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A Step-By-Step Guide to Identify the Most Reliable Inventory Management System for Small Businesses Using Discrete Event Simulation and Pros and Cons Analysis: A Case Study at CAMID-Florida Tech

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by

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Abstract

Title: A step-by-step guide to identify the most reliable inventory management system for small businesses using discrete event simulation and pros and cons analysis: a case study at CAMID-Florida Tech.

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According to the Department of Labor Statistics (2022), 20.6% of small businesses fail in their first year of operation, 42.6% fail after five years, and over 62.6% fail by their tenth year. One factor that can affect continued viability is the lack of knowledge and experience among small and medium-sized firms in inventory management. Despite the fact that inventory control is one of these businesses' most ignored management responsibilities, the expense of procuring inventory often accounts for a considerable portion of their budget. Due to poor inventory management or an inability to appropriately supervise their inventory, small firms may have large sums of money stashed away in an accumulation of goods. Most of these small businesses employ manual systems or simple techniques to manage their inventories since they have a limited workforce and frequently occurring skill and knowledge shortages. The possibility of lowering losses due to recording errors and excessive purchases can be addressed by having a step-by-step manual that can assist small businesses in selecting a better inventory management system. Investigating possibilities for a better inventory management system that would result in fewer inventory errors can be done effectively using discrete event simulation. Business owners can use this method and cost projections to get information to help them choose the optimal inventory management strategy for their particular application.

Table of Contents

List of Figures

List of Tables

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Dedication

My dedication could not start in a different way; I dedicate it primarly to the person who made me reach all my achievements in my life, my mother. A few years ago, I thought that I would never be able to do a Master's degree in the United States, but she stood by my side and she never stopped believing it. I thank her for all her emotional and financial support. She usually says that she is lucky enough to have me as a son, but I truly believe that I am the lucky one to have her as a mother, like a guardian angel on Earth to me. This thesis and master's are for you!

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Chapter 1
Introduction

Motivation

Operations management now includes inventory management as one of its most important subfields. Inventory is always seen to be a waste under the lean mindset and that should be removed. (Eroglu et al., 2011) Managers need to recognize how crucial inventory control is to their ability to increase productivity. Nevertheless, inventory management may be significantly impacted by the presence of fluctuating demand and storage costs. (Nakandala et al., 2017)

Not differently nowadays, companies have enhanced effectiveness and reduce expenses in the midst of pressures such as competitiveness all across the world, and also to maintain quality for higher consumer demand. (Gunreddy et al., 2022) Therefore, managing their errors while inventorying has been a crucial topic to discuss and manage in the most diverse industries.

However, many companies are still using manual inventory management. Even though, organizations must choose an automated inventory system that is compatible with their operational procedures to help minimize the detrimental financial effects of inadequate inventory management. (Shteren et al., 2017). According to Zadeh (2016), fraud and inventory tracking mistakes can firms to lose unnecessary amounts of goods, workers, clients, and income. And also, manual inventory tracking techniques are more prone to frequent errors and make it harder to see the actual inventory that is in stock. (Barratt et al., 2018)

Excessive inventory errors are associated with manual inventory management systems. A manufacturing company's usage of a manual inventory tracking system increases the possibility of human error. Misplacement and waste are two types of inventory mistakes that can be expensive. (Shteren et al., 2017). Since that inventory is a crucial asset, successfully controlling and recording manual inventory movement is essential for both production and financial performance. (Chuang et al., 2016)

The cost of purchasing inventory typically consumes a sizable percentage of a small business' budget, despite the fact that inventory control is one of these companies' most neglected management duties. Several small businesses have an exorbitant quantity of funds locked up in an accumulation of items that have been sitting for a while due to inadequate inventory management or an incapacity to adequately control the inventory. A company's cash flow will be adversely impacted by poor inventory management. (Atnafu et al., 2018). Also, Tushabomwe-Kazooba (2006) indicated that inadequate record keeping, and a lack of fundamental business management knowledge and abilities are two main reasons why small businesses fail.

The use of computer systems in general, the use of different systems for taking notes or importing information into the system, and various displays of inventory quantity, usage, and demand forecast are all examples of modern inventory management information systems that help manage inventory quickly and accurately. The development of information systems to assist with inventory management is essential. (Tuan et al., 2018)

Aside from that, moving on to the target of this thesis, small businesses, due to the abundance of entrepreneurship in the United States, a lot of people believe that small businesses have it relatively easy. Nevertheless, according to the Department of Labor Statistics (2022), the truth is that 20.6% of small businesses fail in their first year of operation, 42.6% fail after five years, and over 62.6% fail by their tenth year.

Lack of skills and expertise among small and medium businesses (SME) is one aspect that may contribute to issues with inventory management. SME merchants frequently manage their inventories using their limited ability and experience (Kasim et al, 2015) Due to their small workforce sizes and frequent skill and knowledge gaps, most of these small businesses use manual systems and/or basic techniques to manage their inventories. This reasoning is in line with earlier research, which revealed that many SMEs manage their inventory with the help of their owners or family members. That being said, having a step-by-step guide that can help small businesses to choose a better inventory management with alternatives choices is needed.

Discrete Event Simulation

And as a matter of way to investigate options for a more effective inventory management system that will lead to a lower number of errors in their inventory, simulation is an assertive approach, as using this method, no physical changes must be made in their businesses until the right assessment of their best inventory management alternative is made.

For that reason, simulation is an alternative, discrete simulation is a very powerful and effective problem-solving methodology to study how complex real-world systems behave over time. Using simulations, it is possible to understand how well each part of a company has been performing. It is agreed that a simulation has the most time-effective and cost-effective, because it will not damage or cause any stop to any process in a company while performing real-time simulations to understand how well the processes are occurring. This way detecting causal effects, stipulating critical parameter estimates and clarifying how processes develop over time (Garson, 2009).

The performance of an existing system under different operating conditions can be assessed using simulation as a forecasting tool. (Singh et al., 2022) More specifically, a discrete-Event Simulation (DES), which is one of the strategic management tools, is useful in decision-making by looking at problems as a whole and expressing all the relationships, interactions, and uncertainty sets.(von der Embse et al., 2021) Companies ranging from small to large can benefit significantly through the utilization of DES. This type of simulation can assist in understanding and analyzing systems, assist in decision making, assist in improving operations, and assist in designing real system changes with less costly errors and also the Discrete Event Simulation is one of the most important simulation techniques in decision-making. (Oliveira et al., 2022)

The DES techniques are suitable for improving processes, planning and strategic decisions, and providing the emergent phenomenon from individual interactions, respectively (Ershadi et al, 2019) And is one of the strategic management tools, is useful in decision-making by looking at problems as a whole and expressing all the relationships, interactions, and uncertainty sets (Serper et al., 2022).

In light of this, the ARENA simulation program has long been the best discrete event simulation program available, that Systems Modeling created in 1993 and that Rockwell Automation later purchased. Arena has dominated the discrete event simulation software market for 30 years. The robust operational, object-oriented design of the software and its ability to adapt to many application domains can be used to explain its popularity. (Guseva et al., 2018)

With the help of the ARENA simulation model in this research, we can run many numbers of possible iterations without physically affecting the real working time and effectiveness from its employees, saving a lot of cost of designing, building, testing the complete system. (Gunreddy et al., 2022) Since, the whole project planning for those events will be mapped, simulated to understand how well the current system is working and, how this current process can be scalable. An efficient design of experiments was created to simulate models and conduct analysis to verify the effects of changes. The outcomes of this investigation can be used to improve several small businesses worldwide with similar infrastructure.

Objectives

Therefore, this current thesis has the purpose of developing an easy step-by-step guide that will help small businesses on how to identify between different types of inventory management systems, which one will be the most feasible for them to implement in their businesses using a discrete-event simulation.

For this thesis, a case study will be used on The Center for Advanced Manufacturing and Innovative Design (CAMID). A place where business owners, startups, and even groups from well-established sectors may create and develop new products is Palm Bay, which is where CAMID is situated. This center offers the area, the tools, and the knowledge. However, CAMID currently pursues a manual inventory management system that is causing a lot of issues such as misplacement of many items in their inventory, beyond the fact that around 6-8% of their current purchases are done due to the lack of certainty if they do have that item or not. Right now, CAMID is unsure about which inventory management is the right one for them, to not make those mistakes from keep happening.

The current method that they are using is only a Microsoft Excel sheet and not in a frequent way, therefore, many times new items or even returned to inventory are not inputted to the file, making it impossible to keep the right record of their inventory.

Case Study & Small Businesses Relation

Likewise, many other small businesses with fewer than 19 employees must be facing the same lack of confidence in their inventory management. They are still using a manual inventory management system, which generates a lot of extra costs, as they do not know how to evaluate the best alternative to fulfill their expectations. Hence, this thesis developed a methodology to evaluate the current situation, analyze the problems faced, simulate the possible solutions, and then propose to the small business the pros and cons of each of those options.

With the help of the ARENA simulation model in this research, we can run many numbers of possible iterations without physically affecting the real working time and effectiveness of its employees, saving a lot of cost in designing, building, and testing the complete system. Since, the whole project planning for those events will be mapped, simulated to understand how well the current system is working. An efficient design of experiments was created to simulate models and conduct analysis to verify the effects of changes. The outcomes of this investigation can be used to improve several related facilities worldwide with the same infrastructure.

This way helping those companies to find a highly effective way to measure their current inventory system and elevating their effectiveness and chances to the success in their business.

Inventory Management Importance

Beyond the explained focus on this thesis, where we also evaluate the cost that each alternative/scenario has to be a profitable tool and inventory management. It is valid to highlight that there are other points in the process of handling a small business that are also benefitied from having an effective inventory management.

For example, Maintaining accurate inventory records is helpful for obtaining tax breaks. Additionally, it reduces the possibility of underpaying taxes as a result of inaccurate information about the inventory owned by the company. Inventory makes up a sizable portion of the current assets listed in the balance sheet of the majority of small businesses at any given moment. Given the restricted access to resources that these companies have, it must therefore be controlled effectively. (Ng et al., 1993) And also, The profitability and cash flow of small businesses are also impacted by inventory because it costs money to buy, store, transport, and manage it. For that reason, it is crucial that small businesses use the most effective inventory management systems. The way inventories are managed ultimately affects a company's ability to compete and maintain a healthy financial position because working capital is directly impacted by the approach used to manage inventories. (Vergin, 1998)

Scenarios

As CAMID still uses a manual inventory system, this thesis will test and simulate another two scenarios, using more effective and modern technologies, such as barcode and radio frequency identification RFID. Hence, creating three scenarios to be tested.

- Scenario 1: Using the current and manual inventory system.
- Scenario 2: Utilization of Barcodes.
- Scenario 3: Utilization of RFID.

The hypothesis is that the utilization of technologies such as barcodes and RFID will improve the effectiveness of their inventory management. And depending on the combination of other analyses conducted during this thesis, such as cost analysis and pros and cons analysis, the small business in this case, CAMID, can decide which one would be the most feasible for them.

Outline

The outline for the study and methodology used in this thesis is as follows:

- 5W1H Method – the basis for any problem solution is understanding what is causing and all the parties related to that, a form was created to identify those features at CAMID, listening their side through a form using the 5W1H.
- Simulation – After understanding the current situation and the simulation framework developed by Banks (2004), all the current processes related to inventory were translated into the Arena Software, along side with the hypotheses already explained. That way, being able to explore what outcomes and possibilities of errors might be generated by each of those scenarios.
- Cost Analysis – To also be used as a advantage or disadvantage, it is a common sense that the cost is pertinent to any small business, therefore a comparison between costs for all three scenarios were exposed.

- Pros and Cons Analysis – Combining the simulation results and cost analysis, a table with clear statements for each scenario is prepared for the small business to make it their decision.
- Solution Proposition – Using the information from all previous steps and mainly the business need, in this case from CAMID, the most feasible inventory management system is proposed based on those steps.

Chapter 2
Review of Literature

Simulation

As the base of this thesis will be creating simulations, it is ideal to explain the foundation of this activity, what it is and what can be done via simulation.

