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Optimized Automated Checkout Process for Major Food Retailers

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Executive Summary

There has been a push for automation in countless industries to save time and money, increase customer satisfaction, increase customer purchasing options, increase efficiency, and reduce waste. This design project will focus on optimizing the automated checkout process at major grocery retailers. The goal of the design is to reduce customer wait times at the checkout line, thus increasing customer satisfaction and save the retailer cashier expenses. The design was created using the DMAIC (define, measure, analyze, improve, control) process tool. Customers were surveyed to define if there was a problem, and 52.5% of customers felt the wait times at checkout were too long. Time studies were conducted to gather data and measure the baseline for later design comparisons. The designs were analyzed using Arena, a system modeling software. Also, a cost analysis was also performed on the design ideas to find the most plausible, effective, and efficient design option. Throughout the design process, weekly meetings were held to review the design, define the roadblocks, and improve upon the design. In section 3.2a, any foreseeable roadblocks were defined, and the solutions were supplied to help management control the design once implemented.

The design starts with customers entering the store. At the entrance, they are given the choice to open the store’s application on their phone and take part in the scan as you go feature. There will be a station to grab a bagging rack that can be clipped to the cart to offer the customer a bag-as-you-go experience. There will also be a basket of cellphone clips next to the bagging racks. The cell phone clips will allow the customer to have a touch-free and hassle-free scan-as-you-go experience. The customer will scan their items as they shop and bag the items as they place them in their cart. At checkout, the kiosk will ask the customer to scan the customer QR code in their phone to connect the data of what they have scanned to the kiosk and floor scale.

The kiosk will prompt the customer to weigh the scanned produce items on the kiosk scale and place them back into their cart. Then, the kiosk prompts the customer to push their cart onto the floor scale that is next to the kiosk, remove the bagging rack and cell phone clip, step away from the cart/scale, and press weigh. The customer can then pay as normal and exit the system.

In Arena, the standard self-checkout system and the new design were simulated. The results showed that in one hour the self-checkout system could process an average of 36 customers through the system, while the new design could process an average of 57 customers per hour. This is 1.58 times faster. The main reason this new design is more efficient at moving customers though the automated checkout process is because the scale eliminates the need for the customer to scan their items at checkout, and the bagging rack eliminates the need for the customer to bag their items at checkout. This report will breakdown the design process from start to finish, including all visuals.

Table of Contents

Chapter 1: Project Overview

This design concept will provide an in-depth description of a design process to optimize the automated checkout process at major grocery retailers. It will include all of the steps taken to arrive at the final design. Chapter one will define the problem and generate ideas to solve the problem. Chapter two will show how others have solved similar problems. Chapter three will dive into the design of the optimal solution. Chapter four will use AutoCAD to provide the necessary visual aids to understand the design fully. Chapter five will breakdown the Arena Model Simulation. Chapter six will discuss the results from the entire design process. Lastly, Chapter seven will provide a summary of the report.

1.1 **Overview**[1]

Powerful technology is at our fingertips and can aid in reducing time consuming errands/tasks. The self-checkout process at most major grocery retailers needs to be redesigned and made more efficient. This design process will lead to improving the effectiveness and efficiency of this organizational process across the industry. The DMAIC (Define, Measure, Analyze, Improve, Control) tool will be used to verify all the design steps. There is no funding for this project, so the C for Control will be theoretical (the Arena model) until this prototype is built.

The purpose of the 'Define' step is to ensure the problem being solved exists and determine the opportunity for improvement. A customer survey was conducted to support that this design concept will increase their satisfaction.

The purpose of the 'Measure' step is to find a baseline for determining the success of the design. A time study was conducted to determine the current time it takes for a customer to checkout.

The purpose of the 'Analyze' step is to find and identify the poor performance within the process. An Arena model will be created from the time study and object design to analyze the cause for long customer wait times and where the problem is actually occurring.

The purpose of the 'Improve' step is to create and/or identify possible solutions to the problems or defects that exist within the design. Three potential solutions have been identified to help remedy this current issue, however, one potential solution stands out among the rest. As the potential solutions are tested and observed, the actual end solution changed.

The purpose of the 'Control' step is to control future process performance. A quality control plan that includes the roadblocks in the design will be created to define what is needed to keep the improved process from failing, reverting to its previous state, and/or keep it at its current level of success.

1.2 Objective.

The minimum goal for this project is to create a design process that can be replicated and used to optimize the self-checkout process at major grocery store chains. The design will reduce customer wait-time in the checkout line, increase customer satisfaction, reduce the number of cashier associates needed to conduct business, and ultimately reduce the company's expenses over the long term. Evidence will be required to support the final design. Unfortunately, an exact prototype of the proposed solution will not be possible. To compensate for lack of a prototype, a simulation will be created to replicate a prototype. The simulation will act as the evidence required to support the claims and findings.

1.3 Resources

Time studies will be recorded by cellular phones for data collection. VMWare will be required to access Arena, which will be used to create a simulation of the proposed idea. Most of the tables and data will be created and/or stored in Excel. Microsoft PowerPoint and YouTube will be used to aid in visual representations. Access to certain local food retailers is imperative to complete time studies and surveys. Other resources will include KSU instructors, coworkers, and friends within the industry.

1.4 Justification.

A time study and customer survey were conducted and analyzed to define the problem, assist in brainstorming a solution, and justify the design concept.

The time study was conducted at four major grocery retailers. At each of the four retailers, 20 consecutive regular checkout customers were timed, and 20 consecutive self-checkout customers were timed. The timing for each checkout was broken down into two main parts: scanning time and total time. Scanning time is the time from when the customer picks up their first item in their cart to when they have finished scanning all items but before they begin paying. The total time is the time from when the customer approaches the kiosk/cashier to when they push their cart away from the checkout lane. The size of the cart and number produce items that needed to be weighed was also measured. The size of the cart was broken down into five categories: X-Small (no cart, carried by hand), Small (<=25% full), Medium (>25% full and <=50% full), Large (>50% full and <=75% full), and X-Large (>75% full).

In a separate time study, 20 random customers from each of the four retailers were timed on how long it took for them to weigh one piece of non-barcoded produce. The time started when the produce item was first picked up and ended when it was finished being weighed, picked up, and removed from the scale.

The tables below give a complete description of all data categories collected for self-checkout and regular checkout respectively. The data is broken down by cart size first. Then is shows the percent of customers with each cart size, the average total time and standard deviation the checkout process took per cart size, the average scanning time and standard deviation per cart size, the average number of produce items needing to be weighed per cart size, and the average time spent per cart weighing produce. This data will be used as a baseline and provide evidence of improved/decreased customer wait time at self-checkout later in Chapter 5.

Table 1 Data Analysis: Self-Checkout

Data Analysis: Self-Checkout								
Cart Size:	# of Cart Size	% Cart Size	Avg. Total Time	Std. Dev. Total Time	Avg. Scanning Time	Std. Dev. Scanning Time	Avg. # of Produce	Avg Time/Cart for Weighed Produce
x-small	23	29%	76.74	28.28	39.52	24.26	1.57	16.75
small	32	40%	131.00	44.30	90.91	45.45	2.94	31.42
medium	17	21%	161.12	59.16	119.59	50.59	5.88	62.96
large	8	10%	232.38	117.34	192.75	111.50	5.57	59.63
x-large	0	0%	0.00	0.00	0.00	0.00	0.00	0.00

From Table 1, it can be calculated that the average expected total wait time per customer = (29%*76.74s) + (40%*131.00s) + (21%*161.12s) +(10%*232.38s) = 2.20 minutes/customer. This means assuming there is only one self-checkout kiosk per line, the expected wait time of each customer in line is 2.20 minutes times the number of customers in front of them. If there is more than one kiosk the equation would be 2.20 minutes per customer divided by the number of kiosks times the number of customers in front of the customer.

Table 2 Data Analysis: Regular Checkout

Data Analysis: Regular Checkout								
Cart Size:	# of Cart Size	% Cart Size	Avg. Total Time	Std Dev. Total Time	Avg. Scanning Time	Std. Dev. Scanning Time	Avg. # of Produce	Avg. Time/Cart for Weighed Produce
x-small	11	14%	53.55	38.94	14.64	13.23	1.00	0.00
small	26	33%	90.04	27.16	60.38	27.45	2.15	0.00
medium	19	24%	143.26	22.95	105.26	21.75	3.16	0.00
large	20	25%	204.70	42.00	174.10	36.41	6.45	0.00
x-large	3	4%	298.33	32.15	262.33	42.50	11.00	0.00

From Table 2, it can be calculated that the average expected total wait time per customer = (14%*53.55s) +(33%*90.04s) +(24%*143.26s) +(25%*204.70s) +(4%*298.33s) = 2.21 minutes/customer. This means the expected wait time of each customer in the regular checkout line is 2.21 minutes times the number of customers proceeding them.

The customer survey was conducted to capture the voice of the customer. It included responses to three questions from 20 random customers from each of four retailers; 80 customer surveys in total. The three questions were: Which do you prefer to use: regular checkout or self-checkout? Did you use regular checkout or self-checkout today? Were you satisfied or unsatisfied with the wait-time at checkout?

Table 3 Data Analysis: Customer Survey

Data Analysis: Customer Survey	
Description	**% Customers**
% Customers who prefer Regular Checkout:	41.25%
% Customers who prefer Self-Checkout	58.75%
% Customers Used Self-Checkout	56.25%
% Customers Use Regular Checkout	43.75%
% Customers are unsatisfied with the wait time	52.50%
% Customers are Satisfied with the wait time	47.50%
% Customers who used Self-Checkout who are unsatisfied with the wait time:	32.50%
% Customers who used Self-Checkout who are satisfied with the wait time:	23.75%
%Customers who used Regular Checkout who are unsatisfied with the wait time:	20.00%
%Customers who used Regular Checkout who are satisfied with the wait time:	23.75%

The data in Table 3 shows that 58.75 percent of customers prefer to use self-checkout, 56.25 percent of customers use self-checkout, 52.50 percent of customers are unsatisfied with their wait times, and 32.50 percent of customers who used self-checkout were unsatisfied with their wait time. This provides evidence that most customers use the self-checkout process, and a reduction in customer wait time would increase customer satisfaction.

1.5 Project Background and Design Ideas

The project started by brainstorming potential ideas to reduce the customer wait time in the checkout line. There were three main ideas that were analyzed and decided between.

Idea 1: Creating an application to scan items with customers' personal smartphones as they shop. Then install a scale that weighs your cart at check out, and you pay at the scale with the kiosk. It includes a bagging rack (bag-as-you-go option) and a cell phone clip (scan-as-you-go option).

Idea 2: A 'smart' camera with item recognition technology to determine what is being placed in the cart.

Idea 3: 'Smart Cart' concept. The cart itself has a built-in scale and it also has a scanner connected to the cart.

1.6 Pros and Cons

Table 4: Pros and Cons of Each Design Idea

	Idea 1	Idea 2	Idea 3
User Friendly	x	x	x
Inexpensive To Implement	x		x
Inexpensive to Maintain	x		
Not Reliant on Customer's Device		x	x
Customer Isn't Required To Have A Cart	x		
TOTAL	4	2	3

Table 4 is a breakdown of the pros and cons of each design idea. All of the design ideas are user friendly, but they differ in four major areas: cost to implement, cost to maintain, dependence on a customer to provide the technology, and flexibility.

Table 5 Total Cost To Implement Each Design Idea

Total Cost To Implement	
Idea 1	$ 30,754
Idea 2	$ 446,332
Idea 3	$ 52,342

Table 5 is the price overview for each design idea. The budget breakdown can be found in Appendix D. Design 'Idea 1' is the least expensive option by approximately $21,588; this assumes that the store implementing the design already has a basic application in available to customers. It would just require a few features to be added, such as, creating a customer identifier barcode, scanning barcodes, and searching for items if the barcode doesn't scan properly.

Design 'Idea 1' would be relatively easy to implement because it is just adding onto software and hardware that most major grocery retailers already have. Design 'Idea 2' would be easy to implement because it would only require a camera to be added to the cart. 'Idea 3' would require more resources to implement including changing out all the carts and dealing with theft and numerous maintenance issues. Design 'Idea 1' requires customers to bring a reliable cellphone that has data and a working camera, but design 'Idea 2' and 'Idea 3' are not dependent on a customer providing their own device. Design 'Idea 1' does not require a customer to have a cart because the customer can simply place their few items on the kiosk scale instead. Design 'Idea 2' and 'Idea 3' are not flexible and require a customer to have a cart.

