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Impact of 4IR (The Fourth Industrial Revolution) by applying 3D printing Technology at Khoula hospital

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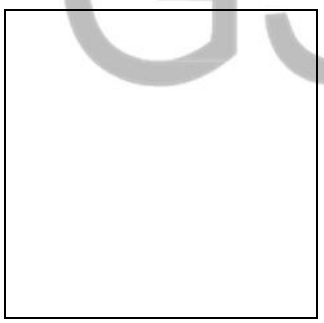

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I / We have examined this report titled" Impact of 4IR (The Fourth Industrial Revolution) by applying 3D printing Technology at Khoula hospital" submitted by Samiya Ali AL Aufi.ID No. PG18F1990 in partial fulfillment of the requirements of MBA (IT) Course during the Sumer 2020 semester.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this research is to analyze the impact of 4IR (The fourth industrial revolution) by applying 3D printing technology at Khoula Hospital. The relevance of 4IR is focused on the boundaries between digital, biological, and physical worlds. Moreover, 4IR is focused on the advance in 3D printing, artificial intelligence, quantum computing, robotics, and IoT, etc. Oman has better health in terms of the industrial revolution with the support of advanced technology. The study is mainly focused on the advantages of 4IR 3D printing technology, challenges face by Khoula Hospital in terms of implement 3D printing technology, determination of new technology requirements, and implementation of 3D printing technology in Khoula Hospital. Primary data collected from the process of interview and survey questionnaire by focusing the employees working in Khoula Hospital.

The interview and survey questionnaire consists of questions related to the topic of 3D printing technology. The interview was face to face interviews by focused on the employees in Khoula Hospital and two companies working in the same field.

The survey was an online survey by focusing on the employees working in Khoula Hospital. The population of the questionnaire was 30 and 26 participants have participated in the questionnaire. Three participants were selected as samples and checked the validity of the information through a pilot study. For doing the interview, the researcher selected the head section of the prosthetic department and companies' managers.

Secondary data collected through the support of books, articles, journals, and online sites. PSPP software is used for the data analysis purpose and charts and tables are used in this study to specify the response of the participants in this study. Mean has been applied to determine the average of the questionnaire data.

The overall intention of this research is to review the literature around 3D printing in the health sector and showcase how 3D printing will benefit the patients and medical staff in Khoula Hospital (prosthetic department) compared to manual measurement and fitting. There were many problems faced by Khoula Hospital due to the lack of advanced technology in

their workplace like the usage of present running technology leads to wasting of time, material, money, and efficiency of a product. The study has resulted that 3D printing technology will benefit the hospital by reducing costs and enhance the quality of work. The study concluded that 3D printing will help them to produce the prosthetic in a shorter time with less price and high quality. It is highly recommended that Khoula Hospital must utilize the benefits of 3D printing technology to enhance its working efficiency and make the patients highly satisfied. More research also needs to be done on the connection between artificial intelligence systems and the new devices to help in the manufacture of prosthetics.

Keywords: 3D printing, Technology, Khoula hospital, and Prosthetics, etc.

CHAPTER 1: INTRODUCTION

1.1 Introduction

The purpose of this research is to analyze the impact of 4IR (The further industrial revolution) by applying 3D printing technology at Khoula Hospital. The Industrial Revolution refers to the transition from a pre-industrial society to an industrial society (Vries 2008). The revolution is not required to be fast or sudden, but it targeted different new industrial sectors to increase productivity.

The industrial revolution started in England (Neuss 2015). Research, it's started there for many reasons. Firstly, the geography of Britain, which has a lot of rivers such as the farthest point from the coastline being at a distance of only 120 km. This contributed to making use of water transport and commercial exchanges between British ports and other coastal regions. Secondly, Britain encouraged entrepreneurs to invest in emerging industries. Thirdly, Britain was a growing Colonial Empire so it can provide the surplus products a market to be sold in. Fourthly, an abundance of natural resources and agricultural progress. Since then, Experts have defined four periods of industrial change, coining them new industrial revolutions.

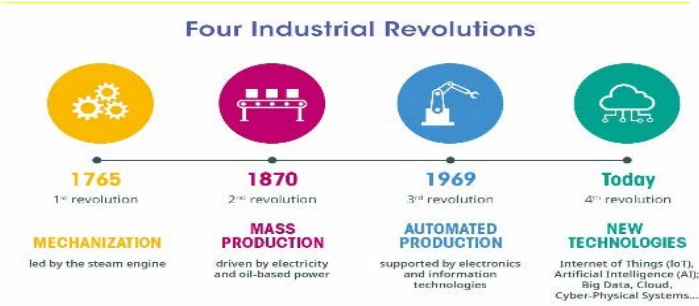


Figure 1.1 Four industrial revolution (visiativ soluation n.d)

First industrial revolution as the quick growth of particular sectors like iron and cotton and the transitioning of large numbers of people from working in the agricultural sector to work in the manufacturing sector (Agarwal and Agrawal 2017). They also discussed that the invention of the steam engine, power loom, improvements in iron technology making and an increased number of banks are the main reasons of the first industrial revolution.

The American Industrial Revolution as the Second industrial revolution (1860–1914). There were a lot of inventions that changed the lifestyle of people and business practices like

novel communication technologies (the radio, the telephone, the telegraph), internal combustion engines, electricity and chemical industries, and petroleum. In this period the rates of death and infections from diseases have decreased greatly as well as public health because of the inventions in medicine (Mohajan 2020).

The third industrial revolution emerged at the turn of the century, with the widespread use of technology in day to day life, with the internet enabling billions to communicate via digital personal computation (Rifkin 2012).

The fourth industrial revolution is one we are currently witnessing the beginning of. It is in many respects an evolution and continuation of the third revolution. It is marked by a transition from hardware to software, and the focus of combining biological, physical, and digital technologies (Guoping, Yun, and Aizhi 2017).

Technology has reached a point in the 21st century such that its development allows innovation and invention to propagate faster than ever. Although this has greatly improved modern life, it also set a new challenge in keeping the pace. The rates at which new technology is developed means that we now more than ever, require a lot of effort to keep up and stay up to date, or risk falling to more harmful or less efficient ways of manufacture. Such an example is the emergence of 3D printing (also known as Additive Manufacturing) over the past 40 years.

1.2 3D printing technology

3D printing is a set of processes in which different manufacturing materials are used in a mechanism that prints layer over layer. It is also a method for making 3D models where a complete model can be created in one whole process.

3D printing can be defined as the ability to produce object on-demand and with special features, after designing the object using programs such as SolidWorks, 3D Studio, LightWave 3D, and other programs where they enable designing complex parts with different shapes, by stacking layers of raw material on top of each other until the object is complete.

3D printing includes many manufacturing techniques; first, we can scan the object or design it, then divide the 3D model into thin layers called slices, then send it to the printer to print the slices layer by layer.

One of the advantages of 3D printing is that the raw material undergoes a single manufacturing process; in contrast to other manufacturing methods in which the piece passes through several stages, attaining new properties and shaping with each pass, thus saving a large amount of time and effort. 3D printing is characterized by the principle of customization, where the product can be customized and made to order.

Recently, 3D printing technology has played a significant role after the coronavirus pandemic. Taking center stage in rapidly prototyping, building, and deploying multiple pieces of medical equipment. The Brescia hospital in Italy ran out of oxygen valves and their supplier was unable to manufacture the required number at this critical time. Cristian Fracassi, CEO of Isinnova, used 3D printing technology to manufacture the oxygen valves and met the hospital's requirement for these valves, saving many patients' lives in the process. Anatomiz3D is an Indian company that manufactured face shields to protect to policemen, healthcare staff, and emergency service employees. Another example is the Chinese company Winsun, which contributed to equipping Xianning Central Hospital with 15 quarantine rooms using 3D technology in the Hubei Province. The local example is Oman InnoTech which produced 5000 masks and 200 oxygen valves with the same technology.

1.3 Healthcare in Oman

Oman has a well-developed public healthcare system, Omanis and GCC nationals get free healthcare through it, whereas residents receive subsidized care. Residents however often seek healthcare via the private sector through employer-provided coverage. Increased access to healthcare has helped increase the lifespan of Omanis from 49 years in 1970 to 76 in 2016. (Oxford Business Group 2020).

According to (National Center for Statistics & Information(NCSI) 2015) the quality and access to healthcare increases, Oman has seen a shift from communicable diseases such as measles and polio to non-communicable diseases such as diabetes. Further, with an increasing

population, set to almost double by 2050, Oman's demand for healthcare is set to increase as well.

Acceding to (NCSI 2020) In 2018, there were 5900 hospital beds, 900 of which provided by the private sector. With over 9600 physicians in Oman, the country has been investing in training its homegrown medical staff, with accredited universities at home, and with students studying medicine abroad, Oman has set its targets regarding Omanization, with Omanis constituting 71% of its workforce in December 2018. (Oman observer 2019).

Khoula Hospital was conceived as the premier surgical hospital in Oman. It was opened in 1974 and has since expanded with different departments added. It was selected by the British Royal Society of Orthopedics, Neurology, Orthotics and Correction as an accredited education center since, and has distinguished itself as the leading orthopedic and emergency medical center in the country. (Ministry of health 2020).