> A simulation is the imitation of the operation of a real-world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system. (Banks, et al., 2004)

As Banks et al. 2004 said, simulation can be described as an imitation of a real-word process, to understand and improve systems and processes. Alongside, in order to scientifically analyze the facility or process of interest, which is typically referred to as a system, we frequently need to make several assumptions about how it operates. These presumptions, constitutes a model, which are typically expressed as mathematical or logical correlations, together that is employed to attempt and understand how the relevant system behaves, that leads to the event, which is defined as a change in the state of a model (Law, 2013)

To add to it, it is necessary to discuss the importance of this trio of words (system, model and event) just explained. A system can be characterized as a man-made or natural thing, concrete or abstract, that is a part of a particular reality bound by an environment. A group of components that are structured in order to accomplish a shared objective can also be referred to as a system. On the other hand, a model is a picture of a certain system that can lead us to comprehend it. And an event is a change in a model's state that plays a significant part in discrete event simulation. A discrete event model updates itself when an event occurs and maintains that state until the next event, as it shall be stated later. At that moment, we can characterize the state of a model by describing the values of its characteristics that exist within a specific time period. (Wainer, 2009)

But then, to create a simulation model, we have a step-by-step that can outline the creation of any simulation model and this plan consists of nine steps. (Banks et al., 2004)

A. Problem Foundation: It is essential to thoroughly explain the problem and formulate it so that the reader may comprehend it before starting a simulation.
B. Objectives and Project Plan: Before starting the simulation, the goals should be well established. A plan that will serve as our guide for the project must also be prepared.
C. Model concept: It is advantageous to start with a basic strategy and keep improving it over time to prevent wasting time or money.
D. Data Collection: The data collection must be thorough, and input must be accurate if the goal is to produce reliable results. It is effective to collect as much data as you can both before and while building the model.
E. Verify and validate: Validation poses a query. Is it the appropriate model? It looks into the compatibility of the developed model with actual processes. Verification, on the other hand, is concerned with how the model is constructed.
F. Experimental Design: Additionally, it's crucial to experiment with various scenarios and keep track of the number and length of model runs. Better accuracy results from running more simulations.
G. Runs and Analysis: To see the model performance during simulation runs, many analyses must be done. In this step, several statistical theories and methodologies are applied.
H. Simulation Runs: Similar to the sixth step (Experimental Design), it is beneficial to determine if additional runs are necessary to achieve accuracy
I. Documentation and Reporting: It is more than known that not everyone has experience in simulation. Even many engineers could be completely ignorant about simulation models. We should create enough documentation to make it understandable to everyone for this reason.

A better explanation of those steps can be found on the following figure 1.

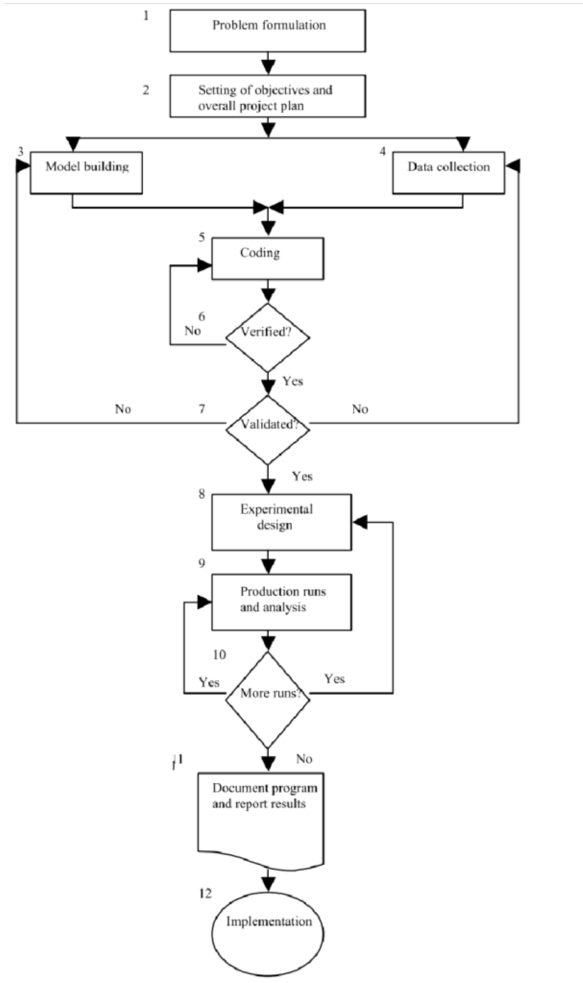

Figure 1: The outline of Creating a Simulation Model (Banks et al., 2004)

Advantages and Disadvantages

Therefore, after a brief explanation of what simulation is, and its steps, it is valid to talk about which advantages and disadvantages of using simulation instead of experimentation with the real system.

As previously said, simulation has a lot of benefits. The reasons for using simulation in our operations are as follows. (Robinson, 2003)

1. Cost: The cost of testing the real system is usually high. Interrupting regular processes to test out new concepts is expensive. In addition to the expense of changing something, it can be required to shut down the system for a while as adjustments are made. Additionally, if the changes result in a decline in the operation's performance, it could be expensive in terms of diminished client satisfaction and lost business. However, with a simulation, modifications can be made without affecting how the system functions in the real world and at the cost of the time it takes to update the model.
2. Time. Experimenting with a real system takes time: Before an accurate reflection of the system's performance can be produced, it can take several weeks or months (or even longer). A simulation can go much quicker than in real-time, depending on the size of the model and the speed of the computer. As a result, system performance data can be acquired in a few minutes or even hours. Additionally, results can be achieved over very extended periods, possibly years of operation, if necessary. Additionally, quicker experimentation makes it possible to quickly examine a variety of concepts.
3. Control of the experimental conditions: Controlling the experimental circumstances is helpful when comparing alternatives since it enables direct comparisons. When testing this on an actual system, is challenging. For example, it is impossible to manage patient arrivals at a hospital. The Hawthorne effect, in which staff performance increases merely because some attention is paid to them, is also likely to result from experiments with the real system. Sometimes the genuine system—like a military campaign—occurs only once, making it impossible to repeat an experiment. The settings under which an experiment is conducted can be reproduced numerous times using a simulation model.
4. The real system does not exist: Another very common problem happens when the structure where you want to test still does not yet exist. So, instead of recreating a completely real system, it is much more affordable to create a simulation, develop a model and therefore see which scenario would be the most appropriate for your experiment.

However, the same author (Robinson 2003) also clarifies that there are disadvantages to simulation, as follows.

It might be expensive. Simulator software is not always affordable and developing and using a model can be very expensive, especially if consultants are required.

Time. The time-consuming nature of simulation has already been mentioned. Because of this, using it becomes more expensive and the benefits do not materialize right away

1. Data. The majority of simulation models demand a sizable amount of data. This isn't always readily available, and even when data is, the extensive study may be needed to prepare it for the simulation.
2. Need for expertise. Simulation modeling entails more than just creating a computer program or using the software. It calls for expertise in working with people and project management, as well as knowledge of conceptual modeling, validation, and statistics.
3. Subsequently, it is understandable how simulations are important and that the advantages of doing it are much higher than their disadvantages. Moving along, that is necessary to identify the types of simulations. There is a categorization of two types of simulations, discrete and continuous. A discrete system has state variables that change instantly at distinct times in time. A bank is an example of a discrete system since state variables, such as the number of people there, only change when a customer enters or exits after receiving service. A continuous system is one which in this time-dependent state variables change constantly. Since state variables like location and velocity can change continuously concerning time, an airplane in the air is an example of a continuous system. (Law, 2013)

Discrete Event Simulation (DES)

Due to the work of renowned American scientist C. Shannon, a discrete event simulation methodology first emerged in the 1960s of the twentieth century. Since then, a large variety of computer hardware tools have been created, including WIMP, DWIM, and powerful processors with the data-processing capability to solve even the most challenging scientific problems. (Guseva et al., 2018)

Today, one of the main strategic management tools in the world, discrete-event simulation (DES), is helpful in decision-making because it views situations holistically and expresses all relationships, interactions, and uncertainty sets. (Arora, 2007)

Simulation techniques are necessary for businesses to analyze their processes. We can, however, ask a query. What other benefits may simulation provide besides system analysis? It is simple to state that discrete event simulation can also be utilized as a technique for optimization. It reduces costs and time, improves product quality and customer happiness, finds solutions to supply and delivery issues, makes better use of available space, and does many other things. (Wang and Nooh, 1995)

For a given allocation of resources and a known distribution of resource service times, a DES model can be used to forecast the mean wait (or queueing time), mean service time, and system throughput for clients. A DES model can be used to pinpoint performance bottlenecks in a system and assess resource usage. A DES model can be used to forecast and optimize costs for a specified level of system performance once costs are assigned to resources. (Embse et al., 2021)

Arena Software

Therefore, after understanding the importance of a DES, it is also important to know better which simulation software’s available in the market that can perform its need with excellence. And Arena Software has been chosen as the first tool for the present thesis.

Arena is a very renowned discrete event simulator and automation software that Systems Modeling created in 1993 and that Rockwell Automation later purchased. Arena has dominated the discrete event simulation software market for 30 years. The robust functional, object-oriented interface of the program and its ability to adapt to many application domains can be used to explain its popularity. (Guseva et al., 2018)

A process dynamic can be animatedly documented, visualized, and demonstrated with the use of ARENA simulation software. Models can run swiftly, analyze data, and be animated graphically thanks to ARENA simulation programs. There are various simulation types available in ARENA, including static, dynamic, continuous, discrete, and deterministic vs. discrete simulation. As a result, ARENA simulation can represent and simulate a wide range of system activity kinds and fields. (Rasib et al., 2021)

Inventory

As the main point of this thesis, it is finding a reliable inventory management, it is more than necessary to also include what inventory means. Inventory is understood to be a stock of goods kept on hand by a business to meet customer demand. (Russell et al., 1995). To be even more precise in this line of explaining, stockpiles of raw materials, suppliers, components, work-in-progress, and finished goods known as inventories can be found at various locations in a company's production and logistics channel. (Ballou, 2004)

Thereore, it is extremely important to control its inventory, as for small businesses, it may signify a lot of investment. A company's inventory is important from both a financial and an operational standpoint. First off, any company must make a significant financial investment in its inventory. For manufacturing companies, inventories account for 25–50% of total assets, while for wholesalers and retailers, inventories account for 75–80% of total assets. (Johson et al., 1974).

In this thesis, we are broad open to this definition and we are considering that we can use this step by step to any type of inventory, either a high value product that need to be stocked, to a low cost product. Before either way, controlling its stock is important either having a high value or not.

Inventory Management

As this thesis will be working closely to create and deliver different possible scenarios for an inventory management, it is ideal to exemplify how important an inventory management is important for any type of businesses.

Inventory management is crucial for any firm to satisfy ambiguous demands made by users or clients. How to maintain enough inventory and how to improve customer service levels are two crucial skills for decision-makers in today's environment in order to obtain advantages in supply chain management. (Yang et al., 2016)

And for that, the simulation already explained is a great opportunity to test different scenarios before implementing it. It will be feasible to identify different possibilities and the optimal scenario that will optimize the inventory level, satisfy demand, as well as reduce stock out and cost by running an inventory simulation model and employing a process analyzer. (Samad et al., 2016)

And to make a proper inventory at CAMID, more feasible, there are some alternatives that will be used in the simulation to really understand which one would be the best alternative for implementation. For this work, Barcode and Radio Frequency Identification (RFID) are two different technologies that can be used to turn the inventory control more efficient, and it will be explained in the following sections.

Barcode

The barcode technology is one of the oldest technologies still used in a regular basis in my different types of inventories. Since its introduction in the middle of the 1970s, barcoding has been used to automatically collect data or identify objects, improving the traceability of products. (Attaran, 2007).

They can be used in a variety of fields, including buying, warehousing, and invoices, and they have applications in inventory management, purchase, and accounting. Barcodes are still used by many industries and businesses despite the rapid advancement of technology and the introduction of new equipment to the market due to their lower operational costs and ease of installation. (Preradovic, 2010).

However, even thought it is a technology with low cost, there are some associated risks that might not be feasible and with time, it will require its barcode change. There are many known variables that can affect how well the scanning process works, including temperature, dirt, and contaminations. Beyond that, it requires an operator to scan each barcode using an extra time and energy. (Wyld, 2006)

For this reason, there are other technologies used in the industry, the so-called RFID, which has been used for years as well.

RFID

As this technology will be of high importance for this thesis, it is extremely necessary to discuss about its creation, importance and benefits for the inventory management industry.

Radio Frequency Identification (RFID) is a technique that recognizes tagged things via radio waves. A reader and several tags make up an RFID system. Using the reply messages from the tags, the reader broadcasts the query messages and locates the tags. (Jia et al., 2010)

The word "RFID" refers to short-range radio technology that primarily transmits digital data between stationary locations and moving devices or between moving objects. RFID systems employ a range of radio frequencies and methodologies. The straightforward gadgets, which are sometimes referred to as tags or transponders, are small and inexpensive, can be used in very large quantities, are attached to the objects that need to be handled, and work automatically. The more sophisticated devices are more powerful and typically connected to a host computer or network (also known as readers, interrogators, or beacons). Radio waves between 100 kHz and 10 GHz have been employed. Surface acoustic wave (SAW) devices, tuned resonators, and other technologies may also be utilized to build the tags, which are typically constructed using CMOS circuitry. The radio signal sent by the reader can be rectified to power tags instead of using a battery. Tags can generate, modulate, and broadcast radio signals or change the loading of the tag antenna in a programmed fashion to transfer data to the reader. (Landt, 2005)

That said, it is ideal to explain the main parts of a RFID technology.

