KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Krishnan Pandian Rajesh

"DEVELOPMENT OF SMART INVENTORY MANAGEMENT SYSTEM FOR MANUFACTURING ENTERPRISES"

Final Project for Master's Degree

Supervisor

Assoc. prof. dr. **Kazimieras Juzėnas**

KAUNAS, 2016

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Industrial Engineering and Management, 621H77003

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DECLARATION OF ACADEMIC INTEGRITY

20 May 2016

Kaunas

I confirm that the final project of mine, **Krishnan Pandian Rajesh**, on the subject "**DEVELOPMENT OF SMART INVENTORY MANAGEMENT SYSTEM FOR MANUFACTURING ENTERPRISES**" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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Department

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(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Development Of Smart Inventory Management System For Manufacturing Enterprises

Approved by the Dean Order No.V25-11-7, 3 May 2016

2. Aim of the project

To develop a cost efficient management tool called the Smart Inventory Management (SIM) System that helps to enhance the inventory management process.

3. Structure of the project

- To establish the need for a cheaper technology for automation of inventory management system.
- Review the methodologies and scripts related to inventory management system.
- Development of the design and analysis of features of the Smart Inventory Management (SIM) devices.
- Cost and efficiency of the developed system are calculated and compared with cost of existing technology.
- Benefits of implementing the devices and automation of inventory management system are discussed.

4. Requirements and conditions

None

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2016 _May_ 20 st.

Given to the student _Krishnan Pandian Rajesh

Task Assignment received ______________________________

____

(*Name, Surname of the Student*)

(*Signature, date*)

Supervisor ______________________________

____

(*Position, Name, Surname*)

(*Signature, date*)

Krishnan Pandian, Rajesh. **DEVELOPMENT OF SMART INVENTORY MANAGEMENT SYSTEM FOR MANUFACTURING ENTERPRISES**. *Master's* Final Project / supervisor assoc.prof. dr. **Kazimieras Juzėnas**; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.
Study area and field: Production and Manufacturing Engineering, Technological Sciences
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Kaunas, 2016. 45 p.

SUMMARY

This master's thesis report deals with the study analysis of Inventory Management and its drawbacks related to the previous practices to develop a system that resolves the issues related to it. The problem prevailing in the inventory management field is the lack of appropriate technology that is affordable for the small-scale industries to implement and capable of increasing the overall efficiency. To counter the drawbacks a management tool called Smart Inventory Management (SIM) device is developed.
The SIM device has been developed into two variants called SIM Stroll and SIM Static, which differs in capacity and dimensions. The overall designs of the devices are analysed and key components involved in the development of the devices and the appropriate material selection processes are done. The circuits for both the variants are drawn and the workings of the devices are explained with the help of Algorithm and Flowchart. The manufacturing cost of the products and the cost efficiency is calculated with supported assumptions and the sales price of the products is compared with existing product.

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Krishnan Pandian, Rajesh. **„IŠMANIOS“ ATSARGŲ VALDYMO SISTEMOS KŪRIMAS GAMYBOS ĮMONĖMS**. Magistro baigiamasis darbas / vadovas doc. dr. **Kazimieras Juzėnas**; Mechanikos inžinerijos ir dizaino fakultetas, Kauno technologijos universitetas.
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Kaunas, 2016, 45 p.

SANTRAUKA

Šiame magistro darbe analizuojamas atsargų valdymas ir trūkumai susiję su ankstesnėmis praktikomis, kuriant sistemą jiems pašalinti. Pagrindinė problema atsargų valdymo srityje yra mažo dydžio įmonėms pritaikytos technologijos, kuri leistų pagerinti bendrą efektyvumą, trūkumas. Siekiant pašalinti trūkumus buvo sukurtas valdymo įrankis (sistema) pavadinta “Išmanus atsargų valdymas” (angl. *Smart Inventory Management* (SIM)).

Yra sukurti du šios sistemos variantai, kurie skiriasi savo dydžiu ir yra atitinkamai pavadinti *SIM Stroll* ir *SIM Static*. Darbe analizuojamas bendras įrenginių dizainas bei pagrindiniai jų komponentai, kuriems parinktos atitinkamos medžiagos. Abiems variantams suprojektuotos valdymo grandinių schemos, o įrenginių veikimas paaiškintas algoritmu ir struktūrine schema. Produkto gamybos kaštai, numatoma kaina ir panaudojimo efektas yra nagrinėti remiantis egzistuojančių produktų analogais.

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INTRODUCTION

The most important aspect that decides an organization’s success is effective overall management. It is necessary to manage every field with equal importance, however mismanaged inventory has caused huge problems in the past to various organizations. This has lead to loss of the organization’s reputation and caused irreparable damages. Inventory management has always been an important field of research as it has huge scope for developments. There is a steady demand for advanced management tools due to the importance of managing inventory efficiently. Efficient inventory management can help the organization to be more successful and plays an important role. So there is a need to minimize the over all cost of inventory management. Documentation and storage of inventory is a major task that requires lot of labor, time and money. Planning the inventory according to the requirements of the organization can reduce the expenses vastly. Automation of the inventory system prevents hidden losses that occur often in a manual inventory system. Automation of the system could be costly to implement at first, but it results in profit in the long run.

Due to the high initial cost of implementation, the small-scale industries find it difficult to invest in the technology requirements of an efficient inventory system. So there is a requirement in the market for cheaper and efficient technology. This has led to the research on Smart Inventory Management (SIM) as a tool that makes it easier and less expensive for organizations to manage their inventory. The SIM is a product that enables to handle and store inventory in a better possible way that could reduce expenses and losses of the organization. The aim of this research is to develop a cheaper technology that will make it easier for smaller organizations to implement and also much effective than the manual systems.

Aim

The aim of this project is, to develop a cost efficient management tool called the Smart Inventory Management (SIM) System that helps to enhance the inventory management process.

Objective

1. Analyze the possible benefits of the SIM device in small manufacturing enterprises.
2. Design and development of the smart inventory management system.
3. Estimate the manufacturing cost and efficiency of the SIM device.

Inventory Management

Inventory refers to the goods or materials that are used or stored by a firm for the purpose of production. They can also be referred to supportive items that enable the smooth operation of the firm. There are three basic types of inventory, which are raw materials, work-in-progress and finished goods. Raw materials are the basic building materials of a product that has to be available at any point of time for an uninterrupted production process. Work-in-progress inventory as the name suggests, are the goods that are in the ongoing process of production. These too form a major part of the inventory and needs proper maintenance. Finished goods inventory is nothing but the final product that is waiting to be sold. Whatever maybe the category of inventory nevertheless it has to be maintained efficiently in order to achieve higher productivity. Inventory management is the concept of proper storage and handling of the current assets of the firm for smooth operation of production and sales processes. It emphasizes the importance of having an optimum control over inventory and helps reduce the total inventory costs.

Inventory management comes under the context of field service management, which also defines work order management, scheduling and dispatching. The FSM is an important aspect of the organization that deals with direct operations of the organization. As years pass by there is a steady increase in demand for better processes to deal with problems faced in FSM. As technology advances the cost of implementing those new technology is added to the organization's vows. Thus the net worth of the FSM market is in a steady rise.

The net worth of FSM market is expected to rise by 17% by next year and that is a huge increase in context of global market scenario. The increase in demand is so rapid that by the end of 2019 the net worth of FSM market is expected to be 3.52 billion USD. With such huge potential the probability of failing to find demand for a product as efficient as the SIM is very low. At this rate of development the market could flourish to unbelievable extent in the next decade or so. [1]

Small Scale Industries

The small-scale industries are the majority of the manufacturing world but they are the ones that are heavily affected by the invisible losses that occur in the organization. A misplaced inventory might cause a noticeable loss to a big manufacturing enterprise but it will be a huge loss to a small-scale enterprise. Moreover these small scale industries do not have the need to implement high tech assembly lines or fully automated manufacturing systems as they do not manufacture products in numbers of thousands, but only a few hundreds a day and they are in need of a cheap option to organize their inventory. This where SIM becomes a desirable option for small-scale industries as it caters exactly to the needs of small-scale industries. It is cheap, less space consuming and can be customized as per the customers needs.

Automation

The Automation of Inventory management process is one of the most favored solutions to the several issues faced by the organization. Automation of Inventory could be a costly process but it is a one-time investment, which has a huge potential in return. It is a widely accepted fact that automation could increase the production rate and profit of an organization by a huge margin when compared to the traditional manual inventory management. It is more accurate and fool proof because the factor of human error is not applicable when it comes to automation. However it has its own disadvantages such a technical faults or shortcomings.

Description Of Problem

The Small scale Industries find it hard to cope up with the current technological advancements because there are very few options available in the market that can be implemented with the limited financial resources that the organization has. This leads to the small scale Industries to operate in a lower technology and that in turn affect the production or the total outcome of the organization. An organization operating without advanced technology is generally less efficient than their competitors who have been updated with current technological advancements. This scenario makes it impossible for organizations with limited financial resources to survive in this competitive environment.

As far as inventory management is concerned manual management could lead to numerous complications when there is a huge number of inventory to be managed. Handling and documentation of inventory becomes tedious and time-consuming when not automated. Unorganized Inventory can lead to various hidden losses like misplaced inventory that can affect the efficiency of the organization. Lack of proper planning leads to slowed down processes and over consumption of time, affecting the overall outcome of the organization. Handling of inventory by manual labor is also a reason of concern because it is slower than an automated process and it adds up to labor expenses, these concerns do not exist when the process is fully automated. Manual handling is also inaccurate making it less dependable when it comes to precise documentation of inventory.

Storage of inventory plays a major role in the overall efficiency of the organization. Efficient storage of Inventory enables timely production and dispatch of products as per the requirements. However the storage of inventory is a complicated process, as it requires a constant documentation process in order to be aware of inventory levels. Regular update of inventory levels is a necessity in an organization because sudden decrease in inventory levels could mean total stoppage of production due to the lack of raw materials or stocks. Thus there is a need for a technology that can help resolve the complications related to manual Inventory management and also cheap enough for the smaller organizations to implement it in their system.

1 ANALYSIS ON INVENTORY MANAGEMENT

Inventory management deals with the process of storage, handling and forecast of warehouse materials in the most efficient way possible. Inventory is one of the fields that needs to be closely monitored as the possibilities of incurring loss due to negligence is very high. There are various hidden losses that occur while storing and handling inventory. Inventory management has evolved to a great extent in the past century, yet there is still scope for development and better techniques.

The following are some of the references from journals that will help us analyze the works and views of various authors in the past and understand the process of automation of inventory management from the research done by them.

1. Peter Kolarovszki, Juraj Vaculík (2013) has described the various Automatic Identification and Data Capture (AIDC) technologies based on RFID tags used in warehousing and storage processes. The various components and basic functions of RFID technology are also discussed. This article is aimed on designing of a warehouse management system using RFID technology to effectively perform processes like recording of data, registering arrival and departure of items in the warehouse. Various tasks are executed with the RFID tag by creating a configuration management using middleware AMP 2. Various tests were performed to check the effectiveness of the methodology. The warehouse management is executed by coding the RFID tags and further applications were created to manage inventory. It is concluded that the middleware AMP2 was adequate enough to code the RFID tags and enabling them to manage warehouse with the help of RFID. However, there are substitutes to the AMP2 middleware that can fulfill the requirements of coding software, which this paper has not discussed. It would be better to analyze the other available software also. [2]

2. Amit Grover (2010) in this paper has described a case study to analyze the various parameters that affect the reliability of bar codes in inventory management. The scanning ability of the bar codes has been tested under various circumstances to determine the efficiency of bar code technology in product tracking process. The paper also focuses on determining the most appropriate type of bar code out of the various types that are available. The various symbologies such as data strip 2D symbology, Aztec code symbology and the data matrix symbology and further symbologies related to bar code technology are studied.

