ESTGOH
Escola Superior de Tecnologia e Gestão de Oliveira do Hospital

Product Traceability in Manufacturing Industries: Business Case and Pilot Project

Report presented with a view to obtaining a master's degree in the scope of the study cycle of master's degree in applied informatics

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[1] CTCV: CTCV Official page

Resumo

A inovação está aumentando rapidamente em todos os setores da indústria. Esta melhoria e desenvolvimento são imperativos para as indústrias. Algumas estão atualizadas e outras estão melhorando. Já estamos testemunhando a era da indústria dependente de tecnologia, onde a tecnologia desempenha um papel fundamental nos processos de fabricação. Tecnologias disruptivas estão mudando a maneira como as empresas operam. É essencial para as indústrias que estão focadas em oferecer um serviço rápido e confiável aos clientes. Como a tecnologia e a inovação estão aumentando, eles poderiam ajudar a indústria cerâmica para as opções atualmente disponíveis em tecnologia inter-relacionada, que já estão impactando o desenvolvimento industrial na Indústria 4.0. Durante as épocas de industrialização anteriores houve muitas melhorias em diferentes setores industriais, que levaram para um crescimento rápido em todos os setores.

A presente pesquisa incluiu a revisão de abordagens para a indústria de rastreabilidade cerâmica. Esta tese apresenta uma discussão sobre a rastreabilidade de produtos na indústria cerâmica, observando o processo de produção. Existem muitas etapas do processo de produção, onde os materiais e os produtos são difíceis de rastrear. No entanto, as indústrias estão preocupadas com a quantidade e o número de produtos produzidos que atenderão às expectativas no final. É um desafio para as empresas gerenciar, organizar e rastrear os produtos durante todo o processo de fabricação, desde a matéria-prima até a embalagem final.

Os sistemas de identificação por radiofreqüência (RFID) são uma ferramenta comum e útil na fabricação, no gerenciamento da cadeia de suprimentos e no controle de estoque de varejo. Códigos de barras ópticos, outro sistema universal de identificação automática, têm sido um recurso de embalagem familiar em itens de consumo há anos. Devido aos avanços na tecnologia de fabricação de silício, os custos de RFID caíram significativamente. Em breve, os "códigos de produtos eletrônicos" ou "etiquetas inteligentes" de RFID de baixo custo podem ser uma substituição prática para códigos de barras ópticos em itens de consumo. Infelizmente, a implantação universal de dispositivos RFID em itens de consumo pode expor novos riscos de segurança e privacidade que não estão presentes em ambientes de fabricação fechados. Esta tese apresenta uma introdução à tecnologia RFID, identifica várias ameaças potenciais à segurança e privacidade e oferece várias propostas práticas para mecanismos de segurança eficientes.

Palavras-chave

Código de Barras, RFID, QR Code, Indústria 4.0, rastreabilidade.

Abstract

Innovation is increasing rapidly in every sector of the industry. This improvement and development are imperative to industries. Some are up-to-date, and others are improving. We are already witnessing the era of technology-dependent industry, where technology plays a key role in the manufacturing processes. Disruptive technologies are changing the way enterprises operate. It is essential for the industries which are focused on delivering fast and reliable service to the clients. As the technology and innovation are increasing, they could help the ceramic industry for the options presently available in interrelated technology, which are already impacting the industrial development in Industry 4.0 During previous industrialization eras there have been many improvements in different industrial sectors, which have led to rapid growth universally across industries.

The present research included the review of approaches towards the ceramic traceability industry. This thesis presents a discussion on traceability of products in the ceramic industry by observing the production process. There are many stages of the production process where the materials and products are difficult to track, However, industries are concerned about the quantity and number of products produced that will meet the expectations at the end. It is challenging for the enterprises to manage, organize and trace the products throughout the manufacturing process, from raw material till final packaging.

Radio Frequency Identification (RFID) systems are a common and useful tool in manufacturing, supply chain management, and retail inventory control. Optical barcodes, another universal automatic identification system, have been a familiar packaging feature on consumer items for years. Due to advances in silicon manufacturing technology, RFID costs have dropped significantly. Soon, low-cost RFID “electronic product codes” or “smart-labels” may be a practical replacement for optical barcodes on consumer items. Unfortunately, the universal deployment of RFID devices in consumer items may pose new security and privacy risks not present in closed manufacturing environments. This thesis presents an introduction to RFID technology, identifies several potential threats to security and privacy, and offers several practical proposals for efficient security mechanisms.

Keywords

Barcode, RFID, QR Code, Industry 4.0, traceability.

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Acronyms List

CEPT	European Conference of Postal and Telecommunications Administrations
COM	Common on Most
CW	Continuous Waves
DIY	Do it Yourself
EAN	European Article Number
EAS	Electronic Article Surveillance
ECC	Electronic Communications Committee
EPC	Electronic Product Code
ER	Entity-Relationship Model
FCC	Federal Communications Commission
FIFO	First-in, First-out
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HF	High Frequency
IaaS	Infrastructure as a Service
IATA	International Air Transport Association
IDE	Integrated Development Environment
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFF	Identification Friend or Foe
ISBN	International Standard Book Number
ISO	International Organisation for Standardisation
ISSN	International Standard Serial Number
ITF	Interleaved Two of Five
ITU	International Telecommunication Union
JAN	Japanese Article Number

KB	Kilo Byte
LF	Low Frequency
MAU	Monthly Active Users
MIC	Ministry of Internal Affairs and Communications
MIT	Massachusetts Institute of Technology
MSI	Medium Scale Integration
PaaS	Platform as a Service
PC	Personal Computer
PDA	Personal Digital Assistance
PLC	Programmable Logic Controller
QR Code	Quick Response Code
RF	Radio Frequency
RFID	Radio Frequency Identification
RO	Read Once
RW	Read / Write
SaaS	Software as a Service
SCM	Supply Chain Management
SOA	State of the Art
SQL	Standardised Query Language
SSMS	SQL Server Management Studio
UC	Use Case
UHF	Ultra-High Frequency
UI	User Interface
UID	Unique Identification
UPC	Universal Product Code
URL	Unique Resource Locator
URN	Update Request Number
VS	Visual Studio
WLAN	Wireless Local Area Network

WORM Write Once and Read Many

1 Introduction

1.1 Background

Industrial revolution is a frequently discussed topic amongst many modern industries, describing the transition of hand labour to intelligent product production process where machines and products impart each other cooperatively within an internet of things. The first industrial revolution was the birth of innovation and has its immediate beginning in the cotton textile industry which confined (limited) in England during 1760 [1]. And slowly two Englishmen William and Cockerill, brought the industrial revolution to Belgium by developing machine shops at Liège during 1807. And slowly it became the first country in continental Europe to transform economically.

The second revolution also marked an important breakthrough in the industrial revolution during 19th century. Modern industries begun to exploit common and synthetic resources like metal composite items and alloys. The combination of these two developments in machine, tools and computers gave rise to modern factories and the first major significant achievement was in the second half of 20th century [2].

The third revolution appeared from the need of the new type of energy which would leave behind the former inventions. This revolution has witnessed the rise of transistors and microprocessors and telecommunication. This revolution gave rise to high-level automation in production. A big thanks to PLC (Programmable logic controller), and robotics).

Industry 3.0 is focused on single processes. Industry 4.0 vision is total digitization of industries. Industry 4.0 stands for fourth industrial revolution. Every company wants to revolutionize the way they operate using the technology, to achieve better operational results. Technology is the scientific knowledge used for practical purpose. One can find its application in vast areas, ranging from industries to non-industrial companies. It is also said to be a problem-solving accurate method. It is a way industry modifies according to the needs of the society. The organizations which have implemented Industry 4.0 platforms do not have clear definition but only describe about the technologies with case scenarios.

Industry 4.0

Leading researchers say that the fourth revolution may shape the future of industries. The work presented in this thesis contributes to the research on ceramic industry traceability mainly focused on the traceability technologies which can be game changers to solve tracking of products from production to supply. This is with the intention of providing end to end solution for the industries which want to use Industry 4.0. Industry 4.0 focuses on digitisation and real time data analysis, as described in Appendix-A.

Future of manufacturing

One of the main problems the manufacturing firms are facing is the tracking of the products which would increase the efficiency of the production. And it is likely to increase as the world of production will become interlinked and more networked. The complete process of production and devices will be inseparable. i.e., machines and work flow will merge to be a single entity [3].

Today's manufacturing firms are moving towards the digitisation of their production where products are customised to meet the demand. According to [4] Many manufacturing enterprises have moved from mass production to agile production approaches. The emphasis is on both the organisation and technological approach which would drive the smart manufacturing through innovation.

The Ceramic Industry

In addition to the Industry 4.0 discussed this section also covers activities associated to the ceramic industries. The present thesis work focus is primarily in ceramic industry product traceability.

The major sectors which are based on ceramic product manufacturing are as follows:

- Wall and floor tiles
- Bricks and roof tiles
- Ornamental ware [household ceramics]
- Refractory products
- Sanitaryware
- Technical ceramics
- Vitrified clay pipes

Generally, the ceramic products comprise of non-metallic compound made permanent by firing process, as explained in Appendix-B .

1.2 Problem Indication

The concept of industry 4.0 is relatively new, developing and practiced by many firms now. The main challenges in ceramic industries is the limited use of technology for tracking and managing products under the roof. We intend to analyse the present traceability aspect regarding the current industrial challenges. That is important for companies which implement limited technology and have less exposure to the technology that does exist. Tracing technology could help bridge the gap between human and digital world.

Manufacturing industries manufacture products for market like engineering, beverages, petroleum, laboratories, wood, ceramic, Bio-engineering, metal and many more. And they want to track down the product history and lifecycle down from the first stage of production to the delivery end, for the supplier or consumer. This complete chain value of product from production to the delivery end requires a proper method of tracking history which is the most crucial part of the industrial production line in manufacturing industry. The more the demand and supply, the more the complexity and the challenges will arise to find a balance to stabilize the production process. During the last decade product traceability has been an integral part of the warehouse and logistics management across many industries. Manufacturers do provide essential and adequate information about the product or material to the suppliers and it is potentially required to trust. But the consumers are not exposed to certain details about the product specifications namely production cost, its origin and storage days [5]. Certain industries develop products for the consumers which would reach them rotten. That is completely unacceptable, as it would result in distrust and loss of confidence in the industry and supplier by the consumers, besides the economic losses.

We visited a ceramic manufacturing firm which produces ceramic products to its suppliers; we hereafter mention this firm as "*The Case Company*"[2]. They produce a broad variety of ceramic products but lack in tracking them while moving across the production floor.

In ceramic industries there is a concern in product tracking from production to packaging stage. During the production process if the product breaks we must track whether the same kind can be replaced. On the same context, the chemical composition of the ceramic material changes from stage to stage. The final product can be leveraged to start the tracking process. But, while the ceramic is taking shape and going through a series of production stages, the physical state of the product is not suitable to deploy the tracking mechanism.

The primary focus in this thesis is in ceramic industry product traceability using RFID, which could help us bridge a gap between the human intervention and technology advancement. It is one such approach where the scanned tag information is stored centrally to keep track of all the products. Inventory management becomes easy by storing the product information and retrieving it back to the end user for the product information management.

1.3 Purpose

The purpose of this thesis is to perform a research in manufacturing industry where product traceability is a concern especially in ceramic production floor. And furthermore, determining the need for industry 4.0 technologies and based on the research on tracking technologies, we will list out different technologies and we will examine where there is a need for specific technology in the ceramic product production. The proposed method is introducing technology and process innovation.

To introduce the technology, it is required to invest an adequate amount of time in research and development. Industry 4.0 enables us to auto-identify the objects for helping organize inventory management. And will save the scanned product tag data into the database. We can get the image along with the QR Code also for the product information stored in the database. A unique Id for each object label is associated with the product information input by the worker. In this way, it would be an easy task to identify the product out of bulk, whether it is available or not. We also compare RFID to different technologies like Barcode or QR Code which are quite less expensive compared to RFID technology. In case of damage to the code by an external entity, there is a significant problem in code readability. That is why RFID tags are the best to fill that gap. An RFID tag doesn't have to be clean as Barcode or QR code tags. We can witness the use of RFID technology can be seen in many areas like laptops, mobiles, toll booths, building access systems, passport, keys to open car doors, ID cards etc.

KERAMOS NAZARI, Zona Industrial Ligeira, Condeixa, Portugal: http://nazari.pt/

1.4 Research question

Keeping in mind the phenomenon and its effects and features, one research question must be chosen.

Main research question:

- How are diverse Industry 4.0 technologies connected and how its adoption in ceramic industry will bring value when adopted.

1.5 Objectives

This section of the thesis will explain the objective which we intent to accomplish. Research is to examine and fill the missing pieces by introducing industry 4.0 in place with well-advanced product traceability technology. The technologies that we are talking about are RFID (Radio Frequency Identification), QR-code, Barcode, IoT (Internet-of-Things).

The main objectives are therefore:

1 To conduct a research on industry 4.0 and its involvement by many industrial areas. And how it can be solution oriented in "the case company".
2 To visit a ceramic product manufacturing firm ("the case company") to examine the production lifecycle.
3 To study the ceramic product production process (see Appendix) to examine and fill the missing pieces by introducing industry 4.0 in place with well-advanced product traceability technology. The technologies that we are talking about are RFID (Radio Frequency Identification), QR-code, Barcode, IoT (Internet-of-Things).
4 To provide a technical installation quotation to the case company we visit (Not a prototype).
5 To collect the data concerning to the nature of production lifecycle, how many people are employed on the floor, which sections require more people to be employed, administrative section responsibilities, production to packaging steps, and Warehouse area management.
6 Designing a process model of ceramic industry to analyze and study the production lifecycle and to understand where the new technologies can be implemented.
7 Research on materials required to develop and design a prototype.
8 To test the prototype under every development stage, rectify the problems and improve as necessary.
9 To demonstrate the prototype for valuable feedback.

2 Planning

This section explains the detailed process of the work which was carried out along the thesis period. It is further split into two sub-sections where an initial plan and final plans detailed.

2.1 Initial Plan

In this section we present the initial plan of the proposed project work. It lists the set of deadlines proposed at certain intervals along the course of a year. Though it is imposed to complete the project in a set time frame, the tasks may bring new challenges while working on any stage. That will be for the improvement and adding to the result. The below image of a Gantt chart was made using *Microsoft Project*, *Gantt Project* application. This tool is easy and self-explanatory for starters to design the project plan and there are no complications faced while designing.

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		**Product Tracebility**	**240 days**	**Thu 02-03-17**	**Wed 31-01-1**		
2		**Research Phase**	**37 days**	**Thu 02-03-17**	**Fri 21-04-17**		
3		Define Problem Statetment	7 days	Thu 02-03-17	Fri 10-03-17		
4		Identify Industries	5 days	Tue 14-03-17	Sat 18-03-17		
5		Interpret Requirements	5 days	Tue 21-03-17	Sat 25-03-17		
6		Research about RFID	9 days	Tue 28-03-17	Fri 07-04-17		
7		Research about QR Code	5 days	Mon 10-04-1	Fri 14-04-17		
8		Research about barcode	5 days	Mon 17-04-1	Fri 21-04-17		
9		**Design Phase**	**70 days**	**Mon 24-04-1**	**Fri 28-07-17**		
10		Industrial Visits	25 days	Mon 24-04-1	Fri 26-05-17		
11		Understanding Requirements	15 days	Mon 29-05-17	Fri 16-06-17		
12		Proposal of Concept	5 days	Mon 19-06-1	Fri 23-06-17		
13		Design Prototype	25 days	Mon 26-06-1	Fri 28-07-17		
14		**Implementation Phase**	**105 days**	**Mon 31-07-1**	**Fri 22-12-17**		
15		Develop Prototype	45 days	Mon 31-07-1	Fri 29-09-17		
16		Test Prototype at CTCV/ESTGOH	22 days	Mon 02-10-17	Tue 31-10-17		
17		Conduct Company Test	22 days	Wed 01-11-1	Thu 30-11-17		
18		Study Test Results	6 days	Fri 01-12-17	Fri 08-12-17		
19		Apply Changes based on test results	10 days	Mon 11-12-17	Fri 22-12-17		
20		**Demostration Phase**	**28 days?**	**Mon 25-12-1**	**Wed 31-01-1**		
21		Demostrate to Supervisors	1 day	Mon 25-12-1	Mon 25-12-1		
22		Demostrate to Companies	4 days	Tue 26-12-17	Fri 29-12-17		
23		Research Paper Development	15 days	Mon 01-01-18	Fri 19-01-18		
24		Thesis Final Review	5 days	Mon 22-01-1	Fri 26-01-18		
25		Final Demostration	2 days	Tue 30-01-18	Wed 31-01-1		

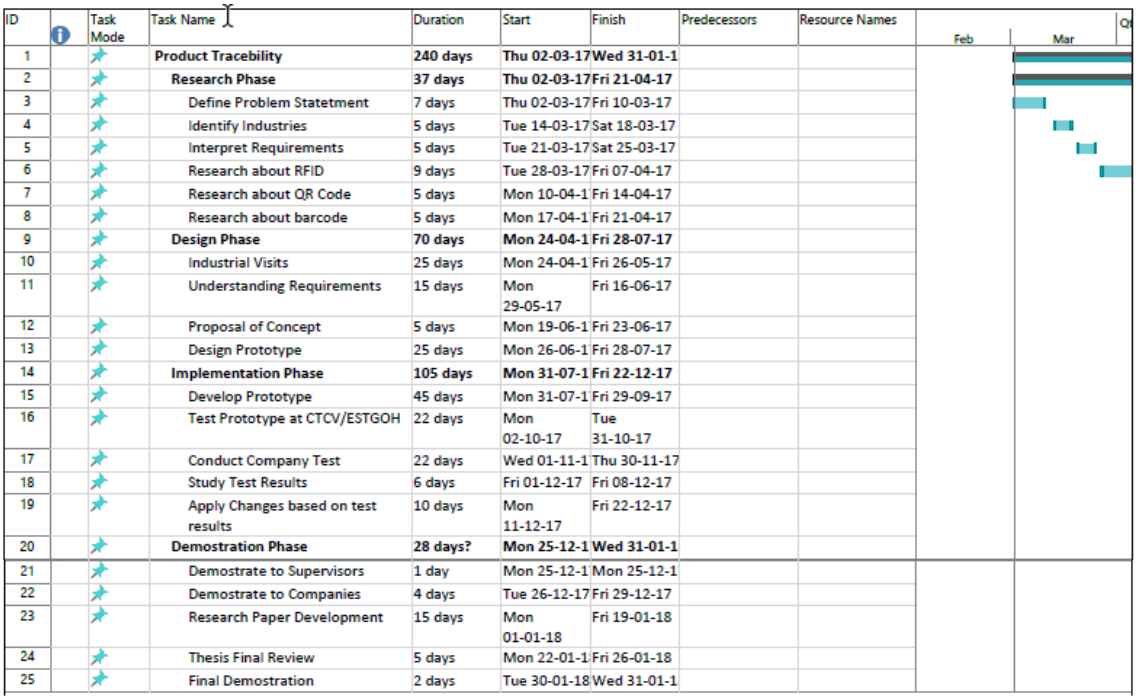

Figure 2-1- Initial plan of our project

2.2 Final Plan

The work presented in this thesis was tried according to the initial plan mentioned in Figure 2-1**.** Initially, a literature review was performed during the thesis research period which took a while. And as a result, at a later stage the research paper was accepted and was published in an international conference successfully[6].

3 State of the Art

This chapter refers to the explanation of the cutting-edge developments, techniques performed and achieved in scientific fields at a time in technologies used in the manufacturing industries for product traceability.

