the design to vent moisture and keep the crust crispy. The increased heat retention capabilities of the design are very beneficial, but the balsa wood in the box would make it unrecyclable. The balsa wood would be a contaminant during the recycling process and would pose as an inconvenience. It would be too much of a hassle for consumers to remove the wood from the box before recycling it and ultimately is not feasible for large-scale operations.



US5385292A

US9296519B2 - Recyclability enhancement of food containers

A plastic coating is used inside the pizza box to prevent contaminants from seeping into the cardboard. The coating can be peeled off to make the box recyclable. Some previous iterations of the design included recyclable adhesive on the coating to further facilitate recycling. The peelable coating is beneficial because the grease from the pizza would end up on this layer instead of seeping into the box. However, the peelable coating would be redundant if consumers do not remove it before disposing of the box. Consumers may feel inconvenienced by the coating and choose to throw the whole box away anyway without removing it.



US9296519B2

US20120024859A1 – Container

This patent is for a pizza circle that utilizes a lid and a bottom surface. It is meant to be taken from the cafeteria of a facility to the office space of the consumer. It is made from various types

of reused material and molded from lines of fiber. The container is designed to keep the pizza warm and protect it during transit. There are special ventilation holes in the lid to allow for moisture to escape and keep the crust crispy. The container is designed to be easy to store before use. The patent is very well thought out, and its design would be effective in keeping pizza warm and fresh. However, if oil gets into the box, it cannot be recycled. There is no apparatus or effort to prevent oil from ruining the box.

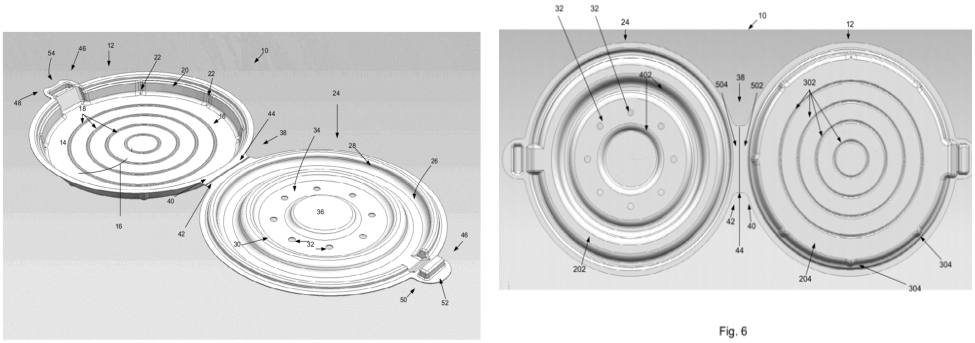


Fig. 6

US20120024859A1

US5160441A - Method of continuous centrifugal removal of residual liquid waste from recyclable container material

This patent is for a device that utilizes a centrifuge to remove excess oil from containers. The invention was designed to separate motor oil from a container, but it is applicable to pizza boxes as well. The invention is designed to separate the motor oil from the plastic in the packaging to make the package recyclable. No solvent or wash process are necessary, so money is saved and there are no additional pollutants used in the process. If so desired, the oil extracted from the containers can actually be recovered and used for whatever it can be used for. The patent is very well thought out and innovative. The many details and specifications of the patent are very good additions. The patent seems to have huge potential, especially in recycling applications.

However, there should have been more examples of how the invention should be used, because suggestions could help sell more of the product if it were produced commercially.