Tags

A RFID tag is portrayed as a data-carrying device that normally includes a microchip and a transmission antenna. Depending on whether the tag has a power supply or not, there are numerous different types of tags that manage the signal and energy in different ways. Passive tags and active tags are the three different types of tags, passive, semi-passive(hybrid) and active tags. (Finkenzeller, 2010)

A hard copper coil with an integrated circuit (IC) connected to an antenna is used to make tags, which are subsequently packaged into a housing device that is suitable for the purpose. RFID tags exist in a variety of shapes and sizes and are incredibly durable. One-third of a millimeter or a rice grain's size is what some can reach. (Attaran, 2007)

According to the following table 1, it is possible to visualize better their differences.

Table 1: Type of tags (Nainan et al,. 2013)

Functions	**Type of tag**		
	Passive	**Semi-Passive**	**Active**
Range	Short (>10m)	Long(>100m)	Long(>100m)
Life Span	>20 years	5-10years	>10 years
Battery	-	-	Yes
Availability	Near to reader	Near to reader	Always
Storage	128 bytes	128 Kbytes	128 Kbytes
Cost	Cheap	Expensive	Very Expensive

Any product that is encrypted with a certain character pattern has the tag attached to it. The pattern is in the data-storing number sequences. This information is kept on the tag's microchip. The memory may be both permanent and rewriteable. The rewriteable tags can be repeatedly programmed into the chip using the reader. The tags come in a variety of styles and sizes. (Nainan et al., 2013)

Active tags have a power source and extra memory to store more information. Due to the power supply, it can read from farther away than a passive tag. (Finkenzeller, 2010) Active tags may activate themselves, while passive tags cannot. Semi-passive tags are those that share traits with both passive and active tags. RFID can operate on microwave frequencies between 2.4 and 2.5 GHz, ultra-high frequencies (UHF) between 860 and 1500 MHz, high frequencies (HF) at 13.56 MHz, and low frequencies (LF) at 125 kHz. (Nainan et al., 2013).

Benefits using RFID System

RFID technology has the ability to offer a number of advantages when applied properly. According to the GAO, the technology can provide a more efficient way for federal agencies, makers, retail chains, and distributors to gather, manage, distribute, store, and analyze the data on inventory, business operations, and security protocols, among many other functions, by enabling real-time information access. (GAO, 2005).

According to Kaur et al. (2011), although barcodes will likely continue to be widely utilized in the near future, the following benefits point to the possibility of using RFID in addition for identification purposes:

- Because tag detection doesn't require human interaction, labor costs are lower and human error in data collecting is eliminated.
- Because line-of-sight is not necessary, tag placement is not as restricted.
- Compared to barcodes, for example, RFID tags have a greater read range.
- Barcodes lack the read/write memory capabilities that tags do.

- In addition to a unique identity, an RFID tag can contain a significant amount of data.
- RFID makes it simpler to apply unique item identification than barcodes, because it can identify goods specifically rather than generally.
- Tags are less susceptible to bad circumstances (dust, chemicals, physical damage etc.).
- Many tags can be read simultaneously.
- Sensors and RFID tags can work together.
- An inventory's time lags and inaccuracies are decreased by automatic reading at several locations.
- Additional information can be locally stored in tags; this distributed data storage may improve the system's fault tolerance.
- Reduces expenses associated with provisioning and inventory control, as well as processing warranty claims.

Comparison between Barcodes and RFID System

After explaining its technologies, a comparison between those technologies is necessary as they will constitute two of our scenarios for the inventory management proposal at CAMID.

Therefore, Akbari (2015) highlights in a splendid way how the RFID technology outperforms barcode in many areas by comparing it to barcode technology and showing off its capabilities. Based on the ID number, both RFID and barcode scanners detect objects. Items are initially scanned and identified by devices, and after that, data is watched in the host computer for further processing. Barcode technology can be totally replaced with RFID, but this is not an economical alternative. The following details the key distinctions between RFID and barcodes:

- In order to scan the identifying number, a barcode reader must typically be positioned at the location. On the other hand, using radio waves that are picked up by the reader or antenna, RFID technology detects objects without any physical contact.
- While barcode readers must read the tag's ID number from closer than around fifteen feet away, RFID systems may identify tagged products at greater distances.
- Barcode scanners are ineffective in many applications where quick traceability is required due to their time-consuming nature because the rate of components tracking by RFID system, which processes more than dozens of tags at a time, is far faster than barcodes.
- Barcode readers do not offer the ability to write to or read from tags' memory. In contrast, the interrogator may easily update the data in the RFID tags as often as necessary.
- Even though RFID can track many tags at once, barcodes need to collect product information one at a time.
- Barcodes cannot be exposed in a severe environment, yet RFID can be used there successfully. As a result, it can survive challenging conditions like high humidity, high pressure, dust, or extreme temperatures.

Case Study 1: "The impacts of RFID implementation on reducing inventory inaccuracy in a multi-stage supply chain"

Dai (2012) investigated the effects of RFID on supply chain information distortion, visibility (correct inventory information), prevention (reduced inventory error), and inventory inaccuracy. An analytical model based on three distinct scenarios was developed to explore the effects.

1. Scenario 1 "The base case": a case in which RFID is not used.

2. Scenario 2 “The RFID case with visibility”: a product-level RFID solution in which every item is given a distinct RFID tag.

3. Scenario 3 “The RFID case with visibility and prevention”: The supply chain integrates RFID technology with additional auxiliary technologies.

To demonstrate the scope and influence of RFID, the analytical model was then contrasted with a numerical analysis that was conducted on a supply chain dataset. Their research demonstrates that the further a product follows the supply chain, the more information is distorted. When RFID is used, information distortion is eliminated. The RFID influence on cost demonstrates that if inventory error is apparent and stopped, the cost is lowered by an average of 1.5%, but if the error is just seen but not prevented, the cost is reduced by only 0.2%. Therefore, even though they note that the products utilized in the dataset are quite expensive, an investment in preventive is still worthwhile.

The study concludes by pointing out that various RFID implementations can yield various benefits because they require various investments. Therefore, it's crucial for practitioners to have a clear grasp of how RFID may provide value and investment returns in order to choose the best RFID application.

Case Study 2: “Simulating and Evaluating the Impact of RFID on Warehousing Operations: a case study”

Karagiannakia et al., (2007) provides a simulation application to a third-party logistics company (3PL) to assess the relative efficiency of RFID in warehousing activities (receiving, put-away, picking, and shipping). An organization that engages in paper trading and uses its own assets and resources to perform several services (such as provisional warehousing, transportation management, distribution management, and freight consolidation) on behalf of other businesses has provided the empirical data for this study. According to the results, RFID reduces the negative consequences of human scanning and verification by automating the warehousing processes. This reduces errors, labor intervention, and the amount of time needed to check for anomalies, while also boosting product throughput and inventory accuracy.

The instance illustrates how simulation may be used to simulate a third-party logistics provider in order to assess the relative value of RFID in warehouse operations.

Vianox, the company where they perfomed the study, engages in paper trading and uses its own resources and assets to carry out a number of tasks (such as interim warehousing and freight aggregation) for the benefit of other businesses. Since there involves manual material handling with "some" computer control, it might be referred to as a manual warehousing system or "picker-to-product" system. Paper rolls are stacked alongside each other in several parallel aisles across the warehouse. The products are stored in up to 4 depths of pile levels rather than on shelves by piling them on top of one another.

The case study shows the as-is warehousing processes, that includes receiving process, put-away process, picking process and shipping process. Therefore, the study used as objectives the following three items, comparing the ais-is model and the one with RFID-enabled model.

1. The typical receiving period (unloading-scanning checking-in).
2. The typical dispatching period (picking-consolidating scanning-checking loading)
3. The percentage of time that the available resources, such as workers, are being used to justify their volume.

Using discrete-event simulation, the theory for the comparison has been tested and the following table 2, exemplifies the results from the simulation.

Table 2: A summary of the simulation model's responses (Karagiannaki et al., 2007)

Measurement	As-is model	RFID-enabled model	Comparison Result
% utilisation of scanning labor	9.60%	2.48%	Reduced 74%

% utilisation of storing/picking labor	19%	17.17%	Reduced 9.6%
% utilisation of unloading/loading labor	3.19%	2.48%	Reduced 22.5%
Average time waiting for scanning	0.21s	0.06s	Reduced 71.4%

As a result, two main domains have been highlighted from the results:

- Labor utilisation: As a result of the greater automation provided by RFID technology, personnel are able to do away with manual scanning in the receiving function, which results in a 74% reduction in labor utilisation overall. The information that has been stored can also make it simpler and quicker for the operators to sort and move the objects to their intended places. The outcome is a 9.6% decrease in labor usage for product assignment and picking thanks to RFID technology. Lastly, RFID does away with the requirement for compliance inspections on the shipping and receiving dock. As a result, RFID more than makes up for the personnel costs (which were cut by 22.5%) incurred when checking for discrepancies.
- Time savings: By increasing automation, eliminating mistakes (such as barcodes that are covered or broken), and improving process efficiency, the average time spent waiting for scanning is reduced by 71.4%.

Small Business

According to the Congressional Research Service Report(2022) that is prepared for Members and Committees of the American Congress, the definition of a Small business was defined by The Small Business Act of 1953, also authorized by the U.S. Small Business Administration (SBA).

The act states that, a small business as one that:

- is formed for profit;
- operates largely there or significantly contributes to the American economy by paying taxes or by using American goods, materials, or labor;
- has at least a location in the United States;
- is completely operated and owned by independents;
- is not the industry leader on a national level in its sector.

However, over the years and the economy growth this wide-open definition has been discussed tiredly, currently the SBA's industry-specific size guidelines decide whether businesses in the 23 sub-industry categories listed in the following 1,037 industrial classifications (hereafter industries) are eligible for the program.

Therefore, every single industry has their own definition and size limitation to be called as small business. A market that according to the CENSUS – Statistics of US Businesses in 2022, pursues 33.2 million small businesses which corresponds to 99.9% of US businesses, but aggregates only 46.4% of US employees.

Due to various definitions and sizes capabilities, this thesis focus is going to be on small businesses with no employees to 19 employees maximum, which corresponds to more than 32.5 million small businesses. As a way of helping small businesses that are facing challenges on implementing an inventory management that can improves order accuracy and a better control of their stock.

CAMID

The Center for Advanced Manufacturing and Innovative Design (CAMID) is a 100,000-square-foot Florida Tech facility for manufacturers of all sizes, camid is intended to operate as a workspace and business incubator. What makes this location special is as follow:

- Professionals in the domains of engineering, materials science, and sophisticated manufacturing, as well as industry resources.
- Modern computer-driven production machinery with a strong focus on additive techniques.
- Providing ongoing education and training on the newest engineering and manufacturing digital-based technologies to the manufacturing community
- The newest digital development and manufacturing software and hardware are available in applied laboratory spaces for the benefit of the industrial industry.

CAMID pursues around 18 employees, between full-time workers and students from Florida Tech that work part-time in there. They have their own budget dedicated to do all activities, including the costs related to inventory system. Currently, they do not have an automated system to manage their inventory, facing a lot of extra costs with inaccuracy coming from their current manual inventory system. Therefore, even being part of Florida Tech, as a case study, CAMID pursues all attributes that are similar to a small business, in terms of scales is ideal to practice the purpose of this thesis, which is determine a easy guide that will help a small business to identify the most reliable inventory system according to their needs.

Chapter 3
Methodology

After the literature review, it is necessary to explain the methodology used to perform the desired action of how to select which inventory management system would be the best option in a small business. The step-by-step process is showed on the following figure 3. This proposed model process is composed by a mix of 5W1H method, simulation framework (figure 1) and pros and cons analysis. This model contributes in a way to guide a small business that does not not where to start when selecting a inventory management system that fulfill their needs.