1.7 Design Decision

Table 4 shows that design 'Idea 1' is the most economic and efficient design, making it the optimum design from the brainstormed ideas. 'Idea 1' is user friendly, inexpensive to implement, inexpensive to maintain, and has the flexibility of not requiring a customer to have a cart. The only negative of 'Idea 1' is that it would require a customer to provide their own cell phone that has data and a working camera. This design idea is not meant to eliminate other check-out processes, just provide customers the option to shorten their wait time. It isn't imperative for a customer to have a working cell phone to be able to shop at the store; those who do not have a working cell phone simply will not be able to use the scan-as-you-go, bag-as-you-go scale checkout design.

1.8 Problem Statement

Currently, the time it takes for a customer to go through the checkout line at a grocery store is much greater than necessary. In fact, 52% of the customers at grocery stores are unsatisfied with their wait time in the checkout line. With the technology available today, it would be easy to decrease that time. The bulk of the time spent in the checkout line is the time it takes for customers to scan their items. This design spreads the scanning time out over the entire shopping experience which decreases the customers perceived checkout process time and reduces the time each customer spends at the checkout kiosk.

Chapter 2: Literature Review

Chapter 2 includes many literature reviews that will provide an understanding of the existing research that surrounds the self-checkout process. The desire to optimize self-checkouts is not a new concept, but through literature reviews we can broaden our knowledge base, narrow the focus on the problem, and create a design that addresses issues in past design ideas.

2.1 A2Z Smart Technologies

Technological evolution is influencing every aspect of our lives including how we shop. Standing in long queues has become significantly detrimental to our time and productivity. In an article written by Borse et al. (2018), the authors argue that the fast-paced nature and lives that people are leading around the globe demand technology and interventions that are equally speedy and convenient. Technology is a powerful problem-solving tool in the world (Karjol et al. 2017). An ordinary shopping experience for customers encompasses picking items from the shelves, standing in the queue, and waiting for the cashiers to conduct the billing process. According to Li et al. (2017), smart shopping is more practical and very advantageous. Mirav (2021) reports that companies such as A2Z Smart Technologies Corp in Israel saw this challenge as a grand opportunity to develop a smart shopping cart and save on time. Another key player in the invention of smart shopping carts is Amazon. Basically, Amazon has been a great player in revolutionizing e-commerce shopping using technology (Borse et al. 2018). The idea of Dash Carts has placed Amazon on the global map as a core pioneer of hybrid items that make shopping experiences more convenient for the people (McFarland, 2019). Amazon has made a remarkable mark when it comes to technology utilization. For instance, the Dash Carts are usually equipped with cameras, built-in scale, smart display, and sensors to automatically detect the items picked during shopping. The Dash Cart is developed to utilize algorithms and sensors to automatically detect, identify, and tally the items placed on the cart. Payment is also faster since the Amazon account can be linked to the customer's Credit Card. An invention like Caper has particularly helped in making checkouts easier and fun (Constine, 2019). Caper is characterized by sensor fusion, machine learning, and artificial intelligence. In the article, Constine (2019) further explains that the use of Caper focuses on eradicating checkout lines and ensuring customers enjoyed a more familiar shopping experience.

The conventional methods of shopping have been long and exhausting. Clients have to spend time choosing products, looking at each product's information, making inquiries with the employees in the store, standing in the queues, having cashiers scan each product selectively, making payments, and then checking out (Suhas, & Prabhu, 2018). Such are the challenges that have led to the development of smart technology that addresses the challenges and seeks to improve the shopping experiences for customers (Karjol, et al. 2017). Countries like the United Arab Emirates have endured havoc in their shopping malls due to the increased population and market for products. The need for efficiency provided by smart shopping carts is what attracted them to the Israel smart shopping cart invention. Mirav (2021), reports that the US-brokered normalization agreement between Israel and the United Arab Emirates has been economically fruitful to both regions (Mirav, 2021). The cooperation has caused corporates like the Israel-based A2Z Smart Technologies Corp to develop smart shopping technology. In the article Mirav notes that numerous supermarkets in the UAE have expressed the need and urgency for the carts to resolve challenges in their malls. A smart shopping cart has now become a rather unconventional invention of the 21st century. The technology behind the creation of smart shopping carts focuses on enhancing the customer shopping experiences. Israel developed the cart to facilitate technological interaction with the clients and promote shopping efficiency. What started as an experimental burst has seen a country like Israel get amazing deals from United Arab Emirates' large supermarket chains. According to Mirav (2021), the cart has attracted deals worth hundreds of millions of dollars. The advantages associated with the smart shopping system are probably why the smart shopping cart developed by Israel is valued at NIS 20,000.

A2Z Smart Technologies Corp envisioned a shopping experience without any checkout. Mirav (2021), reports that A2Z Smart Technologies Corp has made bigger strides and remains a leader in marketing Israeli technology to other parts of the world. The A2Z Smart Technologies Corp developed cart is equipped with a barcode reader, touch screen, and weight at the bottom (Mirav, 2021). The cart is developed with a system that enables detection of the products placed inside during shopping with details of number, price, and type. The weight sensor at the bottom of the cart is connected to the control center in the store. The barcode capture details of the products selected then the products are displayed on the screen. If a customer has selected a product but wishes to return them to the shelves, then they can easily erase the product from the list on the cart's touch screen. Similarly, smart shopping carts are also applicable when shopping in grocery stores. Customers purchasing fruits have the option of selecting them from the cart's list on the touch screen, weighting, and placing them on the cart. Using smart shopping carts will be pivotal in reducing the employees' checkout period at the end of their shifts. In most companies, employees have to spend a lot of time during checkout as they account for their sales and billings. The market for smart shopping carts is very wide and timely. At such a time when the COVID-19 virus crippled all business and created the need for social distancing and lack of congestion, smart carts would have helped deliver quick shopping services with limited or no human contact. Standing on lines during shopping which potentially exposes most patients to the virus would be eradicated through the adoption of technology such as Caper. Caper like other smart shopping carts delivers flexibility and autonomous checkouts.

The main advantages for developing smart shopping carts are achieved through experiencing reduced customer wait-time, enhanced customer satisfaction, reduced need for cashiers, and increased profits with reduced expenses in the shops and businesses (Borse et al. 2018). Introducing smart shopping carts is a customer-oriented service that will extensively aid in eliminating the long queues and save on time. For the smart shopping experience, the customers select products from the shelves, the cart checks for the product information from the main server or the cloud, and then display the details on the touch screen (Karjol, et al. 2017). The details are inclusive of the cost of the product. This technology enhances informed decision-making. Based on the product details clients can make a quick decision on whether to take the product or select something else. In the article Constine (2019) illustrates just how much market players like Amazon are working hard to establish a shopping world that is entirely cashier-less. Wider adoption of the smart shopping cart technology will significantly eliminate the need for cashiers in shopping malls and stores. Embedded with the face recognition ability, the smart shopping carts can be developed to identify specific clients and access their shopping history to facilitate improved selection of products during shopping. The customers can use the cart to access the location of particular products in the shop. This is vital in saving time. The article further explains that after shopping the shopper will have the option to pay by inserting their cards on particular sections of the cart and checking out digitally without needing any help from the workforce. The carts can also be linked to a particular exit point that indicates an attempted exit with products that have not been billed.

There is massive room for innovations in the retail world. However, innovations such as smart shopping carts are giant strides that will not only help save on shopping time but will also enhance the customer experience. Li et al. (2017) explain coherently that the internet of all things (IoT) is one transformative tool that can be used to solve retail challenges by connecting all items in the store to establish a smart shopping system. The most important tool to develop is the server. The server should encompass details of all products before they are placed on the shelves. The server is then linked to the carts for easy access to vital information such as prices and the location of the products in the store. According to Suhas and Prabhu (2018), Zig Bee Adapters can be used to communicate with the server while weight sensors are utilized in weighing the purchased items (Vallabhuni et al. 2020). Moreover, the server can be used to update item prices to eliminate the time wasted writing the cost of each item (Suhas, & Prabhu, 2018). The advantage of the Zig-Bee network to the smart cart is that it is easy to use, monitor, and control. Constine (2019) recommends that startups can begin by developing a shopping cart with an in-built barcode scanner and a swiper for credit cards. The article further explains that the cart should be able to scan items automatically mainly using the weight sensor and recognition cameras (Constine (2019).

Quality microcontrollers are necessary to provide coordination of elements such as sensors, weight scanners, and touch screens. The demand for convenience and reduced workforce is an attractive aspect for entrepreneurs. Consequently, the demand will likely boost the growth of the smart shopping carts market around the world. Li et al. (2017) suggest that the IoT system can be applied to develop inexpensive radio frequency identification (RFID) tags that can be attached to products in the stores (Vallabhuni et al. 2020). These tags make it easier for the smart shopping carts to detect and identify the products automatically. This fulfills the core objective of developing smart shopping carts. The cart can conduct billing and eliminate the long waits experienced in stores that have not adopted such technology. Specifically, it helps in saving time, reduces checkout time, and eliminates the need for cashiers. As Li et al. (2017) highlight, smart cart shopping can be optimized in businesses that adopt smart shelving. Also, Vallabhuni et al. (2020) suggest that the RFID tags make inventory management easier by keeping an automatic and current record of the product stocks on the shelves. Smart shopping systems will make it easier for businesses to automatically know which products to restock with the list of the available decreasing products visible on the server. In the conventional shopping system, the employees would need to walk around checking and noting down the products that need restocking.

This era represents an essential transformational milestone in the adoption and application of the Internet of Things (IoT). The contemporary shopper hare very high demands unlike the conventional ones (Borse et al. 2018). Businesses need to prioritize the customer experiences by incorporating technologies that make shopping quicker and more efficient (Karjol et al. 2017). The changes will impact retail challenges that are associated with communication, billing, inventory management, data management, advertising, and real-time decision making. Suhas and Prabhu (2018) encourage the need for developers of technologies such as smart shopping carts to build prototypes and test their functions as a crucial part of the development process. In developing smart shopping carts, it is important to conduct tests to ascertain the functionality and efficiency of the cart. For instance, the cart should not detect products that have been returned to the shelves or those outside the cart as the customer walks around shopping. Other vital aspects during the development process are a secure communication protocol, evaluation of the performance, and security analysis. Borse et al. (2018) use the article to explain that the incorporation of the RFID technology, Zig-Bee technology, and the Gossamer protocols not only ensure that the shopping experience is smart, instead enhances the security features of the system. During checkout, a scanner on the carts can also be used to automatically raise alarms and indicate if payments have not been processed. This can help eliminate theft and shoplifting tendencies among the customer population (Karjol et al. 2017). Generally, the smart shopping system will guarantee clients better shopping experiences and customer satisfaction (McFarland, 2019). There is a demand for more innovations and the development of smart carts. Large stores such as Whole Foods would largely benefit by adopting smart shopping carts such as Caper or those developed by A2Z Smart Technologies Corp.

In future research, it is recommendable that researchers can focus on studying methods of enhancing the security aspects of smart shopping systems. Security is a serious technological risk. Therefore, firms must also commit to maintenance and consistent risk assessments to inhibit the adverse effects that could impact the retail industry if the smart shopping system failed. Higher efficiency is vital in enhancing computational abilities and ensuring sustainable improvements to the smart shopping system. Questions still lag on the number of items a full cart can process without making errors. These questions the efficiency of the sensors and the checkout lanes. Regardless, innovation is a continuous process that entails solving more problems as they arise to eventually develop the best smart shopping cart for the market.

2.2 How Current Self Checkouts Work

In order to improve a problem, the current baseline or process must be acknowledged and understood. The current process could offer excellent insights on what to improve and how to improve it. Also, it will show pitfalls and will aid in ensuring the same mistakes are not made again.

The article begins with explaining the bagging and scanning procedures. Essentially, this is the most complex part of the entire process. During the scanning and bagging process, multiple steps and processes must be completed simultaneously. When an item is scanned, the checkout system must sort through every item in the store's database to find the information for this specific item. The main two pieces of information that is pulled is: the price and the item weight. Every item must be removed from the cart, scanned, and then placed in the baggage area.

Once an item is scanned, it must then be placed in the baggage area. If the customer fails to place the item in the baggage area, a soft error message will play and show on screen asking the customer to put the item in the baggage area. This error message may also prompt the nearby employee to check on the customer and ensure no major issues have arisen. If no major error happened, a reweigh will happen and the customer can proceed to checkout. The system walks the customer through a variety of checkout options. Once payment is finished, the customer takes their receipt and bags and leaves the store.

From understanding the current self-checkout process, we can then try and eliminate some steps to streamline the process. Comparing the potential solutions to this article, the proposed solutions hope to eliminate the need to remove the item from the shopping cart, scan it, and then place it in the bagging area. The main importance of the article though is to show that the UPC code contains all the information and could help our project with the weighing addition.