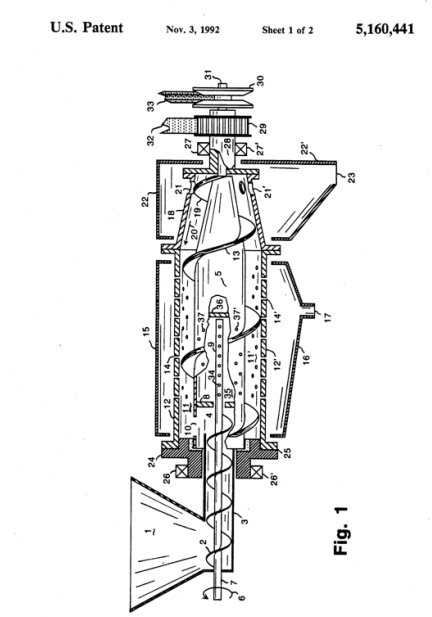


Fig. 1

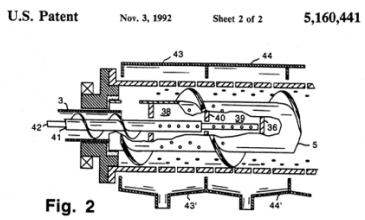


Fig. 2

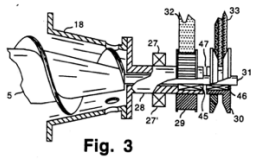


Fig. 3

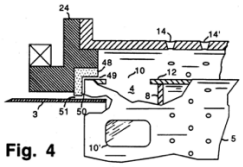


Fig. 4

US5160441A

Summary of Findings

- Materials
    - The ideal solution would be made from sustainably sourced material including bamboo, sugarcane, or recycled corrugated board.
- Cost
    - The ideal solution should cost no more than a traditional pizza box and be easy for companies to incorporate into operations.
    - The final product should be single use to keep costs low.
- Durability
    - The ideal solution must be durable enough to protect the pizza from damage during transport.

- Heat insulation
    - The final product should be able to effectively insulate the pizza and keep it hot until it is delivered to the customer.
- Storage
    - The solution must use storage space efficiently.
- Preparation time
    - The final product should take little to no time to prepare for use.

Conclusion

While there are many products on the market that attempt to tackle pizza box recycling contamination, all of them fall short in at least one important factor. Most of the current products are too expensive or waste too much space, and none of the products can be recycled after being used. None of the patents that were researched were effective solutions to the problem either; most of the patents assumed that oil in the boxes would not cause issues and were not designed to deal with the grease from the pizza. Therefore, there is room in the market for a recyclable pizza box that does not get ruined by food oil.

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Designing a Pizza Box That, When Recycled, Does Not Contaminate Paper Pulp

Element C: Presentation and Justification of Design Requirements

Finn Newman, Izabelle Diesen, and Ryan King

George Ranch High School

Introduction

A survey was given to determine the market for a recyclable pizza box and to find out what consumers would prefer in a solution. Research and the survey results were used to develop constraints that the final product must follow. Professionals associated with the recycling and packaging industries provided feedback on the constraints and helped develop objectives to follow throughout the design process. Based upon input from professionals and survey results, the final product must meet the target cost of $0.25-$0.30, be recyclable, and be constructed of recycled material. Market demographics for the pizza and recycling industries were researched and documented to determine the target market. The target market would be the suburban Northeastern United States due to high recycling rates and high amount of pizza consumption in the region. The target demographic group would be college-educated adults over the age of 35 based upon the demographic's higher rate of recycling and greater awareness of recycling contamination.

Knowing the Market

Market Research

A survey was conducted to aid in market research and determine what consumers would want from the product. The survey results were then used to justify design constraints and different options for the solution. A comment box at the end of the survey was available for any additional questions or comments. The survey indicated that there was consumer interest in a recyclable pizza box and that public awareness of recycling contamination is low.

- Multiple respondents commented that they would want a solution to the problem because they are concerned about the waste generated by pizza boxes.

If you have any questions or comments, please enter them and an email address below and we will be in touch!

58 responses

No questions. Good luck, all!!!

Mod pizza has a paper insert that can be removed for recycling the box, and the Mod we go to will also let us reuse their pizza boxes! :) mhmfoster3@gmail.com

I would rate the company VERY favorably if the pizza was good and they had a recyclable pizza box. Furthermore, I placed a greasy pizza box in the recycle bin BEFORE I knew that it impacted the process.

Through the intro/ instructions of this survey I actually learned HOW it impacts the process! Thank you for that. 🙂

Thanks for making us aware of this. I never knew this about pizza boxes and it seems like it is an easy fix.

Very interesting survey. Thanks for doing this and for caring about our planet. I typically put the top of my pizza box in the recycle bin. It is usually clean. And I throw the bottom in the regular trash because of the greasy stains and I feel a but guilty. So it would be great to be able to put the whole box in the recycle bin.

Great topic!

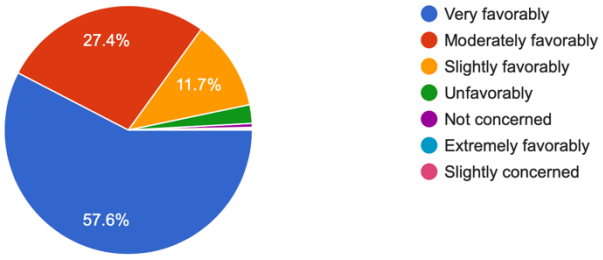
I always tear the cover off the box for the recycling bin and then throw away the bottom. If you can crack this problem, you would be amazing!

Never thought about this problem before. Shall think about it

- Respondents indicated that they would view a company very favorably if they incorporated recyclable pizza boxes into their operations, meaning that consumers value companies with sustainable practices.

How favorably would you view a company that uses a recyclable pizza box?