In October 2018, the newspaper Al-Watan reported that the cost of lifelike American-made limbs for 40 wrist and finger amputees was 40 000 Omani Rails. (AL Watan2018).
Khoula Hospital currently provides 2 types of prosthesis:

1) Artificial limbs: these limbs are for amputees, they receive a custom made-to-fit prosthesis, made by a technician, and are trained to use it in the hospital by the specialist which installs them.
2) Orthopedic devices: these are devices that supplement malfunctioning limbs. Whether through a degenerative bone or muscle disease, cognitive abilities, or for post-fracture care, they are wider in use and help people retain mobility that is otherwise lost.

1.4 Statement of the research problem

The best solutions for people who have lost a limb are artificial limbs, but the prosthesis further imposes different challenges such as discrimination or targeted behavior in public.

The problems lie in the current artificial limb industry that produces designs of general standards, not intended for each case, lacking realism; it is like an external piece that does not

integrate well to the patient's body, beginning with the shape and external color, and ending with its size which cannot fit the patient's body in some cases.

Even if these limbs have good measurements that do not cause additional problems like discomfort or the incompatibility of the artificial limb with the patient's body, it could still cause problems that may affect the psyche of the amputee. Be it the shape of the new prosthesis, which mostly comes in a way that most patients refuse to show, or apparent anomalies either in terms of color or lack of vitality that directly indicate that it is an artificial limb.

3D printers opened a door of hope for these patients, as it will enable them to get identical limbs and in turn restore their self-confidence.

3D printers use digital data to create any 3D anthropomorphic object, it makes a certain number of custom sections, called slices, and then prints each section on a specific layer. 3D printing technology will be used to a great extent in the service of the prosthetic industry, which will enable experts to produce these artificial limbs in more professional ways, about to sizes and the scales and their accuracy for each patient, as well as making artificial limbs that fit the shape and color of the patient's skin and body, and with vitality and proximity to the truly replaced limb in short time with less expense.

The idea of 3D printers is based on combining many different materials with different physical, mechanical, and biological properties in one building process, resulting in a 3D structure according to the inputs that were provided to the printer.

The hospital still using old manufacturing techniques to supply them that have also applied this new technology does not mean that the hospital will not face any challenges. Every new technology comes with its pros, cons, and challenges. Some of these challenges cost, staff needs to be trained to use new technology and other challenges which are explored with more depth in chapter 2.

This study will mainly focus on the advantages of 4IR 3D printing technology, challenges face by Khoula Hospital in terms of implement 3D printing technology, determination of new technology requirements, and implementation of 3D printing

technology in Khoula Hospital. Also, this study will focus on the achievement of Khoula Hospital by using and implementing 3D printing technology in terms of cost and quality basis. Moreover, this study will focus on the overall benefits for Khoula Hospital by using the 3D printing technology compared to the traditional technology in terms of the benefits to patients and employees working in Khoula Hospital.

1.5 Aims and Objectives

1.5.1 Aims

The overall intention of this research is to review the literature around 3D printing in the health sector and showcase how 3D printing will benefit the patients and medical staff in Khoula Hospital (prosthetic department) compared to manual measurement and fitting.

1.5.2 Objectives

At present, Khoula Hospital is following traditional technology and it creates lots of money waste, time waste, and lack of product efficiency. Hence, the researcher would like to overcome these issues by focusing on the adoption of 3D printing technology as part of an industry revolution. Hence, the objectives of this research study to overcome these mentioned issues are appended below.

1- To study and evaluate the current status of Khoula Hospital.
2- To identify the advantages of using 4IR 3D printing technology.
3- To identify the challenges that could stop the hospital from implementing 3D printing technology.
4- Best ways of implementation for 3D printing technology practices in Khoula Hospital.
5- To determine the requirements of the new technology.

1.6 Research Questions

1- What are the weakness that the hospital faces in its current situation?
2- How will 3D printing benefit the hospital?

3- What are the challenges that could stop the hospital from adopting 3D technology?
4- Which ways the employees prefer in helping them in implementing 3D printing? (previous experiences, training)?
5- What are the requirements needed to implement 3D printing technology in the hospital?

1.7 Scope of the study

The main focus of this study is to use the latest technology for manufacturing prosthetics in Khoula Hospital (prosthetics department). The new technology will print prosthetics by using 3D technology which is faster and cheaper. The project will be completed by September 2020 and will target the medical staff.

1.8 Research Significance

The health sector is like most other sectors in the modern era, depending a lot on information technology in order to contribute to providing better, more timely, and efficient.

The importance of this study lies in the introduction of the latest technology in Khoula Hospital (Department of Prosthetics). Where 3D printing technology stands to potentially greatly improve patient care and health services. It will increase the efficiency of work in the health sector and will enable it to keep pace with the widespread use of information technology. The research in Khoula Hospital will highlight the benefits of using information technology in the health sector and how it will save time and cost for the health sector. It will also reduce the patient waiting list, not to mention that the technology may serve other departments of the hospital. In addition, if this technology is adopted, Khoula Hospital will be a pioneer in providing service among the region's hospitals, as it will provide new jobs and contribute to raising the level of economy and building human resources.

1.9 Structure of the research

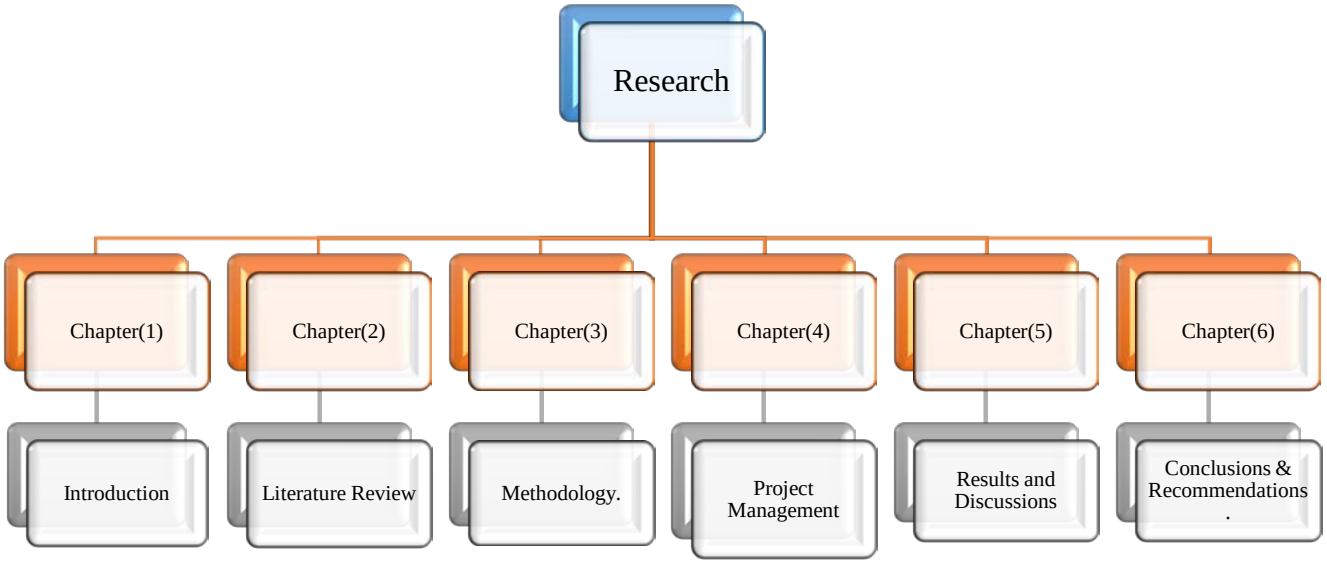


Figure (1.2) Research chapters

1- Introduction: this chapter introduces the problem, gives an overview of the study, and describes the need for 3D printing in the health sector. This chapter also discusses the scope, research questions, objectives, research methodology, significance, statement, hypotheses, limitations, and a summary of the study.

2- Literature Review: this chapter is about reading and evaluating many sources, including previous studies such as books, articles, journals, and meeting experts on the topic to get a clear idea about the research problem. Moreover, the literature review will lead to a deeper understating of how 3D printing technologies work and how it will benefit the hospital. The literature review further assures the readers that the researcher is aware of the research topic, and showcases their ability to evaluate, organize, and select relevant topics.

3- Methodology: this chapter covers the methods that researchers used to reach their objectives and how they answered their questions. This chapter contains research types (quantitative, ethnographic, qualitative, experimental), ways of collecting data (surveys, interviews), analysis methods, and the tools that help in that. In addition to that, the chapter will contain the obstacles faced and the methods used to overcome them.

4- Project Management; this chapter will show the project phases, scheduling, and the risk which could happen during the project.

5- Results & Discussion: the results will come after collecting data and analyzing it. The researcher can present their result by using tables and charts to add value to their research. Whilst in the discussion part the researcher will present their analysis, explanation, and comments on the results.

6- Conclusions & Recommendations: this chapter will show if all research objectives have been achieved, and showcase all limitations and give further suggestions for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Technology always came up with innovations for various aspects of life. The manufacturing sector is one of them. In need of more efficiency, improving its processes, and creating new objects. In traditional production processes (cutting or milling) items are crafted manually or using machines; consuming time and effort. To overcome all these limitations, 3D printing technology was created. 3D printing technology prints layer after layer to reach its desired model. 3D printing technology has become common in the past few years, and many fields such as; medical, educational, industrial, artistic, and culinary. With additional investment come lower costs, and with lower costs comes wider adoption.