We have listed and have reviewed some techniques and technologies implemented earlier. And they are:

- Traceability and sustainability
- RFID (Radio Frequency Identification)
- Barcode
- QR Code
- Blockchain

3.1 Traceability and sustainability

The modern organization that we see around since centuries has been constantly improving management practices by continuous implementation of technology. That has left us with an incredible amount of literature material to review. According to [7] , the International Organization of Standardization[3] (ISO), ISO 9000-2005 and now revised ISO 9000-2015 standard, traceability is defined as "*the ability to trace the history, application or location of that which is under consideration*" and according to the *Council of Supply Chain Management Professionals*[4], traceability is defined as, "*The ability to track the location of a shipment as it moves through the shipping process to the customer.*"

Nowadays companies across the globe are driven by the desire for innovation and improvements as they face increasing challenges to meet customer satisfaction. To manage the level of quality required and other consumer demands is challenging. The product traceability has always been a concern for the industries. For example, Aerospace manufacturers have strong traceability systems to be able to trace down the product during any disaster or quality control [8], as it is a sensitive industry. Similarly, in the case of meat and agricultural industries, they are also cautious about their products. Innovation and incubation of technology in industries are commonly seen in the 21st century. Without them it is difficult for the businesses to stabilize, grow and develop the Industry 4.0.

New industries emerged adopting Industry 4.0 after the innovation and digitalization which created new value for existing and emerging industries [9]. There are many industries which use different technologies in various areas to serve many purposes. Here we are talking about the innovative technologies which could improve supply chain management, product lifecycle, traceability, etc.

[3] ISO standards adapted from: **iso.org**

[4] Council of Supply Chain Management Professional: **CSCMP**

An outstanding problem for businesses is, obviously, the production network. This is the purpose of activities that contribute to efficiency, quality as well as the nature of the item a client purchase. Inventory network administration is a key part of efficiency and this has required a change in perspective in the way it is finished. A standout amongst the most noteworthy changes is the appropriation of present-day innovation to upgrade efficiency and responsibility in the whole production network. A high level of logistics assertion and interaction between supply chain partners have produced various benefits to both ends of the partners [10][11][12].

Mechanized chain administration has disrupted current business by taking into consideration better tracking and tracing. Innovation considers continuous observing of the whole chain including shipping and invoicing. The dynamism in innovation items including cell phones, GPS gadgets, and tablets among others as additionally observed a relentless ascent in convenient inventory network innovation which is significant in checking the production network utilizing remote innovation.

The key advantage that arises from this progressive innovation is, obviously, the adaptability it offers for directors in following and observing the whole chain. Supply directors would now be able to make changes on the fly which prevent some interruptions in the network. This pays back in consumer loyalty.

Worldwide brands, for example, The John Deere Organization are utilizing calculated administration programming to enhance efficiency in the store network [9]. Others like Nike, in a joint effort with DHL Store network, are utilizing this innovation to empower continuous checking of the warehousing and dissemination process [13]. In simple terms, coordinating innovation in production network administration guarantees:

- Reduction in operational expenses
- Enhanced productivity through decrease of mistakes
- More noteworthy consumer loyalty on the opposite end.

According to [14] traceability has risen as a plausible arrangement which cannot exclusively be utilized to demonstrate the ecological supportability part of the item. To understand the industry supply chain need we must investigate the present technologies adopted by the existing industries. RFID technology is implemented in stock and inventory management in shops and industries. In the light of industry 4.0 existence, the major company giants like Wal-Mart had introduced the use of RFID technology as a pilot test case in the year 2003 [15] to increase the efficiency and their customer experience. With this implementation, their revenue improved considerably [15].

Traceability is considered significant in many ways for product chain maximization. It increases control over the stock management and it does help support the environmental impact for better production with less waste. By the same token, we are referring to wood industry. In wood industry cutting, punching, segregating the left out and dust by-product might end up being wasted. This can be optimised to project a positive impact on nature [6].

Similarly, another major company giant Hitachi have implemented a traceability system for intra-company tracking of steel products by embedding a micro-chip on it. And they believe that product tracking information must be secure [16].

3.2 RFID

RFID, a wireless tracking technology was deployed during World War II by the British to recognize different aircrafts during the world war phases [17][18]. It is a kind of technology used to track objects without an actual touch. This works wirelessly using radio frequency. It contains two parts, one reader which emits radio waves and a tag, which gets energized using the electromagnetic field.

There are two types of tags used in practice which are active and passive tags. Active tags are battery powered and passive tags use the electromagnetic wave to energize the tag. This technology helped industries in circumstances where production lines need tracking of products. We have explained more about RFID technology in chapter 4.1.

The RFID tags are categorized into three frequency bands [17]. Refer chapter 4.1 to view the details on frequency bands.

Low frequency [LF, 30 -500KHz]
High frequency [HF, 10 – 15MHz]
Ultra-high frequency [UHF, 850 – 950MHz, 2.4 – 2.5GHz, 5.8GHz]

Table 3-1 RFID tag frequency bands

The most difficult problems for any production network administrator are the expansion in irregularities when a package is in travel. This prompts misfortunes as well as negatively affects a brand. In case an item is lost amid travel, the provider bears every one of the expenses. Using Radio Recurrence Distinguishing proof (RFID) innovation, an organization can successfully screen each item both at the creation line and in the supply chain line. RFID chips are set on all things letting workers to rapidly identify any irregularities in a request. It is an inventive method for remedying an issue before it ruins the whole store network.

Besides the increased problems in supply chain network, the idea of implementation of RFID has become a major issue for the businesses and industries to solve the challenges. Many businesses started using RFID as there are a lot of advantages in it which includes its components' size, price and memory capacity. According to [19] RFID tags processing and memory capacity is exceptionally limited. Therefore, the tags are divided into three types. One is active which contains its own power source and transmitter, other is passive, which grabs the power from electromagnetic waves emitted by the reader and the third one is semi-active which contains its own power source beside that it also grabs the power from reader [20]. The passive and semi-active tag use the past location of the tag and if retrieved successfully it is potentially a security issue [19].

RFID is used in many areas ranging from electronics like mobiles, laptop, computers, passports, building access systems, ID cards, keys, toys [6] and the list goes on. It is deployed in various businesses ranging from supply chain, manufacturing, retail, animal tracking, and transport [20].

In addition to areas where RFID may be implemented mentioned previously, [21] describe the application of RFID system for reducing the collision in metal and non-metal mines. Furthermore, they reported that the test conducted on a custom RFID system along with tags mounted on worker's helmet helped to safeguard them. A worker's tag detected

while in the readers proximity activates the alarm; warning the vehicle operator. An RFID system solves the problem of contact-less, non-line of sight tag detection. It could help avoid accidents on manufacturing floors where workers are exposed to the heavy machines.

Likewise, [22] mention that an RFID system can help in wood traceability to fight illegal logging. Making sure that the wood is derived from a sustainable source to avoid social conflicts and retaining natural value. Also, this system would significantly change the product tracking and improve their logistical operations.

3.3 Barcode

Barcode is a machine-readable code in the form of numbers and patterns on a visual surface that when scanned by a specific type of sensors will represent data. If you purchase a product from a store you will find a barcode with a pattern of black lines spaced with a number below it. This is scanned by the cashier, and the product information will appear on the cashier's computer screen. A visual representation of a traditional barcode is shown in figure 2. More explanation is in Chapter 4.2.

Figure 3-1-ISSN sample EAN barcode for magazine

The focus on barcodes can be seen globally. According to [23] major companies like Wal-Mart, Cisco, Procter & Gamble, Lockheed Martin, and Hewlett-Packard started with EPC global code. In addition, user intervention with barcodes is very simple. To name a company giant Wal-Mart has deployed over 300,000 wireless barcode scanners [24].

According to [24], barcode has an accurate reading capability, i.e., one in a million error or 99.99% accuracy. Furthermore, it is also mentioned in the literature that barcodes do provide distinct advantage over alternative technologies like RFID; during boarding the luggage the barcode tagged to the luggage must contain enough information for the staff to provide routing details [25].

In addition to previous discussion on barcode technology accuracy, [25] say that at Schiphol airport they have 270 degree barcode scanners in practice which provide approximately 75% accuracy while that of RFID provides 99.9% accuracy. To avoid redundancy, they have implemented parallel scanners of the tags. According to IATA barcode read rates notably average 85% accuracy as the scanning pattern must be in line of sight. Baggage handling system is a more complex process. The efficiency of the whole baggage system depends on the 10-digit license plate number being scanned. That is, if

the code is not readable then the problem in tracking persists. Schiphol airport used the same legacy tracking system of barcode as it was low cost for automatic identification. But the Barcode scanning had some limitations, i.e., It required direct line of sight for tag identification and successful reading rate was less, from about 95 to 75% at Schiphol alone. This raised the concern for efficient tag reading system. To solve this problem RFID emerged as a best possible solution.

In addition to automatic identification, [26] mention that this system is ideal for areas like warehouses, logistics area, parking lots, passenger terminals as the visual representation based on data is extractable by the humans. This illustrates the digitalisation of logistics and smart zones.

Table 3-2-Key comparison between Barcode and RFID technologies

	Barcode	RFID
1	Has visual representation of binary data and can be read by latest technology like smartphones and barcode scanners.	Stores the data electronically on tags and uses radio waves to transmit data while scanned by RFID scanners.
2	Cannot process RFID tags.	Cannot process barcode tags.
3	Requires direct line-of-sight to scan and read the data on tag.	Scans the tag wirelessly, no manual touch or line-of-sight is required.

3.4 QR Code

In present world, smart phones play a vital role in people's life. Many businesses around are using QR Code (Quick response code). It is portable and can display the contents of QR Code when scanned by a smart phone. A type of 2D barcode to provide access to required information using a smartphone. Smartphones extract the information from patterns present in both the horizontal and vertical components of the image.

Figure 3-2-Example of QR Code[5]

To scan the code, smart phone owners must download a QR code scanner application. Once the application is available, the user must point the phone camera to a QR code to

5 According to English Wikipedia: **wikipedia.org**

scan. And the QR code scanner application in the smartphone works in conjunction with the hardware of the phone which is a digital camera. The reader interprets the code and displays the information related to the code, for example to download an invitation, link to a video, polling, or redirect to a certain website.

A revolutionary QR code was invented in the year 1994 by Denso, one of the leading global automotive suppliers. And was it was approved as an ISO (International standard ISO/IEC 18004) in June 2000. Its implementation was initially started with 2D symbols to control automotive parts and was successful. Now, we can see QR code use in many different applications [27].

Advantages

- 2D Barcodes were proposed to overcome the problems which existed with linear bar codes, i.e., one-dimensional barcode. 2D barcodes can store the data in two dimensions.
- It can hold a large amount of data and can handle all data types ranging from numeric, alphabetic characters, symbols, binary and control codes [28].
- The price to incorporate QR code is very low.
- QR code is readable on white paper whereas there is decreased level of readability on shiny paper such as Moflon and Natron paper. And it has good readability on harder paper surface type like kunsdruck [29]. The type of paper matters for clear visibility of a QR code. If the background of the code is white, then the QR code is much clear than on shiny paper type material.
- As we are concerned about forward and reverse tracking the product, each product will have a non-unique product code like EPC (Electronic Product Code) and unique id. QR code is generated with certain data pertaining to each specified entity or product, whereas. RFID is used to associate with tracking a group of products [29]. For example, if you buy a batch of class 1 generation 0 RFID tags from Asia and again class 1 generation 0 RFID tags from Europe, then the UID will never collide provided you must buy the batch from the same manufacturer.
- It provides fast and secure log on the website as well as facilitates fast and secure payments [30].

Examples of successful implementation of QR codes

According to [29] QR code was implemented in their library to locate their electronic resources of a physical library and make them readily available for readers, except for the exclusive information or premium access. Student used this system to print the journals which were of their interest.

Similarly, another area where we see the application of QR code is in aquaculture as they generate a large volume of data due to new food regulations. They use QR code for traceability after discarding RFID due to its cost factor. And, for promoting and marketing their company products online by scanning a QR code. Moreover, there are some more benefits found other than traceability, i.e., reducing staff work [31].

In the same light, QR codes are also used in way finding to reach a destination in case of an event at a location. The positions are posted along with QR code tags embedded with

a location information. For every successful scanned tag along the roadmap keeps the user on track and gives a valuable guidance and pleasant experience [32].

For the ceramic industry, we provide a traceability system using RFID. It will play a big role in tracking the products from production line to storage line. As we have noticed at the industrial plant the ceramic products during production line are soft in their physical properties. Thereby using them to print any tag and code is challenging. Therefore, we have made use of them post heating and drying. Once they are ready for packaging we can apparently use them for the RFID tagging. This is the step where RFID tags are numbered and assigned an ID to count during RFID reader scan. This is the most widely used type of method in RFID systems.

Using the technology, we could make use of the available resources to find a best solution for the traceability issue as concerned with the Ceramic Industry.

3.5 Blockchain

Emerging businesses, social, personal, professional and industrial sector, among others, are now implementing blockchain technology.

Examples are:

- Pharmaceuticals for drug integrity from manufacturing to consumption.
- Cross-border payment.
- Agricultural.
- Food safety

Here, data is the prime concern which is valuable to analyse, study and predict the future trends which help businesses to forecast the emerging problem cases. The data can be modified, and someone will be responsible for it, if it is done so. In this case the end party will face major problems if the data is modified in between and it doesn’t match, which is a huge concern for stakeholders and business owners. This is where the blockchain comes into place to solve this discrepancy. With the enhancements in technology and its implementation into industry 4.0 the present system can be made more reliable and is free from any counterfeit problem. For example, 4PL (Fourth Party Logistics) service providers often check the entire supply chain process.

The concept of blockchain is often associated with bitcoin. Nonetheless, blockchain is a technology and bitcoin are an application of this blockchain technology. There are many applications built on this technology. Bitcoin is one of the popular applications where a digital currency is traded. Blockchain has its own limitations in its implementations. Not all transactions can be converted into a blockchain solution. However, it can still be a disruptive technology in the coming years. In simple terms this technology can replace the traditional relational database and will create a new paradigm for transactional data where every transaction will contain the hash of the previous block. And the chain cannot be broken.

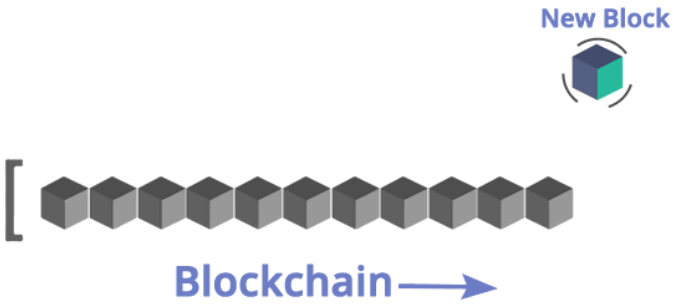

Figure 3-3-Visual representation of blockchain idea[6]

Definition:

A technical definition of Blockchain is a persistent, transparent, append only ledger. It is a system where we can add data to and not change previous data within it. It does this through a mechanism of consensus between scattered or distributed parties that do not need to trust each other, they just have to trust the mechanism.

What is Blockchain?

What is blockchain and how does it benefit the industries is important to know. Presently its definition is not clear as it is a distributed technology. Blockchain technology helps users, vendors and companies to perform a secure transaction for payments. It is a trusted distributed ledger. It is the way for businesses to share data when they don't necessarily trust each other. We can use shared databases, but it doesn't take care of the trust aspect. That is the trust in people we are making transaction with, for any businesses that have many participants working together. And everyone shares some data to share and maintain. If there is a problem in any of the ledger or data, they must go to the root cause and rectify the problem. This is one such scenario where there will be a problem.

Figure 3-4, shows the example of a dummy organisation drawn where the data is shared on as distributed ledger. Where every participant has their own copy of data being shared on distributed ledger. Any person who tries to manipulate the data will have to modify the complete chain.

Therefore, using blockchain, everyone has a copy of the ledger and this way the data is protected, because it can be verified and reconstructed at any time.

[6] Visual representation of blockchain: **Edureka**

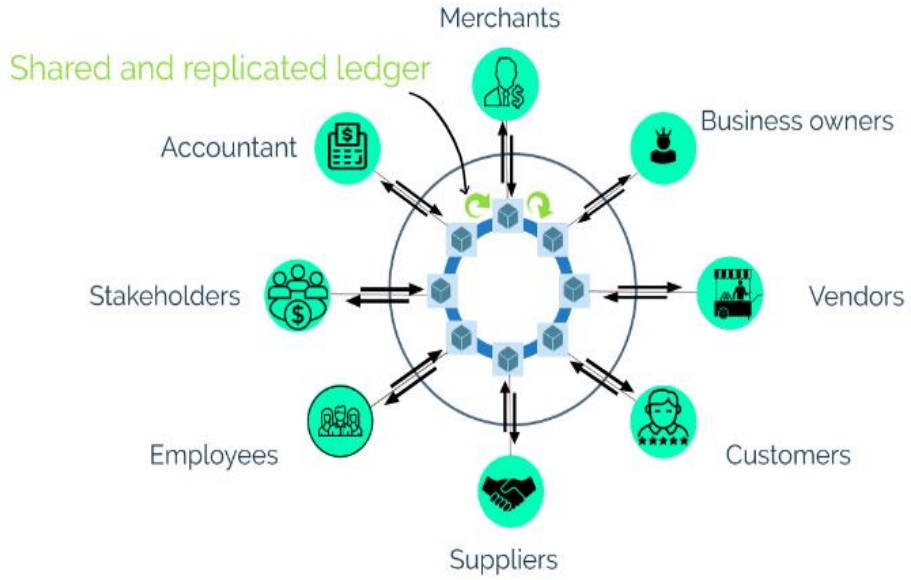

Figure 3-4-Blockchain in a business infrastructure

Blockchain distributed ledger principle

The way it works is, the block of data is replicated itself and available on open web. While performing a transaction the hash of the previous block is checked with the hash of the next block. It is a distributed technology. What comes to mind when we hear about blockchain is the cryptocurrency. In fact, blockchain is a chain of blocks where each block holds a digital signature of the previous block. That is the next signature is based on the current signature and current signature is based on the previous signature. If anything is changed in the past, then it will break the chain of signatures and the data chain is corrupted. Therefore, the change will be easily detected.

If the current business is replacing the existing technology with the latest one, then there must be some problems which are prevailing in them. And how does the blockchain resolve this problem? The idea behind blockchain is that it is immutable. That is once it is written it cannot be rewritten or changed. There are many business use cases out in the world. Many are interested in blockchain but the idea behind that is not clearly understood. When we think about blockchain it is a network of nodes. Every node participates equally. That is, we are not waiting for one node to confirm that the transaction has gone through successfully, but we are waiting on all. Every time a transaction happens it could take hours to get the data across the recipient.

Blockchain for developers is a sort of set of protocols and encryption technology for securely storing the data on a distributed network. For business and finances, it is a sort of securing the digital currencies.

The implementation of this technology in many areas can have profound implications. For the first time in the human history since the last decade people anywhere can trust each other to transact within a large peer to peer network without centralised servers. Trust is granted by the cryptography to secure the data across the network around the

world. The value provided by the blockchain is important as it provides safe transactions using the encrypted technology.

Summary

Nowadays blockchain technology is implemented in many areas ranging from banking (money transactions), products traceability in supply chain to avoid product information counterfeit, for various bitcoin value exchange, health and automobile sector to name just a few. Blockchain is a data structure at its core. Much is heard by everyone that blockchain is complicated, which is not the case, what makes it complicated is its algorithm, and the transactions.

In Table 3-3, all traceability technologies emerged from time are presented, along with their cost and efficiency.