580 responses



- One respondent in the comment box mentioned that they purchase Papa Murphy's pizza, which has no box. Papa Murphy's would be competition in terms of sustainable packaging, but their sales are small in comparison to Domino's, Pizza Hut, Papa John's,

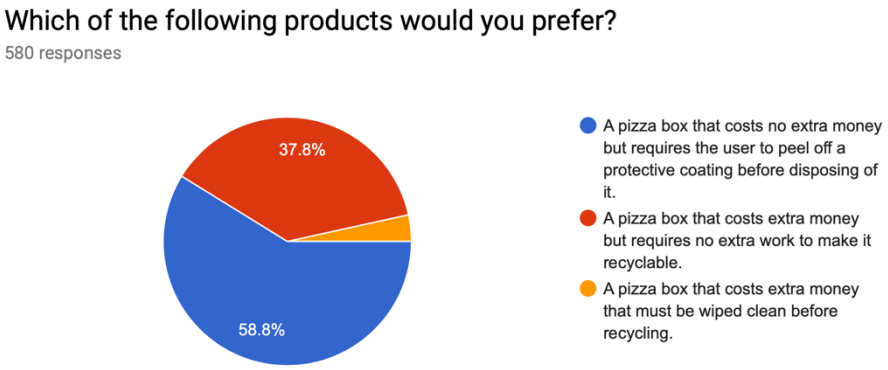
and Little Caesars (Tory, 2018).

If you have any questions or comments, please enter them and an email address below and we will be in touch!

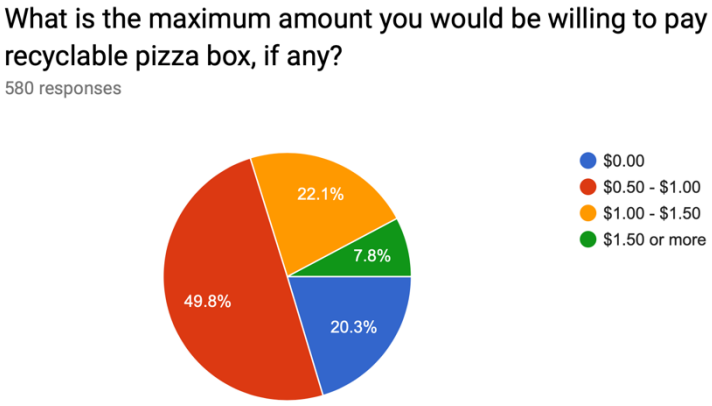
58 responses

I buy Papa Murphy Pizza- no box. I wash all of my recycled containers before putting them in the bin

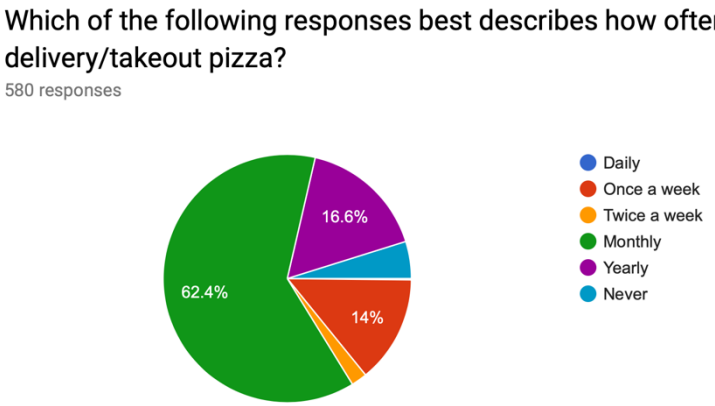
- In addition, 58.8% of respondents indicated that they would prefer a solution that would not cost extra money but have a peelable coating that would have to be removed before the box is disposed of. The feasibility of a product with a peelable coating will be researched more thoroughly and will be more seriously considered due to the favorable response from the survey.



- 49.8% of respondents indicated that they would only be willing to spend up to $1.00 extra for a recyclable pizza box. However, the final product should not cost the customer any extra money so that there are as few deterrents to recycling as possible.

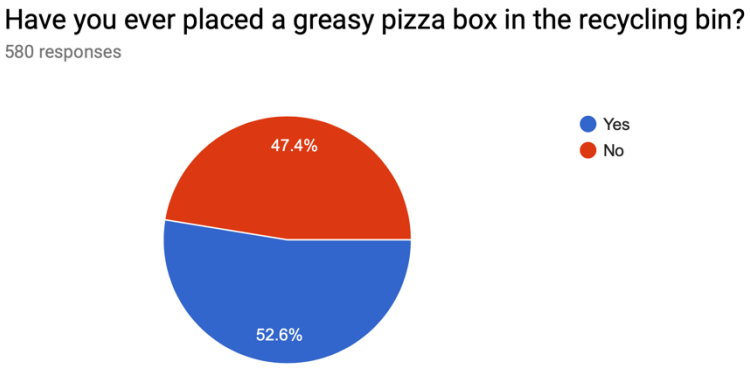


- 62.4% of respondents indicated that they order delivery or takeout pizza monthly, meaning that a majority of people use at least one pizza box every month. Therefore, there would be a large market for the final product because pizza boxes are used very often.