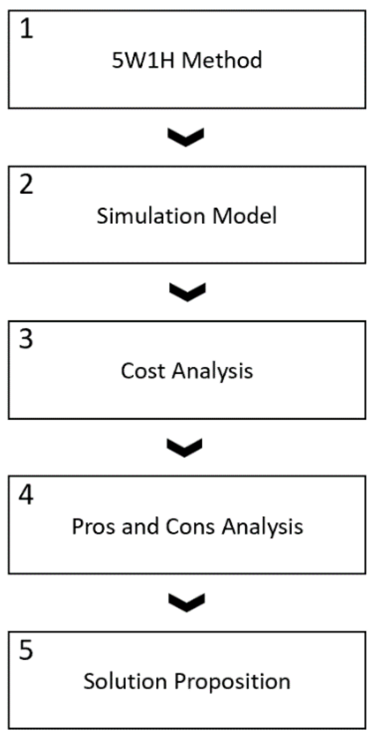

Figure 2: Process for identifying a realible inventory management

Step 1 – Method 5W1H

First, understanding the problem is extremely important to start. Therefore, a form was created to deeply comprehend the small business need of an inventory management system. The basis for this form will be using the 5W1H framework (Who, What, When, Where, Why and How), where the purpose of this thesis is to show the how a small business company, in this case CAMID, can choose their best option for an inventory management.

Said that, see below the proposed questions using a 5W1H framework that will be used to understand our problem, essential to formulate properly our problem.

Dear CAMID,

To whom it may concern,

It is an honor to work with you in order to solve and propose solutions for the problems faced in your facility. Please, respond to those questions below to explain in detail your issues related to inventory management.

For this phase, problem formulation, it is going to be used questions following the 5W1H framework (Who, What, When, Where, Why and How) and by the end of the entire process, the "How" will be responded to you.

Thank you very much.

Questionnaire/Form

1. WHAT is the problem that you face currently regarding your inventory? Do you have any inventory management in use?

2. WHAT do you care more for your solution, efficiency or cost? Or a combination of both?

3. WHAT is your budget for this solution?

4. WHY are you facing those issues?

5. WHEN did it start to cause problems on your business?

6. WHO is/are the responsible for the inventory in your company?

7. WHERE is it located your inventory?

Step 2 – Simulation Model

As a next step, it comes the simulation model development, in other to help the small business to understand the best alternatives for implementing an inventory management, it is going to be followed the simulation model explained.

Problem Formulation

Identifying the issue is crucial, thus we will use the 5W1H method's responses to pinpoint the present issues CAMID is dealing with.

After analyzing and making sure that their problem is a lack of inventory management, further questions must be done to facilitate the fully understanding of the problem. CAMID only pursues an excel sheet with no tags to identify any object that they current have, therefore leading to a high number of errors and generating unnecessary orders.

Setting of objectives and overall project plan

The next stage is to request that our small business, CAMID staff, submit all flowcharts pertaining to their inventory while also incorporating the responses from our survey. This allows for the tracking of how the present inventory process is carried out, locate the variables that are generating errors in the system, and then use that information as the basis for comparing various situations. These factors are crucial since every single error probability has an impact on how well-balanced the inventory management is carried out.CAMID presented the following parts as essentials in their current inventory process. Which are defined in three different parts:

A. Demand from Staff (Part 1): When a CAMID employee requires any item or thing from the inventory, this is the part of process that decribes that. This section will also determine whether or not they need to order a new item. Everything therefore begins with the requirement for an item, and after this they verify the inventory (which in the current process there is a high probability of not checking it properly). T he requirement to order that item in the event it is not present in the inventory, which brings us to the following step. If they can locate it, they must remove it from inventory, give it to the user, and then update the inventory after the task is complete. The process is depicted in figure 4 below.

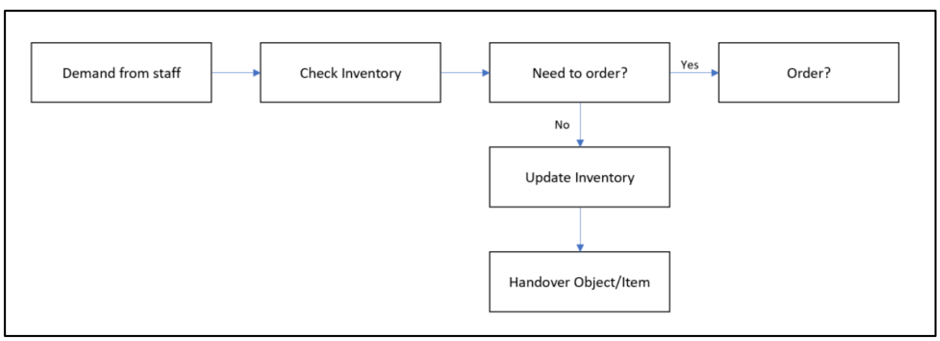

Figure 3: Process flow for Demand from Staff (Part 1)

B. Receiving packages (Part 2): this phase occurs anytime CAMID orders anything. So, the procedure begins with receiving the package, after which the CAMID employee will identify which package is that and update the inventory. After that, move it to the inventory and then put it in the appropriate spot that was previously specified by the CAMID direction. Nonetheless, there is a chance that staff members may have misplaced items. The procedure for receiving packages is now complete. The following figure 5 below illustrates the process flow for this component.

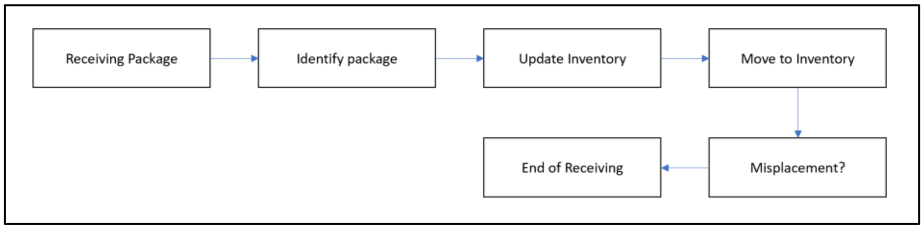

Figure 4: Process flow for Receiving Packages (Part 2)

C. Returning object (Part 3): After a member of staff is finished using an item, they should put it back in the inventory. This final section is similarly crucial to a thorough and accurate inventory. The first step is to add the item back to the inventory. The worker should then update the inventory and place the item's storage in the proper spot. Similar to the previous phase, there is also the chance of misplacing the object, which puts an end to the process of returning the thing. The following diagram, on figure 6, depicts the process flow for this component.

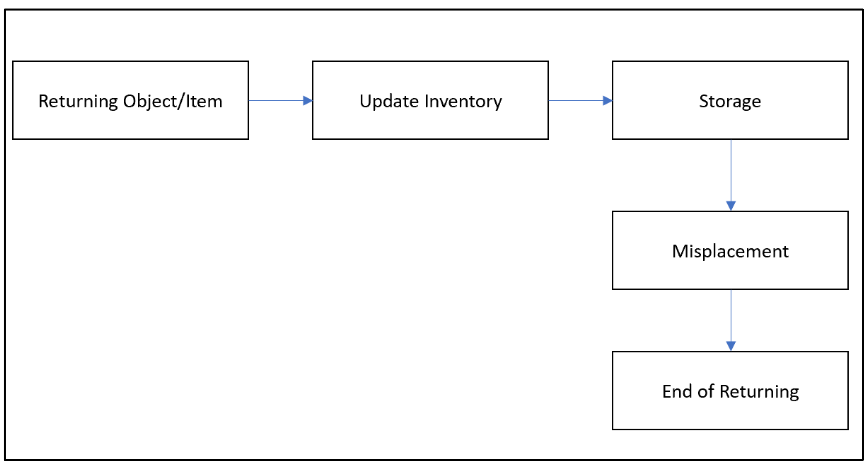

Figure 5: Process flow for Returning Packages (Part 3)

Upon receipt of those flowcharts, it is important to pinpoint the variables (i.e., the potential for errors), when those errors are most likely to occur, and an estimation of how frequently those errors might occur. These variables are displayed in table 3 below.

Table 3: Variables for all parts

Inventory Part	Variable	Variable Name	Explanation
Demand from Staff – Part 1	E_{c1}	Error checking inventory	The probability of someone not checking the inventory properly making to order an unnecessary item.
	E_{eu1}	Error updating inventory. (Part 1)	The probability of someone not updating the inventory when the demanded item is found at the inventory and taken out from inventory.
Receiving Packages (Part2)	E_{eu2}	Error updating inventory (Part 2)	The probability of someone not updating the inventory when a new item is received at the inventory.
	E_{p1}	Error placing the object (Part2)	The probability of someone misplacing the item at the warehouse, causing confusing to find it in another time.
Returning object (Part 3)	E_{eu3}	Error updating inventory (Part 3)	The probability of someone not updating the inventory when an item is returned to the inventory.
	E_{p2}	Error placing the object (Part3)	The probability of someone misplacing the item when an item is returned to the inventory.

Model Building

After establishing the goals and specifying the entire procedure and its variables, a model should be built using the simulation software of choice, in this case Arena. Incorporating those variables with the present inventory process flow at CAMID. Please refer to the image 7 to see how the model appears in ARENA software.

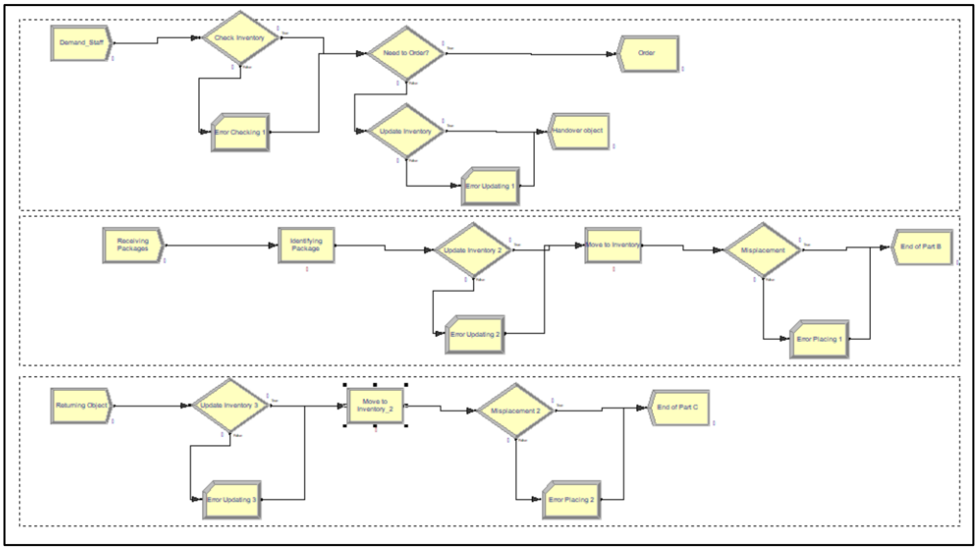

Figure 6: Flowchart from CAMID inventory management system on Arena Software

For Part 1, demand from staff, the two variables discussed for this part are E_{c1}(Error checking inventory) that occurs right after the "check inventory" in the following figure , identified in the flow as "Error Checking 1" and it will be counted every time that this error occurs and the second error for this part is E_{eu1}(Error updating inventory) that goes right after the "update inventory" in the following figure too, in the flow is the "Error Updating 1". Therefore, the number of errors that can probably occurs with be accounted.

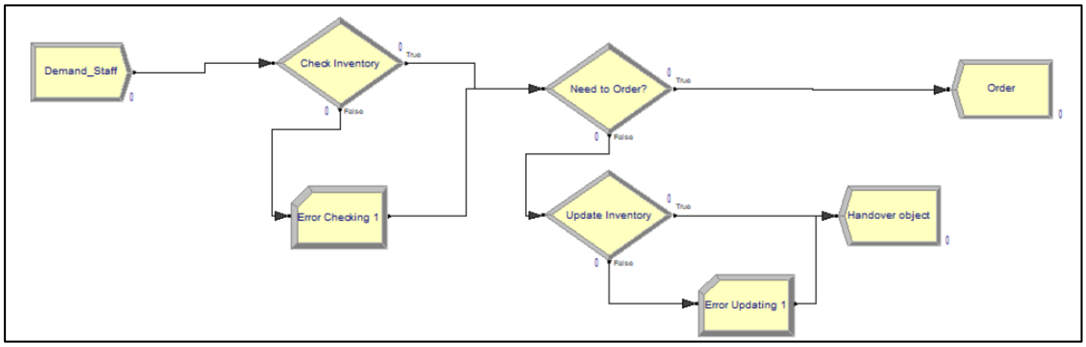

Figure 7: Demand from Staff (Part 1) in Arena Software.

For Part 2, receiving packages (part 2), the first discussed variable is E_{eu2}(error updating inventory) that happens every time after the "Update Inventory 2"and it is identified as "Error Updating 2" and the second variable for this part is E_{p1}(Error when placing the object/item in the wrong place), identified in the flow as "Error Placing 1".