This chapter will review the studies related to 3D printing to gain more knowledge and to show the readers how much the researcher understands the subject. In addition to that, the literature review will summarize, identify gaps, analyze the information, and will help in further research.

There are different sections to the literature review. Definition of 3D printing, how it works, the 3D printing timeline, its applications, types, benefits in the medical sector, and the materials used. Also, this chapter contains possible challenges that could stop the hospital from applying the technology, and a comparison between the traditional way of manufacturing and the new technology ending with what the hospital needs to implement it, and strategies, therefore.

2.2 What is 3D printing?

According to (Gokhare, Raut, &Shinde 2017) 3D printing creates 3-dimensional solid objects from a digital model by laying down sequential layers of material without hollowing or cutting out as in manufacturing. Besides, we can produce different and complexly shaped objects by using different materials.

Whereas (Bechtold 2015) stated that 3D printing as a term refers to a set of technologies that are different from traditional manufacturing (where the objects are produced by cutting, milling, casting, hollowing, manufacture, and stamping). In 3D printing, the objects are

created by extruding layers on top of each other. The 3D printing process starts with taking a 3D scan of a real object or designing an object using CAD software, then converting the model to usable code and sending it to the printer to produce the object.

3D printing is different from traditional methods in the industry, as it prints layer after layer on a scale of up to 1 millimeter per layer. Traditional methods of manufacturing depend on human labor and use several machines to produce the final product, all of this costs a lot of time and money. In addition to that, traditional manufacturing wastes a lot of the raw material during the manufacturing process (3D Printing Industry 2017).

2.3 3D printer timeline

- 1984-1988: Charles Hull worked for a company that produced ultraviolet lamps. He noticed that photopolymers solidified when exposed to ultraviolet light. He built stereolithography (SLA machine which used UV laser to print a simple object parts' layers each one in turn. layer by layer. He sold the first printer in 1988 for $100,000(Gregurić 2018).
- 1988-1992: Carl Deckard invented selective laser sintering (SLS) printer and it was able to print simple plastic objects by turning loose powder into a solid. Scott Crump invented fused deposition modeling (FDM). This technique works by melting a polymer filament to print layer by layer to get the 3D shape.
- 1999: In this year they printed the first organ (bladder) by using 3D printing and it was transplanted into a patient successfully.
- 2004: Dr. Adrian Bowyer invented the RepRap manufacture a 3D printer can print all its parts (self-replicating) (3D Sourced 2020).
- 2008: Shapeways launched a 3D printing service to help the people by printing their 3D files. (Dormehl 2019) and also in this year, the first 3D prosthetic was printed.
- 2011: In this year engineers from the University of Southampton (UK) designed and printed the first unmanned aircraft via 3-D printing technology and there was one part (the electric motor entirely) that was not manufactured by 3D printing only. The total cost was under $7,000 in one week (Marks 2011).
- 2012: In June in the Netherlands, a lower jaw was printed by LayerWise and it has transplanted on a woman’s face (BBC news 2012).

- 2015: In this year the spritam pill was printed using 3D printing and FDA (The U.S. Food and Drug Administration) approved, and the patients started to consume it (Basulto 2015).

(Paoletti & Ceccon 2018) they wrote about the history of 3D printing also;

- 1980–1981: Hideo Kodama filed for a patent describing an additive manufacturing technique utilizing solidifying resin. He did not follow up within a year, thus nullifying the patent.
- 1984: Jean-Claude André, Alain le Méhauté, and Olivier de Witte also filed a patent (and subsequently abandoned) whereby a sequential cross-section is traced by a UV laser, printing on the hardened resin in the process. Chuck Hull also filed for and was granted a patent for UV AM using resin in a tub, His company 3D Systems still manufactures 3D printers today, and as such, his use of the. STL format is still widely in use for Am
- 1987: Carl R. Deckard invented an AM technique whereby a powder of metal, ceramic, glass, or plastic is preheated in a bed just below its fusion temperature, allowing a pulsing high power laser to fuse the material into the desired shape. R. F. Housholder filed for a similar patent in 1979 but did not commercialize it.
- 1989–1990: S. Scott Crump patented a new technique, fused deposition molding (FDM), where a plastic-based filament is extruded from a print head in layers, utilizing. STL files. His company Stratasys commercialized patented machines starting in 1992, expiring in 2009.
- 1993: MIT developed a new technique that bound layers together using an inkjet printer and a bed of powder. Sanders Prototype, Inc., now Solidscape developed a new high-precision technique utilizing a polymer jet supported by soluble materials.
- 1995: The Fraunhofer Institute invented the selective laser melting process, This yields both precise and strong products. It is similar to selective laser sintering, but is superior in complexity and strength, as it completely melts and fuses the metal powder.
- 1999: Wake Forest Institute for Regenerative Medicine experiments with bio-printing techniques successfully.
- 2004: Adrian Bowyer developed RepRap, aiming to make self-replicating 3D printers.
- 2008: Shapeways launches in the Netherlands, a website where users upload 3D files and buy prints back. Today they employ a multitude of materials and methods.

- 2009: Makerbot releases the first DIY 3D printer kit.
- 2011: Southampton University Laser Sintered Aircraft successfully 3D printed a UAV structure via laser sintering machine, requiring no tools to assemble and printed with a resolution of 100 microns/layer.
- 2014: Airbus Operation GmbH patents a technique to print an entire plane's structure, utilizing inter-material deformation to further strengthen its structure.

2.4 How does 3D printing work?

(Mawere, Mukosera, & Mpofu 2014) wrote, the first step is designing a 3D graphic model by using a 3D modeling software like CAD (Computer-Aided Design) packages or scan existing objects to have a digital copy to manipulate in CAD. The second step is digitally slicing the model and this process divides the model into many horizontal layers by using a special slicer program like Astroprint or CraftWare. The final stage is to send the data to the printer to start printing its layer on layer.

The printer acts as a hot glue gun. After feeding the printer with strands of plastic it will heat it and the print head will move and deposit layer after layer until it forms a 3D model.

The process begins with a 3D model designed with a CAD program, and since the printer cannot turn the 3D mesh into a final printed model, the user will need to convert or decode the digital 3D model into printing instructions by using a program like Astroprint or CraftWare to slice each print layer in turn until we get our 3D object (Heddings 2018).

3D printing Applications

2.5.1 Education

3D printing is now used in many schools and colleges to help students understand in a better and novel way by modeling objects and studying it without the possibility of damaging the original one. An image on paper could not be as clear as dealing with a 3D model. For example, 3D models of chemical compounds and molecules can help chemistry students, and 3D models of human body parts can help biology students attain a better understanding.

1- To simplify complex theories for students.

2- Improving the student's skills and developing learning.

3- Increases the interaction of students and teachers with the subject.

4- The students will be more creative and it will improve their skills in design and problem-solving.

5- Encourage learning through exploration instead of learning from textbooks.

6- Scientific concepts will be more understanding by using physical prototypes.

7- It gives different models for different disciplines like robotics, medicine aerospace, and engineering (Reid 2018).

2.5.2 Construction and Architecture

There are a lot of benefits of using 3D printing technology in construction. From allowing more accuracy and complexity, reducing labor costs, faster construction, and less waste. 3D printing can produce foundations, concrete and walls to be assembled later in the site.

Examples: - In 2017 in Yaroslavl, Russia a full house was built with an area 298.5 sq meters. Everything in the house, walls, roof, and decoration were all printed with 3D printing technology (Watkin 2017).

3D printing technology was used to make a bridge in 2016 in Madrid, Spain, and was made from 8 concrete pieces that connected to create the bridge (12 meters in length and 1.75 meters in width) constructed by Acciona company (3ders.org 2016).

2.5.3 Art and Jewelry

3D printing helps jewelry makers in creating unique pieces with a complex design which they could not create with traditional methods. It also helps the artists to convert their ideas to real design with the same technology.

Jewelry designers will not be worried about massive production or complex design because since they have a 3D file. They can modify, customize the design, and print the plastic model first to check if the design and quality are up to par (Fabian 2016).

For example- the Boltenstern jewelry brand used 3D printing to create The “Resonance” collection. Marie Boltenstern created a bracelet in 18-karat gold and was printed by a 3D printer (Lansard 2020).

The Prado Museum in 2015 displayed paintings by José de Ribera and Greco, Gentileschi printed in 3D to allow blind people to feel these works.

2.5.4 Textile and Fashion

3D printed fashion can print everything from accessories and shoes to dresses. 3D printing technologies can easily produce jewelry and shoes but still find it very challenging to produce a dress without using a mesh system.

3D printing helps the designers in creating any design they imagine quickly and through new materials. This helps them to differentiate themselves from other traditional competitors. Further, 3D modeling applications and CAD help to create clothing that suits the customer depending on their body type.

For example: -

Adidas (sportswear manufacturer) cooperated with Carbon Company to create 3D printed shoes (Futurecraft 4D). In 2017 Adidas produced 5000 pairs of shoes with 3D technology.