- 52.6% of respondents indicated that they had previously placed a greasy pizza box in the recycling bin in at least one occasion, which provides a good idea of the extent of public awareness of the problem. Based upon the responses to this question, it can be assumed that public awareness of recycling contamination is very low and that there is a

demonstrated need for a recyclable product so that greasy pizza boxes are less of an issue for recycling facilities.



Future Competitors and Barriers to Entry

Potential future competitors include products that are patent pending and products currently in development. As climate change and the state of the planet worsen, there will likely be more attempts to create sustainable packaging, meaning more competition in the industry. There are also many barriers to entry. Preexisting corrugated packaging companies are tough competition and will not be welcome to more competitors. According to Rick Stephens, the Vice President of Sales at Transcontinental Group, the corrugated packaging industry is extremely competitive and there is little room for entry for new products (R. Stephens, personal communication, December 11, 2019). Pizza houses must also express interest in the product and be willing to purchase it. New competitors must be able to design a product that is most convenient to the target user and has the most benefits for the least drawbacks.

Identifying Users and Buyers

Demographic	Target	Justification
Age	People above the age of 35	People above the age of 35 were found to be more inclined to recycle than people aged 18-34 (LeBlanc, 2019). Therefore, the target age demographic would be adults above the age of 35.
Income	Salaried Workers	A study by Understanding Society found that people who are on a salaried wage are more likely to recycle than those who are on an hourly wage ("How does your income affect your recycling habits?", 2015). The target income demographic will be workers who are paid a salary, because

		they are the demographic who recycle the most.
Geographic Location	Suburban Northeastern United States	Simmons Consumer Research found that those living in suburban areas were more likely to report that they recycle “very often” (Jula, 2019). In addition, the Pew Research Center found that seven-in-ten people in suburban and urban communities have curbside recycling (DeSilver, 2016). The Northeastern United States will be the main target because they have the most pizza stores per 10,000 people ("The 2019 Pizza Power Report: A State-of-the-Industry Analysis", 2019).
Education Level	College graduate	Worcester Polytechnic Institute found that as education level

		goes up, the amount of waste that is recycled also tends to increase (Russell, 2011). Therefore, the target audience would be college-educated adults because they would be more likely to recycle the product.

Justification

The effort and expense required to design a solution to the problem is worth it because of the market size and the potential environmental benefits. The quick-service pizza industry is approximately $33 billion, with takeout pizza comprising $15 billion of that figure and pizza delivery with $10 billion (Jaaskelainen, 2018). Takeout and delivery pizza both utilize pizza boxes, so there is a $25 billion market that would be available to market to. While the market is inundated with pizza boxes made of recycled material and products that claim to be recyclable after use, there still is no pizza box that can be recycled after it is used (Albeck-Ripka, 2018). In addition, experts have expressed interest in a solution, such as Randy Rasch of Rasch Graphic Services Corporation and Scott Williamson, the Corrugated Specialist at Veritiv Corporation. The industry of pizza boxes has remained relatively void of innovation in recent years, and with the growing importance of environmental conservation, the market for a recyclable pizza box will likely grow. Harvard Business Review found that consumer purchases of sustainable goods were up in 2019, which is a good indication that the market for environmentally focused goods is

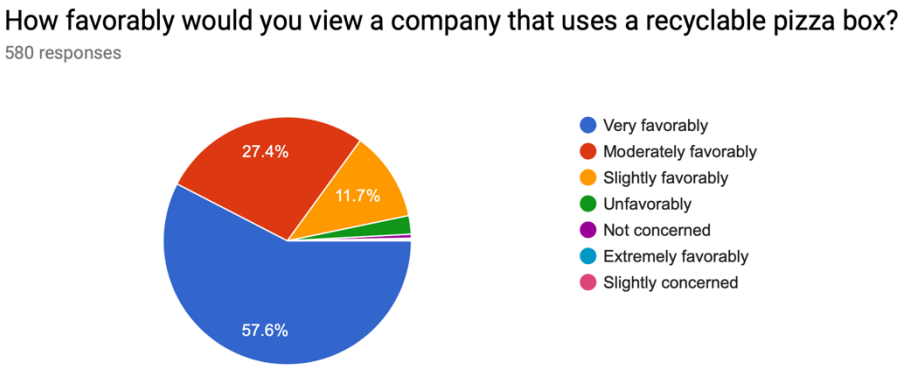
growing (Kronthal-Sacco, 2019). In addition, a recyclable product would prevent billions of boxes from ending up in the trash and less trees would have to be cut down to manufacture pizza boxes. The potential revenue and environmental impact resulting from the development of a viable product are worth the effort and expense required to design a solution.