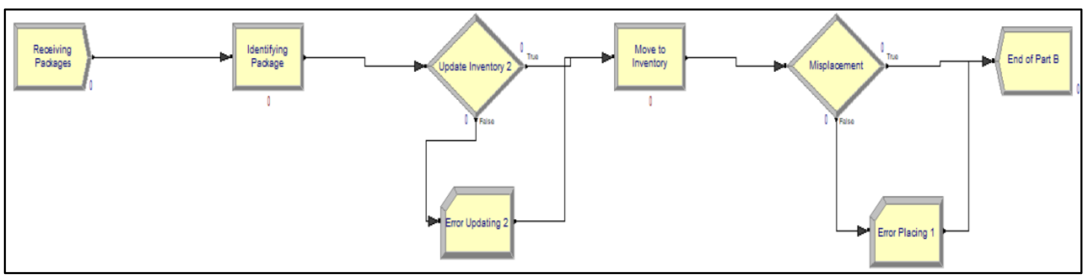

Figure 8: Receiving Package (Part 2) flowchart in Arena Software

For Part 3, there are also two variables as discussed. The first one is E_{eu3}(Error updating inventory), that is identified as "Error Updating 3" in the following figure and E_{p2}(Error Placing object/item) that can also happen again and it is counted by the "Error Placing 2" block in the following figure as well.

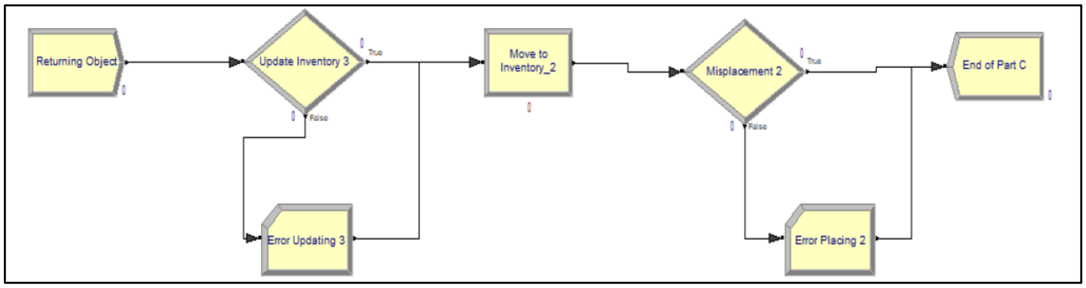

Figure 9: Returning Object/Item (Part 3) flowchart in Arena Software

Data Collection, Verify and Validate

With all constructed, it is necessary to include data/numbers to the process. A meeting with CAMID was necessary to define and collect times and probability of those variables as well.

According to them, the starting point for all three parts identified on their inventory management process is:

A. Demand from Staff (Part 1): around 20 objects per day are demanded, leading to 100 objects per week.
B. Receiving packages (Part 2): per week, CAMID receives around 30 orders, leading to 6 orders per day in average.
C. Returning object (Part 3): CAMID team usually returns 15 objects to their inventory, leading to 75 objects returned per week.

The proposed model designed on Arena is shown to CAMID staff, so they could it validate and verify it that those chosen variables are accurate.

Experimental design

When verified and validated by CAMID. A experimental design has to be made to determine and test our possible solutions to the problem.

In CAMID's case and according to the literature review, two different technologies are going to be used to verify and test possible scenarios for solution to the problem.

The following scenarios are:

1. Scenario 1: A base model from the current method currently used by CAMID, where only an Excel sheet is used to control the whole inventory. Generating a lot of misplacements, errors when updating the inventory.

2. Scenario 2: A model using Barcode to every item in the inventory along side a system to control the inventory.

3. Scenario 3: A model using RFID tags, RFID reader and complementary system to control the whole inventory system.

For each of those scenarios, variables with different probabilities were estimated in joint discussion with CAMID. More specifically for Scenarios B and C, the estimation was based on Helltstrom et al. (2010) and as well, Wang (2010). Table 4 decribes what is the dedicated value for each variable.

Table 4: Variables and their values

	Variables					
Scenario	E_{c1}	E_{eu1}	E_{eu2}	E_{p1}	E_{eu3}	E_{p2}
1	6%	6%	6%	8%	6%	8%
2	4.9%	4.9%	4.9%	8%	4.9%	8%
3	1%	1%	1%	1%	1%	1%

Scenario 1 is base model for the current status showed on CAMID. After interactions with the CAMID, this information was acquired. The CAMID could only establish an estimate because they lacked a precise data on how frequently these mistakes occur. As a first base, CAMID discovered that between 6%-8% of their orders could be avoided as it was caused to a lack of precision in their inventory system. From that, we could estimate that checking the inventory in the first part (E_{c1}) occurred on average 6% of the time, as the E_{eu1}, E_{eu2} and E_{eu3} which are the errors possibility when they forget to update the inventory. And CAMID highlighted that misplacement occurrence where even bigger, leading to E_{p1} and E_{p2} to have average of 8% of time.

Scenario 2 is based on the utilization of barcodes to track all the objects/items in the warehouse. In our model, there are two types of errors, either by not updating the system or by misplacing the object/item in the wrong place. For this system, it was used based on Helltstrom et al., (2010). According to their study, the system pursues a 4.9% chance of errors in general. The cause for this might be caused by the damaging of barcodes over time and also, there is still need of a person to manually scan the barcode before any interaction, if my any chance, no one check the barcode before taking out from the inventory, errors will happen anyway. As also the possibility of misplacing the object/items in wrong places been hard to identify the location afterwards. To be fair, in agreement with CAMID, the errors probability for checking/updating the system, it will be followed by the discussed study, turning into 4.9% average of time for E_{c1}, E_{eu1}, E_{eu2} and E_{eu3}. However, to follow the same logic, as having barcodes don't change the possibility of misplacing the object/item and not being able to find it later, it will have the same probability of 8% chance of errors related to E_{p1} and E_{p2}.

Scenario 3 is the one that will represent the lowest chance of errors as it uses a system that mostly will depend on the system to do its way. The inventory will have RFID readers and at the entrance/exit doors, other RFID readers as well. This type of implementation gives an assertive traceability, because whenever the object/item is taken out from the inventory, it will automatically update the inventory system. Therefore, the probability of not checking or updating inventory is nearly 0%, as it gives more than 99% accuracy, according to Helltstrom et al. (2010) and as well, Wang (2010). To be fair, it was agreed in mutual agreement of 1% error for E_{c1}, E_{eu1}, E_{eu2} according to those studies, as it can be caused in case of a remote possibility of a broken equipment. As it also affects the misplacement error, as the RFID reader, even though when object/item is placed in the wrong location, an error message will be shown to the CAMID staff notifying that the object was placed in the wrong location, turning the possibility of misplacing at nearly 0% as the CAMID staff will be alerted and having to correct the error. But to be fair with the same possibility of broken equipment, the errors for misplacing E_{p1} and E_{p2} will be set for 1% in this scenario.

Production Runs

As all the variables and possible values were determined the simulation can run.

It was determined that the simulation runs in every single business day in the year of 2023, and each business day pursues 8 hours. Therefore, for this simulation, CAMID in 2023 has 249 working days.

Report Results & Documentation

After the simulation, report results are generated from the ARENA Software and excelling well-done graphics that can be shown with results.

Step 3 – Cost Analysis

As small businesses, it is all known how it is importing to understand the cost of a technology and to implement it. That is why it is extremely necessary to know how much each system costs.

Barcodes generally is a cheap inventory system that have been used everywhere, however RFID can become expensive depending on the facilities sizes. The cost was estimated according to the website "Amazon" which is the website that CAMID feels comfortable and go almost all their purchases. The final values are an estimation based on March 2023, regarding the tags, it was estimated that the current inventory has around 1000 items. And also, the turnover of items from the inventory is around 600 items.

Table 5: Costs for each scenarios

Scenario	Material	Cost
1	Only usage of Microsoft Excel, currently CAMID pursues their license in a daily basis for other activities, so no extra costs for this scenario.	$0
2	Price per tag ($0.01)	$10
	Barcode reader	$20
3	Passive RFID tags ($0.10 for non-metal, liquid material, in case of IT or metal assets, such as laptops, screens costs $1.00)	$200
	UHF Reader Passive Tags	$500
	Cables, support materials	$200

Therefore, the total cost for Scenario 1 is $0, scenario 2 is around $30 and lately scenario 3 around $900.

Barcode may be the best option from this standpoint financially because it is less expensive and offers fewer faults than scenario 3. But, there is still another crucial point to take into account. As previously said, around 6-8% of extra objects/items are ordered as a result of those errors from their current inventory system, and therefore small business, in this case CAMID, must present the expected amount of additional expenditures associated to the ineffective inventory system.

Hence, in order to complete the cost analysis, it will be determined how much it would cost CAMID to implement each scenario as well as how much it would cost extra as a result of mistakes made over the course of the next two years for each scenario. So, it will be able to calculate the financial impact of those errors on CAMID.

For this case, as it is with focus on small business and to turn it into an easy tool for small business usage, the inflation and taxation will not be taken into consideration as the focus is understanding the amount of lost capital due to a lack of accuracy in their inventory system.

Step 4 – Pros and cons analysis

After all this analysis, all three scenarios will be put into a pros and cons analysis, highlighting the positive and negative points for all scenarios. Following the standard table below.

Step 5 – Solution Proposition

It is fair to determine which solution proposal would be the ideal one for the needs of the small business based on their needs. As a matter of fact, the small business is the one who will employ the solution in their facility, so it is their ultimate decision, but a proposal is shown to assist them in making it. The focus must be on what the small business is searching for. Using a combination of factors from all 4 previous steps.

Chapter 4
Results

Step 1 – Form answers

Therefore, all those questions were answered by CAMID administration, very briefly and are displayed their answers in the following part in italic letters:

1. WHAT is the problem that you face currently regarding your inventory? Do you have any inventory management in use?

   Nowadays at CAMID, we do not have a proper inventory system. Everything in general is definitely manual, so whenever something comes and goes from the inventory, we do not have much control.

2. WHAT do you care more for your solution, efficiency or cost? Or a combination of both?

   A combination of both, we have a budget of around $46,000 per fiscal year to spend with our orders at CAMID and at the same time, our expenses with inventory would have to be included in that.

3. WHAT is your budget for this solution?

   We are open to see what the possibilities are, we are pretty much open as we still do not have a specific budget for that.

4. WHY are you facing those issues?

   As we have a manual inventory system, time over time, we lost items and have not control over what we have or not. Leading us to spend around 6%-8% of our budget ordering items that we probably have but due to the inaccuracy in our current system, we cannot locate them.

5. WHEN did it start to cause problems on your business?

   As our facility manages a lot of events, the number of items in our inventory has been increasing a lot, a lot of our employees have complained about finding items and this year, when we did an estimation that we spend 6-8% of our budget reordering items that we do already have, made as realized that we should change something.

6. WHO is/are the responsible for the inventory in your company?

   Currently, around 2-3 students oversee the inventory. However, at the same time, a lot of students/employees might use it.

7. WHERE is it located your inventory?

   Our inventory is mostly a warehouse room with around 14ft x 10ft located in our facility in Palm Bay FL.

Those answers were really important to help the purpose of this thesis and understand what are the problems that CAMID are currently facing with their inventory system.

Step 2 – Simulation results

This part will present the output results from the simulation that identifies the number of errors that were generated by each scenario for over a year at CAMID. All setting for the simulation below where described in the previous chapter.

- Errors in Part 1: Demand from Staff

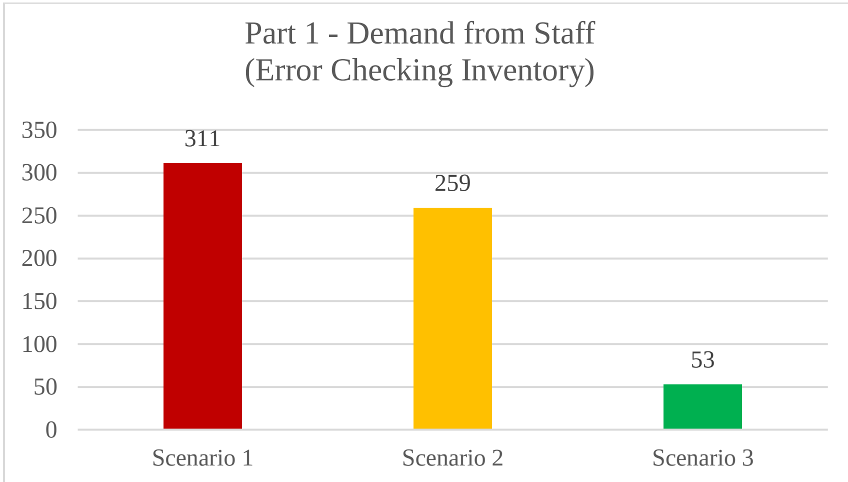

Figure 10: Part 1 – Error Checking Inventory(E_{c1})

As it can be seen from the figure 11, just in this variable, the scenario 1 generates more than 5 times compared to the scenario 3. While on scenario 2, barcode method, also presents a high number of errors, as discussed before, it might be due the fact that a barcode on an item do not avoid the possibility that that item might be found.