Table 3-3-Comparison of forms of traceability technologies

	Technology	Year	Costing	Efficiency
1	Barcode	1952	Low cost	Presently, less efficient.
2	QR Code	2002	Low cost	Efficient in certain sectors.
3	RFID	2009	Potential for low price despite depending on deployment area.	Most efficient in all sectors.
4	Blockchain	2008	Open source	Risk of exposing the company's sensitive data to the public internet.

4 Tracking Technologies

Many technologies are present around which are fit for tracking products. Several technologies merged to create a complete tracking system. For example, current technologies used around are GIS (Geographic information system), GPS (Global positioning system), RFID (Radio Frequency Identification), WLAN (Wireless Local Area Network), Barcode, and QR (Quick response) code.

4.1 RFID

4.1.1 History of RFID

Doing something without having to touch anything is possible with the technology called Radio Frequency Identification (RFID). It has been there for decades now. Ernst F.W. Alexanderson demonstrated the first continuous wave (CW) radio generation and transmission of radio signals in the year 1906 [18]. This achievement marks the beginning of modern radio communication, where all aspects of radio waves are controlled. The early 20th century was considered the birth of radar." A radar is detection system, which uses radio waves. In addition to radio generation and transmission of radio signal technology, first radio frequency technology used was long range transponder system IFF (Identification Friend or Foe) which was used by the British in the Second World War [17] systems for aircraft. The first RFID was created in 1946 by the well-known Russian Physicist Leon Theremin [33] which was developed and used initially in the US military to identify and differentiate military aircraft to determine which were friendly and which were not. And since then it has been used in military and commercial airplanes. According to [34] a scientific research and explanation was conducted during the years of 1950's. Later in the 1960's a first prototype was developed and commercial systems like sensormatic and checkpoint were launched with the electronic article surveillance (EAS) equipment used as an anti-theft device [34]. The year 1970 marked the time for real time application in animal tagging [34]. In 1980 several US states decided to use RFID for toll gates, ski passes and gasoline [17]. In 1999 was the time when Auto-ID Centre at MIT was founded where its task was to develop a global standard for item-level tagging [17].

4.1.2 How RFID Works

It is a technology, which was discovered, advanced and used in practice for many years helping industries to solve their store and industrial supply chain management concerns. It works on the Faraday's law principle of magnetic induction, which is the basis of near field coupling between the tag and reader used for its complete operation [35]. RFID reader connected to a transponder generates an electromagnetic field, which generates current in the antenna coil in turn powering the chip on the tag. The powered tag sends data to the reader.

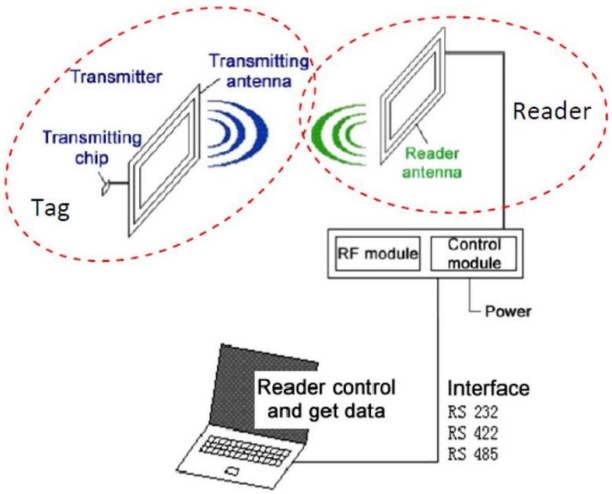

Figure 4-1-Working principle of RFID[7]

RFID technology uses electromagnetic field to automatically identify and track tags attached to objects. The RFID reader emits radio signal or data along with power source, this will create an electromagnetic force at a certain proximity. When the tag's antenna is the range of readers electromagnetic field, the coil in the tag induces current which power the chip in it. This tag is embedded with a tiny chip that contains electronically stored information.

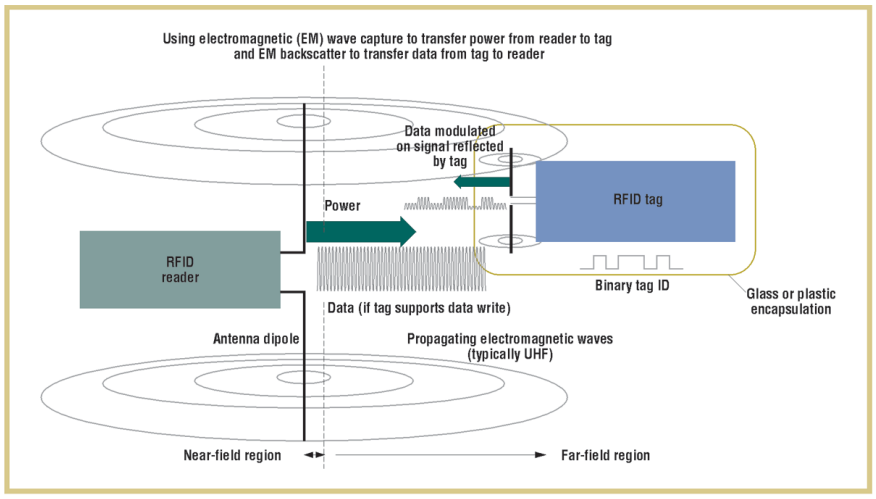

Figure 4-2-Communication mechanism for RFID tag operation greater than 100Mhz[8]

[7] Working principle of RFID: (**adapted from** [50])

[8]Communication mechanism for RFID tag operation for range greater than 100Mhz, Source: **ResearchGate**

The RFID tags are broadly classified into active and passive.

Passive RFID Tags:

Contains three components, an integrated chip, substrate (form of polyester resin or a plastic film) and an antenna. Passive tags are usually smaller in size. And have a read range of 6.096 meters. Chip stores data and depending on the design the chips are listed as follows:

- RO (Read Only) and write once.
- Write once and read many (WORM) or read-write (RW).

Active RFID Tags:

It contains two components, a micro-chip and an antenna and are large in dimension. These Have more capability than passive tags. They contain a power source which enhances its strength of transmitting data to the reader at a range greater than 30.48 meters and/or more. For example, UHF tags can transfer data faster than any other tags as the frequency range is high. We will explain frequency range in the next sub-section.

Table 4-1-Comparison between active and passive tags

	Active Tag	Passive Tag
Power source	Contains inside the tag	Energy transferred from reader by radio frequency.
Battery	Yes	No
Power source availability	Continuous	Within the field range
Required signal strength from reader to tag	Considerably low	Potentially High
Available signal strength from tag to reader	High	Low
Cost	Costs varies from 50 to 250 dollars	Costs around 10 cents to few dollars
Storage	Provide high storage of 512Kb	Limits from a couple of bits to 1Kb
Scan range	Provides long read range of around 91.44 meters.	Provide short read range of 1.2 to 4.57 meters.

4.1.3 RFID Types and Frequencies

RFID tags are classified into different frequency bands and are displayed in Table 4-2 where different frequency bands and operating frequencies are explained [36]. Each

country has its own frequency specification and operates under a different band according to the IEEE (2005). There occurs four radio wave bands and frequency waves used for RFID systems. See Appendix-C for RF-Spectrum details.

Table 4-2-RFID operating under different frequency band[9]

Frequency	Range	Application
LF (low frequency) **125 – 134.2 Khz and** **140 – 148.5 Khz**	up to 3 inches or up to ½ meters	Can be used globally without license. Often used in automobile door locks, pet or animal identification.
HF (high frequency) **13.553 – 13.567 MHz**	up to 3 feet or 1 meter	Typically used in product identification in stores like book store, garment tracking, contactless payment.
Ultra-high frequency **433 MHz**		Implemented in defense areas using active tags and remote car keys.
Ultra-high frequency **858 - 930 MHz**	up to 36 feet or 1 to 10 meters	Used in logistics, supply-chain tracking of cartons, packages.
Microwave **2.446 - 5.8 GHz**	up to 6 feet or up to 3 meter and more	Highway toll for vehicle identification
Microwave **3.1 - 10 GHz**		Backscatter coupling. Not widely used for RFID.

4.1.4 Security and privacy concerns

Many industries, small and large-scale businesses use RFID on their products and according to [37], over billions of tags are used and are scanned around the world. Every tag is scanned once for its life time.

The data on the RFID tags can be changed by unauthorised devices without the knowledge of the person. According to [38] here are two main privacy concerns for the users, clandestine tracking and inventorying. In accordance to [38] “RFID tags respond to readers interrogation without altering their owners or bearers. Thus, where read range permits, clandestine scanning of tags is a plausible threat.”

In general RFID tags emit a unique identifier, even those with cryptographic algorithm based protected data. An RFID tag whilst broadcasting the fixed signal can be read by the nearby readers to manipulate it [38]. In addition to privacy of data RFID is effectively implemented in many areas to protect the data being manipulated.

Passive tags are mostly compromised due to its low-cost mechanism [37]. For the privacy of the data, in accordance to avoid the threat explained previously, RFID was introduced

[9] RFID operating under different frequency band; source: **Radio-Electronics**

in Euro Bank notes, libraries, passports, human implantations [38]. As we have many advantages of RFID for its non-line of sight and contactless communication there also prevails a security threat to a card holder at the payment section. If the scanner can read your card's information to take payments, then even a criminal can. As the RFID card code can be intercepted once, that one fraudulent transaction is also a threat [37].

According to [39] RFID are generally leveraged as a replacement for traditional barcodes as it can be implanted onto objects. And object scanning does not require line of sight. Furthermore, by introducing RFID tags on objects in manufacturing industries may help counterfeit and improve refined stock management in warehouses [39].

4.1.5 Regulations and Standards

The radio waves are strictly governed and controlled by the agency known as International Telecommunication Union (ITU). They split the world into three regions. Table 4-3 displays the details of the countries in accordance to the region.

Table 4-3-International Telecommunication Union Regulation and Standards

Region	Countries
1	Europe, Middle East, Africa, the former Soviet Union, including Siberia; and Mongolia
2	North and South America and Pacific (East of the International)
3	Asia, Australia and the Pacific Rim (West of the International Date Line)

The regulations governing each frequency vary by Region and by Country. Each region and country have their own regulation and are governed by a certain body or authority. For example, in the USA, it is governed by the FCC. In Europe, CEPT (Electronic Communications Committee (ECC)). In Japan the Ministry of Internal Affairs and Communications (MIC).

4.1.6 RFID Applications

RFID tags are attachable to almost anything ranging from items like pallets and carton to high value goods. In the supply chain, logistics, clothing, electronics, super market products and in manufacturing, production, stock level management, retail, security, vehicles, assets and livestock, its possibilities are endless.

Passive Tags:

It contains three components, an incorporated circuit or chip, a receiving wire, and a substrate. The RFID chip stores information and performs assigned operations. And it does not contain a power source. It will wait for the signal to be transmitted from an RFID reader.

Figure 4-3-Passive RFID inlays[10]

RFID inlays are grouped into three types

- **Dry Inlays** – An RFID chip and an antenna attached to a substrate.
- **Wet Inlays**- An RFID chip and antenna attached to a substrate with an adhesive on its back. This helps stick the tag onto the package.
- **Paper Face Tags**- These are like wet inlays along with an ample space to print the logo for identification.

Regularly, RFID chips convey 96 bits of memory. However, they can extend up to 1000 bits.

Figure 4-4-Active RFID tag using power source

[10] Passive RFID Inlays adapted from: **Atlasrfidstore**

Advantages of RFID

As the traditional inventory management system turned out to be less efficient. RFID technology can be implemented for its major advantage, which is that it does not require line of sight for product identification as it uses radio waves to communicate [15]. On the same note, it can scan multiple items simultaneously. The advantages are:

1. **Scanning range:**
    a. RFID can scan the tags within the scanning range.
    b. No line-of-sight limitations.
2. **Capability:**
    a. It can scan multiple items simultaneously.
3. **Speed:**
    a. It can scan items in milliseconds and is automatic.
4. **Cost:**
    a. Reduced labor cost for its operation.

Limitations of RFID

- Although the RFID technology has positive aspects for its implementation, it still has some problems. RFID can scan through certain non-metallic products but still has problem with metal and water.
- Tag collision may occur if multiple tags are scanned at the same time picked up by the same reader.
- If two readers interfere with each other's signal.
- Initial setup cost is high.
- Security concerns: Any unauthorized devices maybe able to read and modify the data.

4.2 Bar Code

A barcode can best be depicted as an "Optical Morse Code", i.e., a symbol consisting of a series of dark bars and blank areas printed representing value. Which is like 0's and 1's. 0 means space and 1 represents a bar. It can be defined as an electronic machine-readable code which holds some information in it. The barcode is represented by the pattern of lines which is the result of converting an information like text, image or URL called encoding [40]. Barcode is read by a bar code scanner which consists of a camera or laser sensor. When scanned and decoded, it represents the data. There are many ways of arranging the series of lines to represent any data. The line of the barcode may be in 1D (1 dimension) or 2D (2 dimensions). At first, barcodes were just scanned by uncommon optical scanners called barcode readers. Later applications were developed which are accessible for gadgets that could read pictures, for example, cell phones with cameras.

The first barcode scanner arrangement had a patent recorded by Bernard Silver and Joseph Forest, on 20 October 1949. The arrangement was because of an accidental demand by a leader of a chain of nourishment stores, who needed to record points of interest of items, at the point of sale.

Figure 4-5-Simple barcode with a series of lines[11]

4.2.1 Symbology

The standardized tag was organized by the Universal Product Code (UPC), an improvement of IBM [41]. There are 13 major barcodes; to name are UPC, EAN, Code 39, Code 128, ITF (2, 5), Code 93, CodaBar, GS1 DataBar, MSI Plessey, QR, Datamatrix, PDF417, and Aztek barcodes. There are a variety of choices to select from for barcode implementation for any sector. And the most popular variety of barcode types in use is the UPC code.

Below are some examples of barcode types:

- UPC code, widely used in retail industries and has variants like UPC-A, UPC-E.

Figure 4-6-UPC code example[12]

- EAN code, utilized as a part of retails like the UPC code, with the variations, EAN-13, EAN-8, JAN-13, ISBN, ISSN.

[11] Simple barcode with a series of lines image adapted from [51].

[12] UPC code example adapted from [52].

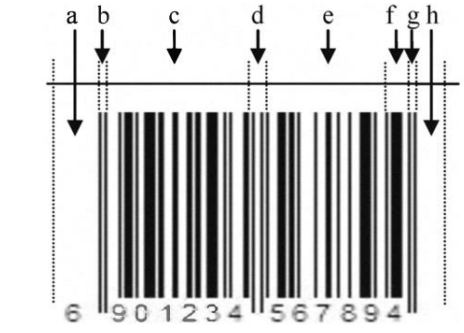

Figure 4-7-EAN-13 Barcode[13]

- CODE 39 is used to name merchandise crosswise over numerous enterprises and is regularly found in the car business and the US branch of defence.

Figure 4-8-CODE 39 barcode[14]

4.2.2 Benefits

There are numerous benefits of using barcodes. Some of them are listed below.

- The main benefits of using barcodes in any application is that it is easily printable, scalable, and readable.
- Implementation of these 2D barcodes helps in tracking, managing shipping delivery of orders to suppliers from industry warehouse, prevent counterfeit of expensive and luxurious products during peer to peer transportation according to [40] [42].

[13] EAN-13 Barcode image adapted from [52].

[14] CODE-39 Barcode adapted from [52].

- It allows a good degree of readability of damaged symbols as it supports error detection and error correction [42].
- It has the highest degree of accuracy and contributes to the safety of data according to [43].

4.3 QR-Code

4.3.1 History

Widely used term QR Code, abbreviated as Quick Response Code. From hereafter Quick Response Code will be referred as QR code. It was created in Japan in 1994 in car industry by Japanese organization Denso Wave which is one significant car organization and was affirmed as an ISO universal standard (ISO/IEC18004) in June 2000 [9]. A kind of lattice standardized tag can be said as a two-dimensional. Its patent expresses that anybody can utilize this for nothing out in the open space [9]. It is utilized in numerous areas from cell phones to business following applications [27] It is used in many areas from mobile devices to commercial tracking applications. Because of its popularity for its operating speed at which they can scan, its accuracy, and their various functionalities. It was recognized everywhere as anyone had access to it in a software or on a website. The QR code generated can be decoded using a scanner, and a scanner can be a device for decoding QR code.

4.3.2 Standards

To learn more about the QR code, we must understand what its features and standards are.

The QR code provides the following features:

- High capacity encoding of data as compared to traditional barcodes which could hold only few digits. It is capable of handling much more information than a barcode.

Figure 4-9-Random gibberish text encoded into a QR code[15]

- Dirt and damage resistant, i.e., it can manage error capabilities. It is completely alright to restore the information if part of the code is damaged or smeared.

[15] QR code generator web link adapted from [53].

Figure 4-10-Damaged QR code[16]

- Can be performed a structured appending, which is a fascinating feature of QR code. Where multiple QR codes can be stored into a single new QR code. As shown in the figure.

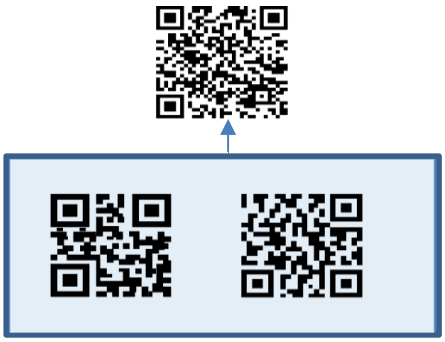

Figure 4-11-Structured different QR code into a new code[17]

4.3.3 Variants

There are various types of QR codes, out of which some are listed below.

- Larger QR code and upgraded version of larger code.
- Micro QR code- A noteworthy element of smaller scale QR Code is it has just a single position recognition design. In contrast a consistent QR Code require a specific region to scan as the position identification designs are situated at the three corners of an image.

[16] Damaged QR code adapted from [53].

[17] Structured QR code adapted from [53].

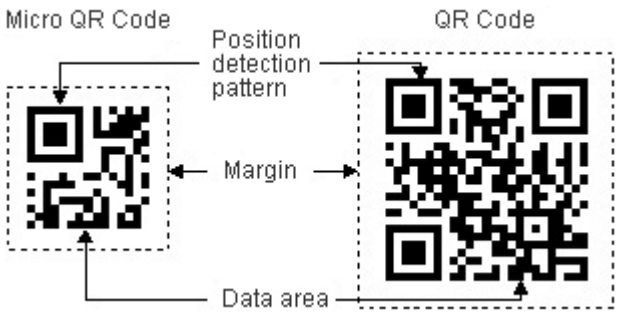

Figure 4-12- Micro QR-code[18]

- iQR code- It is a rectangular unpredictable QR code that can be produced into a square or rectangular frame.

Figure 4-13-iQR code[19]

There are many more types of QR codes, but we have given an outline of present QR codes used in the world.

4.3.4 Limitations

There are a few limitations we find with PDA gadgets as these gadgets are delicate and not weather proof. Hence as per [32] protective measures to be taken to keep them in great condition. For example, if the camera is damaged in PDA gadgets, it would be difficult to scan the code efficiently.

QR code additionally can allow error correction. The level of error correction plays an important role in how much information it can store. There are normally 4 level of error correction Low, Medium, Quality and High and are represented as L, M, Q and H respectively. The highest level of error correction can restore 30% of the corrupt code.

A QR code is made up of many small squares. The number of available squares always determines the maximum number of rows and columns a code contains. It is advisable to keep mind the size of the code to be large as the person with scanner need to be very close to scan the code.

[18] Micro QR code adapted from [53]

[19] iQR code adapted from [54]

Table 4-4-QR Code data capacity[20]

QR Code data capacity	
Numeric only	Max 7,089 characters
Alphanumeric	Max, 4,296 characters
Binary (8 bits)	Max 2,953 bytes

[20] QR Code data capacity adapted from [55].