The material that the bar code is made from and the receiver device or the scanner also affects the readability of a bar code. Several parameters and their characteristics are analyzed in this paper. The paper concludes that the bar codes are capable of encoding high content data theoretically but the readability of the content of the bar codes were still affected by various parameters. The results conclude that the readability of PDF417 type barcodes were much better than that of the QR Code barcodes. Based on this research it is denoted that the material that the bar code is made up of, plays a major role in the readability of the bar code and also the characteristics of the receiver and the scanner also affects the quality of the output. [3]

3. Anas M. Atieh (2015) in this research paper has investigated the impact of warehouse management on supply chain performances. The study is focused on developing a warehouse management system (WMS) to enhance the inventory management process. Software is designed to takeover the warehouse management process and its efficiency are tested. The activities carried upon in the warehouse before the implementation of the software are recorded and also the data of activities under gone after the implementation of the software are recorded to calculate the efficiency of the software. The whole idea of this paper is to reduce the cost of warehouse management by automation of the inventory management process. It focuses on reducing the storage and maintenance cost of inventory and increasing the over all efficiency of the firm. The difference between manual management and automation are studied to prove the effectiveness of automation. The paper concludes with the results that automated inventory is much efficient than the manual management system and automation provides better handling and control over inventory. Automation has helped control the movement and storage of the products and also enabled safer storage and quicker handling. Thus automation has transformed the warehouse management system more efficient and simplified. However, the cost efficiency by labor substitution that could be achieved by automation on the warehouse management process was not discussed. Analyzing the reduction on salary expenses could be focused as an important aspect of automation and can be taken as an important advantage achieved through automation. [4]

4. An Molenaers (2011) in this article discusses about the need of an efficient spare parts management methodology for better storage and handling of spare parts. This article also aims on developing a classification system that enables better assortment of spare parts based on the level of criticality of the spare parts. Here the items that are considered to be spare

parts are stored and handled in methods suitable according to their criticality. This avoids the expense of over maintenance on specific items that are not critical and prevents losses due to under maintenance of critical items. So the criticality levels are obtained and are used to rationalize the efficiency of the spare parts inventory maintenance. The criticality of an item cannot be decided based on one aspect of the item but various factors determine it. Due to this a multi-criteria criticality method was proposed, which determines the criticality of the spare parts based on various features of the spare part such as criticality of the equipment, probability of failure, replenishment time, availability of specifications, type of maintenance and number of suppliers. After the multi-criteria criticality scheme is developed, the spare parts are segregated based on their criticality levels into 4 major categories (hi, medium, low, no). The developed method was implemented in a petrochemical plant and the effectiveness of the method was tested. The accuracy of the system was determined to be significantly high, which is 95.4%. It means this method of classification succeeds in determining the criticality of spare parts with high accuracy despite the numerous features that has to be considered before determining the criticality. The 4.6% inaccuracy in determining criticality is due to the specific requirements like safety, functionality, lead-time and repair time. The paper not only aims on development of a methodology theoretically, but also implements the developed method in an existing system and definite results are achieved. [5]

5. Phichet Wutthisirisart (2015) in this paper has discussed about the material location selection problem that occur in an organization due to the need of larger warehouse space to meet with increasing demand. When companies run out of space to store their inventories, they rent a secondary space for warehousing the excess inventories. This could mean that the two warehouses are far apart from each other in most cases and the third party warehouse could be located away from the company. This change of location of warehouse affects the organization in more than one way. The need to rent a secondary warehouse adds to the expenses of the company and the change in location decreases the effectiveness of the system. Due to distance between warehouses and the company, the time required to transfer finished good to the warehouse or the transfer of raw materials and spare parts from the warehouse to the company may increase multiple times, causing the overall operation to slow down. To reduce the transportation and storage costs of inventories in two separately located warehouses 4 material location models are proposed to solve the problem. The four models as defined are, 1. Shipment level model, 2. Material level model, 3. Material level flexible storage model, 4. Material level strict storage model. These models are tested with the help

of data collected from real industrial scenario. The results show that the cost expenses on storage and transportation of inventories between on-site and off-site warehouse decrease as restrictions on item selection gets more constraint. These models that are proposed will not be very beneficial if the demand of product decreases and the reassembling of inventories can cause unwanted transportation costs. The results show that, for the current scenario the proposed models have been able to reduce the cost of storage and transportation by 20-40% by reassigning materials between the owned and third party warehouses. However, it is more effective to minimize the space consumed by the inventory by installing space efficient, compact storage and handling systems. This may eliminate the requirement of a secondary warehousing space. [6]

1.1 METHODS OF INVENTORY MANAGEMENT

There have been various developments in the field of automation upon management. Inventory management is one of the most experimented fields due to its necessity to be efficient at all times. The various methodologies used to manage inventory in the past has been analyzed below.

1.1.1 Manual Inventory Management Analysis

Manual management has been the only possible way to manage inventory in the past when technology was not as developed as it is today. However it is still practiced by a large percentage of organizations even though it is less efficient than automated management processes. This is primarily due to the high initial investment costs required to implement sophisticated technologies. Manual management can be analyzed to understand its effectiveness in the current scenario in the manufacturing industry.

Figure 1.1 Manual Inventory management [7]

Simplicity

Manual management can be suitable for firms that don't have to deal with large number of inventories or spare parts. They do not have to invest in sophisticated technologies or inventory maintenance software. Manual handling of inventory is much simpler compared to automated system because it does not require skilled labor or large initial investments.

Sense Of Control

Manual management only suits firms that deal with meager amount of inventories. When the quantity of goods that has to be managed is small, there is no need to depend on a computer to provide the inventory levels and to refill the stocks. However when it comes to managing a large number of inventories in bigger industries, automated maintenance is a must to maintain high efficiency.

Labor Intensive

One of the major expenses faced by the organizations in this economy is the high cost of labor that is involved in the management process of inventories. Organizations prefer to reduce their work force to cut down on the expenses. They implement technologies that replace excessive labor even though the technologies could be highly expensive to implement because of the assured returns on investment that the technology provides in the long run. Manual management usually requires a numerous labors thus making it less preferable in efficiency-centered organizations.

Human Error

Human error is an inevitable aspect in any process that is done manually. This may not occur often but when it does, it may have a considerable effect on the outcome. In a maintenance process that is critical for a firm to run successfully, it is important to be as accurate as possible. Manual inventory management too is prone to human errors and that makes it even more inaccurate and inefficient.

An unstable management system can lead to misplacement or loss of valuable inventory. Manual management has its own pros and cons, but mostly cons since it is prone to various errors and inaccuracy. [8]

1.1.2 Automatic Identification And Data Capture Technology

The frequent failures that occur in the manual management of inventory have created the need for a technological advancement in the management process. It was necessary to track every item in an inventory at a constant basis in order to have total control over the inventory levels. Labeling of items too is not an efficient technique because once again the labels had to be manually checked by the staff very frequently and this becomes even more illogical when the inventory is large. This process of identifying and tracking of items had to be automated in order to be accurate and more efficient than manual operations. This paved way for the Automatic Identification and Data Capture Technology (AIDC), which identifies each item by reading the data stored in the tags that are attached to the item by data capture technology. This technology was a revolution in inventory management process as it provided the required automated process of product identification. AIDC is not only more accurate and efficient but also much cheaper method of inventory management that the manual process. [2]

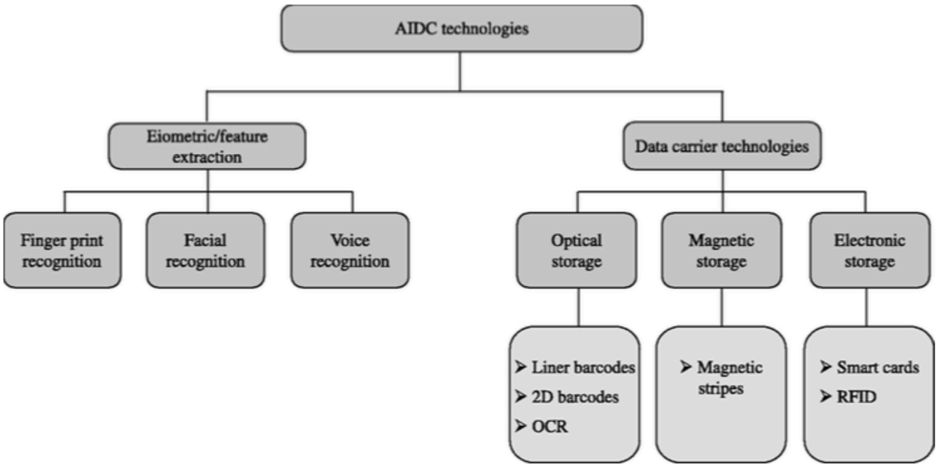

Figure 1.2 AIDC Technologies [2]

1.1.3 Bar Code And Quick Response (QR) Code Technology In Inventory Management

Bar Code is a symbol that contains plain text data that can be recognized and read by a scanner or a decoder. These bar codes and Quick Response (QR) codes use light as a tool to transfer data that is stored in them to the scanner and then to the computer where the entry of the item is made and an automatic update of inventory levels is registered. The black color stripes in the bar code blocks the light and the white portion reflects the light back to the scanner or decoder that has receptors in them. This technology is widely used everywhere to keep track of goods or simply transferring data for authorization purposes. This technology can be seen usually in supermarkets while the goods sold are scanned before they reach the customer as the billing process and the documentation process are simultaneously done just by scanning the bar code attached to the goods with the help of a scanner connected to a computer. This method has made the product identification and tracking process of large quantity of inventory more precise and less time consuming than the manual method. [3]

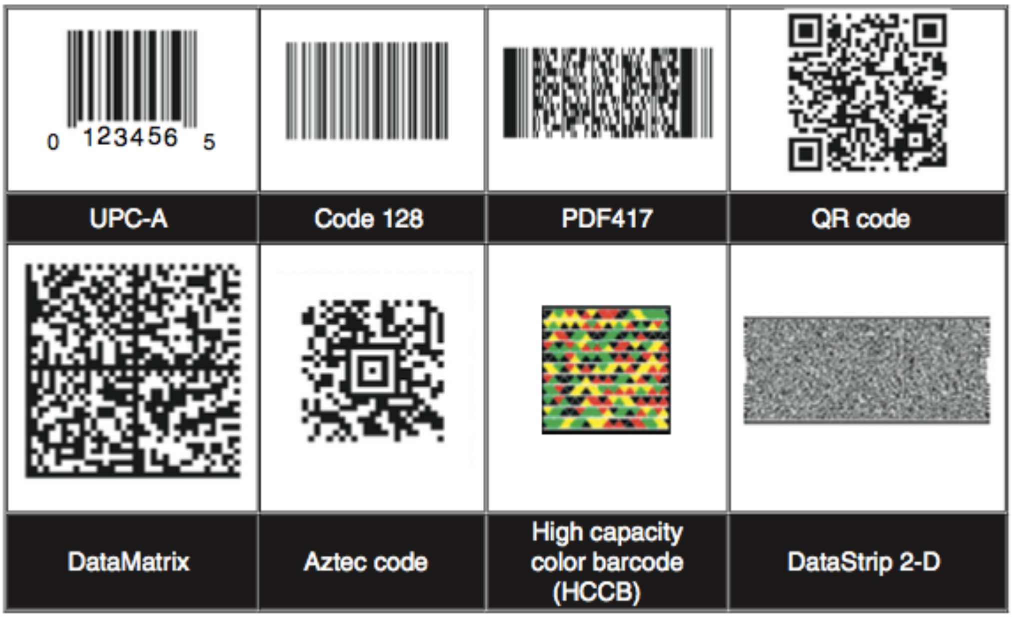

Figure 1.3 Types of Bar Codes [3]

1.1.4 Limitations Of Bar Code And QR Code

Bar codes and QR codes have influenced the process product identification and tracking in inventory management to a large extent. However like any other technology this too has, its own limitations. Various factors affect the readability of the codes and it could directly have an impact on the efficiency of the system.