On the following figure 12, still in part 1, it shows the number of errors on the variable (E_{eu1}), that happens when the CAMID staff has found the item which he/she needs and it will be taken out from the inventory, therefore it is needed to update the inventory.

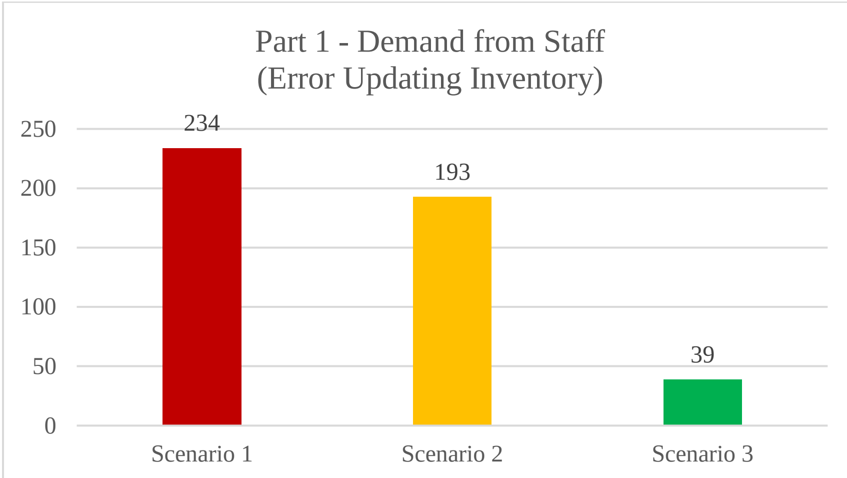

Figure 11: Part 1 – Error Updating Inventory(E_{u1})

Once again, the scenario 1 presented the highest number of errors generated by the simulation on Arena Software. The pattern is followed and the scenario generated around 6 time more errors that the scenario 3. While as in the previous variable, the scenario 2 presents a very close result from the scenario 1.

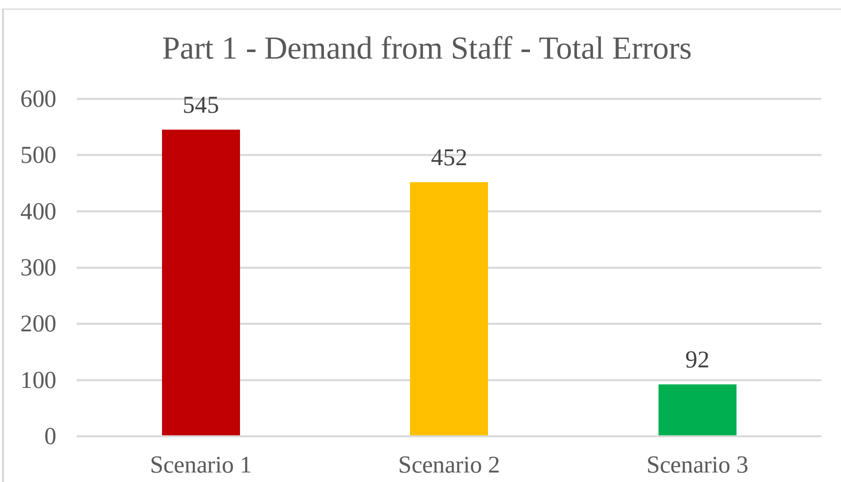

Figure 12: Total Errors on Part 1

In the figure 13 above, the total numbers of errors in all scenarios in phase 1 is demonstrated. As expected, the number of errors in Scenario 1 is much higher than the others and followed closely by scenario 2 and with the best results and below 100 errors, is the scenario 3.

This shows that scenario 3 consistently creates the least amount of errors when the staff wants an item from the inventory, which would eventually result in fewer unwanted purchases through CAMID.

- Errors in Part 2: Receiving Packages

In this second phase, Receiving packages shows the amount of errors made by the CAMID staff when they receive a new package or order. Additional errors could be made, such as updating the system with the new packages or placing them in the wrong place, which would make it difficult to locate them in the future and probably cause them to order unnecessary items.

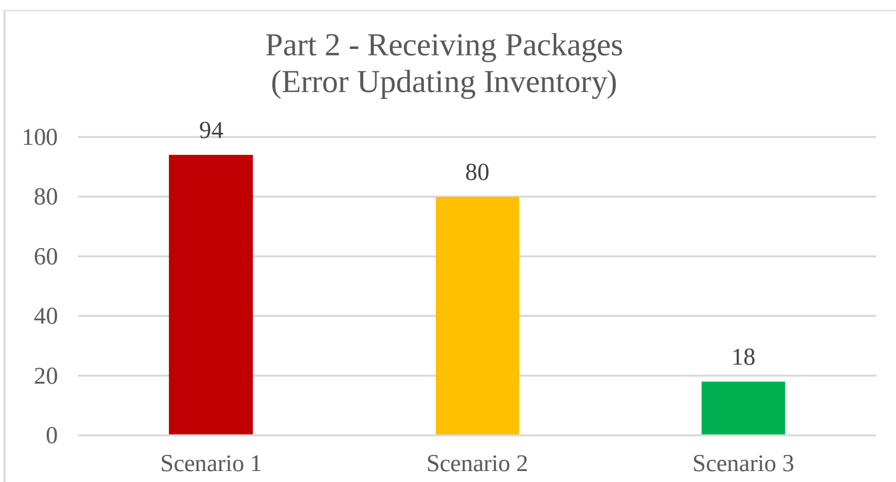

Figure 13: Part 2 – Error Updating Inventory(E_{u2})

Following the same trend as on part 1, the scenario 1 generated the highest number of errors, with 94 errors, when is needed to update the inventory whenever a package is received at CAMID. Scenario 2 generates a very close result with 80, and scenario 3 with the lowest number of errors, only 18 over a year.

In the following figure 15, it will show the number of possible errors that might happen when the staff from CAMID need to place the new object/item at the inventory.

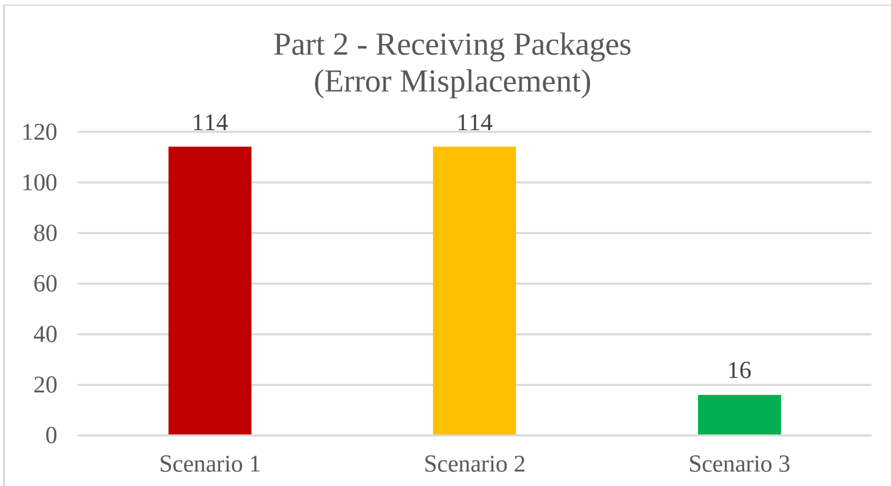

Figure 14: Part 2 – Error Misplacement(E_{p1}**)**

Related to this error, both scenarios generate the same number of errors, Scenario 1 and 2. Not having an identification at the object (Scenario 1) or being identified by a barcode (Scenario 2) do not avoid the object of being misplaced by a CAMID staff member, however, having a RFID tag, Scenario 3, when the system is notified when placed in the wrong place consequently results in lower number of errors, as in this case only 16.

The combination of those two errors in part 2 leads to the following figure 16 which shows the number of errors committed in part 2 over a year. Impressively, scenario 1 and 2, each one of them, generate more than 5 times more errors than the scenario 3.

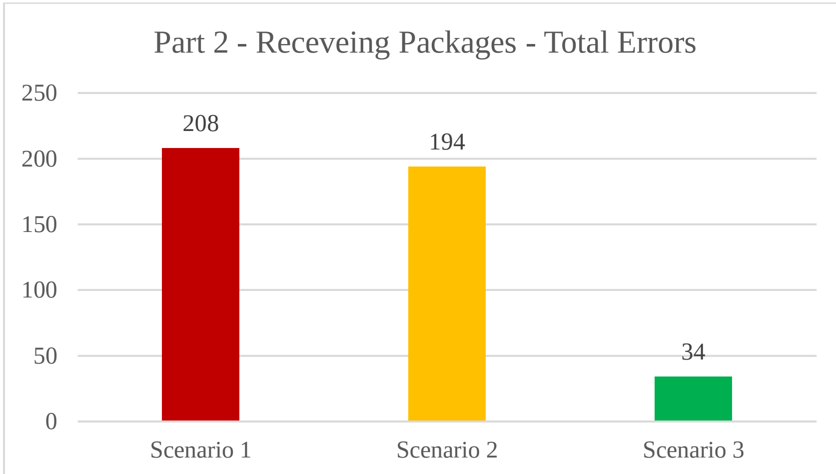

Figure 15: Total Errors on Part 2

- Errors in Part 3: Returning Packages

Returning the item to the inventory is the final step. Every time a member of the CAMID staff finishes utilizing an object or item, they must return it to the inventory, which should then be updated. Errors, however, are conceivable and might be overlooked. The most errors are once again found in Scenario 1, with 203, compared to 194 in Scenario 2 and 34 in Scenario 3.

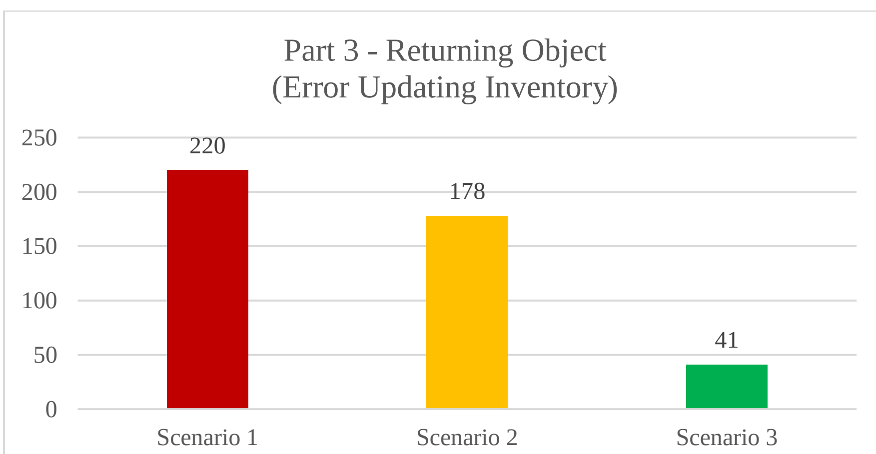

Figure 16: Part 3 – Error Updating Inventory(E_{u3})

The last variable on part 3 is the one related to the possibility of misplacing the object/item to the wrong place when returning to the inventory. Similarly, to the one in Part 2, scenario 1 and 2 have similar results, while scenario 3 only 41.