2.5.5 Food

3D food printer creates layer by layer by using the extrusion technique from stainless steel capsules filled up with fresh ingredients. Printing and customizing different shapes and designs from chocolate is very easy with 3D printing because of chocolate's natural properties (It melts and solidifies quickly).

According to (Wiggers 2017) 3D printing will help in solving the hunger issue in the world, improve the nutritional value of meals, and produce complex designs.

For example: -In 2006 NASA started research for 3D printed food to help astronauts to have food on a long trip. In 2013 NASA cooperated with BeeHex to develop the Chef3D project which was able to 3D print a pizza for astronauts in space travel.

Food Ink is the first restaurant serving 3D-printed food. Opened in London and with everything in the restaurant being produced by 3D-printing; from the food to the chairs and tables.

2.5.6 Entertainment

The details in the entertainment and animation industry are very important, and entertainment professionals need to work for a long time and be well versed in what they are doing to get perfect models and turn imagination into reality. 3D printers help in creating complex designs with more innovation in shorter time frames and lower costs. 3D printing also creates characters, costumes, props, and even the entire set. In the Iron Man movie, the costume was printed by using 3D-printing.

2.5.7 Automotive

In 2019 the revenues related to additive manufacturing in the automotive industry reached $1.4 billion and according to a (SmarTech Analysisn.d.) report the expectation of the revenues will be $5.8 billion in 2025.

There are many benefits from using 3D printing in the automotive industry like: -

- Making quick changes and modifications in the design.
- Vehicles will be lighter and stronger.
- Replacing spare parts easily.
- Customers like to get unique cars and that cost the company and the customer a lot of money, but by using 3D printing in that matter it becomes easier and cheaper to build.

Examples: - Bugatti using additive manufacturing to produce car parts. They printed fin rear lights for Divo Supercar using 3D printing. Ford 3D prints two brake components parts for their Mustang Shelby GT500.

2.6 Materials of 3D printing

When it comes to choosing your material, you need to be aware of the purpose of the print, its quality, material characteristics, and cost. For example, to print food containers, food-safe materials such as PETG must be chosen, and if you need to print a prototype, why use an expensive material? There are a lot of materials available to 3D print, and the table below will explain some.

Material	Printers	Characteristics	Applications
Plastics			
ABS (Acrylonitrile Butadiene Styrene) plastic	FDM	Lightweight Abrasion resistant Affordable	Toys Sports equipment Prototypes
PLA (polylactic acid)filament	FDM- SLA-SLS	Environment friendly Renewable Made from raw materials	Surgical implants Food packaging Disposable clothing
Nylon	FDM- SLS	Flexible Strong Abrasion resistance	Textiles industry Medical prosthetics Phone cases
PETG (Polyethylene Terephthalate Glycol)	FDM	Food-safe material Hardness Ductility	Water bottle Medical tools
PEEK (Polyether ether ketone)	FDM - SLS	Resilient to stress, chemicals and temperature	MRI Spacecraft parts
PVA (polyvinyl alcohol)	FDM	Easily soluble Odorless	Paper adhesive Thickener Packaging film
Metals			
Aluminum	Binder Jetting	lighter	Automotive
Cobalt-Chromium	SLM	Corrosion resistance High strength	Medical and aerospace
Inconel	Direct Metal Laser Sintering.	Hold high temperature	Chemical and oil industries
Nickel	DMLS	Corrosion Resistant	Aircraft Coins
Stainless Steel	SLM	Strength Resistance to corrosion	Cookware
Titanium	Binder Jetting	Light Weight High Strength, Corrosion resistance	Aircraft Prostheses
Other			
Ceramics	FDM , SLA	Chemical stability Low density Dimensional stability	Kitchenware Art, pottery Biomedical Teeth
Wood	FDM	Wood-textured finish Flexibility	Household Decorations Toys

Table 2.1 3D printing materials (Pick 3D Printer 2019)

2.7 3D printing Types

Not all 3D printer uses the same technology to achieve their prints. It depends on the material that you need to create the object from. The table shown below showcases the most common technologies (Jasveer and Jianbin 2018).

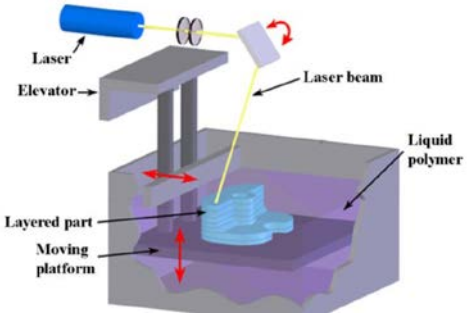
<table>
<tr><th colspan="2">Stereolithography
(SLA)</th></tr>
<tr><td>1- Fill the container with liquid photopolymer resin
2- Point the laser into the container and start creating the first layer by hardening it.
3- The platform descends by a small amount to allow another layer to be hardened
4- Repeat the process, layer by layer, until your model is complete.
5-Wash the model using alcohol.
6- Expose the model to intense light.
7- Cut off the support structures
8- Sand the surface into the desired smoothness.</td><td> 

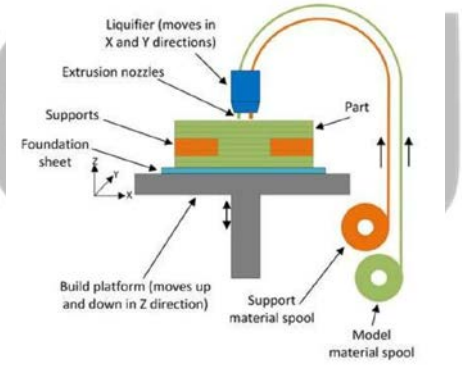
Figure 2.1 SLA technology(Hanzlicek & Pentek 2014)</td></tr>
<tr><th colspan="2">Fused Deposition Modelling
(FDM)</th></tr>
<tr><td>1- Pull in filament material to heat, melt and extrude.
2- Print the first layer onto the foundation sheet.
3- Continue the extruding layer by layer to form the model.
4-Temporary supports which come from the support material spool will be removed at the end of the process.et</td><td> 

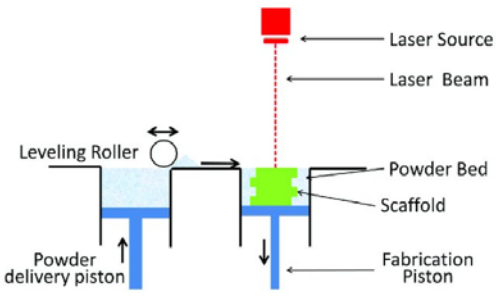
Figure 2.2 FDM technology (Gebisa & Lemu 2018)</td></tr>
<tr><th colspan="2">Selective Laser Sintering
(SLS)</th></tr>
<tr><td>1- Heat the powder to below its melting temperature.
2- leveling roller will bring a thin layer from the powder to the bed.
3- Laser starts to heat the first layer to above the melting point fusing it into a solid it. There is no need for support structures here.
4-The fabrication piston will move down to allow the new layer of powder to come.
5- Repeat steps 3 through 5 until the model is complete.
6- Leave the model to cool down.
7-Clean it.</td><td> 

Figure 2.3 SLS technology (Rider et al 2018)</td></tr>
</table>

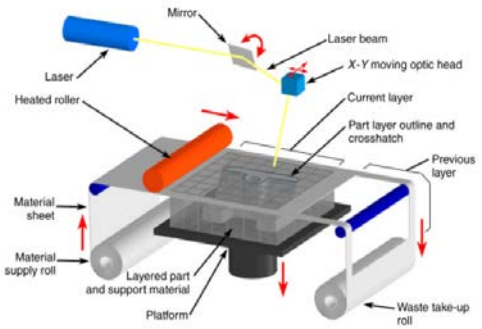
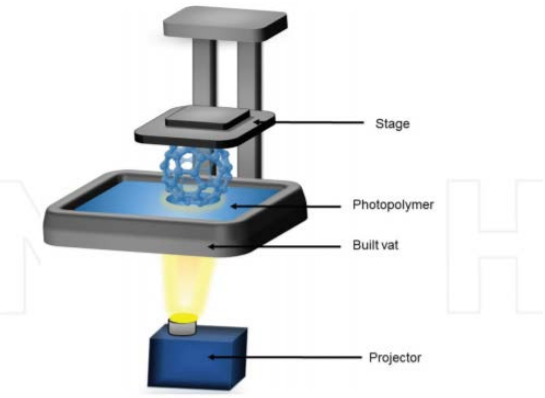
Laminated object manufacturing (LOM)	
1- A roll of material loads a sheet into a cutter. 2- The cutter (laser or blade) cuts the first layer onto the printing platform. 3- The roll provides a fresh sheet. 4- New sheet is stuck to the old layer (glue or fusion), and the new layer is cut. 5- New sheets and layers are stuck and cut until the model is complete (Sandeep & Chhabra 2017).	 Figure 2.4 LOM technology(Moritz and Maleksaeedi 2018)
Digital Light Processing (DLP)	
It is similar to SLA but using conventional light sources instead of a laser.	 Figure 2.5 DLP technology(Al-Hariri et al 2016)

Table 2.2 3D printing types

2.8 3D printing in medical application

- Optics
- hearing aids
- prostheses
- Virtual surgical planning
- Health Dental
- Medical Devices
- Bio-printing – printing living tissue using cells as ink/Printing Tissue and Replacement Organs
- Creating Surgical Implants
- Printing drugs

2.9 Benefits of 3D Printing in the Medical Field

(Aimar, Palermo, &Innocenti 2019) wrote that, in the healthcare field, 3D printing is helping to improve and save lives by offering more and more applications every year. 3D printing technology can be used in many areas such as neurosurgery, gastroenterology, oral, cardiology, and pre-surgical planning.