Readability Based On Material

Bar codes are printed in various types of materials depending upon the product to which they are tagged. Mostly they are printed in paper but sometimes in other materials too. The scanner or decoder absorbing the amount of light reflected from the white spaces in the bar code reads the data from the bar code and so the amount of light reflected is directly related to the readability of the bar code. Different materials do have their own level of reflectivity and this can affect the readability of the bar codes. When the material that the bar code is printed on, reflects more amount of light, it becomes difficult for the scanner or the decoder to read the codes. Thus it is important to use the appropriate material to print the codes.

Geometrical Deformity

The readability of the bar code depends on the condition of the bar code at the time of scanning. Due to wear and tear or during storage and handling of the product, the bar code tags connected to the product may be damaged. The bar codes are mostly printed on paper and stuck on the package of the products. This type of codes on paper material is prone to damage when subjected to stress or dampness. Damaged codes are impossible to read and do not provide the required data, this affects the reliability of the system. The possibility of geometrical deformation occurring in bar codes leads to inaccurate inventory control. [3] [9]

1.2 EXISTING TECHNOLOGY

The SIM is basically a storage device that helps in efficiently organizing and controlling the number of inventories that an organization holds at any time of its operation for better results. However, this technology is under development in a different perspective of catering to the retail business sector. It is an RFID controlled device that uses radio frequency technology to sense the product in the shelf and to alert the system about critical stock levels. Where as the SIM device is primarily focused on manufacturing enterprises and small-scale industries. [10]

The existing technology provides shelves to retail shops or supermarkets where the customers are displayed the price of the product and various details like general information or advertisements. The shelf used in retail shops also keep count of the number of products placed in the shelf at a point of time, but this is all done in a commercial approach catering to the public directly and attracting the customers. Thus there is more emphasis on technology that is more interactive with the customer. Whereas, the SIM is a device that belongs to the manufacturing department or the assembly line where there is only a need to provide solutions for cheaper and efficient manufacturing processes. Thus, the SIM is a device that is designed to suit the needs of a small-scale manufacturing unit with an assured return on investment and lower risk factor.

Highly renowned organizations like Panasonic have entered the competition of manufacturing smart shelves, American retail giant Wall-Mart is planning to implement the technology sooner in all their outlets. Thus the scope for better stock handling technology is on the steady rise. [11]

2 DESCRIPTION OF DESIGN

The basic idea behind the development of the SIM is to provide a cheaper solution to the various management issues faced by the organizations. Small scale industries do not have the luxury of investing big money in technological advancements thus they demand for an inexpensive management device that can make a huge difference in the overall outcome of the organization.

The Smart Inventory Management (SIM) device helps in effective storage and handling of spare parts and other type of inventories. It is basically a rack that consists of multiple drawers that provide data about the components that are within them. Each drawer is fitted with a load cell in the bottom surface and these load cells are connected to a common micro-controller, an Arduino board to be precise. The battery that powers the microcontroller is enclosed in the base of the device.

2.1 3D and 2D DESIGN

There are two variants available in the device depending on the requirement of the company.

The SIM comes in two variants.

1.SIM Stroll

2.SIM Static

SIM STROLL

In small-scale industries where there is limited production of goods, the number of inventory required to be stored is minimal compared to huge inventories stored in large-scale industries. Thus the SIM Stroll is a compact device capable of being moved around to the convenience of the user and can be used as a personal device too.

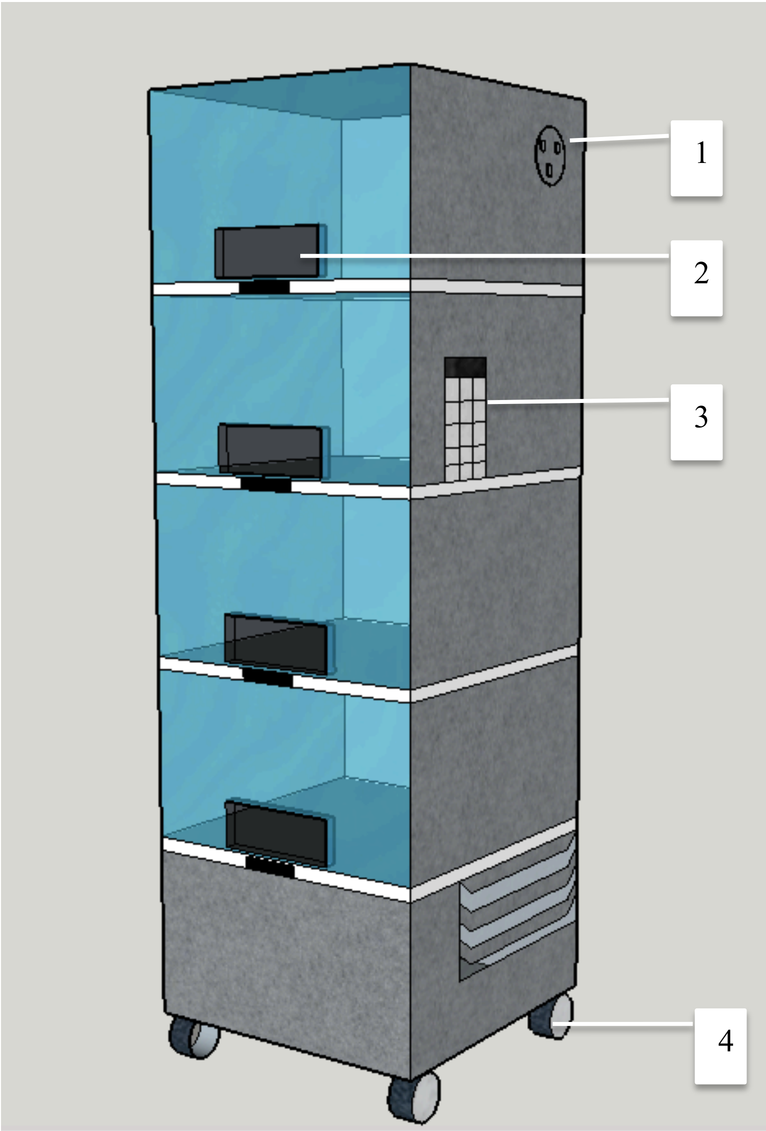

Figure 2.1 3D Design of SIM Stroll: 1 Utility sockets, 2.LCD display, 3 Keypad, 4 Wheels

The mobility of the device helps in reducing the time taken to transfer the inventories from storage to the assembly line making the production process quicker. The upper surface of the SIM Stroll can be used as a worktable since the device is designed in such a way that makes it possible for a person of an average height to work on it conveniently.

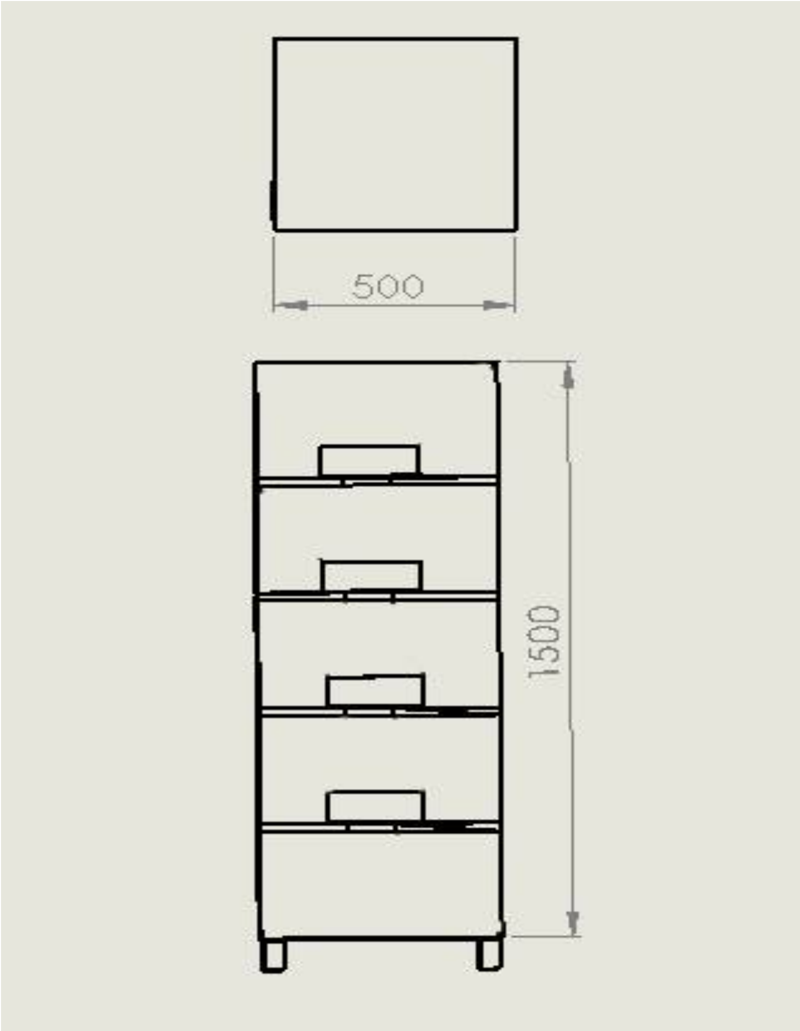

Figure 2.2 2D Design of SIM Stroll

Each rack is provided with a transparent glass front fitted with LED screen. The transparent glass front makes it easier to monitor the level of spare parts in the rack, as it is see through. The LED screen fitted to the front wall of the rack shows the number of spare parts currently stored in that particular rack.

SIM STATIC

The SIM Static is a bigger version of the Stroll variant and it is immobile due to its size and capacity. The need to store larger number of inventories in a smart way has lead to the development of SIM Static, which works identical to Stroll but has about 11 times the capacity. SIM Static resembles a display rack with a transparent front and LED screen just like the stroll variant. Firms that need a bigger and cheaper solution than SIM stroll can opt for SIM Static.