2.3 How Trucking Scales Work

When looking at the proposed solutions, the trucking weight scales are comparable to the primary solution. The primary solution being referred is the idea to roll the shopping cart onto a scale and measure the weight as a whole. Both concepts are very similar so the established trucking scale should be able to be used as a comparable process. In order to compare a process though, a process must be understood. This article breaks down the basics of the trucking scale.

To begin, the way a truck is measured on a scale can be broken down into two different types of measurements, axle or gross weight. An axle weight scale calculates the amount of weight per axle. Then it can be totaled as a whole or shown separately to show and help with trailer weight distribution. The gross weight scale measures the gross weight of the trailer as a whole.

Regardless of the type of scale, the scales are designed to handle massive amounts of weight and abuse. Manufactures also design them for long term use and apply warranties to their scales for up to 25 years. The scales can be manufactured out of concrete, steel, or both can be used in most cases.

As for the technology within the scales, several different types exist. The three most common types are the load cell system, Piezoelectric system, and the bending-plate system. The load cell system, most widely used, consists of steel or concrete with a device called a strain gauge attached to or placed within it. The strain gauge is made of a wire or wires that emit a pulse or signal that represents the change in the wire. The change being if the wire is compressed or altered. The wires can either be compressed or tension based so the wires can be stretched or compressed to signal that change. The pulse goes to a junction box that then alters the signal to a measure of mass.

The bending plate system has strain gauges that are attached to a metal plate. As weight is applied, the plate undergoes an amount of stress proportional to the object applying the stress. The amount of stress per gauge is then added together to get a total amount. The Piezoelectric consists of multiple piezoelectric sensors that are placed into conducting material. When pressure is applied, the weight alters the flow of the voltage going through the conductor. The load or mass of the object applying the pressure is calculated from the change of the voltage. From there, the amounts are added together to get the total weight.

In conclusion, the primary solution and the trucking scale can be seen as closely related. If the same principles of the trucking scales are applied to our project, except on a smaller scale, then it should guarantee that the primary solution would work. In the least, it is an excellence benchmark that the scales can compare to or go off of.

2.4 Smart Grocery Carts Coming to Change The Way We Shop

Necessity is indeed the mother of invention. The evolution of the retail industry and the technological advancement of this century have been instrumental in the invention and development of tools that improve autonomous shopping. In 2018, Amazon made tremendous steps in revolutionizing retail by opening the Amazon Go convenience stores (Bandoim, 2020). On Amazon Go, the retailer used cameras and QR codes to enhance the shopping experience and save time (Bandoim, 2020). Further progress led to the development of the Dash Carts which sort to make the shopping experience even better. Amazon is one of the key retailers that have identified the need to transform autonomous retail systems (Bandoim, 2020). Other retailers such as Kroger have been engaging in partnerships with brands such as Caper to enhance the shopping experiences by developing smart grocery carts (Price, 2021). Although smart shopping carts are more expensive to develop, their efficiency, safety, and cost-saving effects are vital in modern-day retailing.

According to Price (2021), the pressure of the rapidly changing era is the reason retailers have been actively involved in research to eliminate the traditional checkout lines by the introduction of smart shopping carts. Retail has seen major inventions especially with the introduction of QueueHop which provided mobile self-checkout solutions (Up!, 2019). The technology was among the first solutions to promote shopping safety since it was fitted with the anti-theft tag that only unlocks once the payment transactions for the shopping are completed (Up!, 2019). The radio-frequency identification is also important in detecting products added into the cart and in indicating the user interface information (Chiang et al. 2016). The article further suggests the need for the cart to have the search option. This option can provide details such as the cost of the item and the location inside the mall. It is advantageous in promoting navigation and facilitating efficiency. Chiang et al. (2016) highlight the advantage of incorporating smart shopping carts fitted with an efficient user interface as a strategy to promote the shopping service.

The core features in the Caper autonomous shopping care comprise item identification using image recognition and a weight sensor (Price, 2021). A study conducted by Wang and Yang (2016) illustrates the need to ensure the shopping carts are fitted with sensors to detect client behaviors and respond to their needs based on the feedback in real-time (Gangwal, 2013). It is important that the sensor-based smart cart is lightweight and simple to deploy. Smart shopping carts can be effectively used by the retailer to enhance sales promotion (Wang, & Yang, 2016). For instance, the data from the cart can be used to identify the products that most customers have an interest in and boost the clients' purchasing desire through introducing offers or discounts.

Smart shopping carts save people the fatigue and misunderstandings that could potentially occur as a result of waiting on the queues for billing by the cashiers. Price, (2021) recommends that carts should also be linked to the main store server to provide details on the products. The smart system speeds the process and enhances productivity within the facility (Machhirke et al. 2017). Smart shopping carts also impact the experiences of the staff members by giving them easier checkout times after their shifts. Initially, employees would need to conduct manual calculations of their sales and money before the end of their shifts. With computation, the system can make the shopping experiences more efficient and time-sensitive.

The internet of all things is gradually transforming the world through aiding better connections of technologies (Li et al. 2017). The smart shopping carts are designed with a built-in barcode scanner, equipped with a scale, and computer abilities to automatically weigh, scan, and tally the items in the shopping cart (Gangwal, 2013). The radio frequency identification tag is added to the products in the retail store for ear identification by the cart sensor when placed inside. The sensor can also be able to retrieve crucial details on the product including the cost information. Li et al. (2017) emphasize the need for the retailers to have smart shelving to assist in monitoring the stock and updating the number of items remaining to the main server. This is important in facilitating restocking to prevent shortages.

The RFID readers can be placed on the shelves for the acquisition of the aforementioned details. Instead of using barcodes, the use of scanners and RFID tags is more efficient but costly. The benefit of this technology is that it facilitates improved management of the inventory management systems (Price, 2021). A credit card swiper is effective in enhancing transactions and payment for the goods purchased (Gangwal, 2013). Clients can use the swiper that is card-reading enabled to scan their loyalty reward cards and pay automatically. Caper's shopping cart ensures that the customer receives an email on the payment receipt after the shopping transactions are completed. A retailer like Amazon has been consistent in maintaining the tradition of improving cashless retailing Price, 2021). Chiang et al. (2016) highlight the essence of automatic billing services and cloud saving information for easy retrieval and safety.

The adoption and demand for smart shopping carts have been progressing rapidly due to technological suitability in the retail industry. The retail autonomous devices promote wireless sensor networks with computing features to make the technology suitable. For instance, Kroger's smart shopping carts are equipped with a touch screen to assist the shopper in accessing the shopping lists, product details, promotional offers, and available discounts. To inhibit any interference with the smart cart's scale and camera during tallying and weighing of the items, a retailer like Kroger provides a front basket where customers can place their wallets, phones, or purses. An effective smart shopping cart should be energy-saving, cost-effective, and environmental sensing abilities. Investing in an efficient smart communication system ensures that even when the store has many clients, the system remains fast and effective due to the stability of the communication gridlock (Gangwal et al. 2013).

A shopping experience without smart shopping options requires a lot of time and patience especially in retail stores that attract many clients. Weekends and holidays are hectic and tedious and the cashiers attend to each client a factor that contributes to the long unending lines. Clients in retailers such as Walmart would experience frustrations standing on queues considering the high population of clients (Karjol et al. 2017). The retail industry has been undergoing automation to resolve such challenges and ensure the shopping experiences and cost-effective and reasonable. Karjol et al. (2017) explain that the smart features added to smart shopping carts are fundamental in saving time and making shopping easier.

The smart shopping cart also revolutionizes payment processes during shopping. According to Price (2021), customers have to use their debit or credit cards as the smart shopping carts cannot read payment in cash. The concept of smart shopping carts should ensure they are technologically oriented, scalable, and economical (Ali, & Sonkusare, 2014). The impact of the COVID-19 pandemic has emphasized the need for smart shopping cards to enhance safer shopping. Moreover, the use of credit or debit cards has enhanced safety by ensuing payment is touch-less. Sarwar et al. (2020) explain that the advantage of the self-checkout system is that it reduces costs and speeds the clients' purchasing process by avoiding long queues.

Megalingam et al. (2019) denote the extraordinary nature of android applications. The article highlights ways in which mankind has utilized technology to develop and find solutions to life problems. Long lines are among some of the issues that have affected the retail industry. In populated areas, these stores have had to hire large human resource teams to attend to the customers. The long and crowded shopping makes shopping a pain-striking and tiring experience. The solution to the inconvenience of the long lines during shopping is technologically centered in order to resolve the dilemmas and boost the shopping experiences (Gangwal, 2013). Research indicates the fact that there has been an urgent need for retailers to remain in consistent-efforts to improve customer experiences through innovation and adoption of new technologies. The automated shopping carts were developed as a result of the need to advance retailing. Moreover, they impact customer experiences by eliminating the need for cashiers and using human resources to assist the shoppers as they select and trace items in the store. The use of cashiers in the billing system is a very expensive option. Further, the use of the carts allows for the human resources time to stock the shelves and boost the retailer’s profits.

Smart shopping carts are significant in facilitating interactions with customers and providing efficient shopping services to the customer population (Chiang et al. 2016). The smart carts collect data from the shopping experiences which are vital in influencing shopping behavior. Using the data collected, retailers can analyze the products that require more stocking, products that require discounts to attract shoppers, and the sections that customers focus on the most. This information is valuable in arranging products within the facility and in enhancing accessibility by the customers. Sarawar et al. (2020), indicates the fact that smart shopping carts are essential in providing clients with speedy checkouts especially because they do not need the help of the staff members or to wait in the long queues (Sarawar et al. 2020). The responsibility of the staff members should be reserved for monitoring the self-checkout processes lowering labor costs. They can also help in case the system suspects any discrepancy that could potentially affect the check-out process of the paper.

An article by Ali and Sonkusare (2014) demystifies the impact of electronic commerce with the rise of wireless technologies and other communication inventions. Big malls and retailers usually attract a large number of shoppers that easily cause traffic and long queues. The process of selecting the items and queuing for the billing can be tedious, time-consuming, and exhausting. Smart shopping carts are characterized by convenience and efficiency (Ali, & Sonkusare, 2014). The aim of every retailer should be on remaining innovative and embracing innovative ideas to help each customer spend less time shopping but achieve a positive shopping experience. The RFID code system is suitable for facilitating the identification of every product; the product's information can be saved on the EEPROM and communicated using the Zigbee module for automated billing (Wang, & Yang, 2016). ZigBee is an alternative to a barcode reader, cost-effective, and effective in providing product information broadcasting.

One of the disadvantages of technology advancement is the risks of malfunctioning. The possibility of malfunctioning is highly eminent as automation is also characterized by its unique challenges. In an article written by Up! (2019), the author recommends the need to ensure the store's security system is linked with the shopping carts to easily detect potential cases of shoplifting. Smart shopping carts inhibit deception by the customers through automatic billing and smart checkout procedures. Alternatively, retailers can consider the use of camera systems monitored by the staff members. Human resources can also be used to guarantee continued shopping in case the smart shopping system malfunctions. Retailers need to engage in further research to make modifications to address the evolving needs of the shoppers. The self-checkout systems are expensive to develop and maintain (Sarawar et al. 2020). The hardware required in developing the smart shopping carts comprises smart cameras, sensors, RFID, and scanners which are expensive to purchase and maintain.

It is important that the smart shopping system does not only provide solutions to retailing services but instead handle issues that develop as a result of the automation process. For instance, the developers ought to account for the possibility of malfunction and other issues such as energy consumption for the carts. Preferably, innovators such as Caper have mastered the need to develop prototypes of the smart shopping systems and testing them to ascertain functionality and security protocols to make the system practical (Li et al. 2017). Further research is equally important to enhance decision-making and ensure retailing shopping is customer-oriented. As the world develops, innovation remains vital in sustaining the smart shopping systems and in solving the retail shopping challenges. As Machhirke et al. (2017) explain, with the internet of all things, it is imperative for retailers to partner with innovators and develops convention shopping systems that suit the conventional customer's expectations.

2.5 Amazon's new smart shopping cart lets you check out without a cashier

Amazon is one of if not the leading company in the world working towards automation and technologically advanced workplaces. Early on they innovatively created and optimized their own warehouse robots that helped itemize and randomize its products to ensure easier packaging.

They have followed others in the efforts to “Go Green” by investing in electric vehicles to distribute their merchandise. Now, they have created the “Dash Cart” (Statt, 2020) that you will see in some of their local Whole Foods who they have partnered with to test out their newest innovation.

As mentioned above, Amazon has set the bar high with many of their processes and products. The smart cart is up to par with some of the other innovative creations in their past. Amazon had already partnered with many Whole Foods in the California area and attempted to pilot test their newest product. The trial went better than they could have expected. Much like the decision behind our team’s model, we were unsure of all the extra benefits when we began running with the idea. The need to be touch free and not have to interact with anything other than the cart was a benefit in the COVID era. We believe, as I'm sure Amazon does too, that this will continue to be a benefit for the customers that do not wish to interact with the employee.