3D printing has been used in medicine since the 2000s, making custom prosthetics and dental implants. Recently, 3D technology has been used in exoskeletons, cell cultures, tissue, ears, eyeglasses, drug, and jaw bone. There are a lot of benefits from using 3D printing technology:

1. Save time and money by reducing the use of unnecessary resources, and manufacture complex products that would traditionally require frequent manual intervention/assembly.
2. Pre-surgical planning reducing the time and complications that could occur during the operation and human errors. In a study by (Sodian, Weber, & Markert 2008) it was shown that with the given set of patients, after having undergone multiple heart operations which resulted in the need for a full transplant, that 3D printing and rapid prototyping allowed the surgeons excellent pre-surgical planning; as “the surgeon can hold a replica of the patient’s heart” providing them with the best approach to the surgery, and giving the explant team patient-specific requirements.
3. Modeling the organ allowed for a better understanding of anatomy for each case separately.
4. Manufacturing prostheses and surgical tools.
5. 3D-printed improves medical students’ performance and increases their confidence. Instead of using cadavers for dissection, they can use 3D moldings to understand anatomical details better. It will help health organizations by sharing and printing many copies easily with different colors and densities.
6. 3D printing technology is used to educate patients; because in many cases the patients cannot understand 2D images, MRIs and CT scans as well as if the doctor explains to them using 3D molding.
7. Keeping the data about rare cases to train doctors and to perform more studies and research.

8. 3D technology helps jury members in court to understand the situation better overusing 2D images.
9. Help patients who need transplantation and saving lives by reducing the waiting list.
10. Bioprinting: to print tissue to help who are suffering from burns and reproduce their cells.
11. Customization and Personalized drug 3D printing. Medical equipment is often manufactured in specific shapes and sizes for all patients although each person's body is different. 3D technology can manufacture and customize medical equipment that will help the patient recover fast and reduce pain (C. Lee Ventola 2014).
12. The same technology helps serve different departments.
13. 3D printing data files can be shared between researchers. For example, instead of reproducing the model from scratch, the research can download files from a database and print the same model or exact medical device.
14. Flexibility. (Give the patient the freedom to choose different forms, sizes, designs, and colors).
15. Massive production so it will help many hospitals, and patients by extension.
16. High-quality Products.
17. 3D printing technology is flexible. Using different materials that help to design anything and produce them with any material.

2.10 Comparison between Traditional manufacturing and 3D printing technology

Regular manufacturing methods involve machining material down to its desired shape. It is thus dubbed subtractive manufacturing, as a material is removed to create the object. Additive manufacturing has only been recently made viable with the rise of 3D printing in all its forms. Its barebones operation revolves around creating an object by adding material in layers. Additive manufacturing has multiple advantages over its regular counterpart. Firstly, waste can be reduced significantly; a 3D printer only consumes material required to make the object in most cases, only wasting some when needing support structures, or if the technology used inherently wastes some material. When compared to regular manufacturing, milling and machining metal for example creates a lot of scraps; and even if it gets recycled, it still adds complexity and wastes energy. Injection molding. often require material to be injected and molded only to be removed.

Another advantage that additive manufacturing provides is in prototyping. Creating objects using a 3Dprinter often requires no novel tooling or machining, and a single printer can be used for multiple different prototypes. Prototyping using regular manufacture often requires large upfront costs, as new tooling or machines need to be purchased, and molds can cost thousands, using 3d printing only requires the material and the printer.

Additive manufacturing can also be useful in creating complex and customized parts. Complex geometries can be hard to achieve using regular manufacturing, whereas additive techniques can create objects within objects, or can combine several parts into a single assembly, with minimal post-printing processing required, and have the flexibility to customize each object as compared to a rigid unmodifiable process.

Regular manufacturing's biggest advantage is Large scale production, as opposed to prototyping, heavily favors regular manufacturing. 3D printing takes hours even for the smallest usable parts and mostly creates one piece at a time. Regular manufacturing can create objects at a much higher rate and enables mass production and assembly lines. Regular manufacturing has also matured to encompass a much larger pool of workable material, and with an extensive history, creating a non-novel item can be cheap and plentiful. Since the hospital is dealing with a few cases so the massive production is not a problem. What this research focus is to introduce the technology to the hospital and also in other advantages that the patients will gain.

According to (Kol et al. 2019) the comparison between the processing time of making prosthesis in both ways is almost the same. But using 3D scanning is not requiring any effort from humans and it will be saved in a database of patients in the purpose of using it again and the model also can be customizing for each patient.

3D printing Technology		Traditional manufacturing	
	Scan the feet to know the diminution and to get a digital file data.	 	Press the foam box to create the model.

	Used software like CAD to work and to prepare the model for printing.	 	Work in the model to get the right shape by smoothed and trimmed it.
	Print the model.		Vacuum forming and add the heel.

Table 2.3 Comparisons between 3D printing Technology & Traditional manufacturing (Jin, Y. et al. 2015)

2.11 Challenges of Implementation of 3D in hospital

- Cost
- Fear of Change
- Lack of specialized human resources
- Country economy
- Ignorance of modern technology and questioning its efficiency
- Administration
- Few patients
- Articles from outside the country
- Lack of researchers specializing in technologies in the health field
- Lack of technical laboratories to keep pace with technological progress in the world
- The desire to continue hospital use of old techniques
- Lack of volunteer patients to use the new technologies
- Lack of societal cultural awareness
- Failure to abide by the state's strategies for developing the health sector.
- Maintenance

2.12 Example of using 3D printing

2.13.1 Canada

Nia Technologies is a non- profit organization supported by the University of Toronto research. Nia helps the people in Uganda, Tanzania, and Cambodia who lost their limbs. CEO of Nia said they can produce in one day and a half instead of the five days and they use nylon

to produce it. Nia also transfers knowledge and train people in those countries. In 2015 Uganda produced 40 prosthetics for children. (University of Toronto 2016)

In 2017, 140 children got benefited from this technology and the studies showed how much is this prosthesis is durability and appropriateness and that after they tested it and meet ISO 10328:2006 standards. (Nia 2018)

2.13.2 Jordan

(Al Jazeera 2018) mentioned that Doctors Without Borders (MSF), established a prosthetic production center in the Jordanian city of Irbid. A team of doctors and technicians use this technique to help people born with genetic deformities as well as war-wounded people from all over the region.

2.13.3 Untied Arab Emirate

Dubai Health Authority uses 3D printing in many medical fields. The Health Authority cooperates with international companies to become a leader in the region, and further, the world. In 2017, the authority made a prosthetic leg for a British woman residing in Dubai, and a year later also made two legs for an Emirati citizen after he lost them both when he was seven.

Belinda Gatland and Fahd Muhammad showcased their complete satisfaction with their prosthetics because it enabled them to practice their normal lives and how a three-dimensional technique has made their prosthetics appear more natural.

This technology has also been used in manufacturing dental molds. It is possible to manufacture 54 dental molds in one day compared to making one using traditional methods, taking an hour and a half each (Albayan 2018).

2.13.4 Oman

A medical team at Sultan Qaboos University Hospital replaced a leg bone for an 18-year-old patient, through a 3D printing technique. It is the fourth of six operations around the world (three operations in Germany, two operations in the Sultanate, and one in Australia) (Times of Oman 2019).

2.13Critical evaluation of literature review

Some studies discussed the 3D technology in a general way (no specific topic) but the structure was organized very well and the reader can create a general and quick idea about 3D technology. The studies which discuss one topic gave further information such as the study which was about explained four different types of 3D printers and this study adds one more type.

The gapes in some studies needed to use both methods (qualitative and quantitative) to have a clear idea about the topic.

The range of cited studies is 7 to 89 on Google Scholar which gave reliability to the information in those studies.

Most studies agree that using 3D printing in the production of prosthetics will benefit the patients more. In addition to that, advantages are much more than negatives (which can be overcome such as financial resources and training) and technology improve quickly in this field.

This research gives a platform based on using 3D technology in the medical sector and need to do more research in terms of which material is better? further investigation in processing, performance, and stability of artificial parts.

2.14 Conclusion

This research pointed out the benefits of 3D printing and what are the challenges that the hospital could be facing? The literature review gave also some examples of (types, materials, application) of 3D technology. After this chapter, the methodology chapter will discuss, research method and design, sample size and technique, and population of the study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the approach of the researcher regarding collecting data about 3D printing technology in a hospital setting, its advantages, challenges, and requirements to implement. The research design addresses the researcher's overall structure and methodology.

Research design covers collecting data, measurements, and analysis. A clear correlation between the problem at hand and the approaches are chosen (surveying, experimenting, studying, etc.) enable the researcher to establish credible results and recommendations. Designing a framework of data collection by which the researcher then acts to gain the required knowledge.