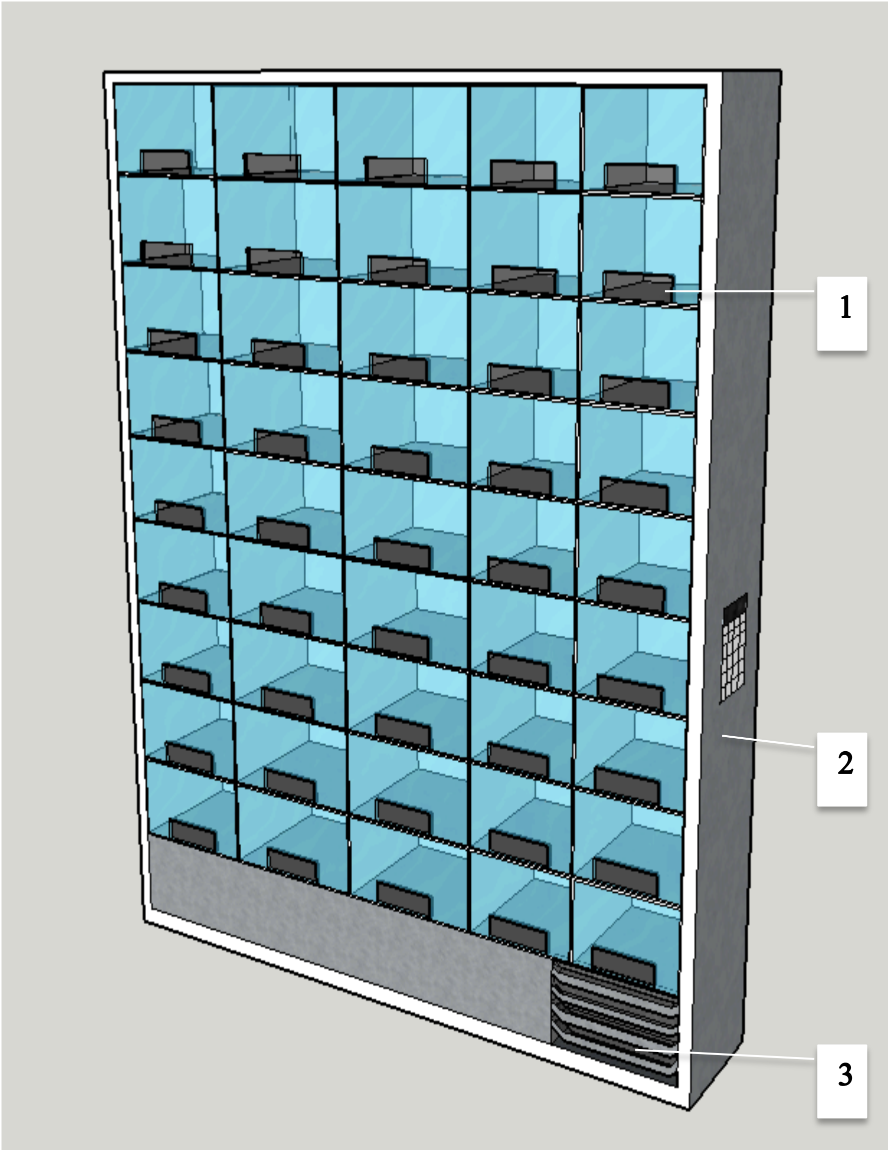

Figure 2.3 3D Design of SIM Static: 1 Glass panel front, 2 Frame, 3 Ventilation

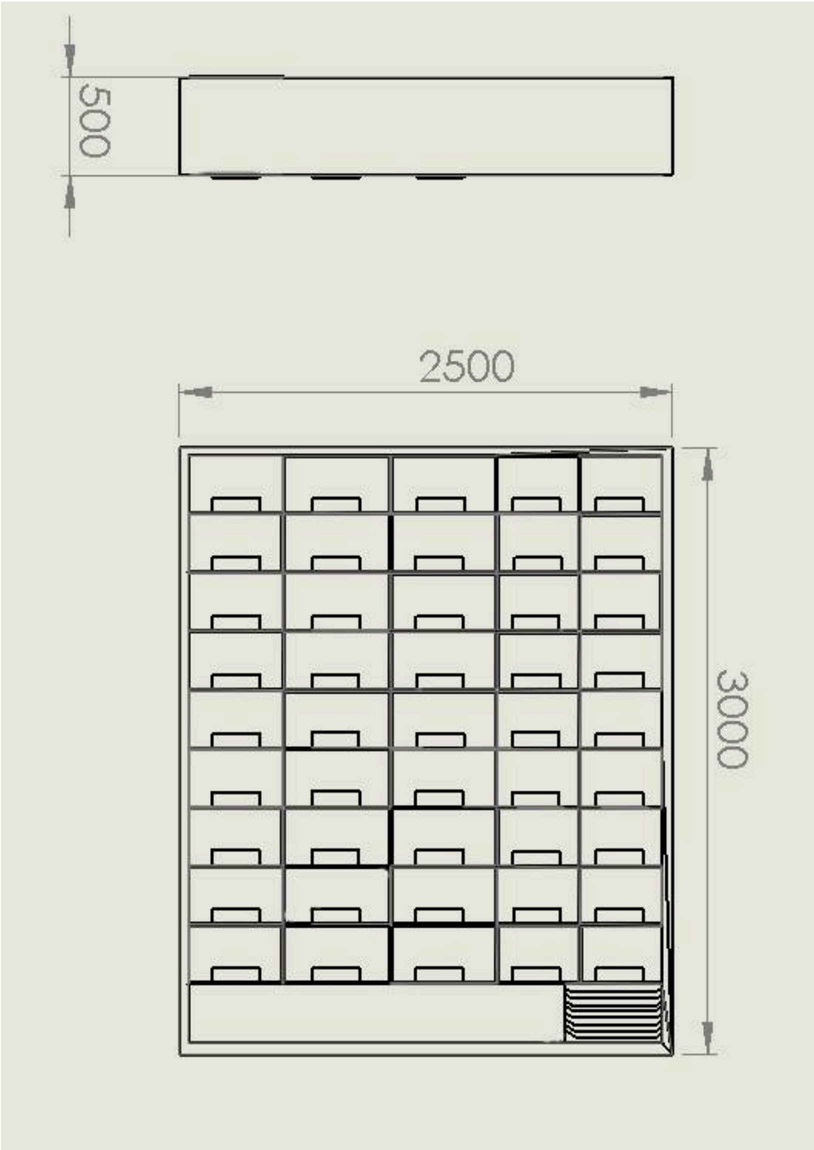

Figure 2.4 2D Design of SIM Static

2.2 MATERIAL SELECTION

Material selection is one of the most important steps involved in the designing of a product. The right material provides the opportunity to build the required characteristics of the product. Each part of the product needs to be provided with the right material for it to work as per intended. The material should also be able to handle the pressure induced upon it during the operation of the product. For example a generator is a device that exerts high amount of heat when on operation and also produces considerable amount of vibration. To withstand the heat and vibration for a prolonged period of time the material chosen to build the generator should be sturdy and have high resistance to heat. Building a product with unsuitable materials failing to meet the required characteristics degrades the overall quality and dependency of the product.

2.2.1 Frame

SIM Stroll

The material chosen to build the frame of the SIM Stroll device should complement the characteristics that the device requires to achieve. It has to be widely accepted and used in building of equipment similar to the SIM stroll device. The Stroll device is a mobile device, so it has to be built with a light material in-order to make it easy to move around. So the need to build a cost efficient yet a quality device the material selected is the versatile Aluminium. Aluminium is a metal that has various favorable qualities that suits the characteristics and criteria that the SIM Stroll device has to meet. To justify the decision of selecting Aluminium as the base metal to build the frame work of the device, the qualities of the metal has to be discussed.

Aluminium alloy 6061 is used in the designing of the SIM device, as it is the most suitable for requirements of the device. The composition of the alloy and its properties are discussed below. [12]

Table 2.1 Composition of Aluminium alloy [12]

Component	Amount (wt.%)
Aluminium	Balance
Magnesium	0.8-1.2
Silicon	0.4 – 0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

Table 1.2 Mechanical properties of Aluminium alloy [12]

Temper	Ultimate Tensile Strength (MPa)	0.2% Proof Stress (MPa)	Brinell Hardness	Elongation dia (%)
0	110-152	65-110	30-33	14-16
T1	180	95-96		16
T4	179 min	110 min		
T6	260-310	240-276	95-97	9-13

Weight

Aluminium is one of the light weighted metal that is widely used to make equipment much lighter when compared to the ones that are made using iron. The density of Aluminium is 2700 kg/m3, which is one third of the density of iron. This quality of Aluminium makes it one of the most preferred metals.

Strength

Aluminium alloys have a tensile strength of the range 110 – 310Mpa. The metal has resistance over low temperatures. It does not become brittle in lower temperatures like iron; rather it becomes stronger in lower temperatures. However at higher temperatures of above 100 degrees on a steady basis, the strength of the metal decreases and seems to weaken. This character of the metal has to be taken into consideration before selecting the metal for heavy load devices.

Machining

Another important aspect of Aluminium that makes it designer friendly is its ability to be machined easily. The Aluminium is a versatile metal that is both sturdy and also soft enough to be machined or shaped. Milling, cutting, punching and drilling can be done easily such that the input energy required in the process is also low.

Formability

Formability of a metal is its ability to be made into desired structures. Aluminium is highly malleable meaning it can be made into thin sheets or spirals. At high temperatures Aluminium can be shaped easily to required thickness and size. This quality of Aluminium makes it even more suitable for designing purposes.

Corrosion Resistant

Unlike many metals that easily corrode, Aluminium is corrosion resistant. It reacts with oxygen and forms a very thin layer of oxide, which is about $1/1000^{th}$ time thickness of an mm. This thin layer of oxide protects the surface from corrosion. This layer is a also self repairing if broken. When used in outdoor environments the thickness of the oxide layer is increased 15 to 25 times by anodizing the metal. This increases the natural ability Aluminium being corrosion resistant. Metals tend to corrode easily in acidic environments but Aluminium has amazing resistance to corrosion in neutral and acidic environments. This property makes it possible to store reactive materials and acid related equipment like battery in boxes made of Aluminium.

Non – Magnetic

Aluminium is a non – magnetic metal, which is fondly used in the building magnetic x-ray devices because of its ability to co-exist in a magnetic environment without interfering with the magnetic fields. [12][13]

SIM Static:

The SIM Static is a totally different device when compared to SIM Static in terms of dimensions and characteristics. The Static device is the one that is immobile and it is multiple times bigger than the Stroll. The capacity of the SIM Static device is approximately 11 times of the Stroll device and this means the weight of items stored will be 11 times more compared to the Stroll device. This has led to the need for a stronger frame than that of the smaller version. Aluminium cannot be used to build the frame because of the huge load that is involved and there is possibility of deformation or breakage during extensive and prolonged usage. To build a stronger frame, a stronger material than Aluminium has to be chosen. Steel being one of the strongest metals available; it qualifies as the suitable metal to build the frame of the SIM Static device.

Steel is of various types depending on its chemical composition. Basically, Steel is an alloy of Iron and Carbon, which makes it one of the strongest metals. The numerous varieties of Steel are the product of multiple combinations of various metals to bring out the favorable characteristics required. Steel is categorized into

1. Carbon steel
2. Alloy steel
3. Stainless steel
4. High strength low-alloy steel (HSLA).

As the content of carbon increases the strength and toughness of the steel increases but the formability, welding and handling gets tougher. HSLA steel are used in heavy load constructions like bridges and heavy equipment like trucks and cranes due to their high tensile strength. However, the SIM Static device does not require such strong steel. It is adequate to use low-carbon steel that is just strong enough to hold the items that are placed in the device. Thus, A36 alloy, which has high tensile strength with low to medium carbon content and also easy to weld, bend and handle is chosen as the material to build the frame of the SIM Static device.