5 Methodologies

5.1 Methodologies

This section defines our research methods and previous and present generations have a lot of differences in the way they operate. The way they maintain ledger, production lifecycle, and supply chain management (SCM) have changed.

A possible study to define areas of development and improvement in ceramic industry is by introducing modern approaches. In context to this there are a series of tools required, for example, data collection and analysis [44], by social intervention, i.e., involving in quality discussion with responsible teams or their members instead of following the theoretical patterns [44]. Rather than just to follow the theoretical approach it is advisable to follow the human discussion to analyse a situation and provide solutions.

The goal of this research is to analyze and examine the need for modern technological approaches in ceramic manufacturing industry.

The research performed will not explicitly provide an insight into the work under any circumstances. But to put in action, a series of discussions with individuals in the case company will provide the knowledge as a part of case study [42].

Initially, in chapter 3 we performed a literature review where different authors mentioned and explained how the industries were operating since decades with limited technological resources. But to narrow down the source of information we required a real scenario to account for live situations which would help us analyze the situation. In that ground we made a visit to the case company under the supervision of our supervisor.

During the visit it made all sense, that a real-world industrial floor exposure marks significance in the study. We had a quality meeting with the ceramic industry staff regarding the production process line of product from start to end. Performed a series of questionnaires beginning at the stage one of production line. Which lists the details about the numbers of employees responsible to perform certain operations. Some expertise in designing the traditional hand-made molds and some operating the heavy machinery. Every process involves certain quality, responsible human and machine participation. This approach is significant in industry 4.0 as it would help connect human and machine.

We tried to understand these smart industries where new technologies are implemented by investigating the present industries which have introduced them. This would provide us the market knowledge of technologies which can be designed, developed and deploy them in the future. This approach is very helpful for analyzing the present industrial 4.0 stage.

We analyzed the stages where product traceability methods can be employed in different phases under different conditions.

We went through research papers where RFID technology is implemented in healthcare, healthcare asset management, supply chain, library, logistics, manufacturing, constructions and many more. Although, every industry has implemented the smart RFID system. Study of these industrial technologies will help us find the missing pieces, if any.

performing the industrial visit will be helpful for us to analyze the present situation before stepping into the development phase.

Our research involved going through papers published by various authors and publications and journals where regular updates on technologies are displayed. We performed a detailed study on papers related to RFID, QR-Code, where one can find many citations of most papers and the Google scholar do provide many searches related to "product traceability" + "RFID", we get more than 5,710 results.

We craved information to see and grasp the knowledge by many projects developed using RFID, QR-Code, Barcode in many applications in real life scenarios Examples can be found on IEEE, Instructables.com, Arduino.org etc. These projects developed once marked the idea behind the mainstream projects deployed into the industries. It is significant that one must understand the small projects as to how they work and how a new piece of information can be added to the existing project. This way the project starts to take shape into a large-scale enterprise, ready to deploy.

There are many projects and their significance can be found in various areas. Our goal is to study and custom design the technology it if is required without reinventing the wheel.

5.1.1 Selection of tools

5.1.1.1 Graphical Modeling Application

With the industrial revolution and customer satisfaction as the main priority all industries must adopt emerging technologies to scale up their business. It implies keeping track of every move of a product journey. In case of any failure, fixing it has always been a concern. So, we tried to understand who plays an important role to achieve their respective goals. And how these goals are interlinked to different actors and how the same tasks are associated to different actors is all analysed using **jUCMNav** tool [45] an Eclipse-based goal editor for URN models which enables the graphical modelling of requirements with goals and scenarios. To get a closer look we visited a ceramic industry to perform a visual inspection. After visiting the industry, we had a visit to the academic institution to get access to Electronics laboratory to work on RFID access card module kit.

We developed a graphical business model of the case company by closely analysing the case company using the **jUCMNav** and **Bizagi modeler** for customers and end users. The same model was also published in the research paper which was later published.

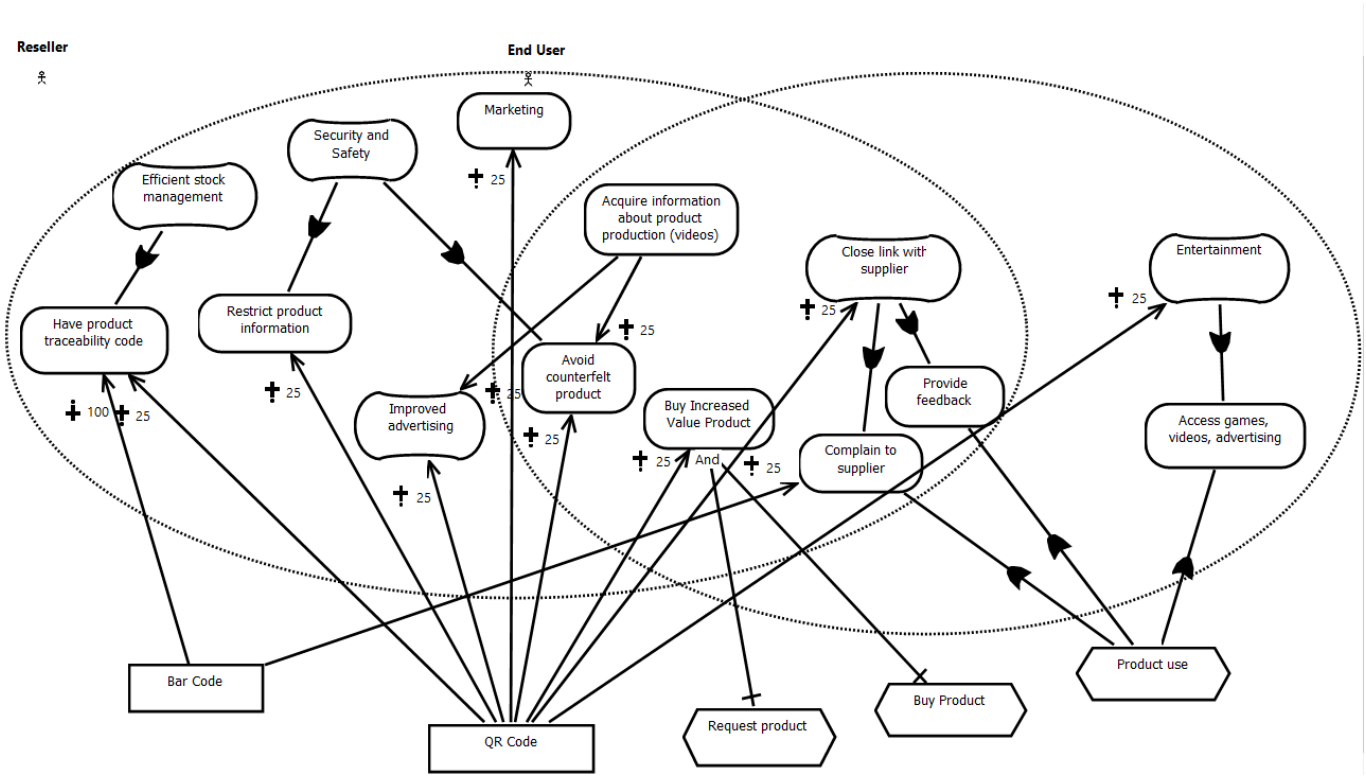

Figure 5-1-Goal model for traceability identification[21]

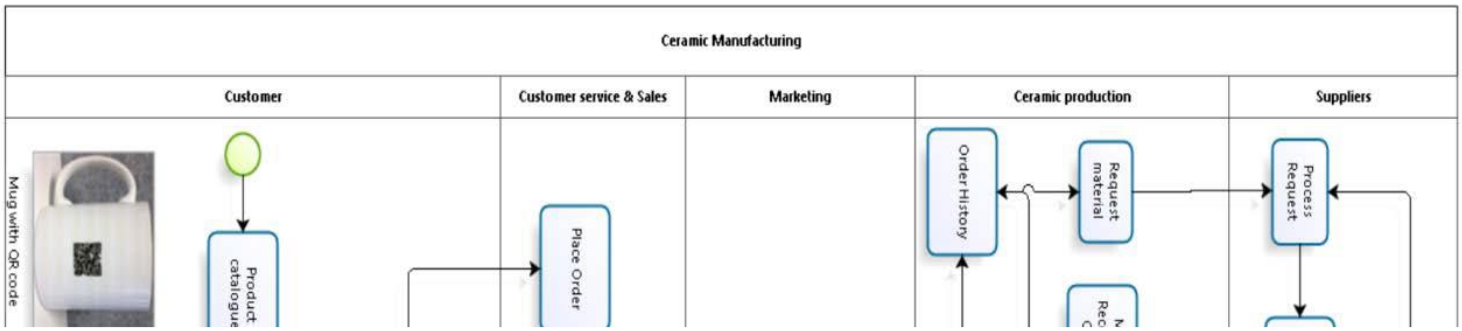

Figure 5-2-Business process model for traceability identification[22]

[21] Goal model for traceability adapted from "*A Systematic Approach to Design Product Traceability in Industry 4.0: Insights from the Ceramic Industry*" [6]

[22] Business process model of the case company: "*A Systematic Approach to Design Product Traceability in Industry 4.0: Insights from the Ceramic Industry*" [6]

5.1.1.2 Arduino UNO module

Arduino UNO is an open-source microcontroller used widely. And is based on ATmega328P microcontroller developed by Arduino.cc. It is used in many projects for its simplicity for beginners and flexible for advances users.

Arduino Uno is the most common version of Arduino family. It has an 8-bit Atmel microcontroller to program connected circuits. This has an exposed connector to make use of while working with modules to interconnect. Arduinos utilize a quantity of chips, particularly the ATmega8, ATmega168, ATmega328 and ATmega1280. There are many other sources where we can find cloned versions of boards.

To perform the tasks described in the project plan there are certain tools we must use. For product traceability we must require a wireless technology. As mentioned in tracking technology under ***section 31*** the RFID does not require line of sight to read the tag. It just needs to be present in the proximity of the reader. We will be working with RFID devices. This provides a reliable method of tracking products.

Technology is disruptive and keeps changing. We have enough resources like software or hardware available which can be used to find a better solution for gaps in industry. For instance, RFID scanner + reader module is connected to a desktop computer to store the scanned tags. But what if the computer system is away from the location of the RFID module. We do not want wires running all around the floor. Hence, we thought it would be quite impressive if we could design a prototype module implementing the open source development kits like Arduino or Raspberry Pi boards. Arduino board has endless capabilities and according to [46] it "brings the advantages of a PC to the domain of sensor network, what makes it the perfect platform for interfacing with a wide variety of external peripherals." Main motive is to provide a low cost, Internet of Things based, bare metal prototype which would have the capability.

We require a local web server which will provide "access to the Internet and become a complete and ideal system (hardware and software) for building Sensor Web nodes" [47].

But later we planned to develop the system implementing SQL server for data storage which will be explained further.

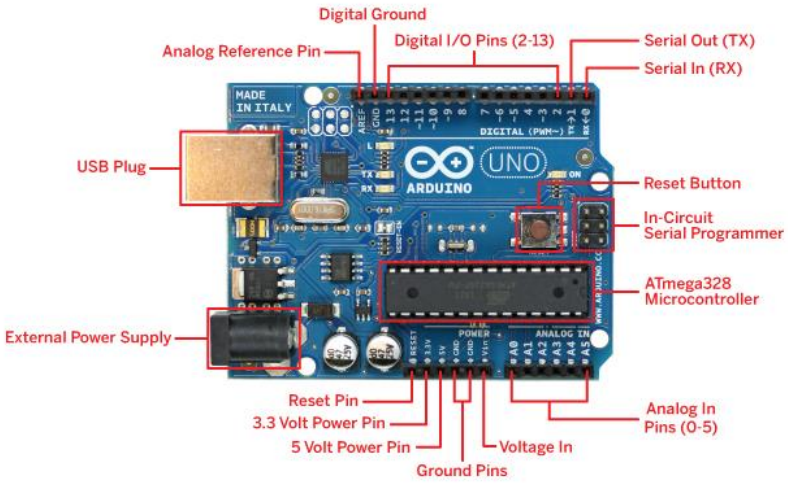

Fig 5-3: The Arduino Uno development board[23]

So, we chose the Arduino Uno platform for the project. This development board is used extensively for projects across many areas in academic projects and prototypes across various technical and semi-technical or combination of sectors ranging from electrical, mechanical, automobile and many more.

5.1.1.3 RFID Tag

The RFID tag reader we used is MIFARE MFRC522 RFID Reader/Writer. It is a highly integrated reader/writer IC for contactless communication at 13.56 MHz and reader supports ISO/IEC 14443 A/MIFARE mode.

Normally it is used in user access control methods at restricted entry places. This electromagnetic card or tag along with keychain is reasonably priced. Its price range is from $1.22 to $5 on e-commerce shopping platforms. Each tag has his own Unique identification number (UID).

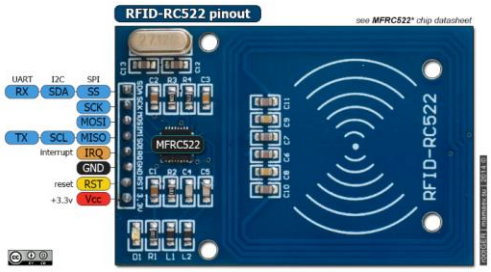

Fig 5-4: MiFare MFRC522 RFID Reader/Writer[24]

[23] The Arduino Uno development board: **Arduino Uno**

[24] MiFare MFRC522 RFID Reader/Writer: **Arduino-Uno-board-pins-description**

Fig 5-5: MiFare MFRC522 RFID Reader/Writer – key chain[25] and electromagnetic card

5.1.1.4 Integrated Development Kit

To make the above devices work together, we require a code editor which is a part of an Integrated Development Kit (IDE). We selected Microsoft Visual Studio 2015(community edition), an open source, light weight, fully featured, stretchable, IDE for developing any king of desired modern applications for mobile, desktop and web exclusively available on Microsoft community.

Features:

- Advanced debugging.
- Source control (Git repository upload- helps to manage code from anywhere) simplicity.
- Various programming languages flexibility.
- Self-explanatory installation.
- Large support community.

5.1.1.5 C# (Sharp) Programming language

With the intention of achieving our desired set of tasks, we must combine all the modules.

Apparently, C# is a high-level programming language, and we have picked it to code in Visual Studio IDE for its following features:

- It is a general-purpose programming language.
- Its simplicity – It was designed to be simple and easily readable.
- Scalable – It is static type language by which we mean that its syntax is checked before the application build is complete.
- Fast – As mentioned earlier that it is static type, it is faster, as things are defined clearly in it.

[25] Key chain image adapted from: **dxcdn**

Apparently, we can use any programming language to code and that is completely left to the programmer. Visual studio IDE is very flexible for any programmer to select the type of language to pick from and begin their project development.

5.1.1.6 SQL Server

We selected SQL Server Management Studio 2008 R2 from Microsoft. From here after we refer it as SSMS. It is completely free standalone product and it is not bounded to any version or edition of SQL server. And does not require any specific license.

There are many flavors of SQL server ranging from 2005, 2008 or 2008 R2. We can still download an older release of SQL server alongside with 2012, 2014 or the latest released build.

To download visit Microsoft[26] webpage. The installation is very easy for intermediate users who have prior experience in computers. It has a clear wizard which explains present import experience leveraging an intelligent framework commonly known as Program Synthesis.

[26] Microsoft Download Centre: Microsoft Download Page

5.2 Use cases

To achieve the objective, we must define the use cases which describe the outline of the prototype we try to develop. This significantly clarifies which parts and sections require focus and how we can reduce time during development.

Purpose: Use case diagram for inventory solution for ceramic industry product tagging using RFID

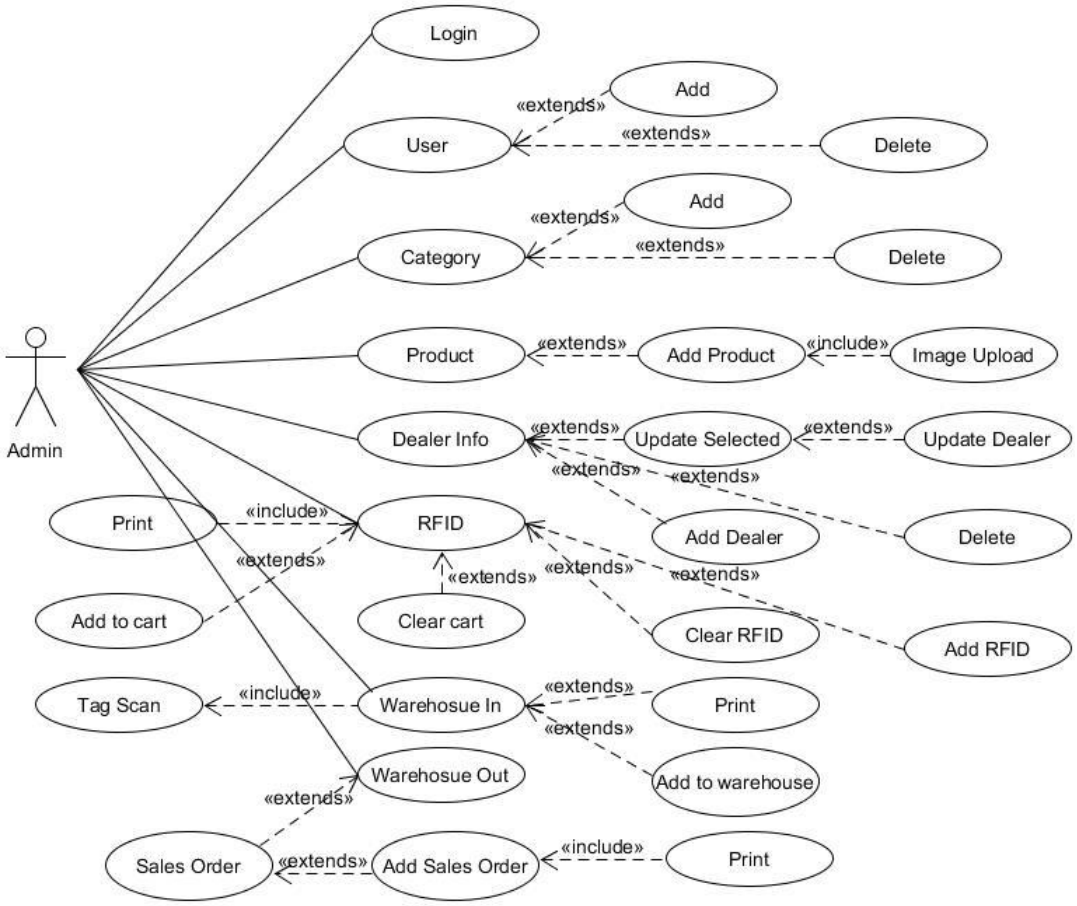

Figure 5-6-The Use case diagram of prototype application with "ADMIN" as actor

The use case diagram shown in Figure 5-6 consists of one actor "ADMIN" and Figure 5-7 consists of one actor, i.e., "USER".