3.2 Research Methodology

Research is a systematic process of collecting a lot of information to analyze it, come to a conclusion, and document it so that others can use it. The research process includes eight steps: -

1- *Identify the problem* it could be a problem to solve, the question to answer, or needs to satisfy.
2- The researcher must *review the literature* related to the research questions and read more to get a clear idea about their topic.
3- Clarify the problem by *narrowing the scope of the study* and that cannot proceed without the literature review.
4- *Concepts and terms* should be clear and more specific to reduce the reader's confusion because terms can often have different definitions that will otherwise depend on the reader's knowledge level about the research topic.
5- The researcher has many options to identify their study group *(Population).* They could investigate a specific age, gender, or group of people living in the same area. Selecting an appropriate population allows the researcher to stay concise and to the point, and allows clear research to be conducted (i.e. children would be bad subjects for a political study).

6- The researcher develops an *Instrumentation Plan* to know the data they need, how to collect it, who will collect it, and how it will be collected, ending with how they plan to analyze their gathered data.
7- *The collection of data* is an important step to answer the research question. There are different types of data (primary and secondary) and it could be presented within a literature review, survey, interview, or articles.
8- The researcher finally has *data to analyze* so that the research question can be answered.

3.3 Research Onion

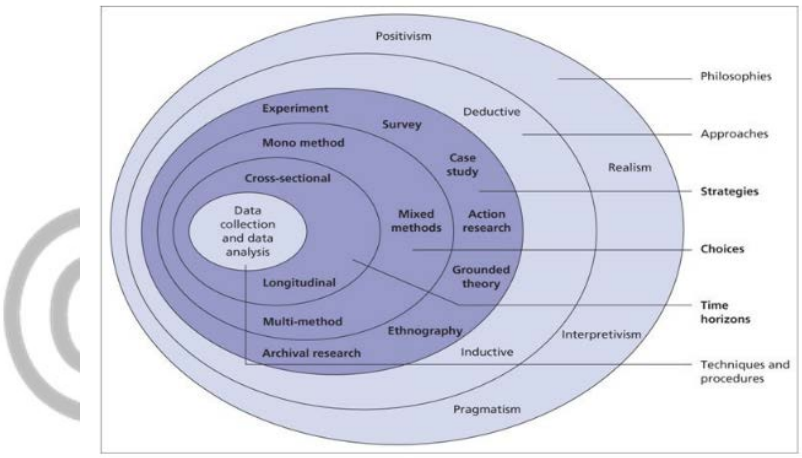


Figure (3.1) Research Onion Image source:https://www.allassignmenthelp.co.uk/blog/research-onion-made-easy-to-understand-and-follow/

The research onion is a methodology devised by Saunders et al. in2007. It describes a layered approach to data collection, whereby a researcher starts by analyzing and defining research philosophies, from which developing a methodical pattern to collect their data, moving into their strategies and time horizon, finally reaching data collection and analysis. This layered approach allows for a methodological approach to research and obtaining knowledge, by which the presentation of the research allows the reader further insight into its credence, and give the reader the tools to recreate or advance the study's findings.

This research will use the onion methodology and will go through the layers' layer by layer. This is the first layer of the research onion and there are three types of philosophies and they are ontology, epistemology, and axiology.

3.5.1 Research Philosophy and paradigms

This is the first layer of the research onion and there are three types of philosophies and each one has its paradigms as shown in figure (3.2)

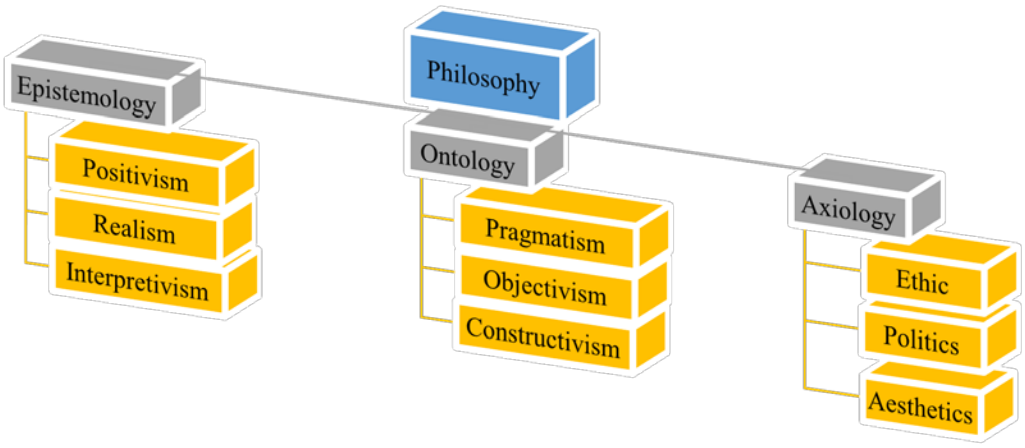


Figure (3.2) Philosophy Diagram

We need to know which philosophy is suitable to study 3D printing and which one is best in answering the research questions. Figure (3.3) gives a quick overview and comparison between the three philosophies and examples of questions that are used in each one.

In this research, epistemology will be used, because it will help researchers to develop their knowledge and understanding about events based on clear evidence and must be supported by evidence and measurements. Moreover, in terms of axiology, this research has strictly followed ethics and this study is free from the ethical issues like social, legal, political, and environmental, etc.

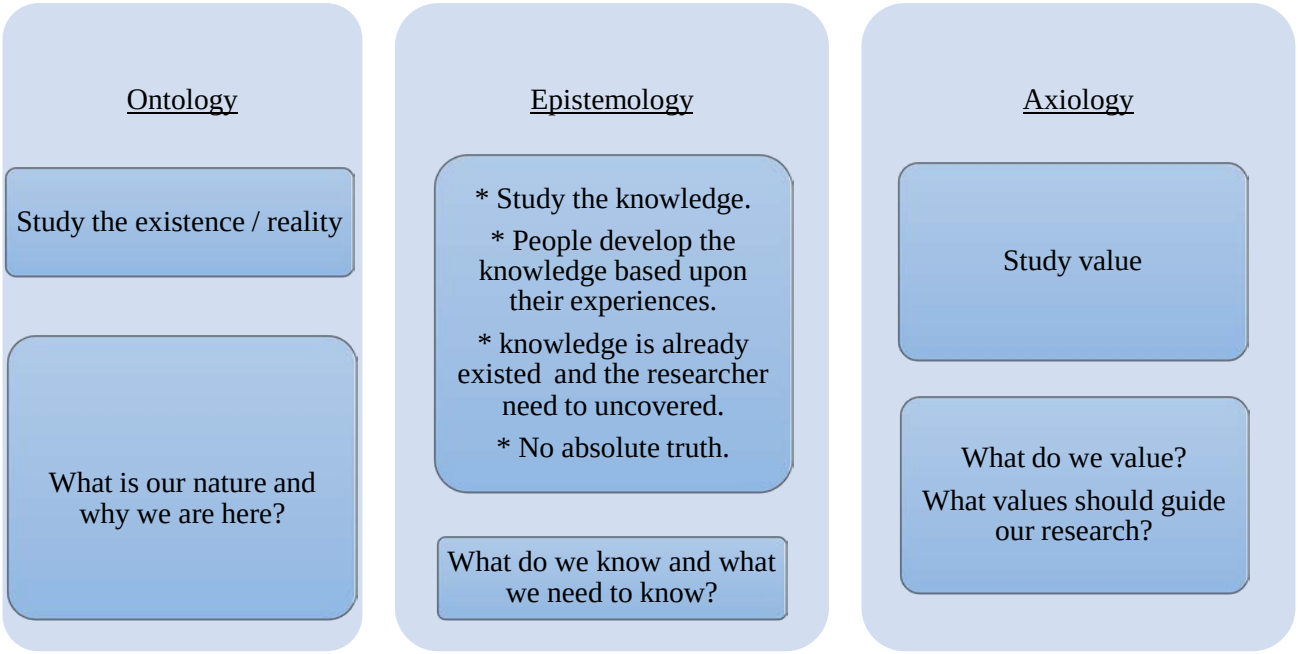


Figure (3.3) Philosophy compression

3.5.1.1 Epistemology

Epistemology the study of knowledge (reality). What reality is and how to approach or gain that reality? In this philosophy there is a relation between the study (reality) and the researcher; because they are trying to examine, understand, discover, interpret and measure the knowledge according to the way they are seeing the world around them.

Epistemology Philosophy is about knowledge (generated), evidence (gained), and findings (transferred) needed for the research and how one can arrive at that knowledge from their point of view (Solomon 2018).

3.5.1.2 Epistemology philosophy paradigms

There are three different paradigms that come under epistemology philosophy: The positivism paradigm, the interpretivism paradigm, and Realism paradigm.

- Positivism paradigm

It helps researchers to develop their knowledge and understanding about events based on clear evidence and must be supported by evidence and measurements (Pham 2018).

- Interpretivism paradigm

It is qualitative research that deals with explaining social facts, avoiding numbers, observing events, actions, work processes, employee's behaviors, and standards from the participants' perspective (Idowu 2016).

- Realism paradigm

The realism paradigm combines the interpretivism and positivism paradigms and it focuses on evaluating the data and giving suitable changes to solve a problem. There are direct and critical divisions in realism.