Table 2.2 Composition of A36 type steel [14]

Element	Content
Carbon, C	0.25 - 0.290 %
Copper, Cu	0.20%
Iron, Fe	98.00%
Manganese, Mn	1.03%
Phosphorous, P	0.04%
Silicon, Si	0.28%
Sulfur, S	0.05%

Table 2.4 Mechanical Properties of steel alloy [14]

Mechanical Properties	**Metric**
Tensile Strength, Ultimate	400 - 550 MPa
Tensile Strength, Yield	250 MPa
Elongation at Break (in 200 mm)	20.00%
Elongation at Break (in 50 mm)	23.00%
Modulus of Elasticity	200 GPa

Bulk Modulus (typical for steel)	140 GPa
Poissons Ratio	0.26
Shear Modulus	79.3 GPa

The A36 steel alloy is most widely used mild and hot-rolled steel. It has good tensile strength and has excellent welding and bending properties. It is easy to grind, punch, drill, tap and machine the alloy easily and it makes it suitable for various applications. The chemical composition of the A36 type steel is shown in the table below. [14]

2.2.2 Front Panel

The front panel of the SIM device is the primary monitoring surface. It is the surface that bears the LED displays through which the availability of spare parts is displayed. The main idea of building a device like SIM is to provide the customer with constant knowledge of the availability of stock at all times. To achieve this it is important to choose a material that exposes the stock directly to the user but also in a controlled environment. So the material that makes it possible to monitor the stock at all times is the transparent glass.

Industrial Glass

Glass is a weak substance when used in its natural form but tempered glass is strong and durable. Tempered glass is used in industrial applications and also known as architectural glass. The usage of glass in industries has been practiced ever since the technology of tempering the glass was introduced. The unique qualities of transparency and durability where combined to produce industrial glass.

Table 2.3 Properties of tempered glass [15]

Properties	Tempered Glass
Thermal Shock Resistance	Up to 250°C
Mechanical Strength	Four to five times stronger than
	Annealed glass
Tensile Strength	65 MPa
Bending Strength	120-200 N/mm2
Surface Compression	> 95 MPa
Design Stress for Architectural Purposes	50 MPa
Fragmentation	Small round crystals
Conducive for Processing	Cannot be cut after Tempering

Glass is also widely used in electrical equipment due to its insulating properties. It is a bad conductor of electricity and heat at room temperature. So, when used in electrical equipment, glass does not conduct heat or electricity, making it very safe from causing electric short circuits or any other electricity related mishaps.

Total Transparency

Apart from the general qualities of glass, the primary reason for designing the front panel of SIM device with glass is to establish the idea of full transparency of stock levels to user at all times. The front panel being totally made of glass makes it convenient for the user to check on the stock levels visibly whenever necessary. Every technology has its own shortcomings and especially electrically run equipment may fail at anytime whatsoever. Even when there is no electricity the user can visibly check the stock levels rather than depending upon the LED displays. Thus, the usage of glass in the designing the front panel of the SIM device serves the purpose of total transparency and continuous monitoring of stock levels even during failure of electrical systems of the device.

2.3 ALGORITHM AND FLOWCHART

The circuit is driven by codes uploaded to the Arduino microprocessor and the working of the code is explained in the following algorithm.

1. Start the program
2. Declare the variable to store the value in kg
3. Initialize all the peripheral components
4. Initialize serial port with baud rate of 9600 in the setup function
5. Initialize the output and input port in the setup function
6. Create main function
7. Implement the application logic, piece=1000/kg
8. Initialize load cell to the microcontroller
9. Get ADC value and store it in another variable
10. Scale the value to desire range
11. Apply that value in the formula to get output
12. Display the final output through serial port
13. Stop the program

Flowchart

The following flowchart gives a diagrammatic explanation of the working of codes. The variables are defined as the primary operations of the process and the peripheral components are initiated. The output of the analog to digital converter is received as the value for variable ‘a’ in the process of calibration. The value of the variable is checked and if it is zero, the process restarts from initialization stage. Else, the process continues by sensing the digital values and the load applied. The number of items stored in the device is calculated by dividing the sensed load value by the calibrated value ‘a’. The output value is the number of items stored in the device and it is displayed in the LCD screen.

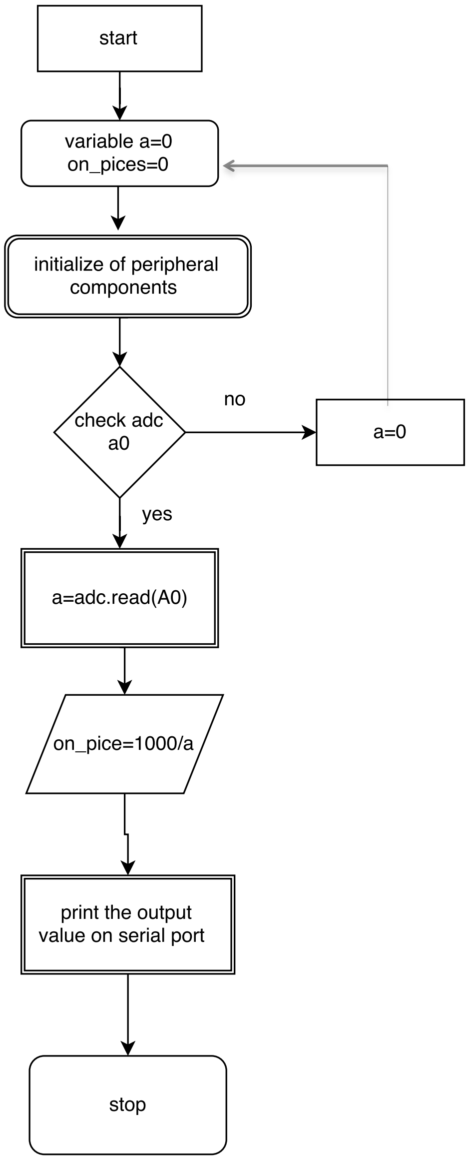

Figure 2.5 Flowchart for SIM operation

2.4 COMPONENTS

The SIM is a device that is designed to be cost efficient and also durable. The components used in the device are of the best quality and configuration that is required for a perfectly operating system. The major components that are used in the design of the SIM device are:

2.4.1 Microcontroller

A microcontroller is the processing unit of any device that helps to store and process the information that is given to it. A microcontroller is better than a microprocessor because it has the ability to accept input and provide output. The most widely used microcontroller for various applications is the Microcontroller 8051. It has a CPU, RAM, ROM, I/O ports, serial ports, timers, clock circuits and interrupts. It is preferable to use a microcontroller rather than a microprocessor because a microcontroller has memory and I/O ports that a microprocessor lacks. A microcontroller can be called as computer in a chip because of its ability to perform various operations.

However, the 8051 microcontroller has become less popular after the development of the Arduino technology, which is an incorporated platform that is preferred by hobbyist and designers due to its versatility. The Arduino board has ATmega microcontrollers and is easily programmable due to its simple user interface.

Microcontroller selection criteria:

(a) Meeting the requirements of the system technically and cost effectively

1. Speed of operation
2. Power consumption
3. On chip RAM and ROM
4. No. Of I/O pins
5. No. Of timers on chip
6. Cost

(b) Availability status of compiler, assembler, debugger and other software development tools.

When compared to microcontroller 8051, the Arduino board fulfills most of the characteristics required than the 8051. Thus, the Arduino platform is preferred over the 8051 in the development of the SIM devices. [16]

Arduino is an open – source platform that makes it easy to build prototypes and bigger projects too. It is widely used by enthusiasts who like to build new projects and designs for educational research purposes. The software used for manipulation of the Arduino board is also open – sourced making it possible for implementing Arduino system in various applications ranging from everyday products to complicated lab equipment. The easy user interface makes it easy to access and experiment with. The Arduino board is a development in the field of embedded systems where a microcontroller is programmed to do tasks by loading the set of codes onto the microcontroller. It is the same concept under which he Arduino board works. The Arduino has its own Integrated Development Environment (IDE) that enables the user to run and test the codes before actually loading the set of codes onto the board.

Characteristics:

1. Inexpensive
2. Cross – Platform (Works on most operating systems like Windows, Macintosh, Linux etc.)
3. Simple and clear programming environment
4. Open source and extensible software (Creative common license makes it possible for anyone to alter and customize it)

In the designing of SIM devices we make use of two types of Arduino boards depending upon the requirement of the devices. The two variants SIM Stroll and SIM Static have different capacities that require different number of load cells. As the number of load cells increases, the system requires higher configuration of microcontroller. Thus, the SIM Stroll uses Arduino UNO board and the SIM Static uses Arduino Mega. [17]

Arduino UNO

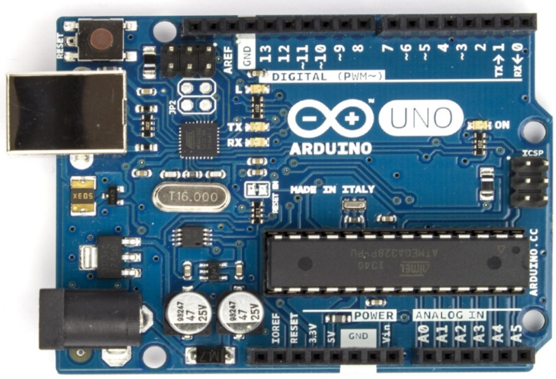

Figure 2.6 Arduino UNO Board [18]

Table 2.4 Arduino UNO Specifications [18]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25g

Arduino Mega

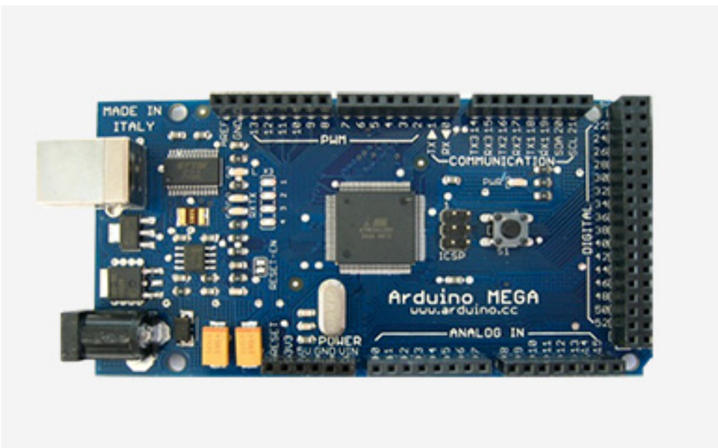

Figure 2.7 Arduino Mega Board [19]

Table 2.5 Specification of Arduino Mega Board [19]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB (ATmega328)
EEPROM	4 KB (ATmega328)
Clock Speed	16 MHz
Length	101.52 mm
Width	53.3 mm
Weight	37g

2.4.2 INA 125p Instrumentation Amplifier

The INA125p is a low power instrumentation amplifier with high accuracy and a precision voltage reference. It provides precision difference input amplification and complete bridge excitation on a single integrated circuit. It has features like low noise and input protection. It has wide supply range as in single supply ranging from 2.7V to 3.6V. It also has sleep mode that allows shutdown and duty cycle operations to save power.