While reading Amazon's release, it seems that some of the ongoing issues with their product is something we will have to take into consideration. As told in the article the Dash Cart is having trouble processing more than a few items, “So the device can handle up to about two bags of items, but it can’t do a full cart quite yet.” (Statt,2020). This is a concern that our team has hurdled by not utilizing a camera system inside the cart. We decided to use a scan as you go approach to get around the camera identifying items individually. Our scale process is a large part of standard deviation calculation at the end to ensure all products have been scanned and paid for. In the article, Nick Statt mentions the importance of the scale and camera combination for accuracy.

In conclusion, the Amazon Dash Cart is still a brilliant piece of technology that Amazon will continue to refine until it becomes commonplace in many of their stores and in others around the US. Our team will use some of the points made in this article to identify roadblocks and other situations that can be avoided. The most crucial point is that this idea is possible! The innovations of this generation will continue to amaze, inspire, and hopefully shape a new better future for us all.

2.6 **Smart shopping carts on the rise as stores adapt to pandemic era**

The ongoing COVID-19 Pandemic has provided the world with many contemporary issues that were unexpected much like the pandemic itself. The need to be cautious about space between individuals as well as the push for no customer interaction was something new that the pandemic arose in the retail consumer base. Our nation scrambled to stores in search of hand sanitizer and other cleaning items to ensure we were all prepared in case of close contact with the Virus. Among this long stint of trying to get back to a place where we can feel comfortable again, there have been a few innovative ideas that may help with the progression of normalcy.

Like many other retail companies, our idea was to create a different shopper experience in the grocery store market by innovating the general shopping cart. While this idea arose from a team of four students discussing ongoing issues during the pandemic, many large-scale companies were lightyears ahead of us. In an article written by the 'Washington Post', they outline one of the leaders in this retail base that has been successful in their Smart Cart technology. This company is Kroger, and they have partnered with an AI company called Caper. The two companies have created a Smart Cart that has blown others out of the water by many standpoints. One of the many differences between the Kroger smart cart and other companies is outlined in the article "Amazon's smart carts require customers to download the company's e-commerce app to their personal smartphone, while Caper's version does not require an app." (Brown, 2021). Much like our idea to provide the customer base with an application, the Amazon

'Dash Cart' will do the same thing. This can be a positive, but the Caper introduced Smart Cart has less issues with identifying items as well as less startup cost used to create the application and sync it with each provider's product base.

Lastly, the main take away from this article has been the benefits that it will provide the consumers from a COVID safe shopping experience. Something that we took into consideration when deciding what to design for our final project. These hands free and no contact with employee experience is something that will be beneficial not only now but, in the future, as well. The new practices of becoming more sanitary are here to stay, and retailers having the choice to provide their customers with a more sanitary experience will be beneficial. The other major benefit that our group will take away from this article is the advertisement availability for the carts. As said in the 'Washington Post' article "Caper says most of its smart cart partners recoup their investment within a year." (Brown, 2021). These advertisements through the smart cart applications or touch screens will provide the retailers with some opportunities to regain their investments.

2.7 Why Should Grocery Stores Embrace the Mobile App?

The rise of technology in everyday life is very apparent. As technology continues to advance, big name companies begin using these tech companies as a useful resource to give them any competitive edge. Companies like Amazon, Nike, Kroger, and many more have developed or outsourced different technological products or processes to provide their consumer bases with easy access to their merchandise. In the grocery store market alone, there have been many technological advances that provide the customer with easier access or some method of creating the purchasing experience better.

In the article written by Prismetric Technologies (Top of the line Mobile App developer) states “Not so long back, it was unimaginable to find out which nearby grocery store has all the items you need as you step inside the store the discounts or offers will be in the palm of your hands “(2017). Which is a valid point! Even in 2017, looking at where things are now in the year 2021 the advances of technology from then to now are unbelievable. The power that we as the consumer base have at the tip of our fingers is something that these grocery store retailers need to consider. By creating an application to connect with our smart cart technology, we are providing the retailers the opportunity to connect with their customer base. The application will provide users with easy and fast checkout, as well as advertisements and suggestions.

In conclusion, technology is a power that all businesses need to be taking into consideration. Our technology and application will provide return profits for the retailer and provide the consumer with a much faster checkout process. One of the biggest complaints for grocery store customers is the long wait to checkout. Our application solves that problem and many more.

Chapter 3: Solution Overview

Chapter 3 will provide a complete description of the new checkout process design. It will include the process the customer goes through with this new design, a visual aid of the kiosk layout, how each roadblock in the process is resolved, the functional and nonfunctional requirements, the timeline, and the budget of the design.

3.1 Problem Solving Approach

We looked at the breakdown of the current self-checkout process and found the most time consuming steps: scanning and bagging items. Several steps need to be added to the current self-checkout process to reduce the time it takes to scan and bag items at the self-checkout, thus reducing customer wait time and increase customer satisfaction while keeping the process efficient and economical.

The new design process will start with a sign at the entrance of the store with a brief description of the scan-as-you-go with scale design and QR code to download the application. The sign will also mention to the customer to grab a bagging rack so they can bag as they go, and a cellphone clip for ease the process on scanning items as they go. There will be a stack of bagging racks and cellphone clips at the entrance. Using the application, customers scan groceries as they pick them up and bag them as they put the items into their carts. When the customer is finished shopping, the kiosk will ask the customer if they scanned their items as they shopped. If yes, the kiosk will prompt the customer to scan their customer ID from their phone within the store's mobile application. Then, the customer will be prompted to remove the bagging rack and cellphone clip so it does not interfere with the weighing process. The customer then will be prompted to roll their cart completely onto the floor scale. The kiosk will ask the customer to weigh the non-barcoded produce on the kiosk scale separately, then add those produce items back to the cart. The scale would sum the weights of all barcoded items, then subtract out the weight of the previously weighed non-barcoded produce items and the cart itself. When the scale confirms, to a specified standard deviation, that the weight of all the items in the cart adds up to the total weight of all items scanned plus non-barcoded produce, the customer will be prompted to pay and exit the checkout.

Figure 1 *Self-Checkout Layout with Scale and Bagging Rack Return*

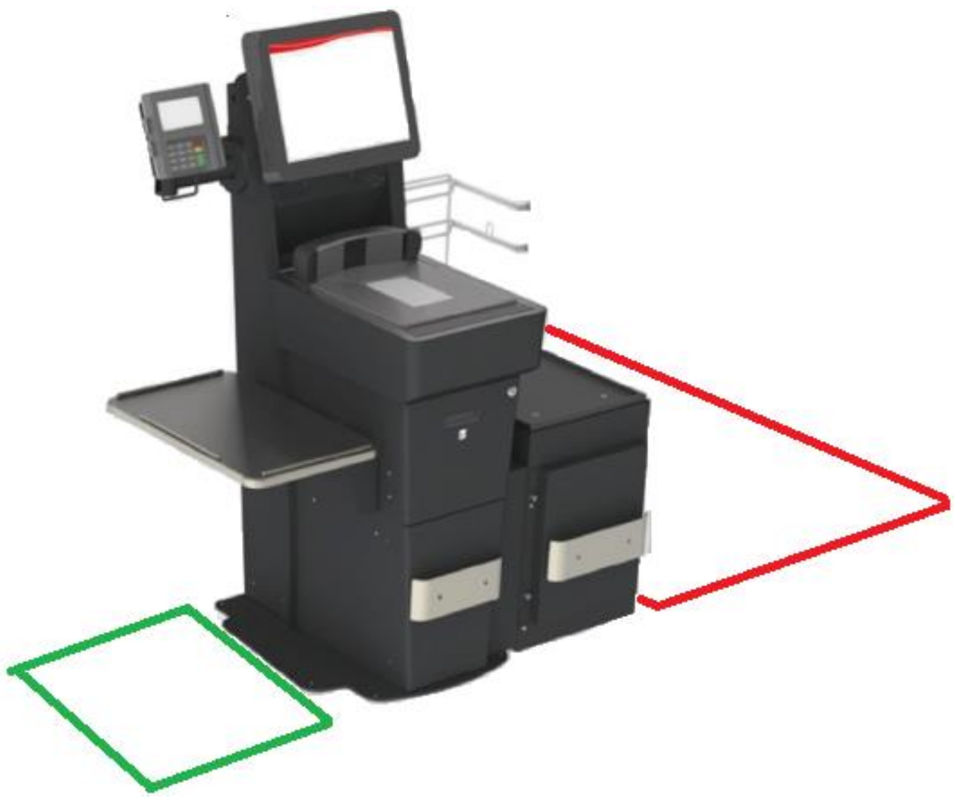


Figure 1 shows the typical self-checkout kiosk. The new design includes the kiosk, but it also adds the floor scale (red box), the bagging rack return (green box), and the cellphone clip return (green box).

Disclaimer:

This design can be used in any major food retailer environment that already has a self-checkout system in place. It requires customers to have their own smartphone, so it is not recommended to have this be the only form of checkout system for customers. This will simply make the self-checkout faster for customers who choose to utilize it.

Every food retailer uses different suppliers, store layouts, and technology; so, this design is not a one size fits all solution. It will provide a blueprint to connect all physical and theoretical parts of the design, as well as research to support each connection and concept. A time study was conducted to determine the time the new design reduces customer checkout time, and a survey was conducted to capture the voice of the customer.

3.2 Potential and Actual Roadblocks

3.2.a Design Roadblocks

Roadblock: Incorporating the weight system into the self-checkout

Solution: Incorporate practices used in the standard self-checkout process. Items weight will be linked to the UPC. When scanned with the customer's mobile application, the item's weight to a specified standard deviation will be drawn from the stored UPC data and added to the total weight of the cart.

Roadblock: Maintaining Scales

Solution: The scales will be placed in a standard maintenance routine that would include calibration, minor repairs, and other needed maintenance. Truck stop scales and maintenance routines can be observed to see common practices.

Roadblock: Lifespan

Solution: To increase lifespan, ensure scale is in bordered area that will only be used for weighing purposes. Limit excessive foot traffic on scales. Do not expose scales to the elements. Use sturdy and resilient equipment in making the scales.

Implementation: Ensure the quality of the scale by know the suppliers reputation and inspecting it upon arrival.

Roadblock: Application Development

Solution: Follow similar applications in the market. Benchmark new application to previous applications already released. Alternatively, partner with applications that are already in the market. Applications, such as Scandit, exist and are used by large retailers.

Implementation: Refer to the Chapter 3 Budget section for a breakdown of design specific features required in the mobile application. Refer to Appendix D for a breakdown of building the application from scratch.

Roadblock: Does the population wish for a new system?

Solution: Conduct a survey to determine population’s thoughts. Sample different areas to diversify results. Forums and additional research suggest that certain populations are disgruntled with current self-checkouts and wish for alternative solutions.

Implementation: Through a customer survey it is determined that 52% of grocery store customers are unhappy with their wait time at checkout. It would be recommended to conduct a further survey to get customers opinion of the design idea and their questions/concerns.

Roadblock: Where does the customer bag their groceries?

Solutions: Promote bagging as you shop. Customers would have the option to bring cloth bags into the store and bag items as they shop. Also, attach small bag dispenser on the shopping cart for quick and easy access to plastic bags. This would further promote the bag as you go approach.

Implementation: Place a stack of bag racks at the entrance next to the carts. Place a sign with a simple explanation of its purpose. Have customers who choose to use the ‘scan as you go’ option hook a bag rack on their cart. At checkout, before the scale weighs the cart, have the kiosk ask the customer to remove the bagging rack to insure proper weight of the cart.

Roadblock: How to deal with produce that needs to weigh individually?

Solutions: Provide an electronic scale to weigh produce at time of picking with scannable code to update phone. Alternatively, provide a scale a checkout area to allow the weighing of produce. Item would be keyed in and weight would be automatically added to customer cart in mobile application.

Implementation: The kiosk subtracts out the weight of each individually weighed produce item from the total weight of the cart.

Roadblock: What if the produce sticker fall off the produce?

Solution: The search feature in the mobile application will make it easy for a customer to search for the item. It would also be recommended to put a barcode on the rack where the items are stored in the grocery store, so the customer can scan that barcode.

Implementation: Add barcode stickers to every item price tag in the store. Add a search feature to the mobile application for it the barcode is missing, damaged, or will not scan.

Roadblock: Checkout Area

Solution: Draft layout of proposed checkout area. Create a streamlined approach that allows easy access and departure. Place the weighing station next to the cart to reduce foot traffic on the scale and to have a safe area to weigh the cart without disruptions.

Roadblock: Checkout Flow

Solution: Focus will be to streamline process in simplest and easiest way for the customer. Base process will be as followed; approach checkout area, roll cart on to the scale, sign into the kiosk, weigh produce if needed, the scale will weigh the cart, pay, and then roll the cart and leave.