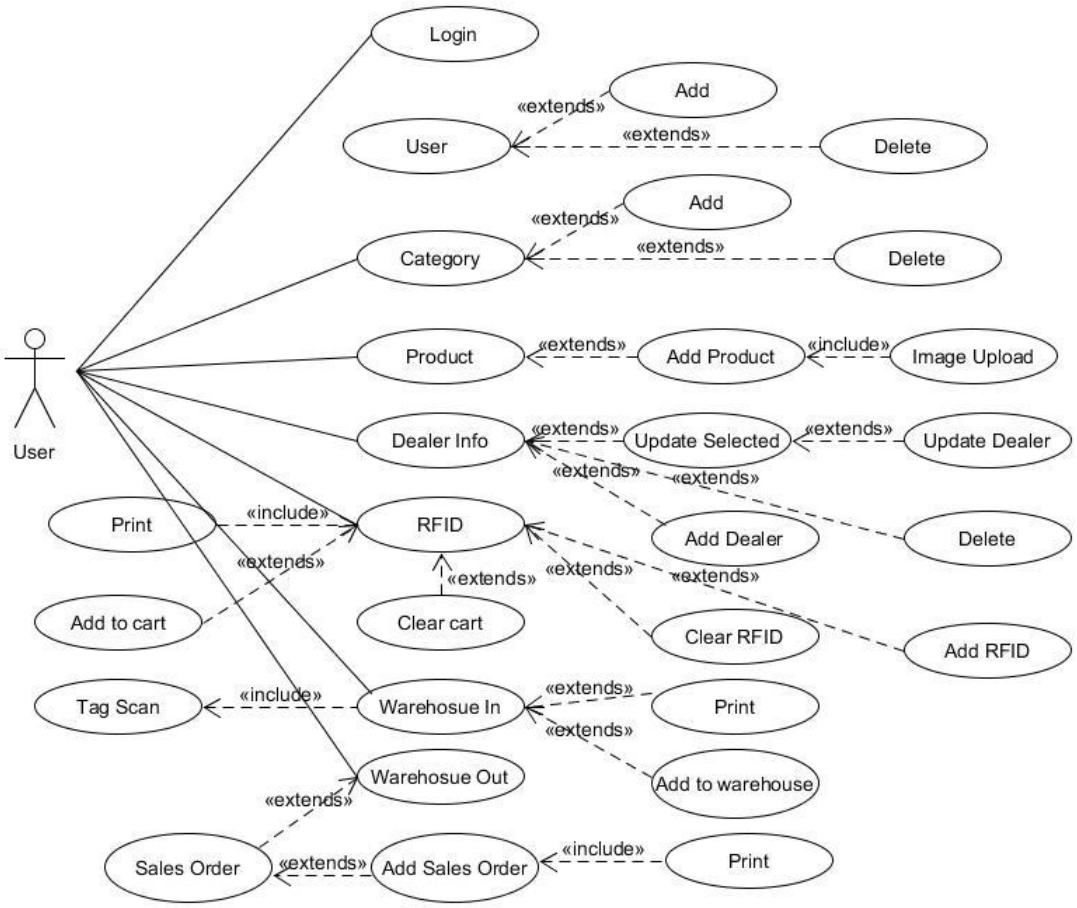

Figure 5-7-The Use case diagram of prototype application with "USER" as actor

5.2.1.1 Login

Masterpanel is the first window of the application which will be displayed to admin as well as non-admin user when he/she log into the system. We define this as the first use case as "**Login**" of the prototype application. Once the logged in the application directs to the *Masterpanel*, which lets both the actors to perform certain operations provided with certain privileges to each on the production floor. The admin has all the privileges. As this is just the prototype we have not defined the authorization system in the application and can perform later in upgrading the application for production purpose.

This application will be employed in the production floor for various actions to perform and will be explained in later sections.

Table 5-1-Use case for "Login"

Identifier	UC - 01
Name	Login
Actor(s)	Admin and User
Pre-condition	Admin and User log into the application
Post-Condition	Admin/User has been authenticated to the application.
Main Flow(s)	1. Admin/User logs in to the Inventory solution application. 2. Admin/User is presented with the Masterpanel which contains a list of options to select from and perform desired tasks as per the requirements. 3. Admin/User can open multiple windows within the main window itself. 4. Admin/User can close the present window displayed and minimize it.
Alternative Flow(s)	1. Admin/User is required to enter the right authentication credentials.

5.2.1.2 Manage User

This is the first tab in the application where the admin/user is presented with a window where admin can add new *user* and can perform a delete operation of the existing user from the system. This application provides the list of users created by the admin in the data table inside the same window while performing addition and deletion of *Users*.

Table 5-2-Use case for "MANAGE USER"

Identifier	UC - 02
Name	Manage User
Actor(s)	Admin
Pre-condition	Admin logs into the application
Initiation (Triggering event)	This use case starts when the Admin clicks on Users tab on the menu strip.
Post-Condition	1. Admin/User has valid credentials 2. Admin/User has been authenticated to the application. 3. User is not displayed the "User" button to perform any action on the *Masterpanel*.
Main Flow(s)	4. The application presents the User details. 5. The admin can perform new user registration into the system. 6. The application presents the list of *new users* created in the data table on the same page 7. The admin can perform delete action by selecting the specific "User" by selecting a row from the data table present.
Alternative Flow(s)	1. Application is not connected to the database and throws a database connection error. 2. If the *username* already exists when creating a new user, then the application will pop-up an error dialogue "*username already registered please choose a different one*"

5.2.1.3 Manage Categories

The application presents this window once the user clicks on this tab. This displays the field to enter the product category type. User creates the new product type by performing a click action on *add* button. Each product type from list can also be deleted by the user by performing a *delete* action.

Table 5-3-Use case for "MANAGE CATEGORIES"

Identifier	UC - 03
Name	Manage Categories
Actor(s)	Admin/User
Pre-condition	1. Admin/User log into the application. 2. Application display the list of product types available in the table.
Post-Condition	1. Admin/User has been authenticated to the application. 2. Admin/User has valid credentials
Main Flow(s)	1. The application presents the list of products in data table. 2. User can input the new product type from the input field and click on *add* button to trigger the Onclick event to save the entered data. 3. The user deletes the product by selecting the product from the list and trigger an Onclick event by pressing *delete* button. 4. The user can close the category window at any time to switch between other windows.
Alternative Flow(s)	Application is not connected to the database and throws a database connection error.

5.2.1.4 Product

The application displays *add new product* page. The user will be able to add a new product for the product type created previously in UC – 03. The user is presented with a list of input fields to fill in and add the new product into the database. This window allows the user to enter the unique *reference number* for each product as the case company required it. The use case below describes in detail the workflow it contains.

Table 5-4-Use case for "PRODUCT"

Identifier	UC - 04
Name	Product
Actor(s)	Admin/User
Pre-condition	1. Admin/User log into the application. 2. Application display the list of products available in the table. 3. Present empty input from fields to enter the product details.
Post-Condition	Admin/User has valid credentials
Main Flow(s)	1. The application presents the list of products. 2. Present the input fields for the user to enter product details. 3. The user has an option to upload images from the local storage. 4. The user will select the desired product type already created in the earlier use case "UC-03". 5. The user will enter a reference number for each product.
Alternative Flow(s)	Application is not connected to the database and throws a database connection error.

5.2.1.5 Dealer

The application displays the *dealer* page where the user will be able to add, edit and remove dealers from the window. This is accessible to admin and user both. The main screen of dealer's windows displays the input form to store data of new dealer. The Admin/User can update existing dealer's information by highlighting the dealer's data from the row and clicking on *update dealer*. And then update form appears on window to make desired changes to dealer's personal data.

Table 5-5-Use case for "DEALER"

Identifier	UC - 05
Name	Dealer
Actor(s)	Admin/User
Pre-condition	1. Admin/User log into the application. 2. Application display the list of dealers present in the table. 3. Present empty input fields to enter the dealer details.
Post-Condition	Admin has valid credentials.
Main Flow(s)	1. Dealer's window presents the dealer's data in the data table. 2. The dealer's window presents the input fields to insert new form data into the database. 3. The user selects the data from table and clicks on *update selected.* 4. The user can select the desired dealer's name from the table and click on delete button to remove from the system.
Alternative Flow(s)	Application is not connected to the database and throws a database connection error.

5.2.1.6 RFID

This window allows the user to scan the RFID tags. Each tag is a cart where the products are placed. There are two distinct functionalities to perform: 1) RFID tag is scanned on the hardware module connected to the computer. When the tag is scanned the application displays the tag UID on the screen, as shown in Figure 6-24**.** While the tag UID is available, the user can add any number of products along with its quantity to the selected tag UID or say *cart.* The detailed work flow is explained in the UC-06 below.

Table 5-6-Use case for "RFID" operation

Identifier	UC - 06
Name	RFID
Actor(s)	Admin/User
Pre-condition	1. Admin/User log into the application. *2.* *RFID tag number* window inside RFID window is ready to scan to display red/ green indication.
Post-Condition	Admin has valid credentials.
Main Flow(s)	1. The application presents the RFID tag data in the tag table and product table associated to individual RFID tag. 2. The *RFID tag number* will show indication when the tag is scanned. When scanned a unique identification number appears. This unique number is added to RFID tag table by clicking on *add* button. 3. The application presents the product form input. Every product selected from the drop-down is added to desired RFID tag or cart along with custom *reference* number. 4. In addition to product entry to each cart, the application does provide provision to clear the contents of the cart. And is performed by clicking on *Clear Cart.*
Alternative Flow(s)	Application is not connected to the database and throws a database connection error.

5.2.1.7 Warehouse In

The application presents the user window where the users perform the action of warehouse entry point for cart scanning. This window displays different functionalities to replicate the real scenario of warehouse cart scanning. The details case scenario is explained in the use case below.

Table 5-7-Use case for "WAREHOUSE IN"

Identifier	UC - 07
Name	Warehouse In
Actor(s)	Admin/User
Pre-condition	Admin log into the application
Post-Condition	Admin has valid credentials
Main Flow(s)	1. The application presents the User/Admin with sections like *Tag scan* and *Report.* 2. The application allows the user to select the RFID tag ID from the drop-down list to display the product added to it earlier in RFID window use case (UC - 06). 3. The application will display all the products added to each tag id selected from drop-down. 4. Once the products are listed, it allows the user to have a visual representation of product quantity at a quick glance on a graph. 5. Further user clicks on *add to warehouse* to add the products to warehouse database table. 6. Additionally, the application allows the user to view the count of each product added. 7. The application allows the user to generate a printable report for records purpose.
Alternative Flow(s)	Application is not connected to the database and throws a database connection error.

5.2.1.8 Warehouse Out

This part of the application allows the Admin/User to remove the products from the actual warehouse and also can print a report for the shipment. This window allows the user to select the required dealers contact and product to be shipped. The user selects the product and its quantity to be shipped. The specific product quantity from the actual warehouse will reduce when a required number is selected for shipment to selected dealers. Additionally, a notification is displayed to the user to alert the remaining quantity of product in stock which allows them to maintain the stock level, to be prepared to maintain the stock by producing the quantity.

The main use case of this application window is explained below.

Table 5-8-Use case for "WAREHOUSE OUT"

Identifier	UC - 08
Name	Warehouse Out
Actor(s)	Admin
Pre-condition	Admin log into the application
Post-Condition	Admin has valid credentials
Main Flow(s)	1. The application displays the *sales order* page. 2. The user enters the dealer's details. User can either enter the dealer's name by autocomplete while typing the dealer's name or manually entering the dealer's details completely. 3. The user enters the product name from the list of the products extracted from *Warehouse In* database. User can only select the product from the list of products already stored in the database. 4. Application allows the user to generate the printable report.
Alternative Flow(s)	1. Application is not connected to the database and throws a database connection error. 2. The application allows the user to view the total number of products and its quantity available in and out of stock. 3. The application will also display the total shipment orders placed for the dealers.

6 Developed Work

The application developed in this thesis is to provide a concept of ceramic product traceability using RFID which would solve the major traceability gap in the case company. The main part of the thesis is to perform research on tracking technologies. It is important to display a test application to show the concept of product tracking. This chapter describes the tasks performed to complete the goals in detail.

We will elaborate each part of the work by breaking into steps. The complete structure of our work is divided into two parts:

The combination of hardware and software implementation is shown in Figure 6-1.

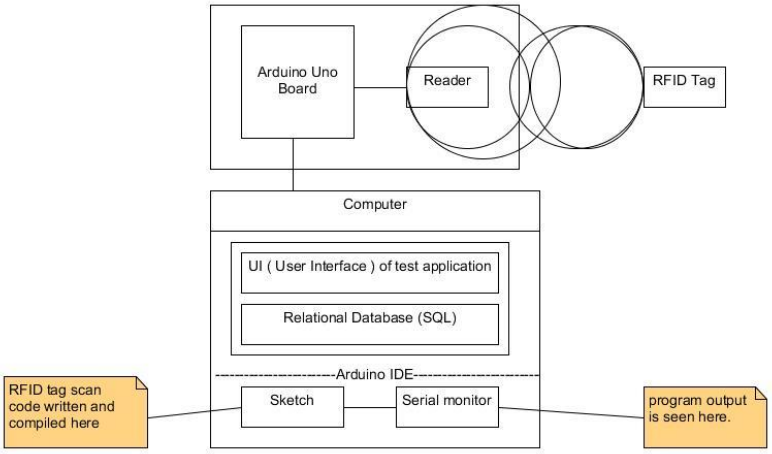

Figure 6-1-Architecture of RFID test application

6.1 Hardware Selection

1) For over-all operation we require a computer with the basic configuration, which may be a laptop or a desktop. We used a laptop for basic configuration, Arduino Uno development board and RFID tags to scan. We also require a serial comm cable for communication between computer and the board.
2) To perform a test on RFID tag we implemented the combination of RFID tag kit and Arduino Uno development board. As the Arduino Uno board is open source to perform tests and extend to work with extensive projects. We intend to test the RFID tag to check whether it displays the default UID code on Arduino serial monitor. A serial monitor is the output window in Arduino IDE to view the output of the code when written and executed.
   a) We connected Arduino UNO board and Mifare MFRC522 RFID Reader/Writer tag to a computer.

Table 6-1-Pin layout of Arduino Uno to MFRC522 RFID[27]

Typical pin layout used			
SL. No	MFRC522 Reader/PCD Pin	Arduino Uno/101 Pin	Signal
1	RST	9	**RST/Reset**
2	SDA(SS)	10	**SPI SS**
3	MOSI	11	**SPI MOSI**
4	MISO	12	**SPI MISO**
5	SCK	13	**SPI SCK**

Figure 6-2 shows the connection diagram of Arduino Uno and MIFARE RFID RC522 read/write board designed using fritzing tool. This tool can be downloaded from Fritzing.org official webpage.

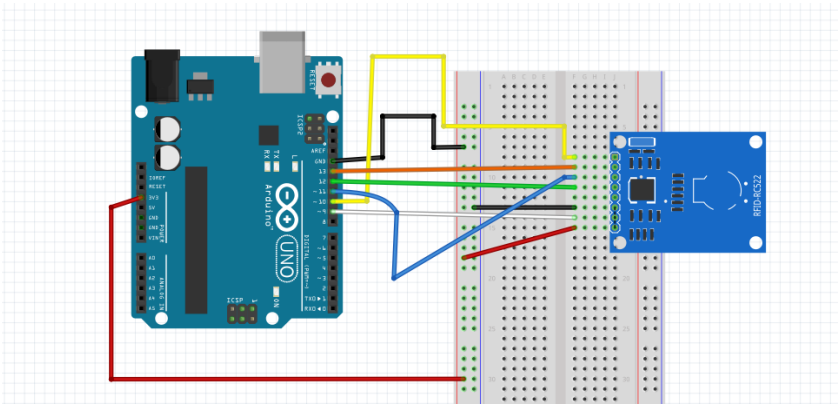

Figure 6-2-Connection diagram of Arduino UNO and MIFARE RFID RC522.

[27] Arduino Uno to MFRC522 RFID pin layout table source: **Github**

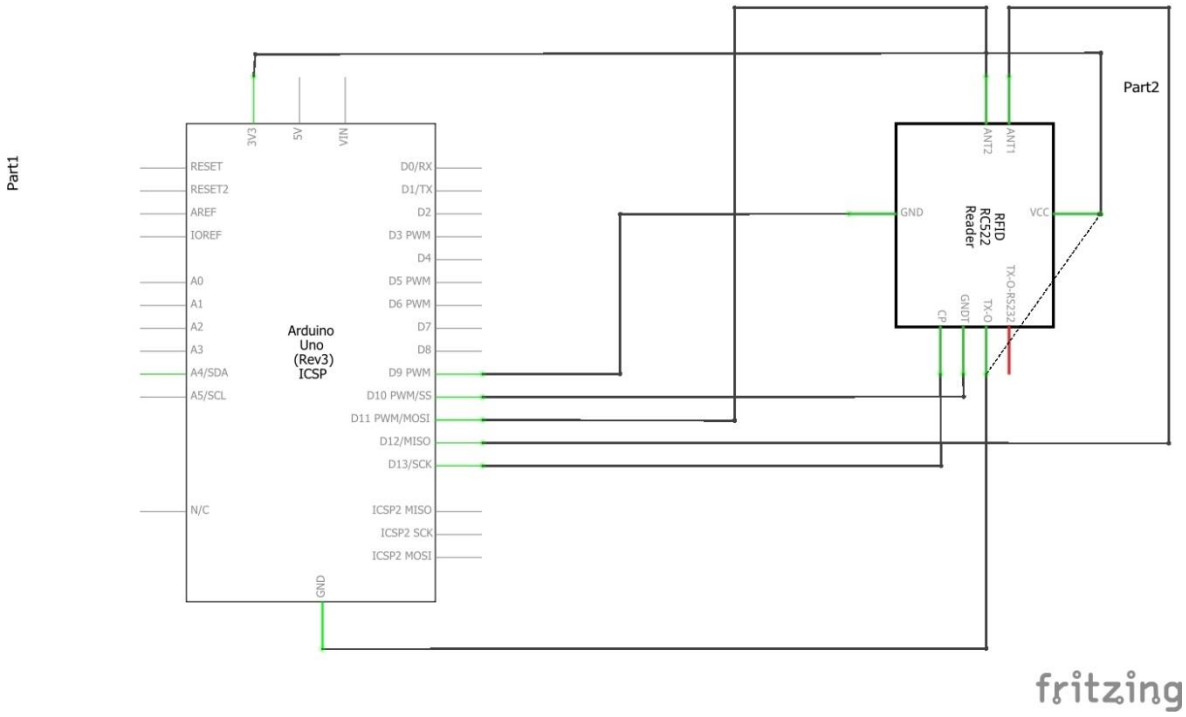

Figure 6-3-Pin diagram of Arduino UNO and MIFARE RFID RC522 read/write board

6.2 Visual studio .NET solution and projects

A complex business application might consist of many projects, code files and other relatively significant items. With so many files loaded in visual studio, one wants a way to navigate through assets. The solution explorer is the one which holds this potential mess. A *solution* in ASP.NET terms is an item or container which contains zero or more projects. A solution must contain at least one project and must contain many files that are used to construct a .NET assembly. i.e., a solution keeps the track of which project needs to be compiled first at runtime.

A graphical representation of the solution explorer is shown in Figure 6-4.

Projects themselves contain source documents. In this section, we will explain in detail arrangements and tasks. And how to utilize them successfully as it would be important.