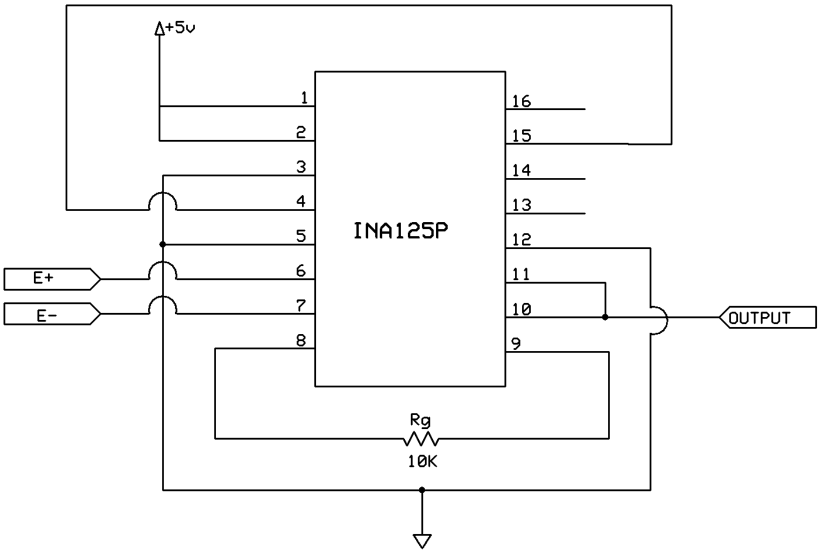

Figure 2.8 INA125p [20]

Applications:

1. General purpose Instrumentation
2. Factory automation
3. Industrial process control
4. Multi – channel data acquisition
5. Battery operated systems
6. Pressure and temperature bridge amplifiers [21]

2.4.3 Analog to Digital Converter

The ADC0808 is a data acquisition component with an 8-bit analog to digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit analog to digital converter uses the conversion technique of successive approximation to convert the signals. The ADC0808 has been developed by collaborating the most desirable features of various analog to digital converters.

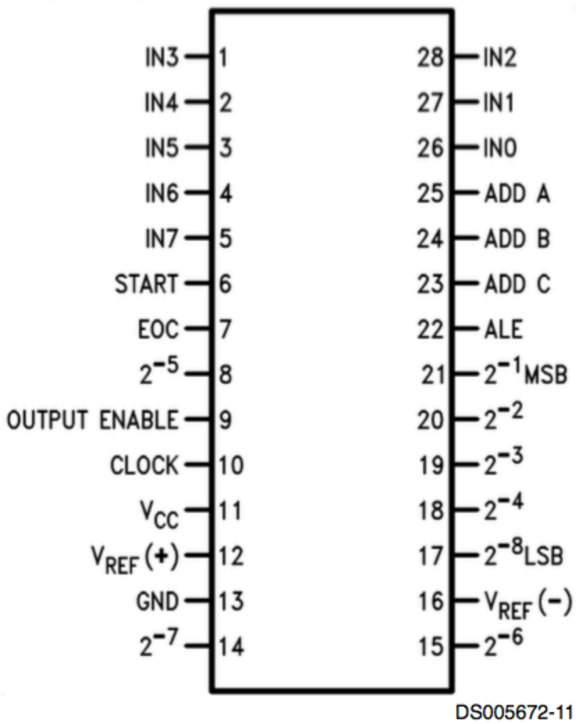

Figure 2.9 ADC 0808 connection diagram [22]

It has distinctive features and provides high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability and consumes less power. These valuable features make ADC0808 as a suitable device for a wide range of applications.

SELECTED ANALOG CHANNEL	ADDRESS LINE		
	C	B	A
IN0	L	L	L
IN1	L	L	H
IN2	L	H	L
IN3	L	H	H
IN4	H	L	L
IN5	H	L	H
IN6	H	H	L
IN7	H	H	H

Figure 2.10 Input Series [22]

The device consists of 8-channel single-ended analog signal multiplexer. The address decoder selects a particular input channel. In the table above the input states for address lines to select any channel is shown. The decoder on the low to high transition belonging to the address latch enable signal has the address latched into it. [22]

2.4.4 Load Cell

Sensors and transducer have been used widely in the field of electronics and there are numerous types of sensors and transducers, but the load cell or the pressure sensor stands out as one of the most important one.

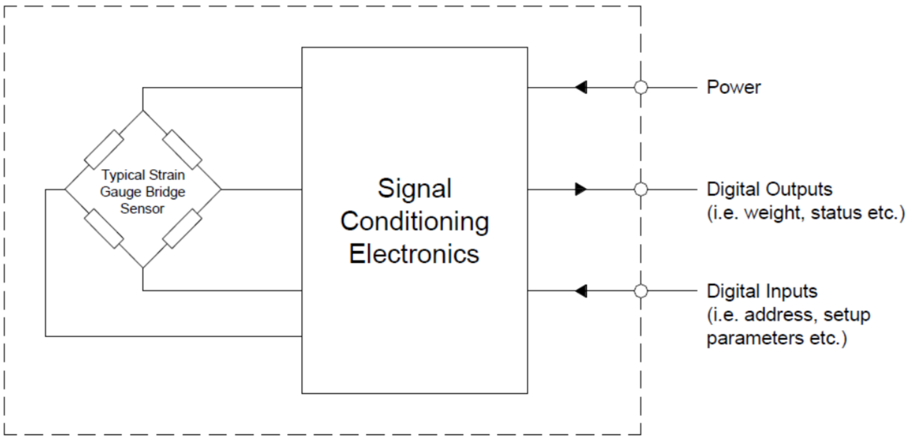

Figure 2.11 Digital Load Cell [23]

A load cell basically measures the deformity created by the weight or force applied on it. Load cells are categorized depending on the type of output signals they generate and by the way they detect weight. Some types of load cells are Mechanical cells, strain gauge cells, fiber optics, piezo-resistive etc. Though there are a variety of sensors available, load sensors are the most preferred sensors due to their high accuracy rate and low cost. Load cells are widely used in industrial applications and automation processes measure weight or force. Strain gauges are used in most of the load cells as sensing element. The strain gauges used in the load cells can be either metallic or semi-conductor strain gauges depending upon their application. The semiconductor load cells are made up of silicon and are very small. They have large gauge factors. The resistance changes in silicon load cells are much bigger than the metallic ones. They are used often in miniature load cells. [24]

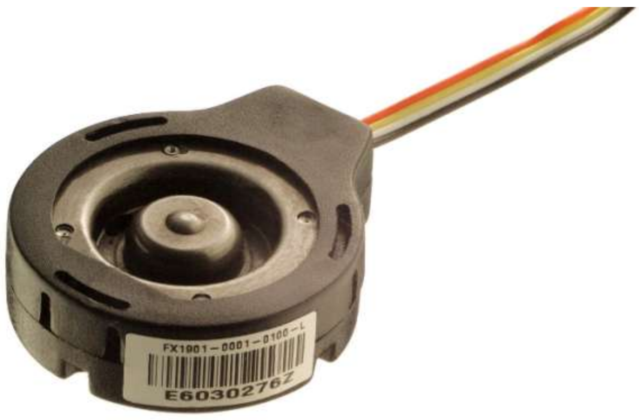

Figure 2.12 FX1901 Load Cell [25]

The load cell selected for design of the SIM is force sensor FX1901. This is a widely used compression load cell in everyday applications and consumer products.

Features:

1. Compact coin cell package
2. Noise free
3. Robust
4. Highly Reliable
5. 20mV/V Nominal output
6. Low deflection
7. Fast
8. Unlimited cycle life
9. Anti-rotation mounting features

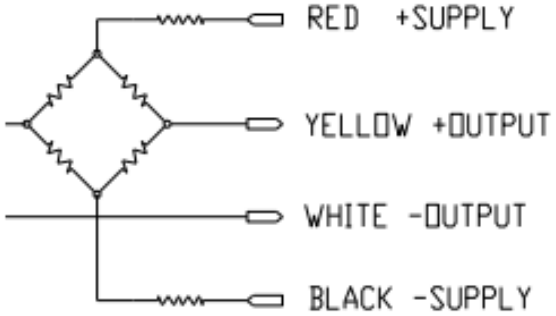

Figure 2.13 Wiring Information [25]

The development of this load cell has been revolutionary in price and performance value aspects. The FX1901 is a 1% load cell with full-scale ranges of 10, 25, 50, 100 and 200lbf compression. Since the load cell FX1901 operates at very low strains, it provides an essentially unlimited cycle life expectancy, higher resolution and high over-range capabilities. [25]

2.4.5 LCD Display

The main output device of this system is the LCD display that shows the digitally converted analog signals as numerical values. The LCD display that is used in the SIM device is the LCD keypad shield designed by DFRobot, for Arduino microprocessor. This LCD keypad shield includes a 2x16 LCD display and 6 push buttons. There are seven pins (4,5,6,7,8,9 and 10) that are used to interface with the LCD and one analog pin 0 to read the push buttons.

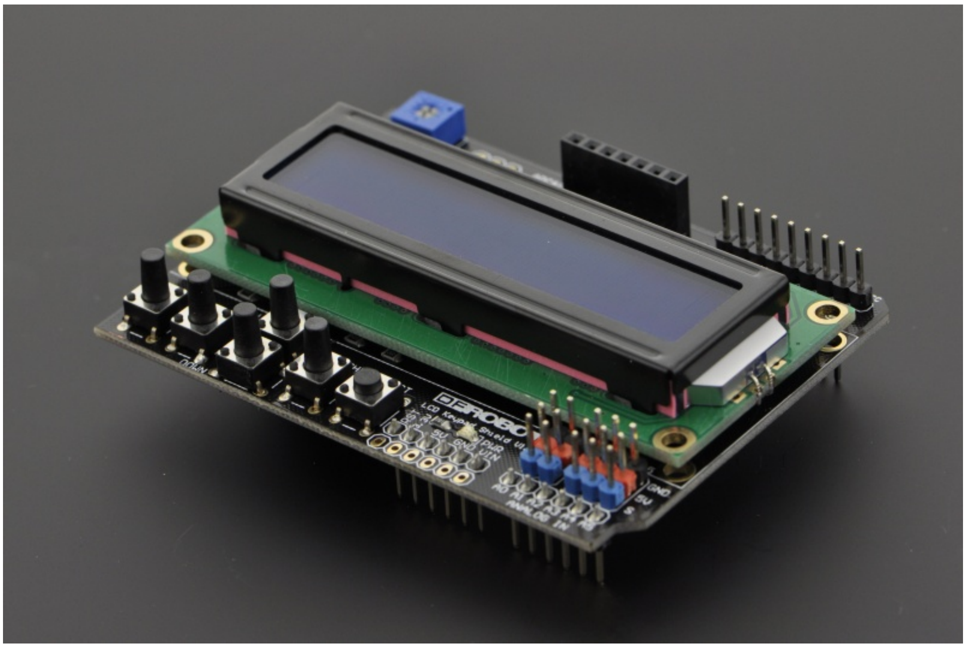

Figure 2.14 DFrobot LCD Keypad Shield [26]

The special design of this device allows it to operate independently without the need for a computer. It is specially developed for Arduino and similar boards. The user-friendly interface allows the user to access a menu and make a selection. There are 5 keys in the device, which enables the user to scroll up, down, left, right and select the desired option. The device uses just one ADC channel, which saves the digital I/O pins.