Roadblock: Pay with Cash Option

Solution: Provide a cash option within the self-checkout area. This may be potentially added to produce weighing area, if produce weigh station is chosen to be at checkout. Alternatively, have this checkout form as a strict pay with application or “touchless” payment.

Roadblock: Weight of Cart

Solution: The average weight of the cart will be deducted from the total weight of the checkout weight. A higher-quality of cart with less deviation to weight may be required for more accurate result.

Roadblock: Standard Deviation

Solution: Standard deviation will need to be calculated for shopping carts, weight as weight increases, and item variance. This will be required for more accurate results. Alternatively, allow a specific tolerance per item and cart that will be totaled.

Roadblock: What happens if the cart’s weight is off?

Solution: Have a soft error message go off. Ask the customer to ensure no items in the shopping cart are moving around then step away from the shopping cart. If weight is off again, have another soft error message ask the customer to check their shopping cart to ensure all items have been scanned into the system. Alternatively, the checkout system could display and state how much the cart is over or under weight by. If all fails, an employee will need to assist the customer.

Roadblock: Implementation into stores

Solution: A slow implementation may be recommended at first. Install the checkout system into a select few test stores. Collect data from test stores and look for ways to improve.

3.2.b Project Roadblocks

Roadblock: Improper Data Collection

Solution: Standardize data collecting practices or techniques. Ensure, all participants measure time studies and analyze time studies the same.

Implementation: Prior to taking time measurements, the group discussed the appropriate means to collect data. A standardize method was established and all participants collect data in the same routing to ensure accurate measurements.

Roadblock: Unable to create physical prototypes for potential solutions

Solution: Create a lifelike simulation of solution in the Arena Simulation module. Act out proposed solution with proper estimation of times from research while conducting a time study. Create CAD drawings to show product specifics and physical portions.

Implementation: To battle to inability to physically create a prototype, the group took two courses of action. An Arena simulation was created to simulate how their proposed solution would look and act in a real-life grocery story. Second, an in-person simulation was conducted with mock props to gain an estimate of time it would take to checkout without solution.

Roadblock: Arena model issues/ Lack of knowledge with Arena

Solution: Assign the correct personnel to work with work with the Arena Simulator. Create a network of professionals or resources to overcome issues. Pertaining to this project, the main source will be Doctor Kyser. Backup sources will include lectures and teachings from previous courses. The Arena help tabs, videos, and documents. Also, past simulations will be used and referenced, if required, to aid.

Roadblock: Team communication

Solution: Create a chat group in the application GroupMe for quick communication with the entire team. Set up static meetings each week where the team meets in Microsoft Teams in a conference call. During the conference call, tasks will be assigned, individual projects will be reviewed, questions will be asked, and all team members will be required to arrive at the meeting prepared.

Roadblock: Teammates not following through with task

Solution: Individual and group tasks will be discussed in weekly meetings. Positive encouragement to complete tasks will be used. Furthermore, assign tasks equally and fairly to promote higher morale so tasks are completed. All documents will be uploaded into Microsoft Teams so all members can track other members' progress.

Roadblock: Store locations not wanting to allow time studies or surveys done within them.

Solution: Prior to taking data, request to speak to the store manager or person in charge. Explain our project and ask politely if we can gather data. If they decline, go to another location and repeat the process.

Roadblock: Overlooking small details

Solution: Prior to performing any task, the details of the task and how to carry it out should be discussed with the team. This allows different perspectives and viewpoints. The chance of overlooking smaller or minute details will be decreased, and accuracy will be increased.

Roadblock: Time management

Solution: Overall time management will fall into the Project Manager's scope. The Project Manager will be in charge of creating and updating the Gantt Chart for the process. The Gantt chart will be readily available for all members to follow. Secondly, each team member will be responsible for completing their assigned tasks within their time frames.

Roadblock: Job roles and assigned tasks

Solution: To ensure no person is assigned with an improper task or a task one cannot complete, strengths and weakness will be discussed by each team member. Task and project roles will be assigned in regard to an individual's strengths. If a task is increasingly difficult, more than one individual may be assigned to that task to increase success odds.

3.3 Requirements

3.3.a Functional Requirements

1. An application design that can:
    a. Be downloaded on personal cellphones
    b. Pull barcode data from the stores server
    c. Pull item weights based on barcode data
    d. Create a customer cart and assign a customer identifier
    e. Connect to the phone camera
    f. Convert pictures of the barcodes to data
    g. Connect the data from the picture to the barcode data from the server
2. A floor scale that allows customer to push their cart onto it without lifting the cart and accurately weigh to a specified standard deviation.

3.3.b Nonfunctional Requirements

1. A kiosk that prompts customers for each step verbally and visually
2. Removable grocery bag holder for cart, so customer can bag as they go
3. Product identification code stickers (not UPCs) that can be scanned on kiosk for produce items that have to be weighed so customer doesn't have to look up produce in system. They simply scan the sticker, weigh the produce item, and place it back in the cart.
4. A cellphone holder that makes it easier for customers to scan their items as they go.

3.4 Gantt Chart

Chart 1 Design Flowchart

Optimize Checkout Process		
Alp Katranci, Daniel Garza, Matthew Ritchie, Tiana Longino		
ACTIVITY	PLAN START	PLAN DURATION
Solidify Direction and Project	12-Jan	3
Determine Roles	12-Jan	6
Brainstorm Possible Solutions	12-Jan	6
Create Pictoral Representation	15-Jan	10
Create Basic Budget Layout	15-Jan	10
Write IDR	17-Jan	8

Chart 1 is the Gantt chart for the project. To help it fit in this document, only the date and tasks for the CDR have been displayed. This is an excel spreadsheet that contains our entire schedule for the project.

3.5 Design Overview Flow Chart

Figure 2 Design Flowchart

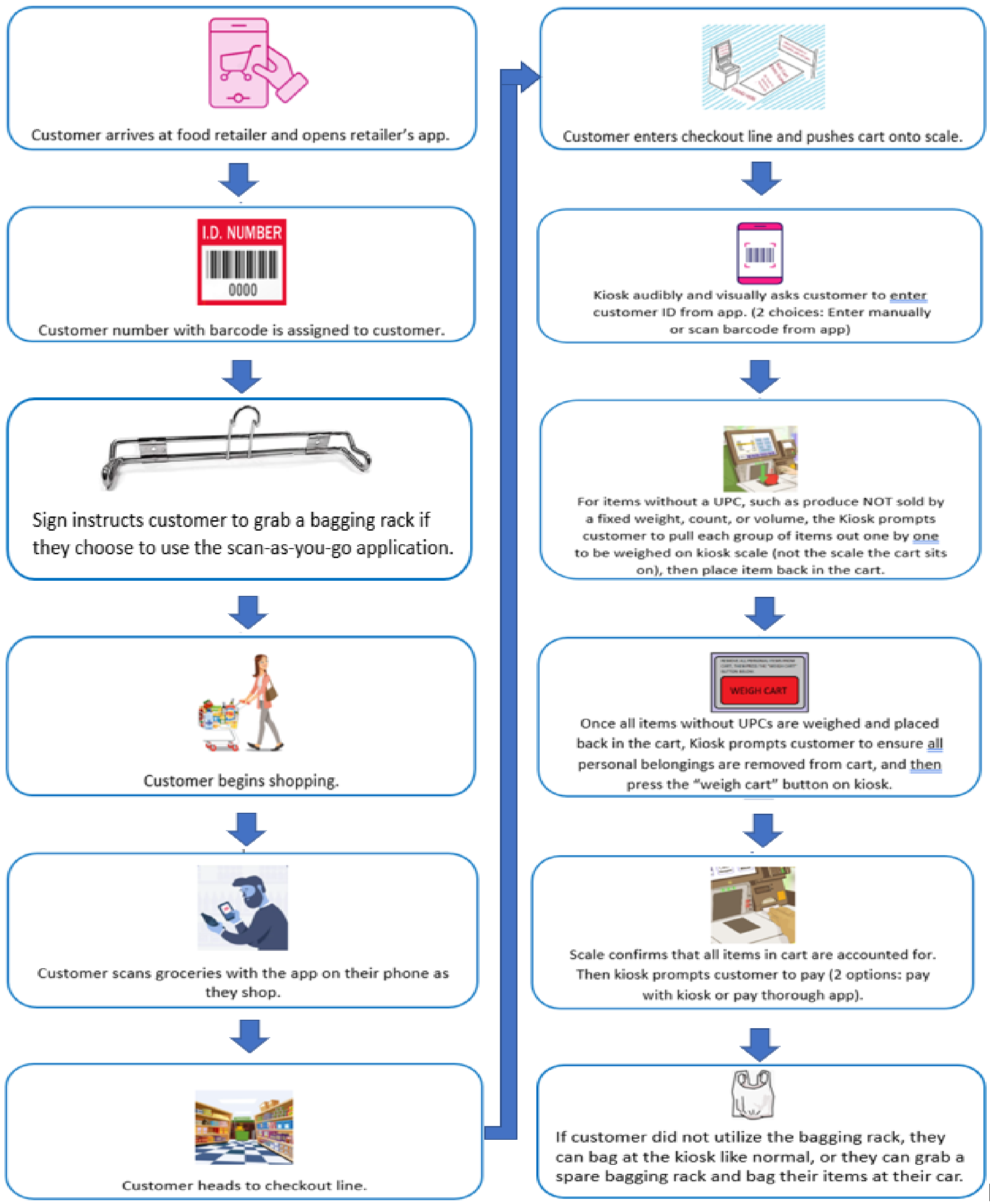


Figure 2 shows the process the customer goes through with this new design. A further explanation of this process can be found in section 3.1.

3.6 Budget

Table 6 Budget for Design Idea 1

Application			
Feature	**Description**	**Approx. Time**	**Approx. Cost**
Customer ID (QR code)	Developing QR Code for customer ID recognition at	75 hours	$6,000
Camera Identifying Barcode	Camera can convert a barcode and identify item	140 hours	$11,000
Ability to Search Items	Feature to search items if items won't scan or missing a barcode	20 hours	$1,600
Scale			
Item		**Approx. Cost**	
Deck Plate		145 $	
Stainless Steel Junction Box		195 $	
Digital Weight Indicator With LED screen		225 $	
Load Cell		115 $	
Retractile Cord (5ft)		85 $	
Load Cable with 4 wires		50 $	
Microcontroller Unit		24 $	
Amplifier		15 $	
Construction			
Job	**Description**	**Approx. Time**	**Approx. Cost**
Construction Manager	Coordinating the project, $55/hr.	7 hours	$385
Construction worker	Performing the physical work, $15.53/hr.	7 hours	$108
Electrician	Wiring the scale cables, $19/hr.	3 hours	$57
Additional			
Item	**Quantity**	**Cost Per Item**	**Approx. Cost**
Bagging Rack	250	$28	$7,000
Phone Holding Clip Attachment	250	$15	$3,750

Table 6 breaks down the cost of implementing this design into a grocery store. This table assumes the store already has an application (most do). If it does not already have an application, refer to Appendix D for a breakdown of the cost for building an entire application for this design. The table is broken down into the cost to add design specific features to the store's current application ($18,600), the cost of the scale ($854), the cost of construction ($550), and the cost of the additional features ($10750). Under the assumption that a store would want four of these types of checkouts, the total cost calculation for this design is: *application cost + [(scale cost + construction cost) * # of scales]+additional cost* = $30,754.

There will need to be some additions to a typical grocery store application for the design to work properly. First, it would need the ability to create a customer ID QR Code to scan at the kiosk so the system knows what items the customer has scanned and placed in their cart. Secondly, it will need the ability to access the customers camera and convert a barcode to data that tells the application what the customer is scanning into their cart. Lastly, it will need the ability to search for items if the barcode is missing or will not scan.