Developing Constraints

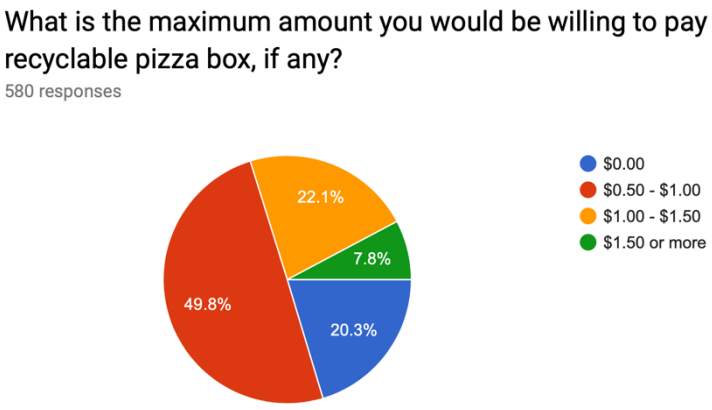
Design Requirements

Design requirements for the final product were developed to use during prototype testing and evaluation of the solution. Each requirement was developed and justified using a combination of research, survey results, and professional guidance. The design requirements will be utilized throughout the development of the product to determine how successful it is at solving the problem and to ensure that it is commercially viable. The design requirements are listed from most important to least important.

1. Global Environment: The final product will not be harmful to the environment and should be made of recycled material. The box will be recyclable after use. Taylor Danesi, the Environmental Manager for the City of Sugar Land, specified that the ideal solution would not contain any sort of film or coating to avoid creating additional waste and contamination in the recycling stream (T. Danesi, personal communication, December 5, 2019). If the film/coating is not removed before the item enters the recycling stream, then the object is no longer recyclable. Additionally, 58.1% of survey respondents indicated that they would view a company that uses a recyclable pizza box very favorably.



2. Target Cost: The target cost of the product is $0.25 to $0.30. Comparable current products cost approximately $0.27 per unit (Webstaurantstore.com, 2019). In addition, Scott Williamson, the Corrugated Specialist at Veritiv Corporation, stated that most 14” pizza boxes cost $0.25 to $0.30, with 8” pizza boxes being cheaper and 16” pizza boxes being more expensive (S. Williamson, personal communication, December 6, 2019). The target cost must not exceed the cost of existing pizza boxes in order to attract as many customers as possible. The survey results justify the constraint because they indicate that a majority of respondents would pay no more than $1.00 extra for a sustainable solution. Taylor Danesi also stressed that people are more likely to recycle when it is the most convenient option and does not cost any extra time, effort or money (T. Danesi, personal communication, December 5, 2019).



3. Materials: The product should be made of sustainable materials and must be recyclable at the end of its life. While not required, the use of corrugated cardboard would help to control costs and would provide efficient heat retention (Bormett, 1981). Mr. Williamson indicated that corrugated cardboard is an inherently recyclable material when it is uncoated, meaning that the design should focus on preventing the grease from contaminating the box (S. Williamson, personal communication, December 6, 2019). Ms. Danesi also recommended that the product have no additional stickers or coatings because they also become contaminants when they enter the recycling stream (T. Danesi, personal communication, December 5, 2019).

4. Performance: The pizza box must be able to hold a pizza and be easy for the customer to carry. It also must be able to keep a pizza warm for at least 30 minutes. The pizza box must also be able to be recycled after having a pizza inside. Mr. Williamson explained that corrugated board is so widely used because it has great insulative properties. Mr. Williamson also stated that dissipation of moisture from the box should be a big focus of the design (S. Williamson, personal communication, December 6, 2019). Both the box and the pizza are degraded by moisture released by the pizza as it cools. The corrugated board becomes soggy and the pizza crust loses crispiness when there is no way for moisture to dissipate. According to PMQ Pizza Magazine, “44% of consumers rated ‘fresh, high-quality ingredients’ and ‘best crust’ as deciding factors,” meaning that customers care about having crispy crust ("The 2019 Pizza Power Report: A State-of-the-Industry Analysis", 2019).