Specification:

1. Operating Voltage of 5V
2. 5 Push buttons to supply a custom menu control panel
3. RST button for resetting arduino program
4. Adjustable backlight with integrated potentiometer
5. Expanded available I/O pins
6. Expanded Analog Pinout for fast sensor extension
7. Dimension: 80 x 58 mm. [26]

2.5 CIRCUIT

SIM Stroll

The circuit of the SIM stroll consists of 4 basic components. The compression load cell is the measuring device, which is FX1901 load cell. It has four outlets red, yellow, white and black namely. Then the circuit uses an instrumentation amplifier INA125P, which amplifies the signal generated by the load cell. The main microprocessor is the Arduino UNO board that controls the whole process by executing the pre-stored codes. Finally there is the output device that is the LCD display DFrobot LCD keypad shield. The connections circuit for the device is shown below.

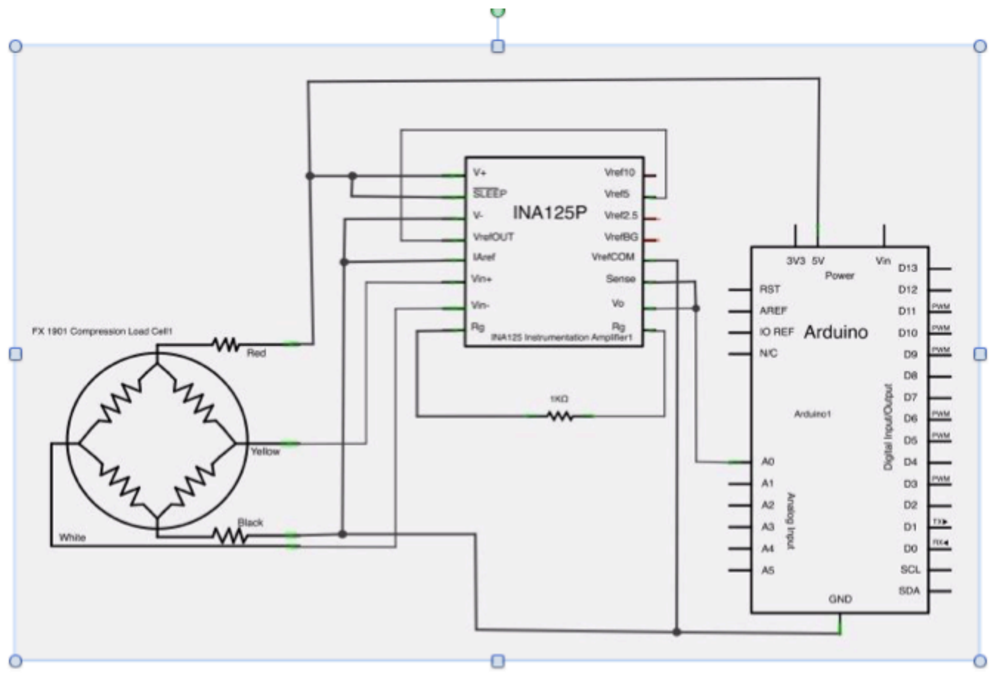

Figure 2.15 Arduino Circuit for SIM Stroll [27]

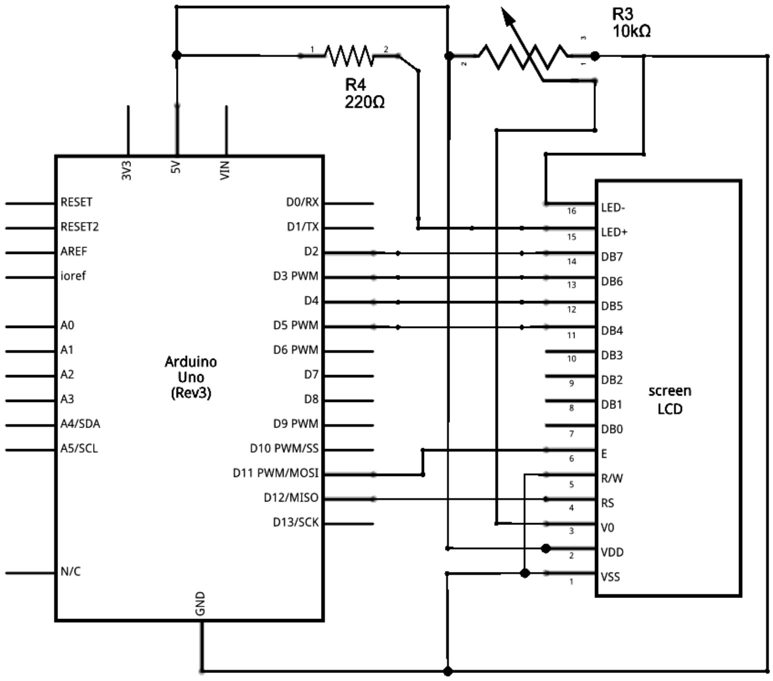

Figure 2.16 Arduino to LCD Connections [28]

SIM Static

The circuit for SIM Static is almost similar to that of the SIM Stroll but with just two differences. The microprocessor used in the circuit of SIM Static is Arduino Mega board, whereas in SIM Stroll it is Arduino UNO. The other component that varies in this circuit is the analog to digital converter ADC0808 instead of the INA125p that is present in the SIM Stroll. The need to replace these components instead of the previous ones arises due to the large number of load cells that is involved in the design of the SIM Stroll device. In this device there are 45 load cells implemented compared to just 4 in the SIM Stroll. Due to limited ports in the Arduino UNO and the INA125p components, the circuit had to be tweaked to fit the requirements.

There are 4 ADC0808 chips used in the circuit to provide adequate ports to the numerous load cells in the system. The signals generated in the load cells are converted to digital signals and are processed in the Arduino Mega microprocessor before being displayed on the LCD display. The connections circuit for the SIM Static device is shown below.

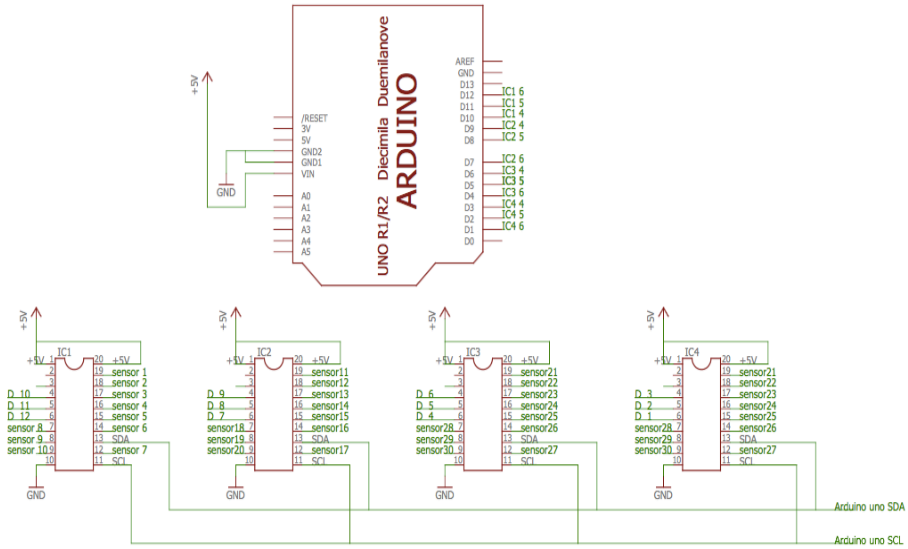

Figure 2.17 Arduino Mega Circuit for SIM Static

2.6 CUSTOMIZABILITY

The ability to provide service as per the requirements of individual customers is an added virtue for any product. This has lead to the flexible design of the SIM devices that are vastly customizable in aspect of capacity, size, cost and energy consumption. The SIM Stroll device is compact inventory storage and handling device, which has 4 racks by default and the SIM Static, is the bigger version, which has 11 times more capacity than the Stroll variant. These two variants cater to small and medium size customers, however there is always a special requirement that does not fit into the categories of the two variants. So, adding more racks can increase the capacity of the SIM Stroll matching the requirement of the customer. Each rack is provided with the load sensing platform, the output device (LCD screen) and an optional locking system.

In an effort to implement Corporate Social Responsibility in the SIM device, the option of running the device entirely on solar energy has been provided to the users. The SIM is provided with a battery box and also an option for direct supply because in places where the solar energy is not viable the direct supply option can be utilized but in places where the solar energy is surplus the battery can be charged with solar energy. The SIM Stroll is a mobile device, which is provided with wheels, so the battery to solar charge controller port is detachable. Once the SIM Stroll is charged enough the device can be detached and placed anywhere in the shop floor. Whereas in case of SIM Static, the device is immobile and so it has to be located closer to the charge controller in order to avoid any loss of transmission. It is advised to run the device on clean and renewable source of energy in order to make it an eco-friendly device.

3 COST AND EFFICIENCY ANALYSIS

3.1 Manufacturing Cost

The manufacturing cost for both the devices need to be calculated separately as there are componential and dimensional differences in the design of the devices. The prices of components are referred from various online resources. It is important to estimate the manufacturing cost of the devices because it is necessary for assessing the efficiency of the device with comparison to the existing products.

3.1.1 Material cost

SIM Stroll

Table 3.1 Material Cost of SIM Stroll [29]

Serial no.	Component	Type	Price (Eur)	Quantity	Total (Eur)
1	Arduino	UNO	24	1	24
2	Instrumentation Amplifier	INA125P	12	1	12
3	Load Cell	FX1901	16	4	64
4	LCD Display	16X2	10	4	40
5	Glass	Tempered	10	1	10
6	Metal	Aluminium 6061 alloy	8/sq.m	4	32
7	Wheels	Ball	2	4	8
					Total 190

SIM Static

The main aim of designing the SIM Static variant is to cater to the diverse needs of customers and also to further reduce the cost of implementation of the system by minimizing the component, development and material costs. The material used in SIM Static to build the frame is steel and it is much cheaper than Aluminium.

Table 3.2 Material Cost of SIM Static [30] [29]

Serial No.	Component	Type	Price (Eur)	Quantity	Total (Eur)
1	Arduino	Mega	44	1	44
2	A to D Converter	ADC 0808	4	4	16
3	Load Cell	FX1901	16	45	720
4	LCD Display	16X2	10	45	450
5	Glass	Tempered	10	8	80
6	Metal	Steel A36 alloy	0.25/kg	120	30
					1340

3.1.2 Mark-Up Cost

Mark-up cost is the additional cost that is added to the material cost before determining the final cost of the product. The main aim of adding mark up cost is to cover up the cost doing business and sales of the product. This helps in preventing loss and also compensates for the production costs and post-production costs such as storage, logistics and marketing costs etc. Mark-up cost addition also provides security to the manufacturer from hidden losses that occur during the handling of the product.

For the SIM devices, the Mark-up cost percentage to be added to the manufacturing cost would be 75% as it is determined to cover up for the hidden costs and losses.

SIM Stroll

Manufacturing cost = Material cost + (Material cost * 75%)

Manufacturing cost = 190 + (190 * 75%)

= 190 + 142.5

Manufacturing cost = 332.5 euros.

SIM Static

Manufacturing cost = 1390 + (1390 * 75%)

= 1390 + (1042.5)

Manufacturing cost = 2432.5 euros.

Capacity of SIM Static = 11 times capacity of SIM Stroll

Cost of SIM Static = 7 times cost of SIM Stroll

Thus, the development of the SIM Static has made the equipment approximately 750 euros cheaper. Therefore, installing 1 SIM Static device in place of 11 SIM Stroll devices makes the cost of implementation about 36% cheaper.

3.2 Cost Comparison With Existing Product

There are very few products in the market that resemble the SIM systems, but as mentioned before, the introduction of smart shelves in retail industry is the closest technology that resembles the SIM devices. The 'Smart Shelves' is a product developed by Co.Cork, which caters to the retail business industries such as supermarket stores.