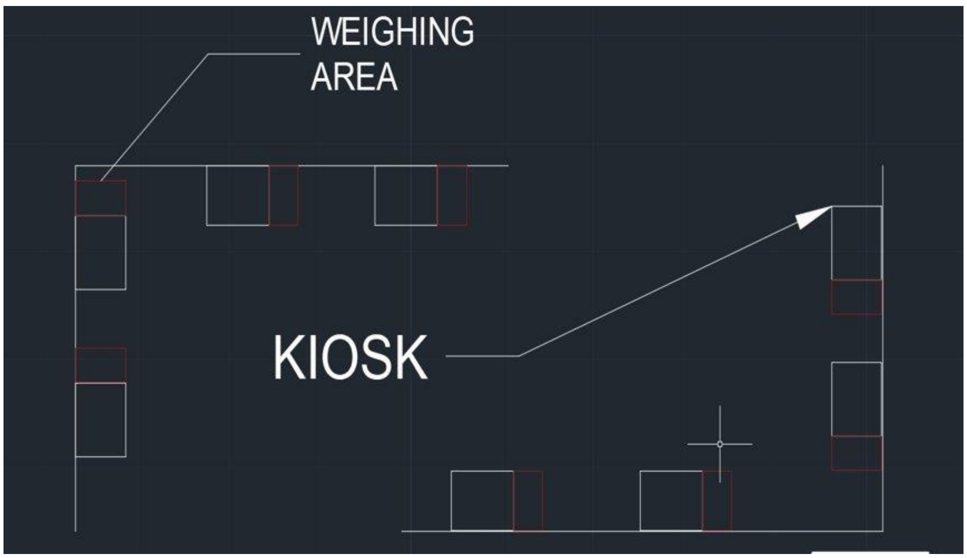
Additional information about the scale: its dimensions will be 61 inches by 28 inches and it will have a capacity of up to 1000 pounds.

Chapter 4: Visual Aids

This chapter will provide the visual aids of the physical parts of the design including the shipping cart design in AutoCAD and the scale design in AutoCAD.

4.1 AutoCAD

Figure 3 Overview Layout of Kiosk Placement with Scales



Within Figure 3, the red outline portions show where the new scales would go into a typical self-checkout area. As shown, it would be out of the way of normal traffic flow and would reduce foot traffic on the scales. The white outlines show the typical self-checkout kiosk a person would find in a checkout area.

Figure 4 Cart Visual with Cell Phone Clip and Bagging Rack

Figure 4 is how the cell phone will clip to the cart for easy scanning feature, and how the bagging rack attaches to the cart for the bag-as-you-go option.

Figure 5 Close-Up Visual of Attachable Bagging Rack

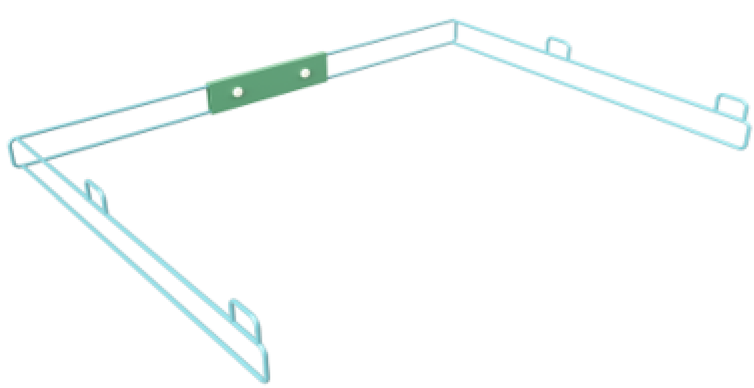


Figure 5 is a close-up visual of the bagging rack that can be attached to the cart for the bag-as-you-go option. This rack is to be detached from cart at the scale at checkout and placed in a designated container.

Figure 6 Close-Up Visual of Cell Phone Clip

Figure 6 is a close-up visual of the cellphone clip attachment. This attachment creates a hands-free option for the scan-as-you-go option. These clips are to be removed at checkout and placed in designated container.

Figure 7 Scale Design

Figure 7 shows how the scale will look and work. The customer simply rolls their cart onto the scale for easy weighing.

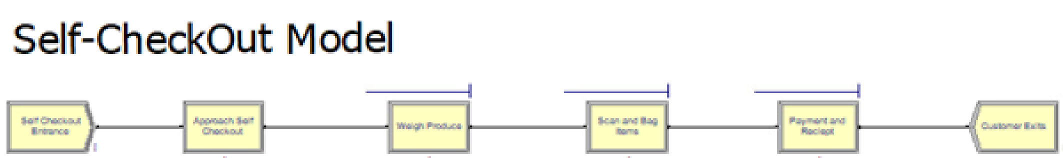
Chapter 5: Arena

An Arena simulation is used to provide a clear understanding of how the process will work. It also provides quantifiable proof that our design moves customers through the checkout process 1.58 times faster than the current self-checkout process, therefore decreases the amount of time the customers spend at the checkout line. This chapter will provide an Arena model as visual for our design checkout process, the input data used, and the output/results from the model.

5.1 Arena

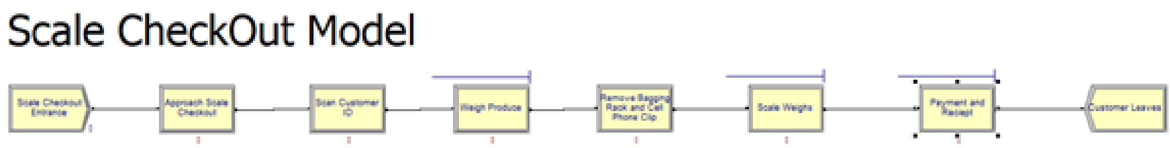
The model below is the typical self-checkout design used at most major grocery retailers. As shown, it starts with the customer entering the line. Next, the customer approaches the self-checkout kiosk. Then, the customer will weigh their produce items. This is split up from the scanning and bagging, because when produce must be weighed, it involves a different process than just scanning the item. Next, the customer will scan and bag their non-produce items. Then, the customer will pay and receive the receipt. Lastly, the customer will exit the system.

Figure 8 Self-Checkout Arena Model



The model below is the new design for the self-checkout process with the added scale feature. As shown, it starts with the customer entering the line. Next, the customer approaches the self-checkout kiosk. Then, the kiosk prompts the customer to scan their customer ID from the phone to connect the contents they scanned in the app to the kiosk and scale. Then, the kiosk prompts the customer to weigh specific produce items and place them back in the cart. Next, the kiosk prompts the customer to remove the attachable bagging rack and phone clip and place in the bin next to the kiosk. This model assumes the customer utilized the bag-as-you-go bagging rack. If the customer did not utilize the bag-as-you-go option, they can simply add the bagging rack back to their cart at the end of the weighing process. Then, the scale weighs the customer's cart. Then, the customer will pay and receive the receipt. Lastly, the customer will exit the system.

Figure 9: Scale Checkout Arena Model



A breakdown of the data calculation for each process module is provided below. All time data is entered as minutes into the Arena model.

Table 7: Data Breakdown for Self-Checkout Arena Model

Process Module	Data	Data Calculation and Explanation
Self-Checkout Entrance	-Constant Arrival --Max Arrival = 1000	-To show the number of customers through the system, these settings assured there would not be a shortage of customers skewing the data if a customer is not available to enter the system.
Approach Self-Checkout	-Mean = 0.5 minutes --Standard Deviation = 0.1 minutes	-The mean and standard deviation of the time it took for a customer to realize there was an available register and walk to the register.
Weigh Produce	-Mean Number of Produce Items Per Customer = 3.43 items --Mean Time to Scan 1 Item of Produce = 0.178 minutes ---Standard Deviation of Time to Scan 1 Item of Produce = 0.06 minutes ----Mean Time to Scan Produce = 0.612 minutes -----Standard Deviation of Time to Scan Produce = 0.22 minutes	-The number of produce items per customer. --The Mean time it took to a customer to lift the produce from the basket, weigh it, and place it back in the basket. ---The standard deviation of the time it took to a customer to lift the produce from the basket, weigh it, and place it back in the basket. ----The average number of produce items per customer times the average time for a customer to scan 1 item of produce. -----The average number of items of produce per customer times the standard deviation of the time to scan 1 item of produce.
Scan and Bag Items	-Mean = 1.53 minutes --Standard Deviation = 0.78 minutes	-The sum of the percent of each cart size (x-small, small, medium, large, x-large) times its respective average scanning time. -- The sum of the percent of each cart size (x-small, small, medium, large, x-large) times its respective standard deviation of the scanning time.
Payment and Receipt	-Mean=0.67 minutes	-The sum of the percent of each cart size (x-small, small, medium, large, x-large) times the average total time by cart size minus the average scanning time by cart size.

*Note: All data for these calculations can be found in Section 1.4 Table 1

**Note: All data points were collected over 80 customers

Table 8: Data Breakdown for Scale Checkout Arena Model

Process Module	Data	Data Calculation and Explanation
Scale Checkout Entrance	-Constant Arrival --Max Arrival = 1000	-To show the number of customers through the system, these settings assured there would not be a shortage of customers skewing the data if a customer is not available to enter the system.
Approach Scale Checkout	-Mean = 0.5 minutes --Standard Deviation = 0.1 minutes	-The mean and standard deviation of the time it took for a customer to realize there was an available register and walk to the register.
Scan Customer ID	-Mean = 0.5minutes --Standard Deviation = 0.1 minutes	-A small separate time study was conducted to determine how long it took for a customer to take their phone off of the cart clip, unlock their phone, and scan it on the kiosk

Weigh Produce	-Mean Number of Produce Items Per Customer = 3.43 items --Mean Time to Scan 1 Item of Produce = 0.178 minutes ---Standard Deviation of Time to Scan 1 Item of Produce = 0.06 minutes ----Mean Time to Scan Produce = 0.612 minutes -----Standard Deviation of Time to Scan Produce = 0.22 minutes	-The number of produce items per customer. --The Mean time it took to a customer to lift the produce from the basket, weigh it, and place it back in the basket. ---The standard deviation of the time it took to a customer to lift the produce from the basket, weigh it, and place it back in the basket. ----The average number of produce items per customer times the average time for a customer to scan 1 item of produce. -----The average number of items of produce per customer times the standard deviation of the time to scan 1 item of produce.
Remove Bagging Rack and Cell Phone Clip	-Mean = 0.17 minutes -Standard Deviation = 0.083 minutes	-A small separate time study was conducted to determine how long it took for a customer to remove the bagging rack and cell phone clip.
Scale Weighs	-Mean = 0.5 minutes --Standard Deviation = 0.5 minutes	-A small separate time study was conducted to determine how long it took for a customer to press the "Weigh" button on the kiosk, and for the scale to weigh and confirm the correct weight. The standard deviation is the same as the mean, in the case that the scale has to re-weigh the cart due to a weigh error.
Payment and Receipt	-Mean=0.67 minutes	-The sum of the percent of each cart size (x-small, small, medium, large, x-large) times the average total time by cart size minus the average scanning time by cart size.

The Category Overview for the two models showed that the average number of customers that can go through the Self-Checkout Model in 60 minutes was 36 customers. The total minimum and maximum time value average for a customer to get through the Self-Checkout Model, including wait time, was 10.81 and 17.35 minutes respectively. The average number of customers that can go through the Scale Checkout Model in 60 minutes was 57. The total minimum and maximum time value average for a customer to get through the Scale

Checkout Model, including wait time was 2.99 and 3.49 minutes respectively. Therefore, our design of the Scale Checkout Model is 1.58 times more efficient at getting customers through the checkout process. On average, using the Scale Checkout design, the customer and store can expect to save the customer between 7.82 and 13.86 minutes in the checkout line. A full category overview can be found in Appendix D.2.

Chapter 6: Results

6.1 Results and Discussions

We have run the simulation in the Arena with the settings as described in Chapter 5 including a runtime of 60 minutes. The simulation of the traditional self-checkout calculated that the average time the customer spent in the checkout system was between 10.82 and 17.35 minutes, whereas using the same settings for the scale checkout system was between 2.99 and 3.49 minutes. Based on the data from this simulation, a customer can expect to get through the system between 7.82 and 13.86 minutes faster. In 60 minutes, the scale checkout design can get 57 customers through the checkout process while the traditional self-checkout system can only get 36 customers through the system. These results show the clear difference in the efficiency of the self-checkout system and the scale checkout system.

To implement this new design process, the cost to the retailer can be calculated using this equation: $y = 1404x + 30754$. The variable x represents the number of scales, and 30754 is the fixed cost to implement. Only the cost of implementing this design is available in this report. The actual cost savings will depend on the number of kiosks the store already has in use and the number of customers and timing of their arrival.

Chapter 7: Conclusion

7.1 Conclusion

In today's world, people are getting busier and busier, and time is becoming a crucial factor in all aspects of life. People want to save time anywhere they can, and one place that time can be saved is the grocery store checkout. With this idea in mind, three different solutions were created to attempt to solve this issue. The three different proposed solutions were whittled down to a solution that had the most promise. From this point, an effort was made to validate the solution and prove it would be effective in a real-world scenario.

To help validate the proposal, the team researched and bookmarked their idea to several different articles and literatures. For example, the ideas that other companies are looking at or attempting to implement was reviewed. By looking at these ideas and progress of other engineers, the team was able to further improve their idea. Also, by reviewing different articles, the team was able to expand their idea or eliminate ideas that had already failed in past experiments or designs.