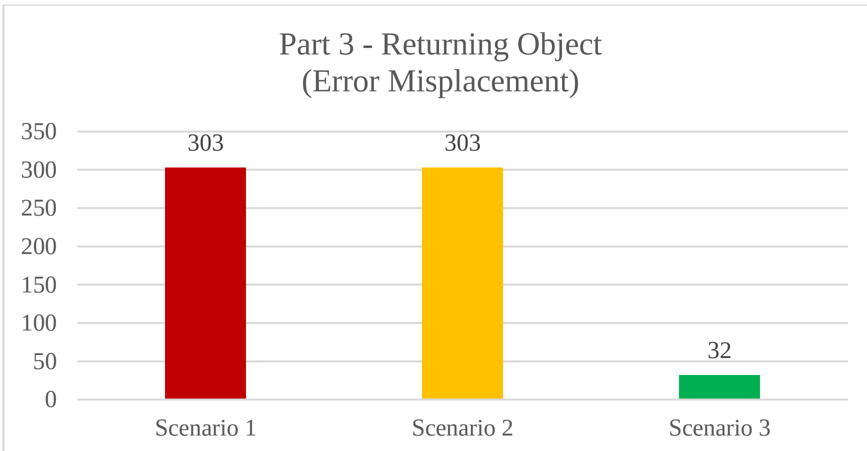

Figure 17: Part 3 – Error Misplacement(E_{p2})

As a total for this part, the scenarios 1 and 2 can generate almost 10 times higher number of errors than scenario 3.

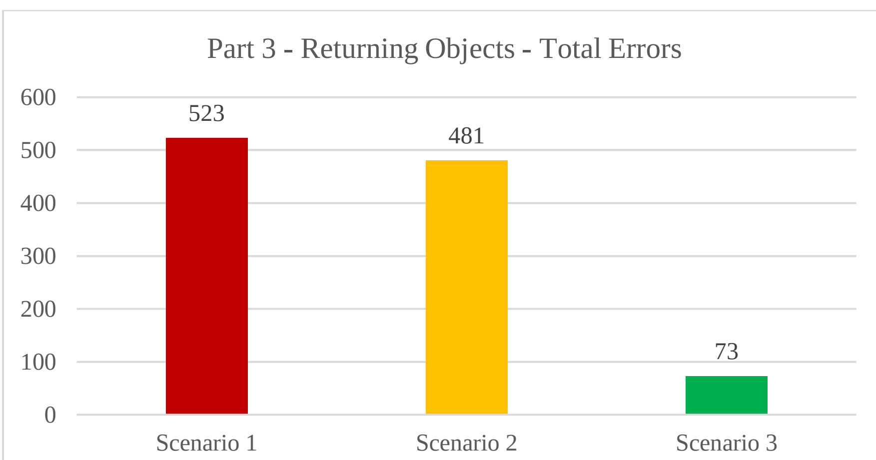

Figure 18: Total errors on Part 3

After all parts, it leads to the following figure 20 that accounts for all possible errors in a year at CAMID related to inaccuracy of inventory.

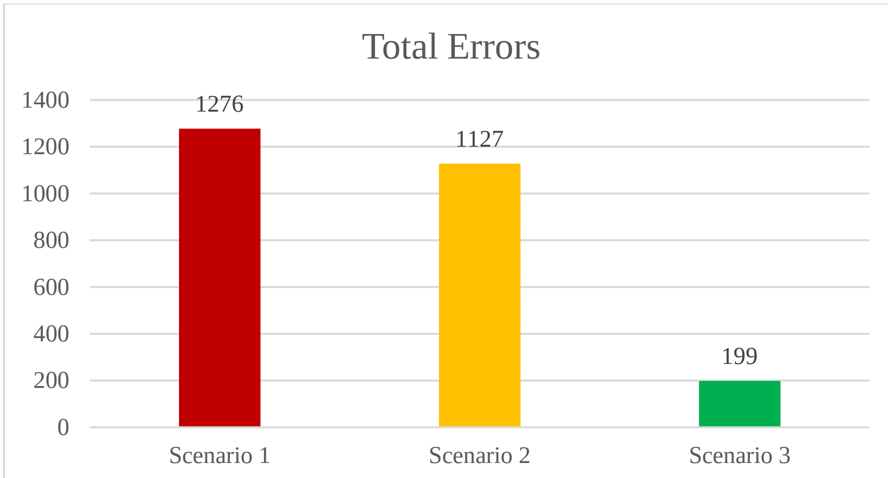

Figure 19: Total Errors in all Parts

Scenario 1 leads with 1393 errors, 6 times higher than scenario 3 with only 231 errors in a year. While scenario 2 presents a similar number of errors than scenario 1 with 1239.

Step 3 – Cost Analysis

The next step is making the average of total average of probable errors for each scenario, including all parts. This part is defined as the rate between total numbers of interactions in that part, divided by the number of errors for each variable.

$$Percentage\ of\ Errors = \frac{Number\ of\ Errors}{Total\ number\ of\ Interactions}\ (1)$$

According to the simulation, the following number of interactions are done over a year, in this case for the year of 2023.

- Part 1: 5200.
- Part 2: 1501.
- Part 3: 3620.

Therefore, for the Scenario 1-2-3, % of errors in the following table, is the # number of errors is divided by the number of interactions in each part.

Table 6: Percentage of errors per Variable and Scenario.

Variable	Scenario 1 # of Errors	Scenario 2 # of Errors	Scenario 3 # of Errors	Scenario 1 % of Errors	Scenario 2 % of Errors	Scenario 3 % of Errors
E_{c1}	311	259	53	6.0%	5.0%	1.0%
E_{eu1}	234	193	39	4.5%	3.7%	0.8%
E_{eu2}	94	80	18	6.3%	5.3%	1.2%
E_{p1}	114	114	16	7.6%	7.6%	1.1%
E_{eu3}	220	178	41	6.1%	4.9%	1.1%
E_{p2}	303	303	32	8.4%	8.4%	0.9%
Total	1393	1239	199	**6.5%**	**5.8%**	**1.0%**

The most important numbers are the ones in bold numbers on the Table 6, which shows the percentage of errors for each scenario overall for all parts, so we can calculate the cost with inaccuracy.

According to CAMID, they have a $46,041.28 annual budget for orders and expenses with new goods and items to CAMID for each fiscal year. But, depending on individual needs, this number may be higher or lower. So, the budget will serve as the foundation for an inaccurate cost computation. So, it is possible to determine how much money is being wasted if they consume the entire budget.

The cost with inaccurate inventory system will be done using the following formula:

$$Cost\ with\ Inaccuracy\ =\ Total\ of\ orders\ value\ *$$
$$Average\ probability\ of\ errors\ in\ the\ inventory\ system\ (2)$$

According to CAMID, total of orders value per year is equal to

- For Scenario 1, the average probability is 6.5%
- For Scenario 2, the average probability is 5.8%.
- For Scenario 3, the average probability is 1.0%.

Those average were determined by the simulation and showed on table 6.

Using that formula, generates the following results:

$$Cost\ with\ Inaccuracy(Scenario\ 1) = \$46{,}041.28\ *\ 0.065 = \$2{,}992.68$$

$$Cost\ with\ Inaccuracy(Scenario\ 2) = \$46{,}041.28\ *\ 0.058 = \$2{,}670.39$$

$$Cost\ with\ Inaccuracy(Scenario\ 3) = \$46{,}041.28\ *\ 0.010 = \$460.41$$

Knowing that, the next step is putting side by side the initial investment, current cost for inventory and cost with inaccuracy by year.

Table 7: Costs per Scenarios over 3 years.

	Initial Investment	(2023-2024)		(2024-2025)		(2025-2026)		Total
		Added inventory	Cost with Inaccuracy	Added inventory	New Inventory	Added Inventory	Cost with Inaccuracy	
Scenario 1	$0	$0	$2,992.68	$0	$2,992.68	$0	$2,992.68	$8,978.04
Scenario 2	$ 28.00	$10.00	$2,670.39	$10.00	$2,670.39	$10,00	$2,670.39	$8,069.17
Scenario 3	$ 900.00	$200.00	$460.41	$200.00	$460.41	$200.00	$460.41	$2,881.23

For the initial investment was used the cost for tags when needed and support materials, as described in the previous chapter, more specifically in table 5. Added inventory column is an estimation cost for cost with tags and materials with new items added to the inventory, in this case, the same amount used in the initial investment, as it is hard to predict specifically how many tags will be used. On the cost with inventory column, it was assumed that the cost with inaccuracy would be repected in the following three years will be the same as they repeat the same inventory management system.

Step 4 – Pros and cons analysis

As the step 4 of our guide, this part is ideal to put side by side the pros and cons for all tested alternatives. This will help CAMID and any small business that are going to pass through the same to decide their best alternative.

Taking into consideration, the answers from the questionnaire, simulation results, cost analysis and technical opinions from the review of literature the following tables were based.

Table 8: Scenario 1 – Pros and cons analysis

Scenario 1 – Current Manual Inventory System	
Pros	Cons
• Cheaper option for investment. • Easier to implement as no time will be needed to create tags and implement asset management software.	• No guarantee that the worker can find what is needed. • It pursues 6.5% probabilities of generating errors in their inventory. • Higher cost with inaccuracy. • Problems will remain the same and even without cost to have it, in a long term can generate high values with reordering items that CAMID already have, in three years leading to almost $9.000 dollars cost.

Table 9: Scenario 2 – Pros and cons analysis

Scenario 2 – Barcode System	
Pros	Cons
• Compared to the RFID, barcode offers a much cheaper solution. • Offers 1% higher accuracy then the current inventory system used at CAMID.	• Cheaper than RFID, however, offers still a high inaccuracy than Scenario 1. • You have to read tag per tag, if you forget it, item can be forgotten

	leading to order more items without need. • It doesn't tell workers when it is places in wrong places, therefore leading to missing items all the item, as we know that human errors are persistent. • In the end, the amount spent with inaccuracy is almost as high as the scenario 1.

Table 10: Scenario 3 – Pros and cons analysis

Scenario 3 – RFID Technology System	
Pros	Cons
• Delivery only 1% probability of errors in the inventory system. • RFID tags have a greater read range. • Many tags can be read simultaneously. • Reduces expenses associated with provisioning and inventory control. • Decrease the amount of people that need to work with that, as mostly will be automated.	• Highest cost compared to all three scenarios. • It requires more time to implement and select the best equipment's to fulfill the needs of their location.

Step 5 - Solution proposition

Now comes the last step, step 5, that leads to the proposition of best solution for the small business.

It is possible to identify the solution proposal that best satisfies CAMID's requirements by taking into account all processes, particularly the final one that compared the advantages and disadvantages of each scenario.

One important point for every single small business is the cost, this factor is determinant to choose the best option, as it is a common sense, differently from large corporations, expenses are still limited. At the other side, every single small company have their differences about that, for example, a small business in the jewelry segment pursues a very high cost of their pieces, so every single lost item will make a huge difference in the end of the fiscal year. So, when the small business is at this step, it has to be careful in determining all those aspects.

Related to CAMID situation, they are have much open to hear an opinion and flexible about the budget, therefore combining all matters, Scenario 3 leads the highest number of pros and generates the most accurate and reliable inventory system with only 1% of errors probability in all three phases of their inventory process. Initially, mainly in the last year, the cost to implement will high as noted in the cost analysis, however in long term, also depending on the chances of upscaling CAMID activities, the need to a well accurate system is ideal and will generate much lower costs with inaccuracy.

The current scenario 1, with manual inventory system, is not ideal. A technology facility as CAMID has to be able to track their inventory with certainty and also, even the Scenario 2, including the barcode technology, as the simulation could prove, if there is no correct track of their items in the system, along side with human errors placing the items in the wrong place, the barcode technology will not save them from inaccuracy and generate as high as their current system leads with inaccuracy.

Thus, the ideal solution proposition for CAMID would be the Scenario 3 – RFID Technology. It is valid to point out that as this is a guide, every single case has to be evaluated individually and taking into consideration all steps before making any decision.

Chapter 5
Conclusion

The US economy is heavily reliant on small businesses, which are crucial to running a significant portion of our society and providing employment for a sizable number of people. Yet, small businesses often neglect inventory management owing to a lack of resources and expertise, which causes many of them to fail after a few years. The goal of this thesis was to offer a step-by-step guide to those businesses, outlining the procedures to take in order to find the most reliable inventory management system possible. According to the findings, by taking these steps, the small business will be able to determine which inventory management system best suits its requirements by using discrete inventory simulation, saving money by avoiding the need to purchase a system that might not be the best fit.

A five-step strategy was suggested. To put all those steps into practice, CAMID was used as a case study. Starting with the 5W1H method, it was possible to pinpoint their requirements, the issues with their inventory, and, most importantly, the kind of inventory system they necessitate. Following that, we proceeded to step 2 of the simulation, where all inventory management processes were mapped with assistance from CAMID staff. From there, all potential error types were identified, including errors in updating the system and even placing the item or object in the proper location. In addition to the current manual inventory system, two additional scenarios were proposed using the literature review, with barcodes and RFID being suggested as potential solutions. To determine which of the three scenarios seemed to have generate the fewest errors, a simulation run was performed using all three scenarios. The RFID (scenario 3) had by far the best results, as would be expected given that its technology allows for better traceability and error avoidance.