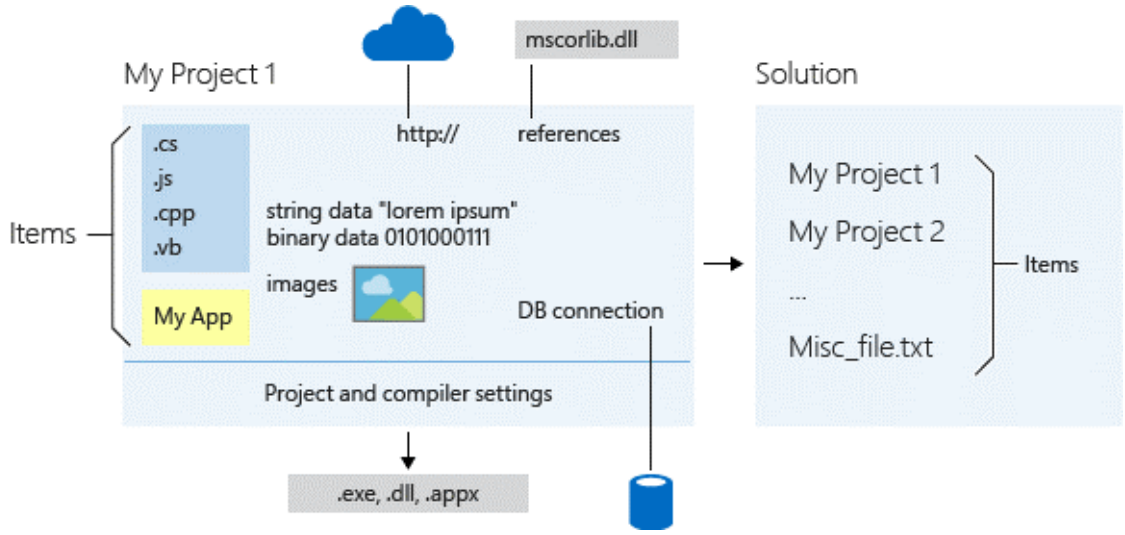

Figure 6-4-A solution and its projects[28]

Furthermore, when we create an application, website, Web app, script, plug-in, etc. in visual studio, we start with a *project.* Logically, a project folder consists of all files and folders related to the project we are working on. A solution has a *.suo file that stores settings, preferences and configuration information of each user who has worked on the project. A project file normally keeps track of all the settings and files that need to be compiled to run the project successfully.

We created a project named 'WindowsFormsApplication3' which contains files and folders necessary to compile a project. Complete project structure can be seen in Figure 6-5.

[28] Relationship between project and solution: **docs.microsoft.com**

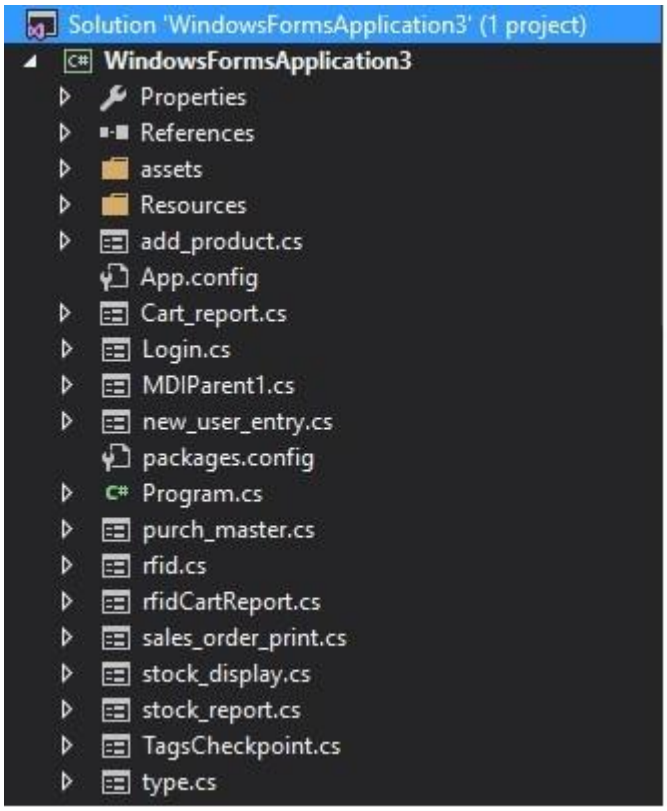

Figure 6-5-Project folder structure

The project file consists of Properties, References, assets, Resources, App.config, packages.config, Program.cs.

Properties	Contains access to project settings.
References	Contains internal and external files that support the execution of the functionalities.
Assets	It contains images, sound files.
Resources[29]	This is the data which can be modified independently from another source code.
App.config	Is an XML file where we specify configuration setting using predefined attributes? Ex: two attributes like version and sKU in our project.

[29] What are *Resources* in project folder? [52]

Packages.config[30]	Contains info about various assemblies.
Programs.cs	This is the entry point or main of the applications and this will be executed first when the application runs.

Table 6-2-Details of project folder structure

We initially built a small desktop application to display the RFID tag ID.

The challenge was that the board must talk to the application. Which required Arduino plugin. This plugin was added to the IDE. Once this plugin was installed into the IDE, we must enable the COM port through which the board sends the bytes of data to the application. The COM port is selected inside the Arduino Uno IDE.

NOTE: While testing the application, *do not open the serial monitor from Arduino Uno IDE. Because, this will not let the application to throw the error saying the port is in use.*

While the serial port is free and ready to use, it must be hard coded to let the application read all the immediately available data bytes, based on encoding from both input buffer and stream of *SerialPort* object.

We import **System.IO.Ports** package in the namespace.

This package contains a **SerialPort** Class and its methods. One of the methods we implemented is explained in Table 6-3.

Table 6-3-SerialPort method (Adapted from [48] **)**

SerialPort.ReadExisting Method	
Namespace	System.IO.Ports
Assemblies	System.dll, System.IO.Ports.dll
C#	public string ReadExisting ();
Returns	String (contents of the stream and input buffer of SerialPort object)
Exception	InvalidOperationException (the specified port is not open)

[30] For details information on Packages.config Visit

```
public void serialPort1_DataReceived()
{

        String myData = serialPort1.ReadExisting();
        label3.Text = myData;


}
```

Figure 6-6-A method to receive data from serial port

An application was developed with a database to store the data. It was Tested with the code mentioned in Figure 6-6 to see how it would respond to the input from serial communication cable to read the input buffer. It worked flawlessly and read the data from the stream and displayed it onto the application.

When we scan the RFID tag onto Arduino Uno-RFID reader circuit, the application grabs the data and displays it onto the application. Figure 6-7 shows the tag UID displayed on the test application.

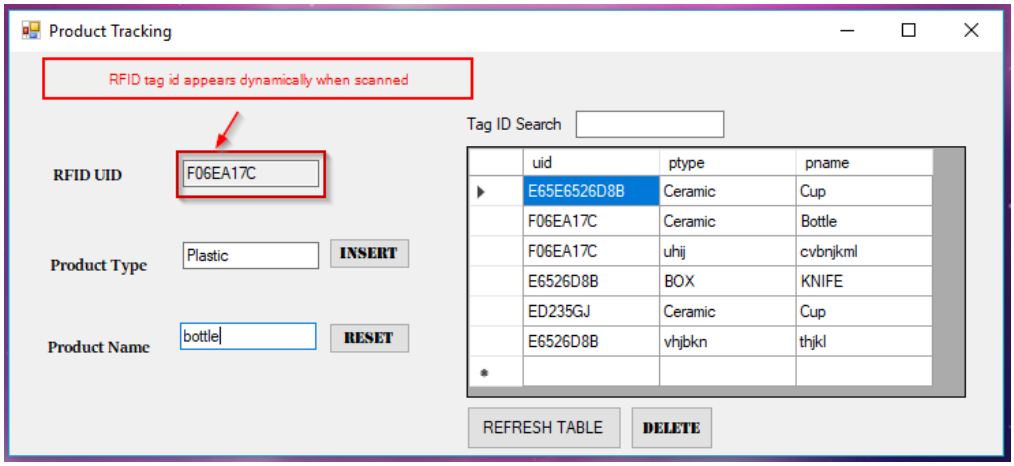

Figure 6-7-Dynamic display of UID of card during scan

As this test application was successful we further started to develop an interface to input the product information organized according to the type of product. Each product will have certain attributes. We intended to develop this application using Visual Studio on .Net framework. As this IDE (Integrated development environment) is a bundled package with a wide range of plugins and community support.

The desktop application consists of user interface and a database for storing the data input into the application. To work with this, we require a relational database to recognize relations between stored items of information, actors who have full access and limited access.

Hence, we created a MySQL database named **inventory** and created a few tables like **registration**, **product_name**, **product_type**, **stocks**.

In *user registration* form, admin will create username and password for employee to whom an authorisation is required. Once credentials are provided to the employee he/she will have to login to the GUI application. In the Figure 6-8 admin creates a new user.

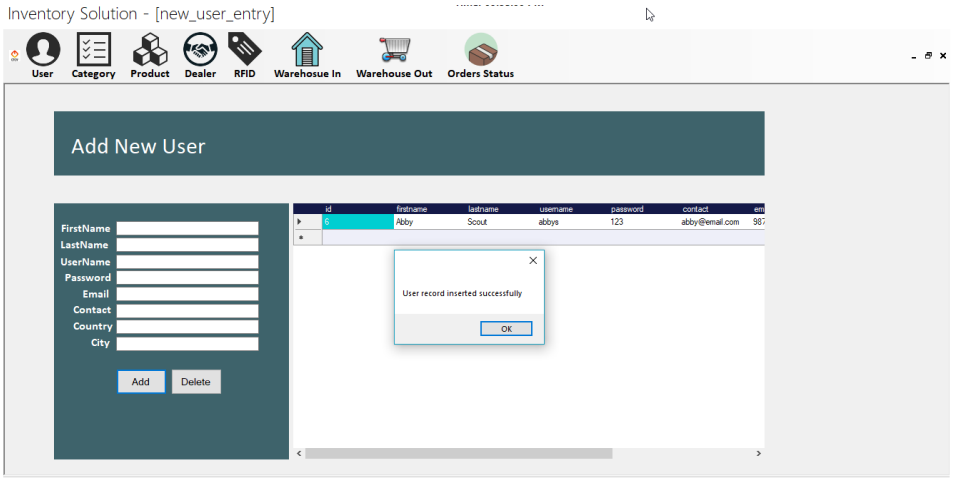

Figure 6-8-New user registration form

Now that an employee is added to the database this employee must login to the application to perform various tasks like add, delete, update a product.

NOTE: *The Mifare MFRC522 RFID card tag here is used differently here. Instead of storing the data into the RFID tag which apparently holds less bytes of data, we bind the data to the tag.*

This card has a **FIFODataReg** register which has an input and output of 64-byte FIFO buffer [49].

Hence, we decided to select the RFID card data and bind the product information to it which will be feasible to add more information. The way data binding done between RFID tag and product data makes it easy to input more information to the tag details. Once we outlined this concept, a database with various types of data storage was required. This will be explained under Section 6.3.

6.3 Database creation

During the process of preparing an interface we implemented an SQL database as a backend server to store the data. And an active user interface application to perform operations as in any warehouse application would do.

An RFID tag is stamped to the cart which will hold products and/or cartons' details. When the tag is scanned, the computer system will record the entry to notify that the product just passed the transponder field area or checkpoint.

Figure 6-9 shows the RFID tag flow from start to end.

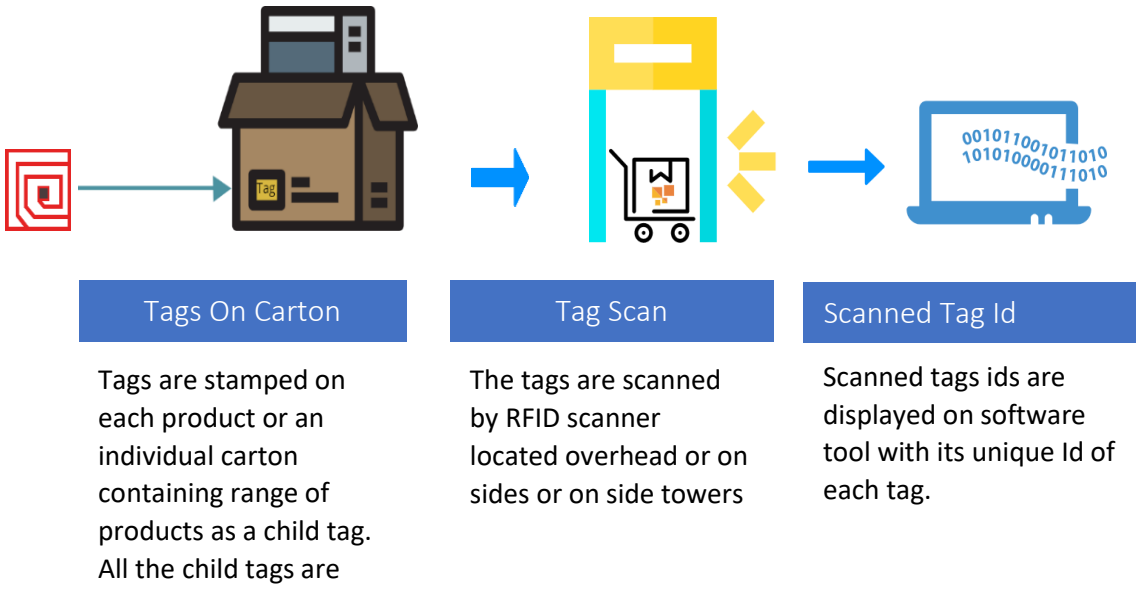

Figure 6-9-RFID tag lifecycle.

We use the RFID tag's unique number to the cart. There will be several products placed into the cart. And while tags are scanned, we will have all the list of products scanned through the database as in our case. This process is carried out across products entering the warehouse to the stack point. From here we can replicate the process when the tags exit the warehouse. The nature of RFID helps to reduce the time and effort of going through the list of products and sorting them to perform *add* and *remove* from the database.

This major advancement helps us solve product traceability in any industry. To achieve this a relational database was developed which is responsible to provide relations between different tables which can be seen in Figure 6-10.

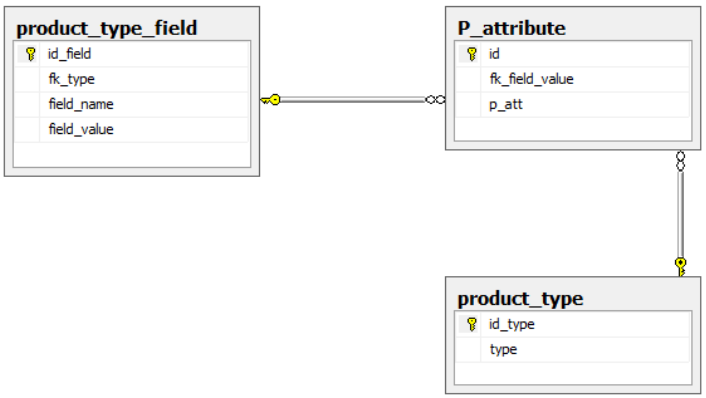

Figure 6-10-Relational database diagram representation

Similarly, a relationship diagram has been drawn between the RFID tag and the RFID tag table. This can be seen below in the Figure 6-11.

Figure 6-11-Relation between RFID tag number and cart number

6.4 Software Implementation

The test application developed for product traceability in the production line required to follow the project structure, which can be seen in Figure 6-5. It contains all the files and folders responsible for actions to perform the desired operations like *login*, *add*, *remove*, *update* user, *product*, RFID tag UID. This software is just the prototype version but not the production version.

It is a desktop application written in C#. The file types that we see in Figure 6-5 ending with .cs are C# files. The entry point of the application is Program.cs file which contains the main method. The assets folder contains the *image* files in *.png* format. This software has many parts which we will explain in detail.

Database connection:

Accessing data from database is one of the significant aspects in any programming and software development. And it is important for any programming language to have the ability to work with databases. There are a few fundamentals for database connectivity.

In this case we have used Microsoft SQL Server 2008 R2 and it is free to download from Microsoft official webpage.

The following four concepts are important to work with the database:

- **Connection**: Consists of required parameters to like Database name or data source, credential and optional parameters.

- **Select data from the database**: Once connection has been established, the program can execute an SQL select command to perform fetch data operation.
- **Inserting data into the database**: The application can also perform insert data into the database in a certain row.
- **Updating data into the database**: The application can also perform update existing data into database.
- **Deleting data from database**: Application can also perform the delete operation to remove data from a specified row in database.

Connection string shown in the Figure 6-12 is responsible to establish database connection to database, in this case we connect to database called "inventory" and connects to a data source which is localhost in our development stage. The connection string is set static string variable declared as *connectionString*. We assign the connection string to variable *con*. Further, we open the connection using *con* variable.

```
public partial class Login : Form
{

    // Database connection code
    static string connectionString = string.Format("Data Source=127.0.0.1;Initial Catalog=inventory;Integrated Security=True");
    SqlConnection con = new SqlConnection(connectionString);
    public Login()
    {
        InitializeComponent();
    }
```

Figure 6-12-Database connection code

6.4.1 Login form

This application is accessed by two actors i.e., admin and user. Admin creates new users as shown in Figure 6-16. Users login with access to certain privileged operations.

- **Admin:** Has access to add, update, remove new and existing users into the system.
- **User:** Has access to rest of the application functionalities to add, remove, update products and dealers from and into the system.

Login page provides access to an authorized person when appropriate details are entered. The basic UI (User Interfaces) can be seen in the Figure 6-13. The following action is performed by initially creating a test user in the SQL server database itself and henceforth logging in with the same credentials in the login form.

Figure 6-13- Login form

When a user enters valid credentials and clicks on login button the following code executes to connect to the database and perform the login action. The button click event will perform the login action into the application's main landing form and is the *MDIparent* form. The user validation code is shown in Figure 6-14.

```
private void button1_Click(object sender, EventArgs e)
{
    int i = 0;
    SqlCommand cmd = con.CreateCommand();
    cmd.CommandType = CommandType.Text;
    cmd.CommandText = "select *from registration where username ='"+ textBox1.Text +"' and password = '"+ textBox2.Text +"' ";
    cmd.ExecuteNonQuery();
    DataTable dt = new DataTable();
    SqlDataAdapter da = new SqlDataAdapter(cmd);
    da.Fill(dt);
    i = Convert.ToInt32(dt.Rows.Count.ToString());

    if(i == 0)
    {
        MessageBox.Show("Username password does not match");
    }
    else
    {
        this.Hide();
        MDIParent1 mdi = new MDIParent1();
        mdi.Show();
    }
}
```

Figure 6-14-User login code

The code shown in Figure 6-14 is inside the button click event. In which the username and password entered in the text-fields is validated to true or false. If valid, it will allow access else deny access and throw an error message. Furthermore, if the details entered are valid, the *Login.cs* form will redirect to the *MDIParent* form which can be seen in the else block in Figure 6-14.

Whilst the user is logged into the application, it displays a window where the user can select the intended operation to perform as per the requirement of the production floor.

Figure 6-15-Application control panel

The MDIParent form consists of eight tabs on the header ribbon. And these are listed as follows:

1. **User:** The tab where admin will be able to add, remove and update a new user.
2. **Category:** In this window the user will be able to create a new product type and its attributes.
3. **Product:** In this section a new product is added into the main product list in the database.
4. **Dealer:** This section allows the user to add, remove and update dealer's info to whom the orders to be packed and shipped.
5. **RFID:** This section allows the user to create a basket with an RFID tags number and this basket allows the user to add a product and quantity.
6. **Warehouse In:** In this window the user will be able to track the number of products scanned when the cart crosses the warehouse checkpoint. Logically, the tag passing the warehouse checkpoint.
7. **Warehouse Out:** This window displays the products exiting the warehouse keeping the count of product exit check list.

NOTE: *This application is solely developed fresh and has no infringement issue with the sense of responsibility and value to the thesis work.*

6.4.2 New user entry

This section of the application is accessible to the *admin* to create a new user into the system and is then stored into the database. In *user registration* form, admin will create username and password for employee to whom an authorization is required along with all other details. Once credentials are provided to the employee he/she will have to login to the GUI application. As seen in the Figure 6-16 admin creates a new user.