To validate the design and proposed solution, the team tackled the issue with a strategics approach to improve customer quality and to cut customer checkout time down. Visual aids and prototype designs were created to aid in visualizing the solution and to help demonstrate what the team is proposing. Furthermore, potential roadblocks and obstacles were thought out and dismantled or prepared for with a clear counteraction being stated.

The true supporting evidence of the solution comes down to the Arena Simulation that was created. The Arena simulation offered the best supporting evidence for our solution. Unfortunately, an actual prototype could not be created, however, the Arena simulation offered a pathway around this. Going off accurate times the team collected, they were able to create a simulation that showed the difference between the current self-checkout and the proposed self-checkout system. The Arena simulation favored the solution and drastically cut down times to checkout.

In conclusion, the evidence that the team provided heavily supported their solution to decrease the time required in self-checkout. Surveys show that the population wants a quicker self-checkout system. The Arena model supports the solution by simulating the quickness of the solution. In the end, the proposed solution drastically reduces the amount of time required for self-checkout and has few fallbacks.

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Appendix A: Acknowledgements

First and foremost, a special thanks to all the professors and administrators within the Kennesaw State University ISYE Department. All the credit for this report goes to them as they were the ones who shaped all the individuals in our team.

We would also like to thank a few individual professors who helped us along the way. Dr. Scherrer, thank you so much for your lessons in logistics and statistics; your teachings helped guide us through this design project. Dr. Esmaeili, thank you for helping us with optimization and statistics. Dr. Keyser, thank you for your continuous help with Arena and Facility Planning; your availability to help each of us even when we aren't currently in your class is admirable and appreciated. Lastly, we would also like to send a special thanks to Dr. Khalid. Thank you for your valuable feedback and guidance every step of the way though this project.

Thank you to all other professors not mentioned; all our professors have played an integral part in the production of this project. Thank you all!

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Appendix C: Reflections

C.1 Reflections

Tiana Longino's:

The overall goal of our design was to reduce the customer wait time to increase customer satisfaction and decrease store costs. The Arena model showed that it would accomplish the goal. This is a heavily researched area, so we are interested to see if stores will implement a design like ours with a floor scale soon. We addressed many roadblocks with the design, but it would be interesting to see an implemented design works as expected.

Matthew Ritchie's:

Looking back on this project and my academic career, it has been a roller coaster ride. Luckily, it was mainly highs with only a few low points. This project has been demanding at times, but the team handled it very well. I enjoyed the teamwork aspect of the project and the freedom to research our own idea for the project. The academic freedom made the project that much better and allowed us to explore different angles or aspects of senior design. In the beginning, we had some bumps due to organizational issues, however, they were quickly flattened out. Overall, this project has be a joy to be a part of and I appreciate all the work my team has done in this project.

Daniel Garza's:

Reflecting on this project and looking back at my time at Kennesaw State has been a positive experience. I am extremely grateful to have been paired up with a group of individuals that took accountability for the tasks they were supposed to, and all around were good and fun people to work with. The project itself was challenging and certainly sparked conversations that I will take with me in my future endeavors. One thing in particular that I will take from this project is that steps that brought us to the ending. Things such as roadblocks, Gantt Charts and coming up with milestones to complete the project is something I see extreme value in. In conclusion, I thoroughly enjoyed this project from start to finish.

Alp Katranci's:

This project makes use of the self-service technology for the checkout at the Hyper market. This technology is particularly important as it will allow the user to get served by the shopper themselves and they do not have to rely on the person. Another important feature is that our design will not require the user to use the machine for the checkout process; rather, they scan the QR code while shopping. This will reduce the que time and the time of waiting for the shoppers. Intact it will not need the customer to wait in the queue. The results we got, and the review of the general literature strengthen our idea. Our proposed process enhances the effectiveness and the efficiency of flow of the checkout operations. This technology is adapted highly by the public due to its time efficiency and not having to wait in the queue.

C.2 Major Contributors

Table 9 Major Contributors

Major Contributors	
Section	**Contributors**
Ttile Page	Matt
Executive Summary	Tiana
Table of Contents	Matt
Chapter 1 Introduction	Tiana
1.1 Overview	Tiana
1.2 Objective	Daniel
1.3 Resources	Matt
1.4 Justification	Tiana
Table 1	Tiana
Table 2	Tiana
Table 3	Tiana
Data Collection	Matt, Daniel, Alp, & Tiana
1.5 Project Background and Design Ideas	Matt, Daniel, Alp, & Tiana
1.6 Pros and Cons	Tiana
Table 4	Tiana
Table 5	Tiana
1.7 Design Decision	Tiana
1.8 Problem Statement	Daniel
Chapter 2 Introduction	Tiana
2.1 A2Z Smart Technologies	Alp
2.2 How Current Sel-Checkouts Work	Matt
2.3 How Trucking Scales Work	Matt
2.4 Smart Grocery Carts Coming...	Alp
2.5 Amazon's New Smart Shopping...	Daniel
2.6 Smart shopping carts on the rise...	Alp
2.7 Why should grocery stores...	Daniel
Chapter 3 Introduction	Tiana
3.1 Problem Solving Approach	Matt & Tiana
Figure 1	Tiana
3.2a Design Roadblocks	Matt, Daniel, & Tiana
3.2b Project Roadblocks	Matt & Daniel
3.3a Functional Requirements	Alp & Tiana
3.3b Nonfunctional Requirements	Alp & Tiana
3.4 Gantt Chart	Matt
3.5 Design Overview Flow Chart	Tiana

Figure 2	Tiana
3.6 Budget	Alp
Table 6	Alp
Chapter 4 Introduction	Matt
4.1 AutoCAD	Matt & Alp
Figure 3	Matt
Figure 4	Alp
Figure 5	Alp
Figure 6	Alp
Figure 7	Alp
Chapter 5 Introduction	Tiana
5.1 Arena	Tiana
Figure 8	Tiana
Figure 9	Tiana
Table 7	Tiana
Table 8	Tiana
Chapter 6 Results and Discussions	Alp
Chapter 7 Conclusion	Matt
References	Matt, Daniel, Alp, & Tiana
Appendix A: Acknowledgements	Daniel
Appendix B: Contact Information	Tiana
Appendix C: Reflections	Matt, Daniel, Alp, & Tiana
C.1 Reflections	Matt, Daniel, Alp, & Tiana
C.2 Major Contributors	Tiana
Table 9	Tiana
Appendix D: Additional Documents	Matt, Alp, & Tiana
D.1 Budget	Alp
Table 10	Alp
Table 11	Alp
Table 12	Alp
D.2 Category Overview from Arena Model	Tiana
Figure 10	Tiana
Figure 11	Tiana
D.3 Description of Arena	Matt
Video	Tiana
Poster	Tiana
PowerPoints	Matt, Daniel, Alp, & Tiana

Table 9 provides a list of the major contributors to each section in this report.

Appendix D: Additional Documents

This section provides a complete breakdown of the budget for all the design ideas mentioned in Chapter 1 and a brief description on what the Arena software is.

D.1 Budget

Table 10 Cost to Build Design Idea 1 Application from Scratch

APPLICATION BUDGET			
Feautre	Description	Approx. Time	Approx. Cost Based on $80/hr
Login	Login with Email Login with Social Media Forget Password Logout	30-45 hours	$2400-$3600
Profile Completion	Add intro Add photo	24-28 hours	$1920-$2240
Profile Edits	Edit Profile Change Password Change Email Add/Remove Credit Card	50-75 hours	$4000-$6000
Search	Search for Item	18-23 hours	$1140-$1840
Payment Management	See Payment Refund/Exchange Item	27-41 hours	$2160-$3280
Notifications	Deal of the Day	10-15 hours	$800-$1200
Map	Item Location Search List of Transactions	75-100 hours	$6000-$8000
Payments	Add Card/Paypal/etc See Balance	63-75 hours	$5040-$6000
Security	Protecting Identity Protection CC Info	40-55 hours	$3200-$4400
UI/UX Design	Creation of Schema Analysis of User Preference	125-250	$10,000-$20,000
Logo	Icon and Logo Design	13-18 hours	$1040-$1140
Maintenance	Improving Performance Adding Support (Latest Version) Bug Fixing	45-60 hours	$3600-$4800

Table 10 is a breakdown of the cost to design each section of the application for a grocery store application from scratch.

Developer and UI/UX Designer: $41,300 - $62,500

Project Manager: $28,000

Business Analyst: $18,600

QA Specialist: $23,800

Solution Architect: $13,000

Total Cost to Build Application (estimated): $124,700 - $145,900

***Note: This cost is calculated for IOS. Android adds $37,860 due to an additional required developer team.

Table 11 Repeat of the Cost of Design Idea 2 without Application from Scratch Cost

Application			
Feature	**Description**	**Approx. Time**	**Approx. Cost**
Customer ID (QR code)	Developing QR Code for customer ID recognition at	75 hours	$6,000
Camera Identifying Barcode	Camera can convert a barcode and identify item	140 hours	$11,000
Ability to Search Items	Feature to search items if items won't scan or missing a barcode	20 hours	$1,600
Scale			
Item		**Approx. Cost**	
Deck Plate		145 $	
Stainless Steel Junction Box		195 $	
Digital Weight Indicator With LED screen		225 $	
Load Cell		115 $	
Retractile Cord (5ft)		85 $	
Load Cable with 4 wires		50 $	
Microcontroller Unit		24 $	
Amplifier		15 $	
Construction			
Job	**Description**	**Approx. Time**	**Approx. Cost**
Construction Manager	Coordinating the project, $55/hr.	7 hours	$385
Construction worker	Performing the physical work, $15.53/hr.	7 hours	$108
Electrician	Wiring the scale cables, $19/hr.	3 hours	$57
Additional			
Item	**Quantity**	**Cost Per Item**	**Approx. Cost**
Bagging Rack	250	$28	$7,000
Phone Holding Clip Attachment	250	$15	$3,750

Table 11 is a breakdown of the cost to implement Design Idea 1. This does not include the cost to create the application from scratch. The total equals $30,754.

The total cost from table 10 and 11 encompass the cost of design idea 1 if the store did not already have a working application.

Table 12 Cost of Design Idea 2

Part	Description	Material	Mass	Price
Basket	Main part of cart	High density Polythene	3.66 lbs.	8.41 $
Back Door	Back part pf basket	High density Polythene	2.86 lbs.	1.76 $
Front Door	Front part of the Basket	High density Polythene	1.32 lbs.	0.81 $
Handle	Placed on top of cart	Antimicrobial Plastic	0.81 lbs.	0.54 $
Lower Tray	Base of the Cart	High density Polythene	8.81 lbs.	5.42 $
Cup Holder	Mounted to handles carries drinks	High density Polythene	0.79 lbs.	0.48 $
Wheel (4)	Mounted under lower tray	High density Polythene	4*1.41 =5.64 lbs.	7.99*4 =31.96 $
LCD Touchscreen Display	Showing information and price of item placed in cart	Glass and plastic	1.75 lbs.	179.95 $
RFID reader	Detect product which placed in cart Automatic Scanning product	Aluminum and chip	2.03 lbs.	1250 $
Ultrasonic Sensor	Detects addition or deletion of item from cart	Polybutylene terephthalate	1.23 lbs.	102*3 =306 $

Table 12 is a breakdown of the cost to implement design idea 2. This total is cost per cart. There is the assumption that the average store has 250 shopping carts. Each cart costs $1,785.33 times 250 carts = $446,332.50.