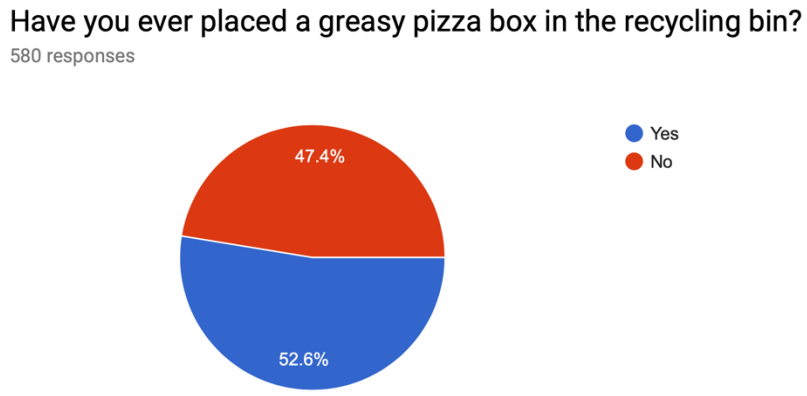
5. Safety and Legal Issues: The box should be insulated enough so that it can be safely carried without risk of burning the carrier. The box should also be an original design and avoid being too similar to existing patents and solutions. The solution must be safe to touch to avoid any potential lawsuits or injuries, and there should not be dangerous sharp edges on the box so that

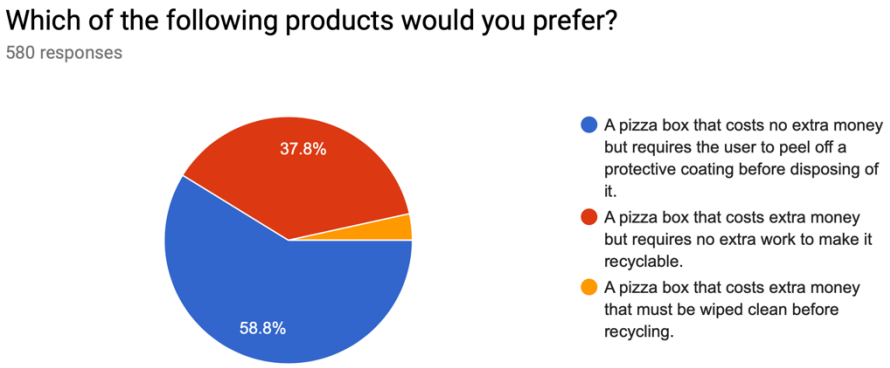
there is a smaller chance of injury. Randy Rasch, owner of Rasch Graphic Services Corporation, agreed that the box should be designed to be safe to carry. Mr. Rasch agreed with all of the criteria and said that the design should be completely safe and purposely designed to be extra safe for customers to use (R. Rasch, personal communication, December 5, 2019).

6. Operating Environment: The pizza box must be able to withstand the heat of a freshly cooked pizza. The product must also be able to withstand the moisture produced by the pizza as it is being transported. The box must be sturdy enough to withstand being stacked and must be able to protect the pizza during transport. Mr. Williamson emphasized the importance of incorporating a way for moisture to escape, because moisture can degrade the corrugated box and cause the pizza crust to lose its crispiness (S. Williamson, personal communication, December 6, 2019).

7. Customer Needs: The customer wants something that is cheap and can be recycled after use. The customer will want a pizza box that is convenient to recycle, because convenience is a big factor in deciding whether someone will recycle or not. 65% of Americans say that they would be less likely to recycle something that is inconvenient to recycle (LeBlanc, 2019). The solution should have clear instructions for how to dispose of it properly and have a note that tells the consumer that it is recyclable. Taylor Danesi suggested that the box have clear instructions printed on it to educate the users on how to properly dispose of it (T. Danesi, personal communication, December 5, 2019). 52.6% of respondents to the survey indicated that they have placed a greasy pizza box in the recycling bin before, indicating that the public is not aware that used pizza boxes cannot be recycled. Directions on the box would help to educate the public and ensure that the boxes are disposed of properly. 37.8% of respondents indicated that they would

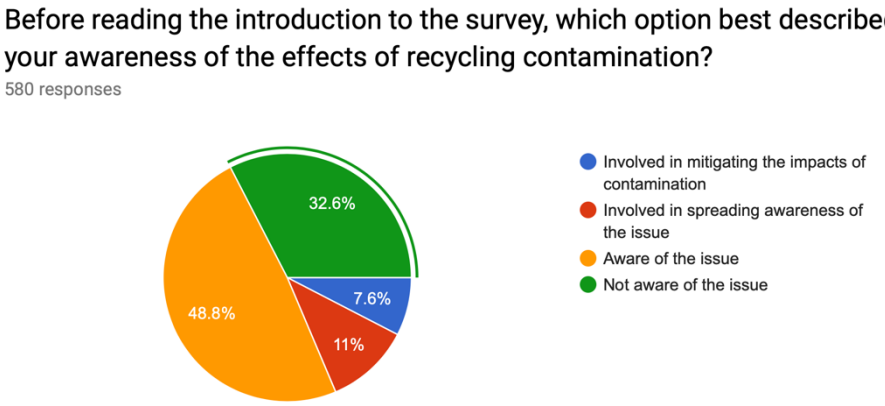
prefer a solution that is most convenient, even if they had to pay extra. The ideal solution would require no extra work to be recyclable and would not cost extra money to the customer.