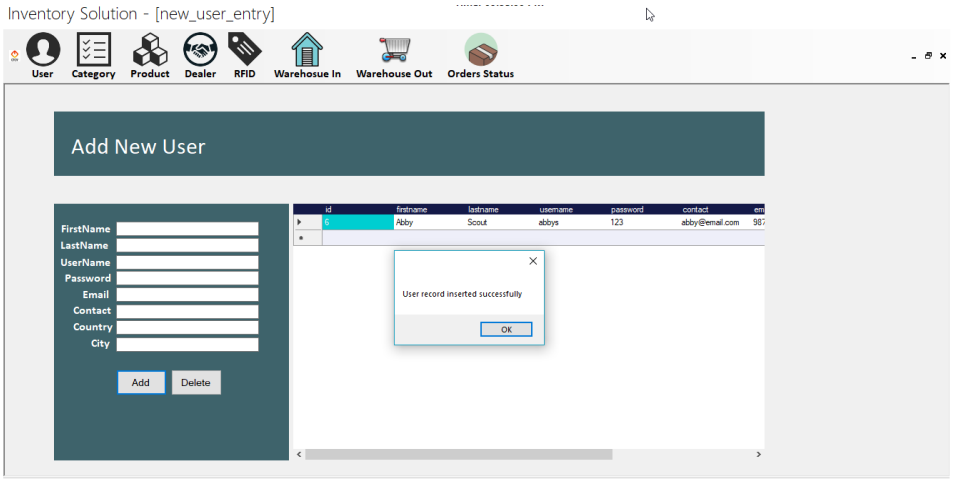

Figure 6-16-New user entry from

Now that an employee is added to the database this employee must login to the application to perform various tasks like *add*, *delete*, *update* a product. The code block to perform this action is defined in Figure 6-17**.**

```
//Adding new user to the database using database connection by querying the database.
private void button1_Click(object sender, EventArgs e)
{
    int i = 0;
    SqlCommand cmd = con.CreateCommand();
    cmd.CommandType = CommandType.Text;
    cmd.CommandText = "select *from registration where username ='" + textBox3.Text + "' ";
    cmd.ExecuteNonQuery();
    DataTable dt = new DataTable();
    SqlDataAdapter da = new SqlDataAdapter(cmd);
    da.Fill(dt);
    i = Convert.ToInt32(dt.Rows.Count.ToString());

    if (i == 0)
    {
        SqlCommand cmd1 = con.CreateCommand();
        cmd1.CommandType = CommandType.Text;
        cmd1.CommandText = "insert into registration values ('"+textBox1.Text+"','"+textBox2.Text+"','"+textBox3.Text+"','"+textBox4.Text+"','"+textBox5.Text+"','"+text
        cmd1.ExecuteNonQuery();
        clearFields();
        display();
        MessageBox.Show("User record inserted successfully");
    }
    else
    {

        MessageBox.Show("this username already registered please choose a different one");

    }
}
```

Figure 6-17-Add new user registration form code

6.4.3 Add product

The most significant part of the application is the product creation where we create a product and its attributes. To create it the user must have a product category type and each product category has its desired attributes like shape, weight, height etc. Users can create a category under the second thumbnail on the control options list named Category. What it contains is shown in Figure 6-18 and Figure 6-19, where each product has an attribute.

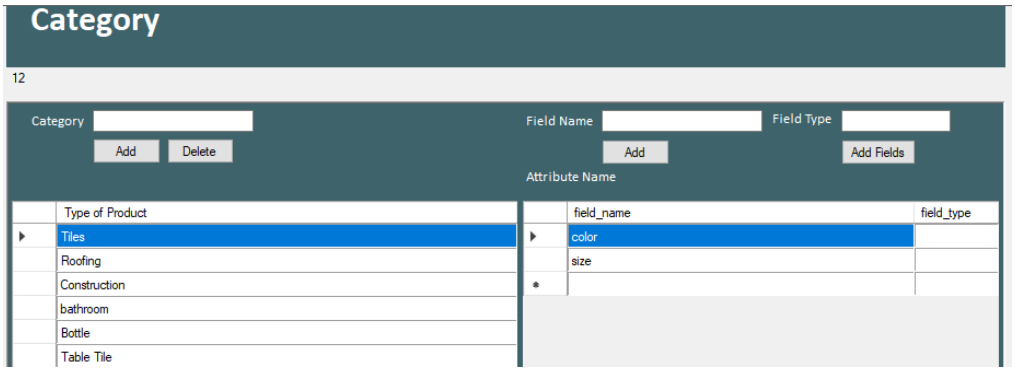

Figure 6-18-Product category for product 1

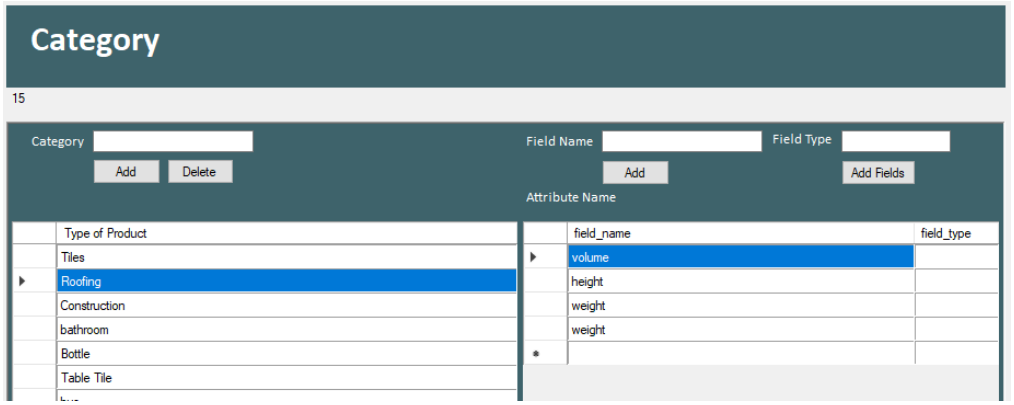

Figure 6-19-Product category for product 2

Now that we have the product category and its attribute created we proceed further to create a new product. To perform this action, click on the product tab on header ribbon and select from a dropdown and click on Add product which will call the “Add Product” form to add the new product.

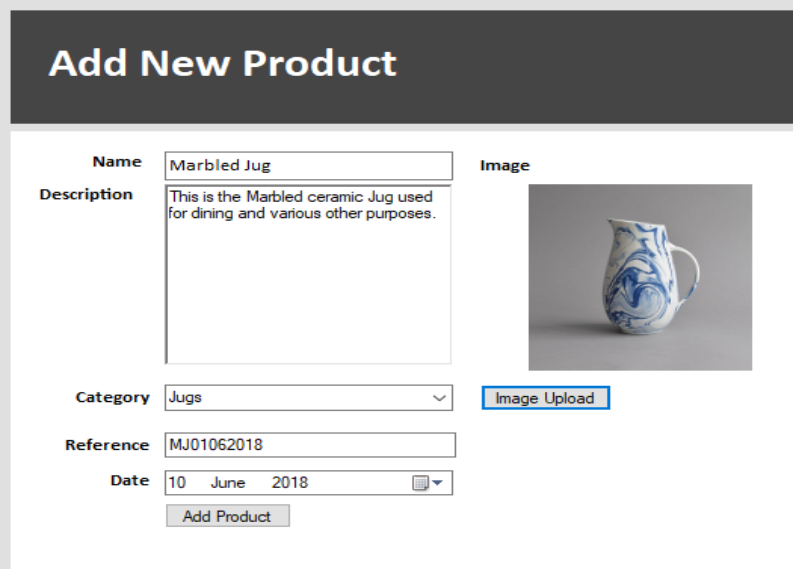

Figure 6-20-New product creation

```
private void button7_Click_1(object sender, EventArgs e)
{
    //Converting the image into hexadecimal value to store data into the database table.
    byte[] images = null;
    FileStream Stream = new FileStream(imglocation, FileMode.Open, FileAccess.Read);
    BinaryReader br = new BinaryReader(Stream);
    images = br.ReadBytes((int)Stream.Length);

    string message_0 = "";

    foreach (TextBox textbox in this.panel1.Controls.OfType<TextBox>())
    {
       // message_0 = textbox.Text.ToString();
        List<string> list = new List<string>();
       // List<T> myList = array.ToList<T>();
        if (textbox is TextBox)
        {
            list.Add((textbox as TextBox).Text);
            string mess = list[0].ToString();
            for (int i = 0; i < list.Count; i++)
            {

                Console.Write(list[i]);
               // mess += list[i];

            }
        }

    }
    SqlCommand cmd = con.CreateCommand();
        cmd.CommandType = CommandType.Text;
        string a = "insert into new_product (name, description, image, fk_type, date, reference, field_value) values ('" + textBox3.Text + "', '" + richTextBox1.Text + "' ,@images ,'
        cmd.CommandText = a;
        cmd.Parameters.Add(new SqlParameter("@images", images));
        cmd.ExecuteNonQuery();
        // table_update();

    MessageBox.Show("record inserted successfully");
}
```

Figure 6-21-Add new product code

To add a product, we must input certain fields, and those fields have a certain field type, like textboxes have string values, but images have binary information which must be programmed to store the values into a row in the database table *new_product*. In the database too, we have the file type as image. To store image file type in our windows application to a database and vice versa, the database stores the value in binary format.

Remaining fields namely *name, description, image, fk_type, date, reference, field_type* is string field type.

Once the data is inserted into the database successfully, a message box is displayed to show “record inserted successfully”.

6.4.4 Dealer Information

A user can add a dealer’s information, so that the user can stack the products in the warehouse according to the dealer listed. That helps the user not to redo the dealer information again and again for multiple orders. This form actions perform like the registration form.

```
private void button1_Click(object sender, EventArgs e)
{
    SqlCommand cmd = con.CreateCommand();
    cmd.CommandType = CommandType.Text;
    cmd.CommandText = "insert into dealer_info values ('" + textBox1.Text + "','" + textBox2.Text + "','" + textBox3.Text + "','" + textBox4.Text + "','" + textBox5.Text + "')";
    cmd.ExecuteNonQuery();

    textBox1.Text = "";
    textBox2.Text = "";
    textBox3.Text = "";
    textBox4.Text = "";
    textBox5.Text = "";
    dg();
    MessageBox.Show("Data inserted successfully");
}

private void dealer_info_Load(object sender, EventArgs e)
{

    if (con.State == ConnectionState.Open)
    {
        con.Close();
    }
    else
    {
        con.Open();
        dg();

    }
    //resize this form to fit its content inside parent window automatically
    this.WindowState = FormWindowState.Maximized;

}
```

Figure 6-22-Dealer’s information code snippet

Add:

The values from the textbox objects is used to get user input while the program is running. Further, the input value from the textboxes is collected to a variable and stored into the database tables *dbo.dealer_info*. This dealer info is used in the further stages of this application and is explained in section 6.4.7.

Update & Delete:

In addition to dealer’s form data insertion into database we can also perform update and delete operation. To update a dealer’s data, user must click on the row of the DataGrid table. This would grab the details from the database table to the textboxes of the update dealer input fields of the form which can be seen in Figure 6-23. Now the user can edit the required information and click on update dealer to overwrite the details of data.

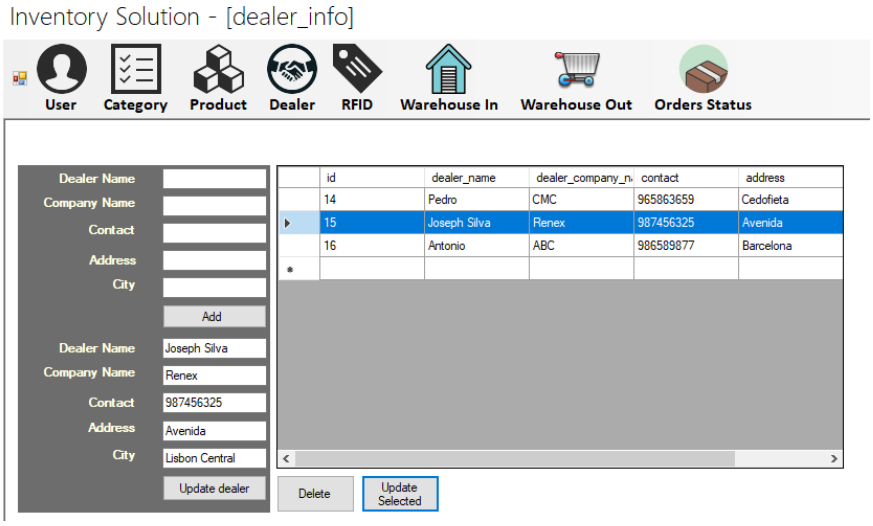

Figure 6-23-Dealer information GUI-Add

Similarly, to delete the data from the table the user must click on the data from the DataGrid table. Click on *delete* button to remove the data.

6.4.5 RFID

The most significant part of the application is this window. When clicked will display the image as shown in the Figure 6-24.

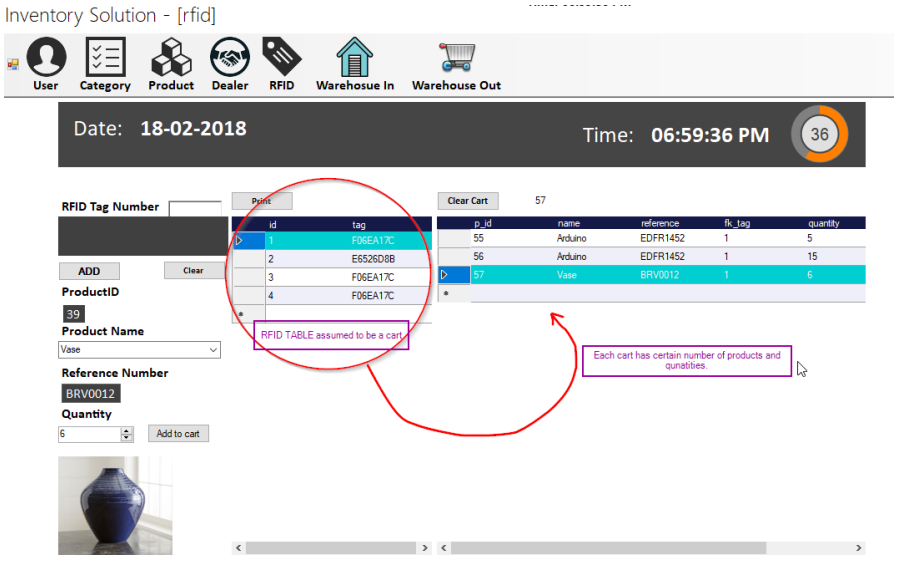

Figure 6-24-RFID scanning page

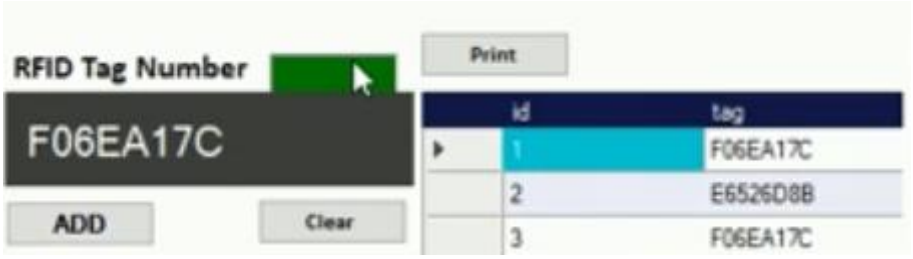

Figure 6-25-UID of RFID tag displayed when tag is scanned

```
public void serialPort1_DataReceived()
{
        String myData = serialPort1.ReadExisting();
        label3.Text = myData;

}
```

Figure 6-26-Code which retrieve the RFID UID from tag during each scan

The part circled in Figure 6-24 shows the table where the tags are scanned and stored in database table. Let us consider this as cart table. Each cart is associated with an RFID number which is depicted in the Figure 6-24. When an RFID tag is scanned the tag UID appears inside the block named “RFID tag number”, as shown in Figure 6-25. Once the RFID tag number is obtained it is then added to the table circled in Figure 6-24. Now that we have the RFID tag number in the table, we can add any number of products to the each UID along with product quantity. This can be seen from Figure 6-24, where each cart has several products and quantities.

In real life scenario, this can be considered as a cart waiting to be filled with products packed in the production area. Those packed products will have to be moved to the warehouse for further storage and distribution to the customers or dealers as in our case. Each cart will have a certain number of products added to it. Then later these products will be scanned at other checkpoints to have a count of the number of products in the cart and added to the warehouse. We will explain about the second checkpoint further in Section 6.4.7.

The code which performs adding the scanned tag ID to the tag table is shown in Figure 6-27.

```
private void button2_Click(object sender, EventArgs e)
{
    SqlCommand cmd = con.CreateCommand();
    cmd.CommandType = CommandType.Text;
    cmd.CommandText = "insert into rfid_tagtable (tag) values ('" + label3.Text + "')";
    cmd.ExecuteNonQuery();
    rfidTableUpdate();
    MessageBox.Show("record inserted successfully");
}
```

Figure 6-27-Storing RFID tag number code

Once the RFID tag ID is stored into the database, we also display it into the table on the RFID page. Now the user can add any number of products to a cart which is depicted as an RFID tag.

Each cart can be cleared once it has been scanned under the section 6.4.6. As the cart will have product movements in and out of the warehouse. The contents of the cart can be cleared by clicking on "*Clear Cart*" button as shown in Figure 6-28. This makes it easy to add and remove products to the cart any number of times.

Clear Cart 57

p_id	name	reference	fk_tag	quantity
55	Arduino	EDFR1452	1	5
56	Arduino	EDFR1452	1	15
57	Vase	BRV0012	1	6

Figure 6-28-Clear Cart table

This action is performed by a button click event. Figure 6-29 shows that button click event code written to access the database to remove the contents out of it.

```
private void button5_Click(object sender, EventArgs e)
{

        SqlCommand cmd = con.CreateCommand();
        cmd.CommandType = CommandType.Text;
        cmd.CommandText = "delete from rfid_cart where p_id = '" + label15.Text + "'";
        cmd.ExecuteNonQuery();
        DataTable dt = new DataTable();
        SqlDataAdapter da = new SqlDataAdapter(cmd);
        da.Fill(dt);
        MessageBox.Show("product removed successfully");

}
```

Figure 6-29-Clear Cart button action code

6.4.6 Warehouse In

This button displays the page where the contents of the warehouse is shown.

In a real case during a cart movement inside a warehouse, each cart is scanned to check for the products. Once the products are scanned, it is displayed on the application data table.

In this application we have used a drop-down button to display the same behavior as scanning the cart. Further when we select the UID from the drop-down, it displays the contents already added in the previous section. Like a cart entering a real warehouse containing packed products.

When the tag UID from drop down is selected, all the products in that RFID are is displayed. Furthermore, while clicking on *Add to warehouse* button the products are added to warehouse stack. It is shown in Figure 6-30.

During a scan checkpoint every cart is scanned to see whether all the products with quantity are present in it or not before stacking. Refer to image in Figure 6-30 to visualize the scanning section.