Positivism	*Interpretivism*
Quantitative	Qualitative
Deductive	Inductive
Questionnaire	Interview
Statistical analysis	Describable analysis
Explanation/strong prediction	Understanding/weak prediction
What is general	what is specific
large samples	Small samples
measurement	investigations

3.2.1.1 Reasons to choose epistemology philosophy

3D printing technology research use epistemology philosophy because it is clearer and knowledge already exists. The researcher needs to discover it and transfer it to others. The study can use any type of knowledge: textual, visual, and numerical data.

This research uses the realism paradigm because some objectives of research need more investigation, be it by conducting interviews with specialists in 3D technology or by using a questionnaire. Exploring alternative methods leads to further understanding deepens the answers to the research questions.

The research covers both, the social science which is relevant to peoples' actions (help to answer a question no 1-2-3-4), and natural science which is relevant to information systems (help to answer a question no 5).

3.5.2 Research Approach Type

Here the study goes to the second layer which disuses the approach type and this research will discuss the inductive approach because it is applying in this research.

3.5.2.1 Inductive approach

The inductive approach works from specific to general (bottom-up), and it is based on observations. Here the researcher can develop a theory because there is little literature on the subject.

The inductive approach has three stages.

Observation → Producing prostheses is delayed with the old manufacture processes

Pattern → Another 30 prostheses are delayed

Theory→ old manufacture process always has delays

Limitations: - Researchers cannot prove any conclusion and can have their theory invalidated.

For example, you watch 30 prostheses being made and all are delayed, lining up with the theory, but you cannot prove that prosthesis #31 will be delayed as well.

3.5.2.2 Reasons to choose the inductive approach

This research will gather data that is relevant to 3D technology to get an overall idea about it. Starting with observations, questioning the current situation to understand how best to meet the needs of the hospital from the new technology.

From this data, the research will develop a set of recommendations and hypotheses for other researchers who might want to do further research on the same topic.

By using the inductive approach, the researcher can move from this specific experience (in Khoula hospital) to a general one (whether it is the use of 3D technology in other hospitals or in other medical applications within the same hospital). One more reason to choose this approach is that it will not test the hypothesis.

3.5.3 Research Strategies

The third layer is about research strategies. The decision here is deciding which method is best suited to collect the information needed to answer all of the study questions effectively. There are many ways to collect data: experimental, interview, case study, survey, focus groups, and observation strategy. For this study, the following will be used:

3.3.3.1 Interviews Strategy: it is the most commonly used method to collect rich data from a small group of people, and it has different types (unstructured, semi-structured, structured). The researcher should be able to communicate with people and have many skills, such as: social, listen, analyses. Interviews consume time and effort but sometimes the researcher needs to answer questions that cannot be answered by using other methods.

3.3.3.2 Survey Strategy: this method allows to researcher more participants and it is commonly used in business research. Questionnaires should be easy to understand, short, and meaningful to answer the research questions. Researchers can use online sites to help them design and distribute the survey to participants because it is cheap, widely available, and helps organize the responses. Researchers need to decide the size of the sample as well to measure the investigated issue accurately.

3.3.3.3 Reasons to choose interviews and questionnaires There are a lot of research strategies and this research will use interviews and questionnaires because surveying can answer questions about the current situation in the hospital and beyond, and identify evaluate challenges in implementing 3D printing. The question about the new technology's requirements need people who have experience in this field so we can benefit from their experiences as compared to possibly inexperienced hospital staff who possibly cannot provide the best answers.

3.5.4 Research Methods

In this layer, the researcher needs to define which method (quantitative-qualitative) they will use. Only one of them or both, and if they will use them equally or one more than the other.

3.3.4.1 Quantitative researchers test theories to reject or support the hypothesis by using arguments, evidence, and logic. Researchers use literature reviews in more detail to justify and identify the reasons for their research, inform their hypotheses, and ask their research questions. Analyzing here is statistical (it's about numbers, measurements, and quantities) and the researcher should understand the relationship between the variables. They can present the results as graphs and tables and test small samples, that could then be generalized.

3.3.4.2 Qualitative methods, the researchers gather data from participants (spend a long time in the field and analyzing their data) by asking questions and communicating with people to discover their opinions to develop a theory and analyze the data by describing the process and using persuasive and expressive language.

Conclusions could continuously change as more data is collected and the researcher can move from specific conclusions or theories to generalizations.

The literature review is brief here and is used to identify the main problem that will be solved by the inquiry and help it in providing evidence for the purpose of the research.

1- Mono-method [one data source only + qualitative or quantitative]
2- Mixed-methods [multiple data source + qualitative and quantitative]
3- Multi-methods [one data source only + qualitative and quantitative]
(AllAssignmenthelp 2017).

3.3.4.3 The reasons for the chosen mixed methods

In this study, mixed research methods (qualitative and quantitative) were used. The research aims to evaluate the current situation in the hospital and attempts to highlight challenges that could prevent the technology's adoption in the hospital.

The research used descriptive and analytical methods because it is best for answering the research questions and gathering comprehensive data about some questions. It also reflects the participants' point of view and reduces the time and effort needed due to modern technology enabling single platforms to collect data using both methods (Zefeiti& Mohamad 2015).

3.5.5 Time Horizon

The fifth layer is time horizon and there are two types of time horizons a researcher can utilize, them being cross-sectional and longitudinal.

1. Cross-sectional: it is used for short-term studies, covering only a single point in time. Researchers using this horizon can look at multiple prevailing characteristics in a population at once and can provide a picture of what is currently happening within that population.
2. Longitudinal: it is used for long term studies, and can cover multiple points in time. Researchers using this horizon look at set variables within the population and observe how they change over time. This method is especially useful regarding lifespan issues or development and can help the researchers examine why such developmental changes take place.

The reasons for the chosen Cross-sectional

This study is a short-term study and will start after approval for the survey and interview questions is granted. The survey will take one day to design and create, using Microsoft Forms. A link will be sent to participants to fill the form in ten minutes, giving a week to complete. The interview will take longer because it needs more arrangements but the data will be collected on the same day. (approximately one week after approval)

3.5.6 Research Techniques and Procedures

The last layer is how the researcher will collect and analyze their data

3.3.6.1 Data Collection

Data collection is a process of collecting, measuring, and analyzing data by using standard validated techniques. There are two types of data, primary data, and secondary data. Primary data is the data that the researcher collects for the first time, whilst secondary data refers to exiting data that the researcher has used. The collected information should be rich, related to the subject, and reliable so the researcher can make the right decisions and give a valid recommendation.

The researcher must disclose and outline their data collection methods, as it is a crucial step, regardless of the research field (Kabir 2016).

3.3.6.2 Research Population and Sampling

To answer their research questions, the researcher will not able to gather and analyze data from an entire population. Thus, they will select a sample and then generalize their findings. This will go through several stages: specifying the target population, selecting the frame, choosing a technique, sample size, collecting data, assessing the response rate (Taherdoost 2016).

- Sampling methods and technique

Probability sampling methods: every individual in the population has an opportunity to be chosen and used in quantitative research. The results represent the entire population.

		Green star = sample
Random sampling	Systematic sampling	
 Age (20- 30)	 whole sample with similar characteristics	
Stratified sampling	Cluster sampling	

Table (3.1) Probability Technique

Non- probability sampling methods: the selection of participants based on specific criteria and not every individual in the population has a chance to be chosen. It is used in qualitative and exploratory research. The results do not represent the entire population.

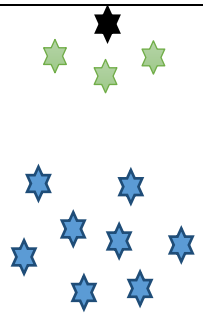
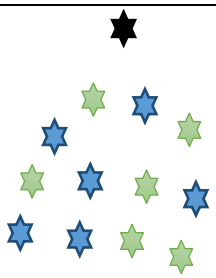
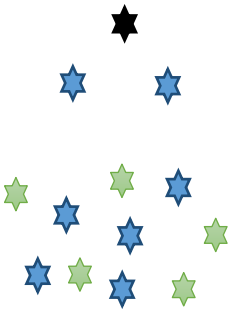
 Accessible sample	 people volunteer themselves	Green star = sample & Black start = researcher
Convenience sampling	Voluntary response sampling	
 Who most befits for the research	 Targeting participants through other participants	
Purposive sampling	Snowball sampling	

Table (3.2) Non- probability Technique

➢ Sampling size

Sample size selection is a very crucial step and leads to accurate findings and the successful running of research. If the sample is small, it might not get the most accurate results, and if it is big it will take the researcher more time and effort to collect.

How to calculate sample size?