8. Size and Weight: The ideal weight of the box must be no more than 12 ounces and it should be able to carry a full pizza ("ATECH's Pizza Boxes"). According to Mr. Williamson, common 14" pizza boxes are about 3" deep to avoid cheese from sticking to the lid of the box (S. Williamson, personal communication, December 6, 2019). The depth of the box can be similar to other boxes to ensure that no cheese or grease stick to the lid of the box. The box dimensions will be 14" x 14" x 3", similar to comparable 14" pizza boxes on the market ("14" x 14" x 1 3/4" White Corrugated Plain Pizza / Bakery Box - 50/Bundle", 2019).

9. Aesthetics: The pizza box should be customizable by the customer so that different business names and logos can be printed on the box if desired. The material should be corrugated board because it is inherently recyclable and does very well with retaining heat (Bormett, 1981). The box must have clear instructions on how to dispose of it, because the survey indicated that 32.6% of respondents were not aware of the issue of recycling contamination. The US Environmental Protection Agency also found that most people are not aware of what should and should not be recycled, so instructions on the box would be an important education tool and would ensure that the box is recycled ("Recycling: Protecting the Environment, and Growing the Economy", 2018).



10. Ergonomics: The solution has to be made out of a recyclable material, preferably corrugated board. It should also be a box shape so that it can be easily implemented into already existing pizza businesses. All of the experts that were contacted agreed with the original constraints that had been laid out. Ms. Danesi stressed that it is important to consider how convenient the final product is versus its drawbacks (T. Danesi, personal communication, December 5, 2019). People are also more likely to recycle when it is convenient (LeBlanc, 2019). The most beneficial and cost-efficient product will be the more successful one, so the final product must have as few downsides as possible.

11. Product Life: The industry for recyclable pizza boxes is not very competitive at the moment. According to Scott Williamson, there has been very little innovation in the industry in recent years (S. Williamson, personal communication, December 6, 2019). Mr. Rasch advised to research why there has not been more innovation in the pizza box industry, and he pointed to the U.S. Patent Office as a place to begin research (R. Rasch, personal communication, December 5, 2019). Innovation in pizza boxes has been limited to the addition of storage space for sauces and other minimal improvements such as the design of the pizza saver, which prevents the lid of the box from crushing the pizza (Heil, 2019). If the trend of minimal innovation continues, then the estimated product life could be more than five years, because there will be few innovations to compete with.

12. Durability and Maintenance: Since the box is designed for a single use, the product will not require maintenance during its service life. The box must be durable enough to protect the pizza but not too heavy (Nordstrand, 2003). According to Mr. Williamson, the durability of corrugated board is one of the reasons why it is so widely used for pizza boxes (S. Williamson, personal communication, December 6, 2019). Mr. Williamson also advised against using a coating inside the box because uncoated corrugated board is inherently recyclable, but the coating would not necessarily be recyclable ("Recycling Corrugated Packaging").

13. Service Life: The required service life of the product is not very long. From manufacture, the pizza box must last long enough to be stored until its use, probably multiple months. However, once the pizza box has been used and is received by the customer, it only needs to last around a week. It is important to design the pizza box to be easy and space-efficient to store, because space is very limited in pizza restaurants (Mills-Senn, 2013).

Appendix

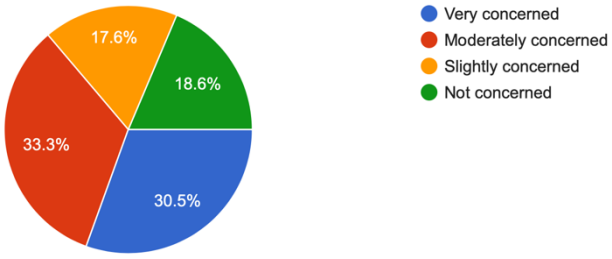
Survey Introduction

"This survey is being conducted to determine whether a recyclable pizza box would be economically viable and desirable by consumers. Currently, when greasy pizza boxes enter the recycling stream, they must be removed by hand by recycling workers. If the boxes make it into the batch of recycling, they ruin the whole batch because the oils cause the paper fibers to have trouble sticking together. This survey aims to gauge responses to help the team find the optimal solution."