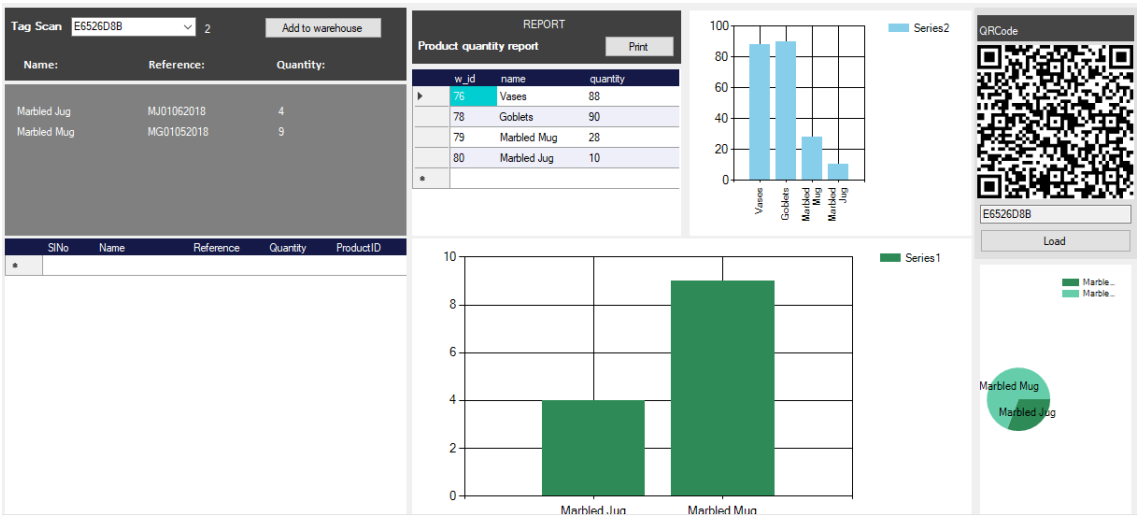

Figure 6-30- "Warehouse In" page displays first checkpoint to holding area

The tag scanned here at the first checkpoint displays the list of products in the cart. In this application a drop-down button is used to portray a similar idea. This helps us test this functionality to work seamlessly to perform as desired. Also, for the records purpose the user/admin can print the total quantity of the products in stock by clicking on the print button under report block which can viewed from the Figure 6-30.

```
private void comboBox1_SelectedIndexChanged(object sender, EventArgs e)
{

    try
    {
        int id = Convert.ToInt32(comboBox1.SelectedValue.ToString());

        label12.Text = id.ToString();

        SqlCommand cmd1 = con.CreateCommand();
        cmd1.CommandType = CommandType.Text;
        cmd1.CommandText = "select * from rfid_cart where fk_tag =  '" + id + "' ";

        SqlCommand cmd2 = con.CreateCommand();
        cmd2.CommandType = CommandType.Text;
        cmd2.CommandText = "select * from warehouse_stock ";
        if (con.State == ConnectionState.Open)
        {
            con.Close();
        }
        else
        {
            con.Open();

        }
        cmd1.ExecuteNonQuery();
        cmd2.ExecuteNonQuery();
        DataTable dt1 = new DataTable();
        SqlDataAdapter da1 = new SqlDataAdapter(cmd1);
        da1.Fill(dt1);

        int C = 1;
        panel1.Controls.Clear();
        foreach (DataRow dr1 in dt1.Rows)
        {

            Label lbl = new Label();
            this.panel1.Controls.Add(lbl);
            lbl.Top = C * 22;
            lbl.Left = 10;
            lbl.Text = dr1["name"].ToString();
            Label txt = new Label();
            this.panel1.Controls.Add(txt);
            txt.Top = C * 22;
            txt.Left = 150;
            txt.Text = dr1["reference"].ToString();
            Label lbl1 = new Label();
            this.panel1.Controls.Add(lbl1);
            lbl1.Top = C * 22;
            lbl1.Left = 290;
            lbl1.Text = dr1["quantity"].ToString();
            C = C + 1;

        }


        if ((chart1.Series != null) && (chart2.Series != null))
        {
            this.chart1.Series["Series1"].Points.Clear();
            this.chart2.Series["Series1"].Points.Clear();

        }
        if ((chart1.Series != null) && (chart2.Series != null))
        {
            SqlDataReader rdr = cmd1.ExecuteReader();
            while (rdr.Read())
            {

                this.chart1.Series["Series1"].Points.AddXY(rdr["name"].ToString(), rdr["quantity"].ToString());
                this.chart2.Series["Series1"].Points.AddXY(rdr["name"].ToString(), rdr["quantity"].ToString());
            }
        }

    }

    catch (Exception ex)
        {
        }

    code();
}
```

Figure 6-31-Program to select the cart from drop-down button

Along with all the features there is also a chart displayed using the C# chart series to have a visual representation of the products along with quantity in digits. This visual chart display will instantly help the user to have a visual look and monitor the stock entry in case the value entered is more or less than expected. In addition to it a QR code is generated for every new cart entry into the “Warehouse In” checkpoint. This lets the user

scan the code using the mobile device to scan the code for each cart for further reviewing the products stacked before and after checkpoint entry. This is best in practice for the user working on the production floor for on the go stock checking.

6.4.7 Warehouse Out

In this part of the application the orders are placed for certain dealers who place orders for certain ceramic products. This is performed by the clicking on "Warehouse In" button on the control panel. A page is displayed which is named "Sales order", where only the existing dealers' information is listed. Once desired dealer's detail is selected, further user can select the product name for them to be shipped. While a product is selected, the application displays the total quantity of that certain product available to select from. Refer Figure 6-32 to have a visual representation on a user interface.

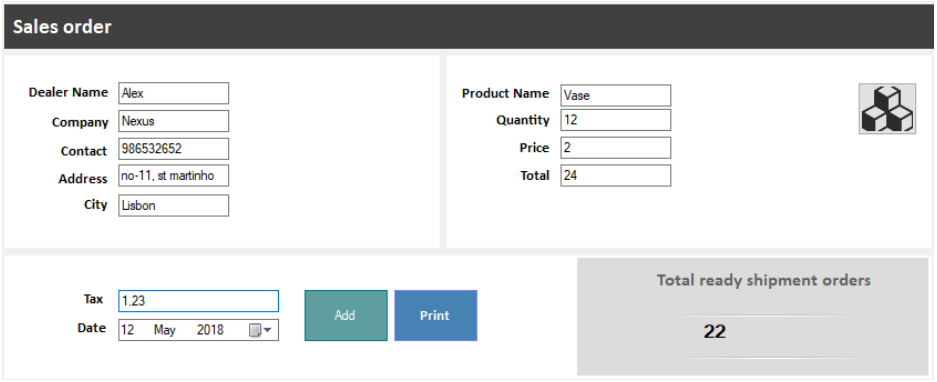

Figure 6-32-Sales order to place product orders

After all the required information is entered, the details can be stored into a single table by clicking on "Add" button shown in Figure 6-32. For the user working in the warehouse section they can generate a printable sheet by clicking on "*Print*" button for records purpose. The printable report for the list of the orders placed for the dealers is shown in Figure 6-33**.**

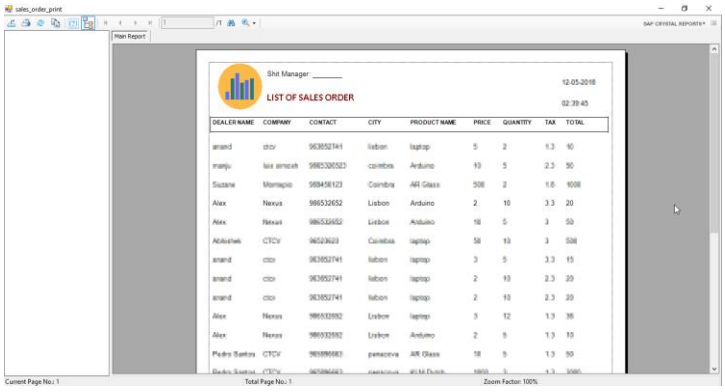

Figure 6-33-Printable report

To interpret the findings different actions were performed, starting with research about industry 4.0 and tracking technologies. During the research and study phase a research paper was also published on the 26th International Conference on Information System

Development (ISD 2017) Larnaca, Cyprus., September 2017 on "A Systematic Approach to Design Product Traceability in Industry 4.0: Insights from the Ceramic Industry"[6].

A successful research on industry 4.0 was conducted to review the type of traceability technologies available. That research has shown there were no reviews on ceramic product traceability earlier. With this thesis a research overview is provided to present an insight into the manufacturing industries, especially ceramic industry for many Industry 4.0 enthusiastic people. The objectives defined in earlier *section 1.5* were achieved in context with the published research paper. We analyzed the business process modelling of the ceramic industry through visual representation and projected a concept of introducing traceability technologies like RFID, Barcode and QR Code.

While performing the research we made an industrial visit to the case company. During the visit we explored many sections of ceramic product production. And further examined how and where they track the products. The following table shows the area where they have implemented certain technologies to keep track of the products.

	RAW MATERIAL PROCUREMENT	PRODUCT PROCESSING	WAREHOUSING	PACKAGING
BARCODE	NO	NO	YES	YES
QR CODE	NO	NO	NO	NO
RFID	NO	NO	NO	NO

Table 6-4-Tracking technologies role in the case company

Based on the research on tracking technologies performed we can define the areas where the following technologies can be implemented.

RFID	1. Product tracking in packaging and warehouse.
Barcode	1. Contains product code traceability. 2. End user can complain to the supplier in case of product defects. 3. End user can provide feedback.
QR Code	1. Contain product code traceability. 2. Restrict product information. 3. Improved advertisement. 4. Helps avoid product counterfeit. 5. Provide buying increased product value. 6. Entertainment (access to games, videos, and advertisement) 7. Marketing.

Table 6-5-Tracking technologies and its significance in ceramic industries

In addition to the research study and review, we furthermore developed a small prototype to show product traceability for the case company. It would allow the tracking of products in warehouse. While developing we have noticed that the RFID tag has less memory wherein we would not be able to store additional information like image file which is more than or similar to 2300 KB(Kilobytes) approximately. Hence, we performed an

RFID tagging to a cart. This will potentially reduce wastage of tags once used. We would add the list of products into the cart which holds a unique identification of RFID tag. Every RFID tag can be reused again without having to buy more. We are not storing the data into the RFID tag chip. But will use the tag number to differentiate each cart.

7 Conclusions

This chapter explains the strengths, limitations, and future work of this thesis work.

7.1 Strengths

The work performed in this thesis shows that the ceramic product manufacturing industries can implement industry 4.0 methods like traceability technologies to improve the product tracking. It is not yet being widely used by industry owners. Many industries are moving towards industry 4.0 for their growth and development in production to shipping. There are many who do reverse tracking as well to avoid product counterfeiting.

This thesis emphasizes on systematic approach in the ceramic industries to introduce tracking technologies like RFID, QR Code, and Barcode. In addition to the earlier technologies mentioned there are other technologies like Blockchain technology, which can also be introduced. We have explained how blockchain can help in supply chain.

The case company does not have a tracking system to keep track on products entering in warehouse. Therefore, considering this case, a test application was developed to perform product tracking in the warehouse. This application performed exceptionally well.

There are many business ERP applications in the market. To name a few, they are, SAP, ORACLE, SAGE, INFOR and many more. These applications provide services to industries at a high price. Therefore, a reasonable product is needed. Hence, we developed an application to perform the operation like product creation, deletion, RFID tag management, dealer-product management etc. This solved many areas of concern for the case company to solve the product tracking inside warehouse and product exit from warehouse.

7.2 Limitations

The work presented in this thesis is the review on the product traceability in manufacturing industries. Despite, industry 4.0 approach in manufacturing industries, there is always a risk of:

Table 7-1-Limitations of performed work

Risks	Limitation
Efficient Resources	Enabling the managers to have access to big data analytics to identify defects in the system to carry out predictive maintenance. The work presented will not allow big data analytics yet.
Talent	The employees or users working in the industry need to be well trained in the work process.
Data Security	With the approach of industry 4.0 the company must be aware of the threats to face as there are more challenges to tackle the cyber risk due. As industry 4.0 deals with internet of things. i.e., everything is connected in a manufacturing industry.
Future Potential	The work presented in this thesis does not predict the future of Industry 4.0 but explains its potential in ceramic manufacturing industry.

7.3 Future work

Considering the work presented in this thesis, we have made a few analyses based on research which can be improved for a modern industry 4.0 approach by the manufacturing industries.

The manufacturing industries must have a research and development team of people to learn and teach the employees to adopt new techniques of industry 4.0.

1. A standardized interface in machines to operate in manufacturing industries.
2. Reduce cost and improve productivity.
3. Sustainable potential in improving warehousing and logistics.
4. Replacing the development boards with much efficient hardware to operate with the application which will access large data.

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Appendix-A

Digitization

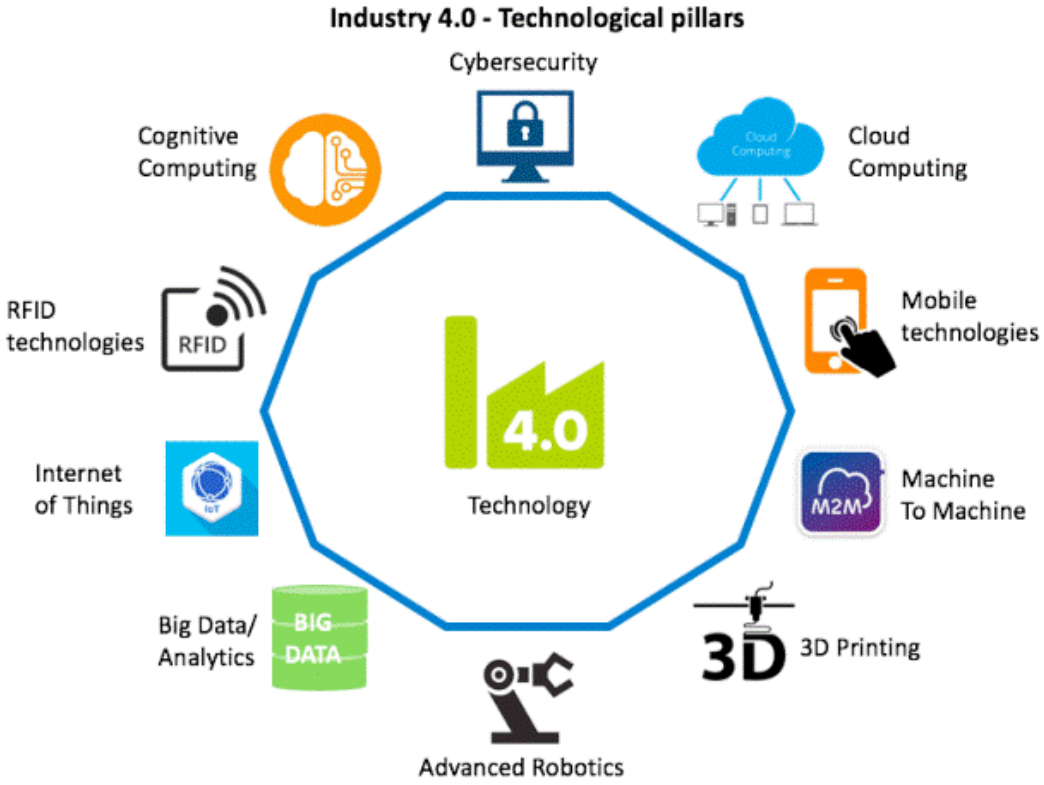
Industry 4.0 is driven by smart technologies to digitize the operation process throughout the entire organisation ranging from employee's data to product manufacturing. Employees can interact and share information digitally which adds value to the organisation. Product manufactured can be traced across all stages from production, packaging and logistics. Every stage of the product lifecycle in industry is available in real time, which make the production process intelligent and self-organised. Alongside this the data generated can also be used for predictive analysis for product development. This way digitisation adds value to organisations and consumers. The nature of product manufacturing is changing extraordinarily because of digitisation. For example, custom product manufacturing is done for consumers as the option available to consumers are in abundant.

Real time data analyze

The digitisation of product by addition of smart technologies like sensors and monitoring tools helps is generating data in real time. This will help in updating the product for consumers. By performing this will add safety, value and strong relationships with them. Industry 4.0 would not exist without data. At present large amount of data is generated and is stored on cloud. Cloud is model designed to store the data on digital pools. Nowadays it is a practice called as cloud computing. For example, many enterprises already started moving their datacentres to cloud with range of services like PaaS (Platform as a service), SaaS (Software as a service), IaaS (Infrastructure as a service). These services offer wide range of services and are flexible and can be made custom with respect to the needs of organisation.

Appendix-B

Ceramic production process



Ceramics are defined as a class of inorganic, nonmetallic solids that are exposed to very high temperatures during its production. Ceramics products include the multitude of products from unrefined clay and combination of refined clay and granulated non-plastic minerals.

Most ceramic products are made from single clay or mixed clays with mineral modifiers such as quartz and feldspar. The basic steps in ceramic product manufacturing operation is explained in detail.

Raw material procurement –

Initial process is acquiring the raw material, transport and store at the manufacturing facility. The raw materials used for manufacturing range from the impure clay materials from natural deposits to pure synthesized ceramic powder. Most natural occurring raw material include silica, sand, quartz, flint, silicates, and aluminosilicates.

Beneficiation –

Although the processed synthetic ceramic power does require beneficiation, the raw material at the storage facility does have to go through this process. Beneficiation process include comminution, purification, sizing, classification, calcining, liquid dispersion, and granulation.

Mixing –

To obtain a more chemically and physically homogeneous material prior to forming, the constitutes of the ceramic power is added with several processing aids during mixing stage or blunging. Mostly pug mills are preferred for this process.

Forming –

At this stage, the materials such as dry powders, pastes or slurry mixed and molded to produce a desired shape. And to achieve a proper shape the mold is suppressed under little pressure.

Grinding or Machining –

At this stage often, the ceramic product is grinded to remove the rough edges. Normally, stated as shaping, punching to create shapes.

Drying –

After Forming and grinding, ceramic must be dried to avoid distortion or shrinkage in shape. The common method used in drying is by convection. In which heat air is circulated around the ceramics. And is often exercised in heating covered chambers.

Thermal Processing –

Ceramic are treated under heat below the firing temperatures. The main purpose is to give an additional drying to vaporize the additional additives or impurities.

Glazing –

In this stage, dried ceramics are glaze coated prior to sintering. It consists of oxides and frit glazes. Oxides are in the form of minerals or ready to melt compounds in raw glazes. Glazes mature at temperature of 600º to 1500ºC (1110º to 2730º F). Raw materials are grounded in ball mills and glazes are sprayed or normally dipped depending on the size of the ceramic product.

Firing –

It is the process in which the ceramics are thermally formed dense. This process is also said to be sintering or densification. The basic parameters that affect the firing process is time, temperature and atmosphere.

Final Processing –

Further, following the firing process, ceramic products are refined to improve their physical characteristics.

Appendix-C

Different operating frequency of radio frequency

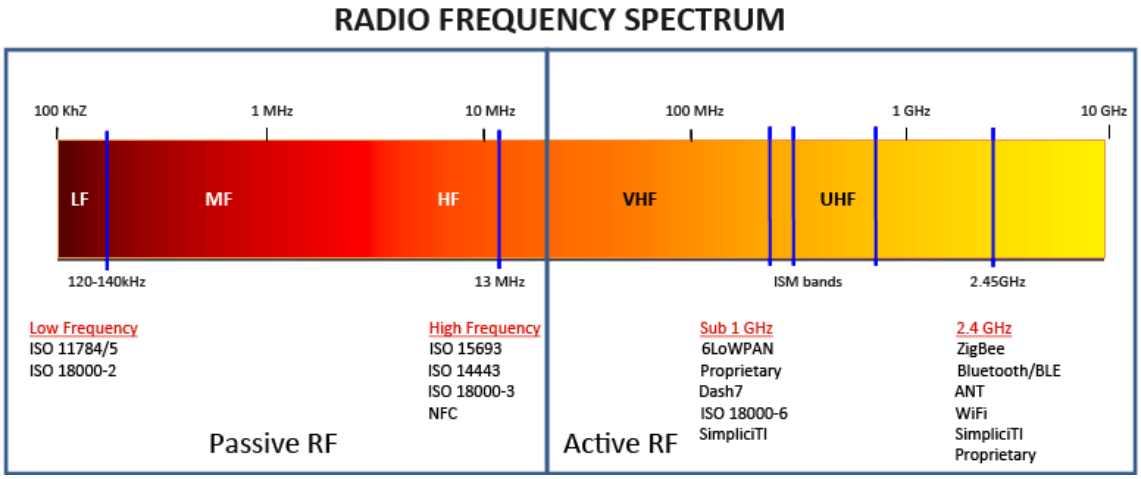


Figure 0-1-Radio frequency spectrum[31]

[31] RF-Spectrum: Coaxicom