Table 13 Cost of Design Idea 3

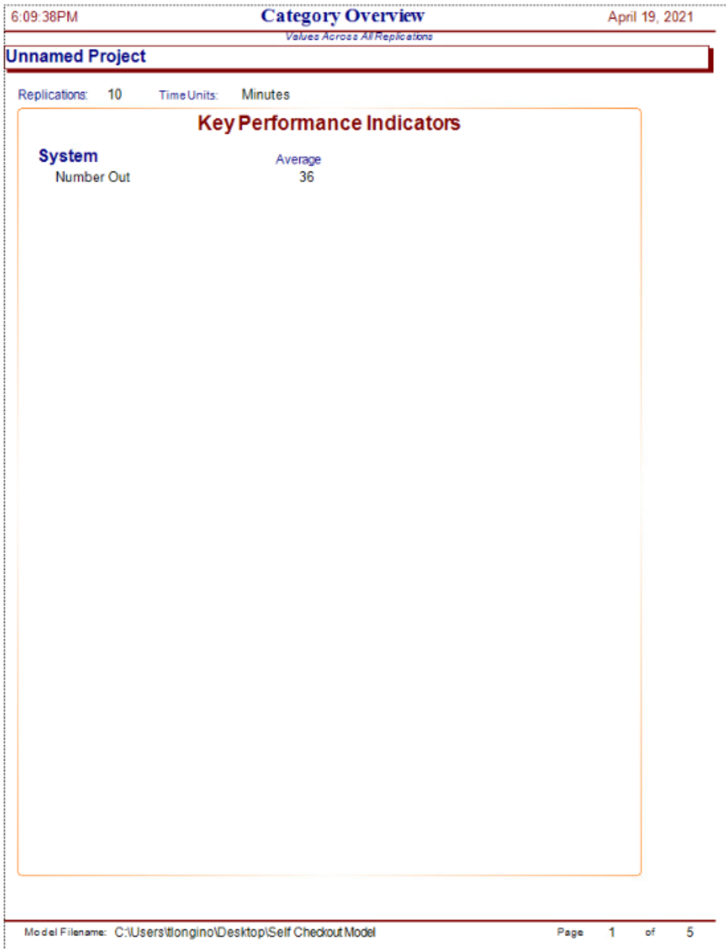
Part	Description	Price
4 Load Cell sensors	Measuring the weight	$8.99
Load Cell Amplifier	Connected with Load Cell Sensor, measuring the weight accurately. Make the weight readable for Raspberry Pi 4	$9.95
Wires	Wiring Load Cells, Amplifier and Raspberry Pi4 to each other	$2.80
Raspberry Pi 4	Receiving values from Amplifier and send it to touch screen monitor	$61.75
7-inch Touch Screen Monitor	Display total weight and payment balance	$69.99
Wireless Barcode Scanner	Read price and information of the product by scanning	$34.99
Barcode scanner holder	Mounted to handle to carry barcode scanner	$20.90

Table 13 is the breakdown of the cost to implement design idea 3. This total is cost per cart. There is the assumption that the average store has 250 shopping carts. Each cart costs $209.37 times 250 carts = $52,342.50.

D.2 Category Overview from Arena Model

The standard self-checkout and the new scale checkout were modeled in Arena, and the figures in this section are the category overview reports showing the results from the simulations.

Figure 10: Category Overview for Self-Checkout Arena Model


6:09:38PM
Category Overview
April 19, 2021
Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Key Performance Indicators

System	Average
Number Out	36

Model Filename: C:\Users\tlongino\Desktop\Self Checkout Model Page 1 of 5

6:09:38PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	3.3645	0.12	3.1269	3.6233	1.6330	5.7367

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	10.7576	1.45	7.5585	13.7244	0.00	26.1690

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	14.1221	1.55	10.8154	17.3478	1.6686	29.3952

Other

Number In	Average	Half Width	Minimum Average	Maximum Average
Entity 1	61.0000	0.00	61.0000	61.0000

Number Out	Average	Half Width	Minimum Average	Maximum Average
Entity 1	36.4000	2.62	31.0000	42.0000

WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	13.3962	1.36	10.6257	16.2130	0.00	30.0000

Model Filename: C:\Users\tlongino\Desktop\Self Checkout Model Page 2 of 5

6:09:38PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment and Reciept.Queue	0.07006082	0.04	0.00	0.1793	0.00	1.3934
Scan and Bag Items.Queue	11.1537	1.60	7.6957	14.5089	0.00	26.8550
Weigh Produce.Queue	0.00008317	0.00	0.00	0.00083170	0.00	0.04990205

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment and Reciept.Queue	0.04640481	0.03	0.00	0.1195	0.00	3.0000
Scan and Bag Items.Queue	10.8501	1.41	7.9881	13.8017	0.00	27.0000
Weigh Produce.Queue	0.00008317	0.00	0.00	0.00083170	0.00	1.0000

6:09:38PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Resource

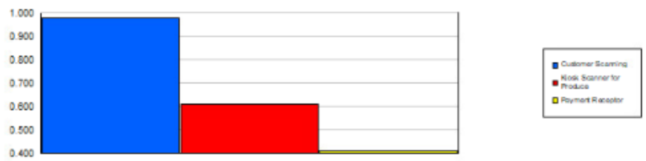
Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Customer Scanning	0.9778	0.01	0.9619	0.9846	0.00	1.0000
Kiosk Scanner for Produce	0.6094	0.00	0.6051	0.6120	0.00	1.0000
Payment Receptor	0.4106	0.03	0.3509	0.4798	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Customer Scanning	0.9778	0.01	0.9619	0.9846	0.00	1.0000
Kiosk Scanner for Produce	0.6094	0.00	0.6051	0.6120	0.00	1.0000
Payment Receptor	0.4106	0.03	0.3509	0.4798	0.00	1.0000

Number Scheduled	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Customer Scanning	1.0000	0.00	1.0000	1.0000	1.0000	1.0000
Kiosk Scanner for Produce	1.0000	0.00	1.0000	1.0000	1.0000	1.0000
Payment Receptor	1.0000	0.00	1.0000	1.0000	1.0000	1.0000

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Customer Scanning	0.9778	0.01	0.9619	0.9846
Kiosk Scanner for Produce	0.6094	0.00	0.6051	0.6120
Payment Receptor	0.4106	0.03	0.3509	0.4798



Model Filename: C:\Users\tlongino\Desktop\Self Checkout Model Page 4 of 5

6:09:38PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Resource

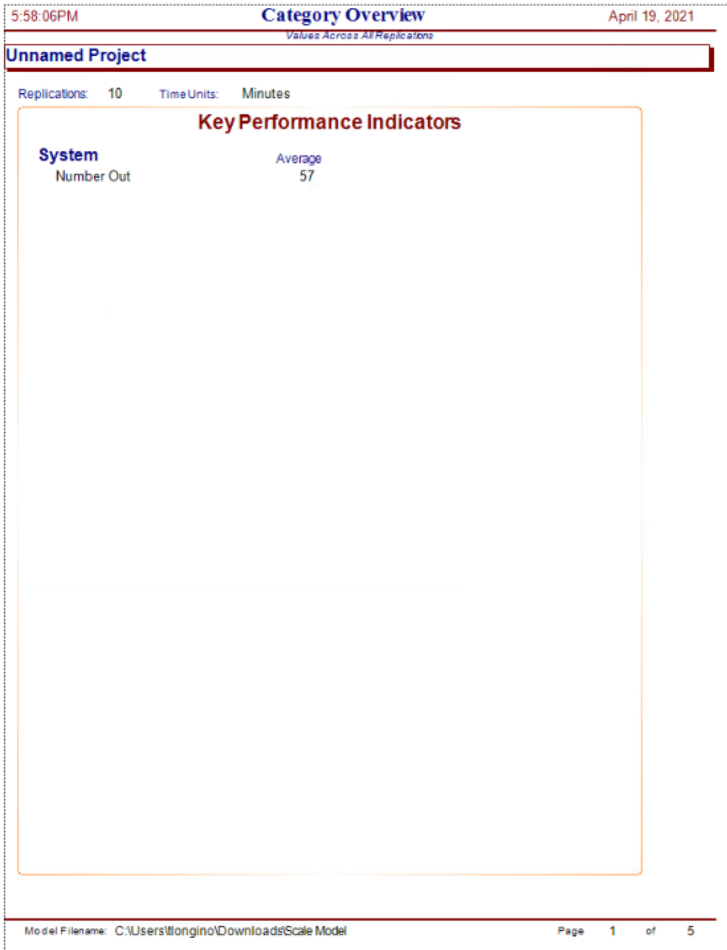
Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Customer Scanning	38.1000	2.56	33.0000	44.0000
Kiosk Scanner for Produce	60.0000	0.00	60.0000	60.0000
Payment Receptor	37.0000	2.52	32.0000	43.0000

Model Filename: C:\Users\tlongino\Desktop\Self Checkout Model Page 5 of 5

Figure 10 is the breakdown of the results from the Arena model of the Self-Checkout process.

Figure 11: Category Overview for Scale Checkout Arena Model



5:58:06PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Key Performance Indicators

System	Average
Number Out	57

Model Filename: C:\Users\tlongino\Downloads\Scale Model Page 1 of 5

5:58:06PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.9890	0.06	2.8515	3.0979	2.1033	4.7160

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.2394	0.06	0.1378	0.3939	0.00	2.6207

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	3.2285	0.10	2.9893	3.4870	2.2289	5.4981

Other

Number In	Average	Half Width	Minimum Average	Maximum Average
Entity 1	61.0000	0.00	61.0000	61.0000

Number Out	Average	Half Width	Minimum Average	Maximum Average
Entity 1	57.3000	0.59	56.0000	58.0000

WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	3.1721	0.10	2.9567	3.4207	0.00	6.0000

Model Filename: C:\Users\tlongino\Downloads\Scale Model Page 2 of 5

5:58:06PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment and Reciept.Queue	0.1489	0.02	0.1048	0.1939	0.00	1.1726
Scale Weighs.Queue	0.08915218	0.04	0.02338058	0.2265	0.00	2.1558
Weigh Produce.Queue	0.00236602	0.00	0.00	0.00498931	0.00	0.2302

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Payment and Reciept.Queue	0.1437	0.02	0.0996	0.1842	0.00	2.0000
Scale Weighs.Queue	0.08853322	0.04	0.02299090	0.2228	0.00	3.0000
Weigh Produce.Queue	0.00235768	0.00	0.00	0.00498931	0.00	1.0000

Model Filename: C:\Users\tlongino\Downloads\Scale Model Page 3 of 5

5:58:06PM **Category Overview** April 19, 2021

Values Across All Replications

Unnamed Project

Replications: 10 Time Units: Minutes

Resource

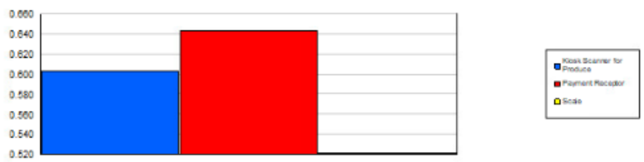
Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Kiosk Scanner for Produce	0.6032	0.00	0.6018	0.6057	0.00	1.0000
Payment Receptor	0.6435	0.00	0.6279	0.6478	0.00	1.0000
Scale	0.5214	0.05	0.4166	0.6162	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Kiosk Scanner for Produce	0.6032	0.00	0.6018	0.6057	0.00	1.0000
Payment Receptor	0.6435	0.00	0.6279	0.6478	0.00	1.0000
Scale	0.5214	0.05	0.4166	0.6162	0.00	1.0000

Number Scheduled	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Kiosk Scanner for Produce	1.0000	0.00	1.0000	1.0000	1.0000	1.0000
Payment Receptor	1.0000	0.00	1.0000	1.0000	1.0000	1.0000
Scale	1.0000	0.00	1.0000	1.0000	1.0000	1.0000

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Kiosk Scanner for Produce	0.6032	0.00	0.6018	0.6057
Payment Receptor	0.6435	0.00	0.6279	0.6478
Scale	0.5214	0.05	0.4166	0.6162



5:58:06PM **Category Overview** April 19, 2021

Values Across All Replications

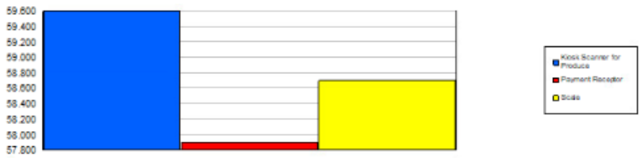
Unnamed Project

Replications: 10 Time Units: Minutes

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Kiosk Scanner for Produce	59.6000	0.37	59.0000	60.0000
Payment Receptor	57.9000	0.41	57.0000	59.0000
Scale	58.7000	0.35	58.0000	59.0000



Model Filename: C:\Users\tlongino\Downloads\Scale Model Page 5 of 5

Figure 11 is the breakdown of the results from the Arena model of the Scale Checkout process.

D.3 Description of Arena

One of the largest obstacles that has arisen within this project is that the idea is mainly theoretical. Unfortunately, the ability or funds to create a physical prototype for this solution is unattainable or undoable. This creates a void within the project itself. With the proposed solutions, data and backing is needed to back the proposed solutions. With the Arena Simulation model, the missing void can be filled, and the missing data needed to support the claim can be found.

What is Arena exactly and how could it help? Essentially, Arena is a simulator that enables the user to create a model to simulate a variety of processes. It is an inexpensive way to test and research a variety of topics. Several ideas can be revied in Arena including, but not limited to, ATMs, airports, restaurants, businesses, logistical processes, and vehicle routes. Values and data are needed to create the model.

After the simulation is created, a variety of information is then collected and reported about the simulation just ran. This is where the simulation model excels in aiding research. It has the ability to show how many customers pass through a certain process within a certain time frame. Also, it aids in showing queue lines and how long a customer waits in the queue line. This data can be critical when comparing to different processes.

In conclusion, the Arena model is a cornerstone of this project to help support its claim. The main reason Arena would be used is to compare the times of the current checkout processes to the proposed solutions checkout process. It would show the total times, the potential bottlenecks of the process, and the number of customers that would pass through. From there a direct comparison could be made and analyzed.