Survey Results

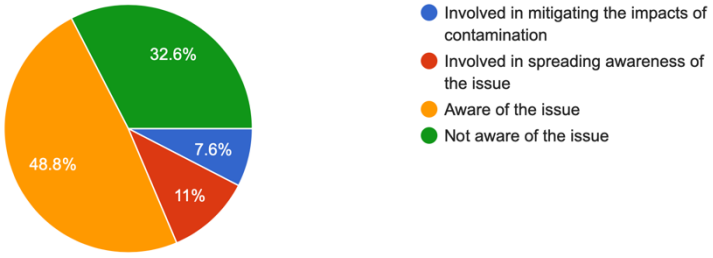
Before reading the introduction to the survey, how concerned were you with the environmental impact of recycling contamination?

580 responses



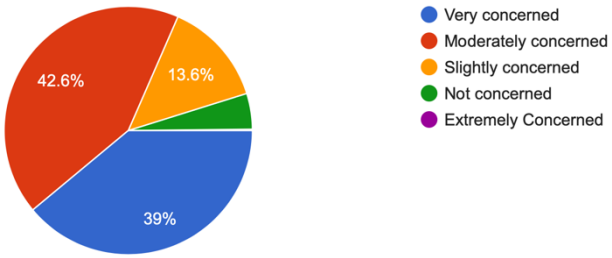
Before reading the introduction to the survey, which option best described your awareness of the effects of recycling contamination?

580 responses



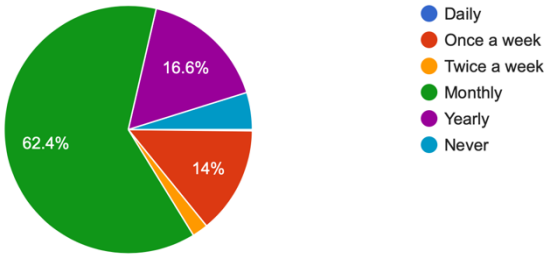
After reading the introduction to the survey, how concerned are you with the environmental impact of recycling contamination?

580 responses



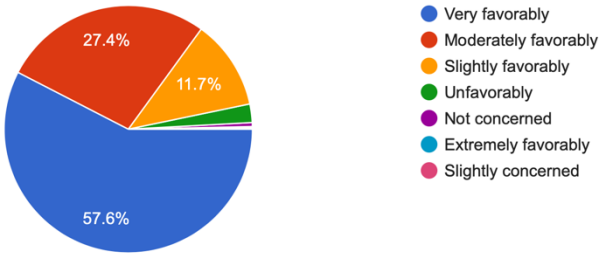
Which of the following responses best describes how often you order delivery/takeout pizza?

580 responses



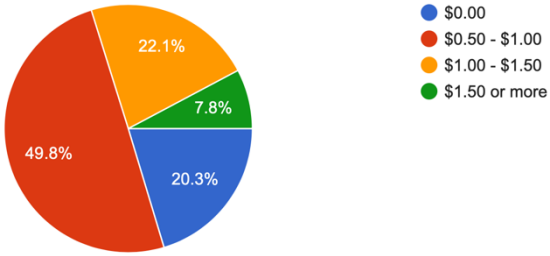
How favorably would you view a company that uses a recyclable pizza box?

580 responses



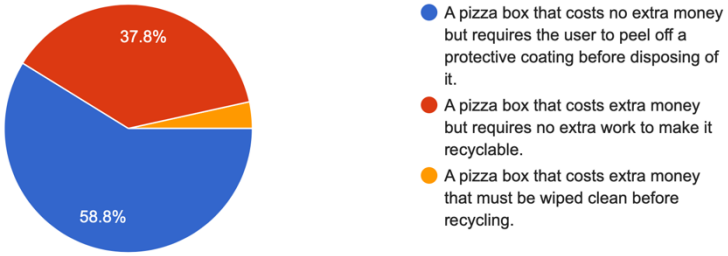
What is the maximum amount you would be willing to pay extra for a recyclable pizza box, if any?

580 responses



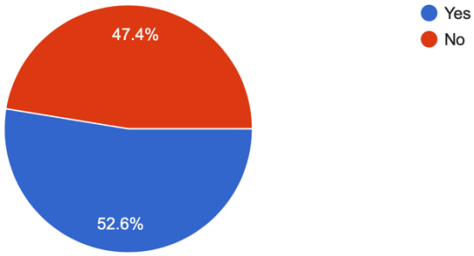
Which of the following products would you prefer?

580 responses



Have you ever placed a greasy pizza box in the recycling bin?

580 responses



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