Beyond the simulations, however, came step 3, which included a cost analysis. We are aware of how crucial it is for each and every business, and even more so for small businesses with fewer than 20 employees. Once more, it was determined that, when taking into account the need for generating capital to implement the system, RFID over a three-year period offered the best results. In order to compare all of those results—the requirements from the 5W1H method form, the simulation results from ARENA, and the cost analysis results—we had to move on to step 4. This step was crucial because it clearly illustrates to the small business the advantages and disadvantages of each scenario.

The implementation of RFID technology, in this case, provided the best outcome over the long term to CAMID, moving from a system (scenario 1) with more than 6% chance of errors to only 1%, positively impacting their finances. Moving on to the final step, it cames the step 5, solution proposition, which was the scenario 3, RFID Technology.

However, it is important to emphasize that this is only a solution proposition, and in this instance, CAMID has the power to decide which one works best for the small business. Additionally, as a suggestion for future work, the monthly software cost for utilizing all of that technology was not taken into account; this depends on the kind of inventory they are using and necessitates a much more involved analysis. Although there are a lot of software options with ambiguous packages and contracts in the market, it can be much less expensive for the small business if it currently has a contract with the software developer for other tools.

Beyond that, it is valid to highlight that as a future work, this thesis focused more on the financial impact/cost that each scenario has. However, it would be great in future researches to understand and amplifly the effective time spend to use all those scenarios, putting into consideration also the capital work for those occasions.

Since the goal of this thesis was to create a step-by-step guide for small businesses, as a result of using this work, they will now be able to use it to follow this guide and make an informed choice about which inventory management system to implement. Helping small businesses succeed in this fiercely competitive economy, particularly in the biggest and strongest economy on earth, the United States of America, will entail assisting them in enhancing their performances and generating less inaccuracy in their inventory, ultimately leading to better profits.

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Appendix

Simulation – Scenario 1

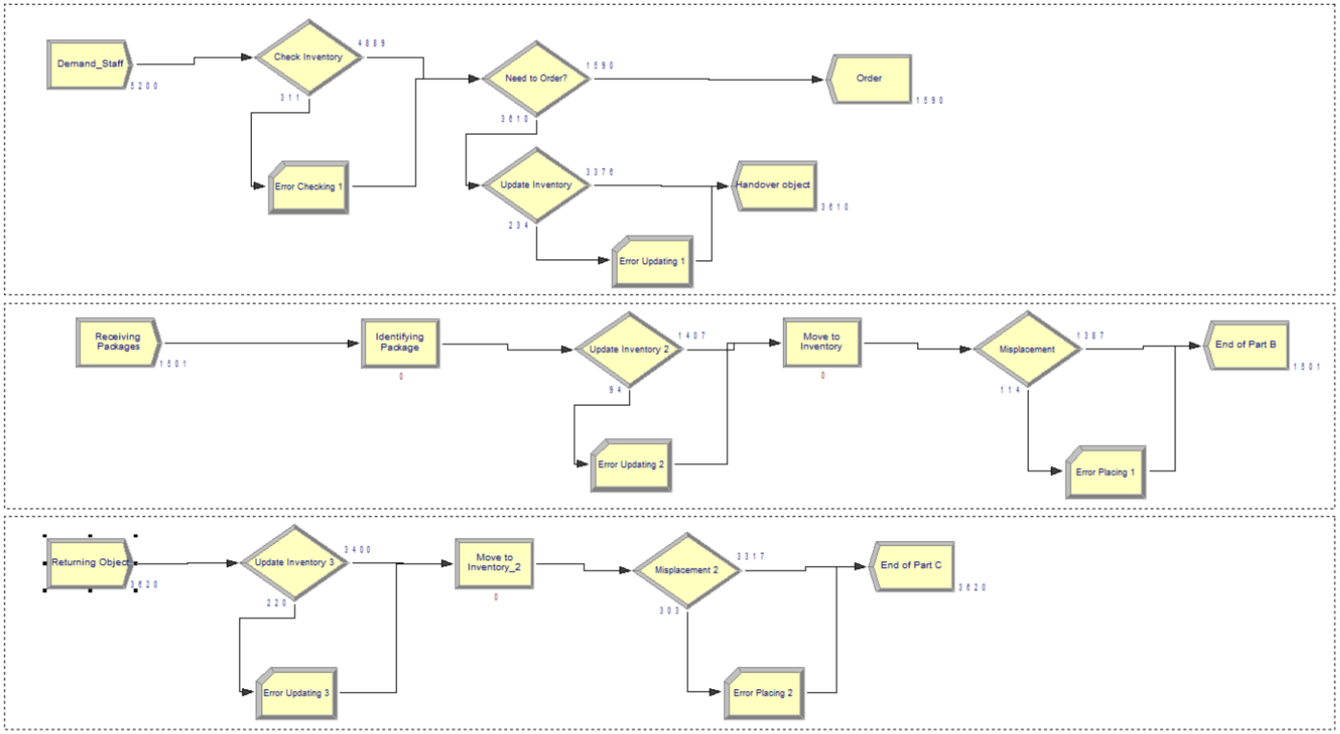

Figure 20: Simulation of Scenario 1

Simulation – Scenario 2

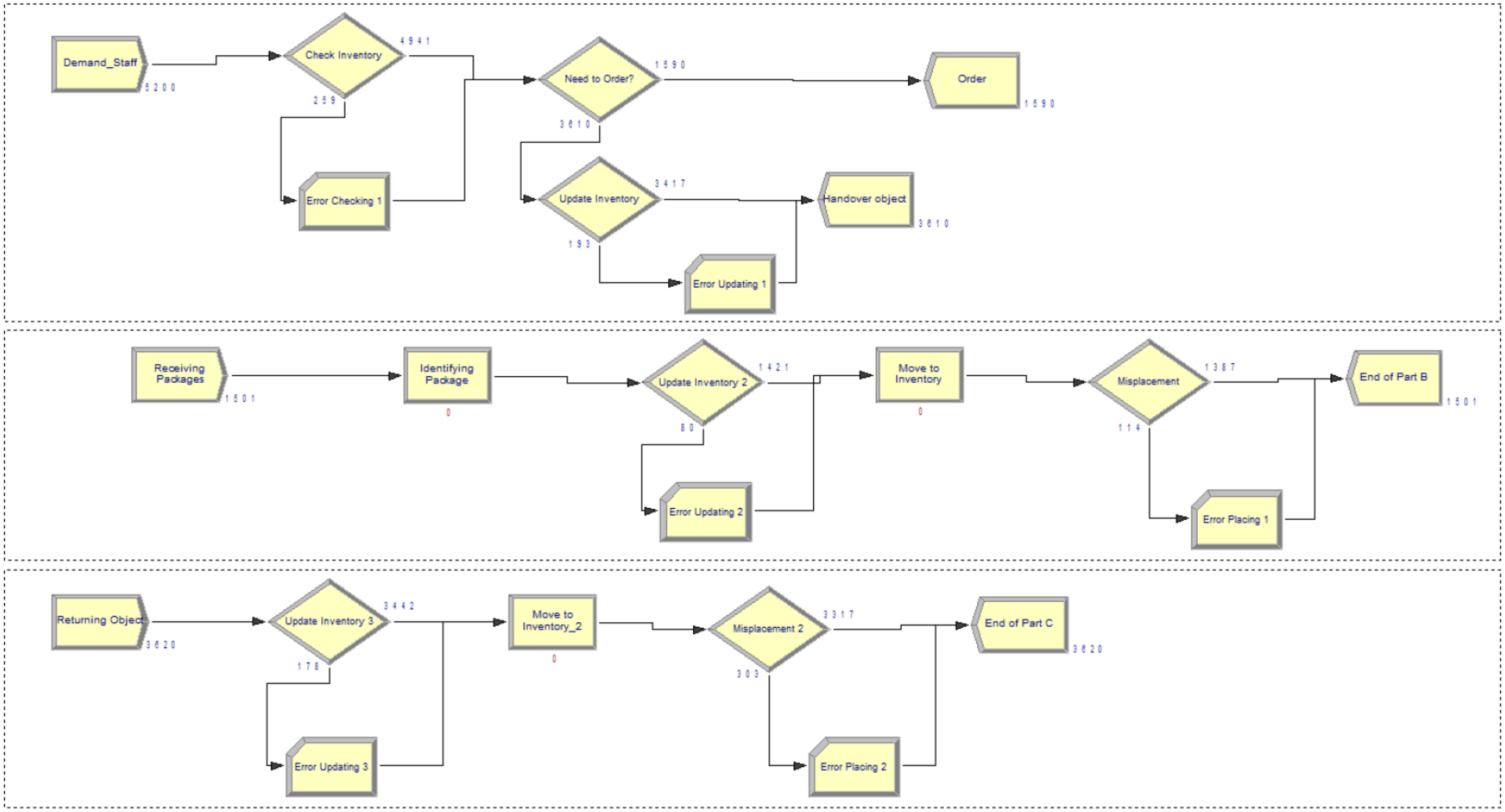

Figure 21: Simulation of Scenario 2

Simulation – Scenario 3

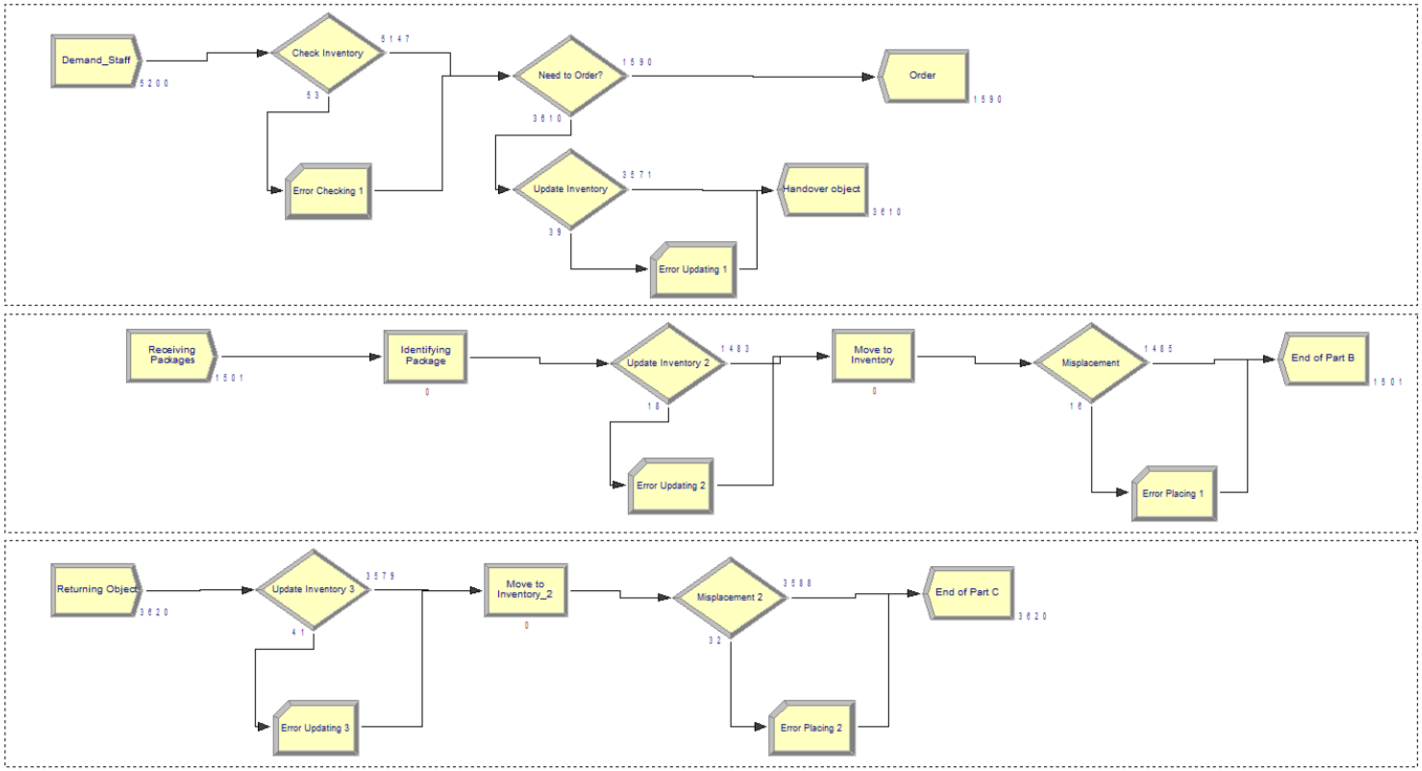

Figure 22: Simulation of Scenario 3