Retail price of existing product = 250 euros

Retail price of SIM Stroll = 332.5 euros

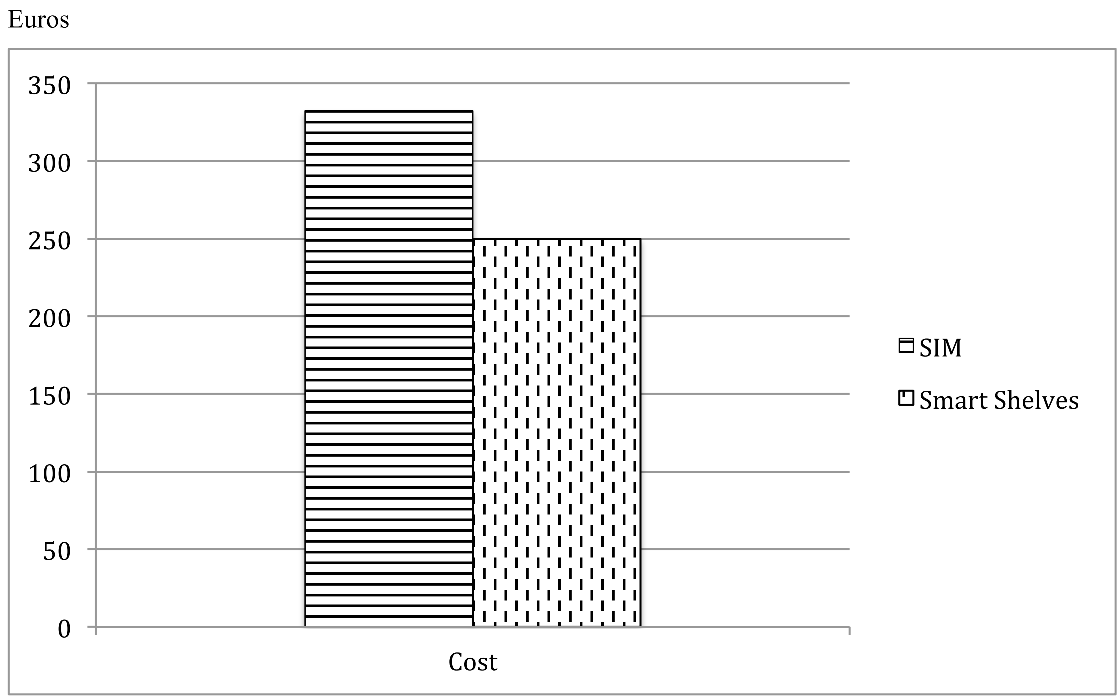

Figure 3.1 Cost comparisons

The SIM Stroll is 82.5 euros or 33% costlier than the Smart Shelf, however the capacity and durability of the SIM device is higher since it is designed for industrial purposes.

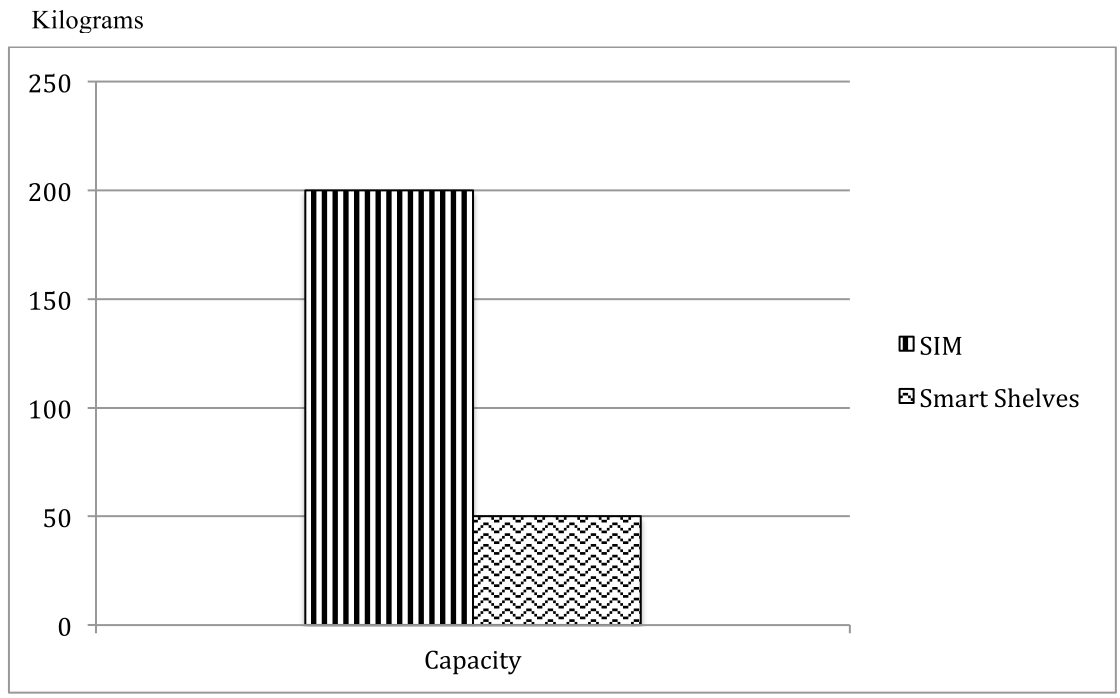

Figure 3.2 capacity comparisons

It is denoted that a large store would require about 2000 units of Smart Shelf, whereas a large manufacturing enterprise would require approximately 500 units of SIM Stroll. When comparing the cost of SIM Static, the capacity plays a major role, as SIM Static is multiple times bigger than the existing product. [31]

3.3 Cost Efficiency By Labor Substitution

Labor costs are a major contributor to the overall expenses of Inventory management process. One of the benefits of automation includes the reduction of labor and costs related to it. The SIM device too does the job of substituting labor in a firm where there is a need to document the inventory on a constant basis. In order to calculate the approximate cost reduction achieved by implementing SIM in a firm, it is assumed that the process of documentation consumes one hour of the working time of an employee on daily basis. If this time consumption is eliminated, the benefits acquired by the firm for a period of 30 days are calculated below.

Time consumed for the process of documentation per day = 1 hour
Average wage per hour in Lithuania = 1.98 euros
Average monthly salary for purchase and inventory employee in Lithuania = 295 euros [32]

$$\text{Cost reduction} = \frac{(\text{total time consumed} * \text{hourly wage})}{\text{Average monthly wage}}$$

$$\text{Cost reduction} = \frac{(30*1.98)}{295} = 0.2013$$

Cost reduction percentage = 0.2013*100

Cost reduction percentage = 20.13% per employee for a period of one month.

The 20.13% cost reduction by labor substitution is 59.38 euros, which is 17.85% of the cost of the developed product.

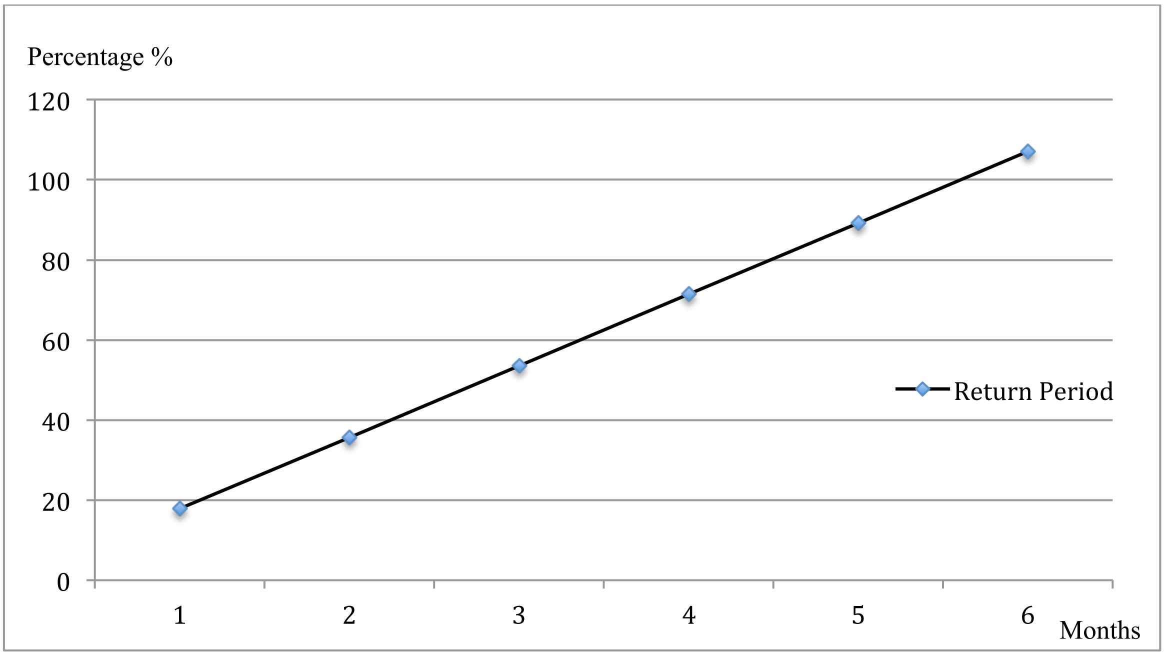

Figure 3.3 Return period of implementation cost

This is the cost efficiency that SIM device provides upon implementation within a period of one month per employee. The period taken to return profit of 7% from the cost of implementation is 6 months, which is considerably a short period. This indicates that Return On Investment (ROI) of the SIM device is significantly high and this adds up to the benefits that SIM has to offer.

4 BENEFITS

1. The SIM device enhances the inventory management process, help regulate and control the stock levels in a firm.
2. It also focuses on reducing the overall cost of inventory storage and handling.
3. High Return On Investment with respect to the salary expense reduction.
4. Reduction of labor enables to cut down on the total expenses of inventory management.
5. Time consumption due to the process of documentation has been reduced, making the process more time efficient.
6. By implementing the SIM device in an organization, the asset performance of the organization can be maximized. Unused or dead stock can be prevented.
7. Organized system leads to hassle free production and thus minimizes the overall production downtime.
8. The possibility of continuous monitoring of stock levels helps avoid emergency purchasing, which in turn minimizes the hidden losses that occur due to emergency purchasing.
9. A steady increase in the accuracy of inventory information due to automation.

CONCLUSION

1. A literature analysis on the inventory management has been done and the need for a better management tool for small-scale industries has been justified.
2. A detailed design of the SIM Stroll and SIM Static devices has been developed and presented as 3D and 2D models. The material selection and key components of the device has been analyzed.
3. The circuit diagrams of both the devices and the flowchart and algorithm explaining the operation of the devices have been developed.
4. The material cost of SIM Static is 190 euros (see table 3.1) and SIM Static is 1390 euros (see table 3.2). The mark-up cost is added and manufacturing cost is estimated to be 332.5 euros for SIM Stroll and 2432.5 euros for SIM Stroll.
5. The cost of the SIM device is approximately 33% costlier (see figure 3.1) than the closest existing product, however the capacities of the products vary. The 'SIM Stroll' device has approximately 4 times the capacity (see figure 3.2) of 'The Smart Shelf'.
6. The cost reduction in salary expenses is calculated to be 20.13% per employee for a period of one month. Thus, providing 7% return on the cost of implementation (see figure 3.3) by the period of six months.

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