1- Calculate the sample size for an infinite population → $S=Z^2 * P * (1-P) / M^2$

S → sample size for infinite population

Z →Z score (determined based on confidence level)

Confidence level	Z value
90 %	1.645
95%	1.960
99 %	2.576

P → Population proportion. [Safe choice is a standard deviation (Assuming 50% = 0.5)]

M → Margin of error. The small amount that is allowed for in case of miscalculation or change of circumstances = 5% = 0.05

$S = [\ [\ (1.96)^2 * (\ 0.5 * (1-0.5)\ )\ ]\ /\ 0.05^2\ ]$

$= [\ 3.842 * (0.5 * 0.5\ )\ ]\ /\ 0.0025$

$= [\ 3.842\ * (0.25\ )\ ]\ /\ 0.0025$

$= [\ .960\ ]\ /\ 0.0025$

$= 384.16$

2- Adjust the sample size to the required population → S=S / [1 + [(S-1)/ population]

Sample = 384.16 / [1+ [(384.16 -1) / 30]

Sample = 384.16 / [1+ [383.16 / 30]]

Sample = 384.16 / [1+ 12.772]

Sample = 384.16 / 13.772

Sample = 27.8

Sample = 28

Since the number of staff is small, the ideal (given full response) sample will be all of them (30 participants) and conduct two interviews companies (InnTech company / Atoms Lab company)

3.3.6.3 Data coding

Data coding is defining numerical codes to non-numerical information. Data is coded to compress information and ease of handling later.

- Quantitative coding

Q.no	Item	Code	Value
1	knowledge	Know	Expert = 1 Adequate = 2 Heard about it = 3 Not at all = 4
2	No of patients	Pat.no	5-10 = 1 10-15 = 2 15-20 = 3 More than 20 = 4

Table (3.3) coding

- Qualitative coding

Inductive coding comes from terms used by the participants themselves around the subject and the code must stay close to the data. The process starts with many initial codes that the researcher can then categorize.

Deductive coding, coding here is complicated, and codes are very limited because the list is predefined (before the researcher can code their data) (Linneberg& Korsgaard 2019).

3.3.6.4 Pilot Testing

Pilot testing is an initial process before launching the survey to all participants to make sure that every question is valid and reliable and the researcher will not get unusable/incorrect answers. It also helps to get feedback from a small group so the researcher can fix any weak points in the survey, make sure that the right questions are asked, manage time and tune and test the validity of the study.

3.3.6.5 Data Analysis

Data analysis is the tool or way that the researcher used to analyze the collected data to answer the research questions and come to conclusions.

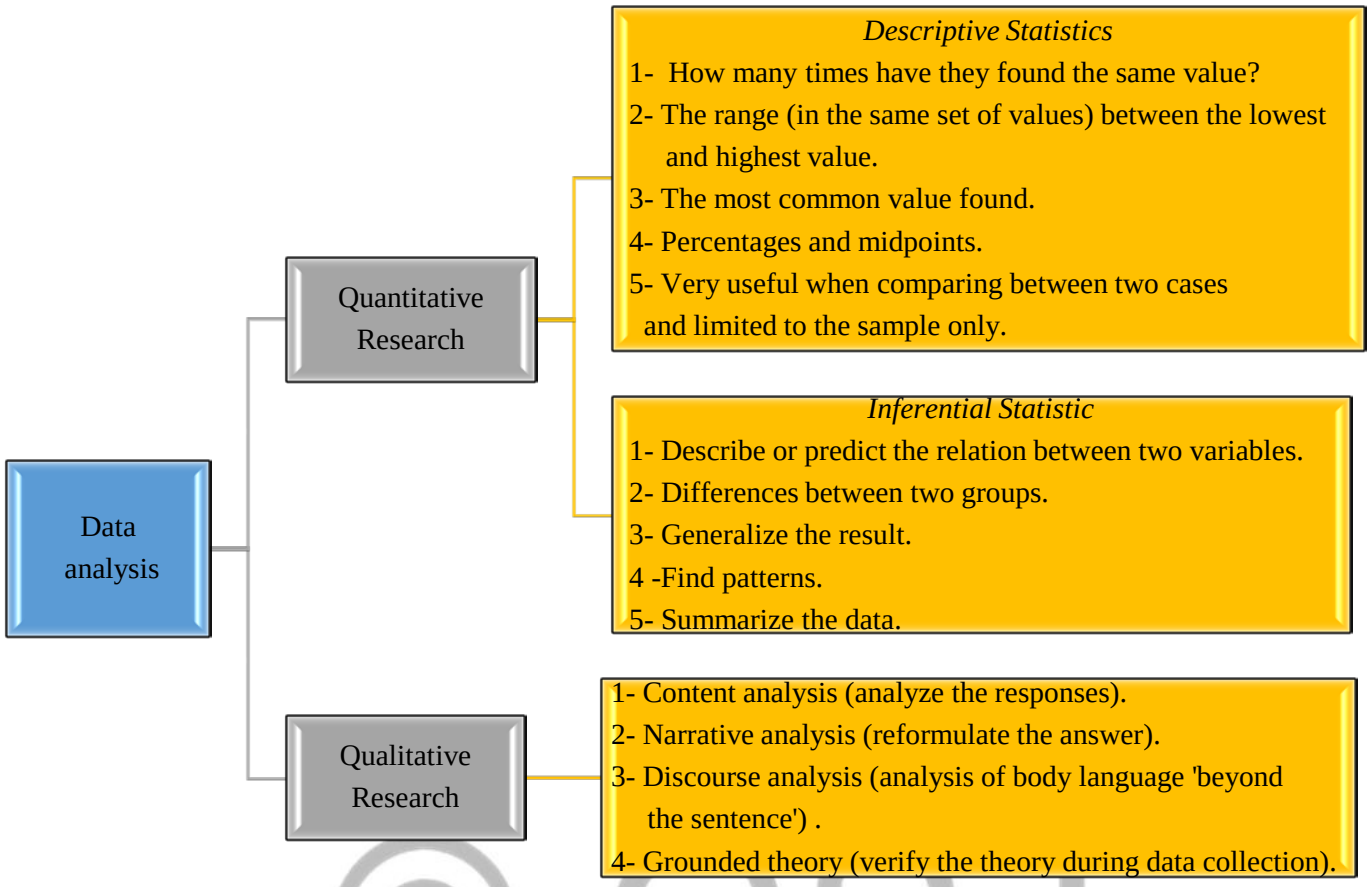


Figure (3.4) Data Analysis

3.4 Ethical Approaches

(Akaranga& Makau 2016) said that research's goal is sharing knowledge with others via publishing studies on websites, books, journal articles, and dissertations. Researchers must conduct themselves in the right manner when conducting their research, and that will not happen unless they follow set ethical principles.

Ethical principles are a set of rules outlining principles researchers should follow when they are collecting their data and how they should deal with their participants. This research follows rules of ethical principles for data collection, dealing with participants, respecting participants, avoiding disciplinary procedures if there is no permission and it is also considered a professional requirement.

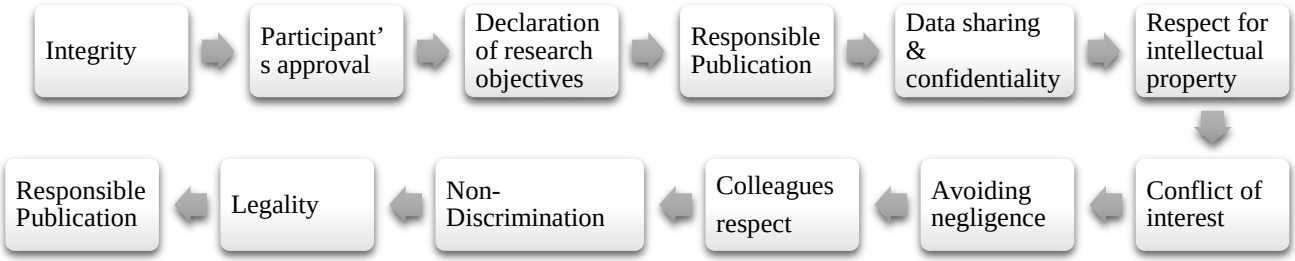


Figure (3.5) Ethical principles

This research is used by qualitative and quantitative methods like the survey questionnaire and the interview for the primary data collection. The importance of interview and survey questionnaire is that it will support to collect the most relevant data related to the research topic. Hence, the strategy of conducting interviews and survey questionnaire will support to address the research problem effectively. The main reason to select interviews and questionnaires is it will support make the research very efficient by providing valid information related to the topic.

Moreover, the researcher prepared the interview and questionnaire and some of the examples for the structure are given below.

❖ Interview Questions

1- Do you have an idea about using 3D technology in Oman?
2- What are the benefits of using 3D printing technologies, as compared to traditional manufacture? (saving time and money / better quality)
3- Do you have any idea of pre-requirements? What requirements did you have to meet in starting your project (hardware/software/budgetary/human recourses)?

❖ Survey Questionnaire

1- As compared to traditional manufacturing, 3D printing will be:
   - o More efficient.
   - o As efficient.
   - o Less efficient.

2- What are the most important advantages you want in 3D technology?
   - o Saving time and money.
   - o Reducing the waiting list.
   - o Higher quality products and Customization.

- Improving the medical staff's performance and reducing human errors.
- All Above.

❖ Interview

The researcher begins their interviewing process by conducting the appropriate research by focusing on not disclose the identity of the person participating in the interview as part of data privacy issues; and obtaining the proper forms, including a letter from Middle East College explaining the data collected by its students has no risk of harm, and will not collect personal information. Then, with the supervisor's approval, the questions are formulated and made to suit the researcher's objectives.

The interview will be semi-structured, allowing for spontaneous questions that might arise, and are open-ended to allow for flexible answers. Purposive non-probability sampling is used to deliberately select to best organizations to advance the research. The selection of participants based on specific criteria and not every individual in the population has a chance to be chosen as per non-probability sampling. From there, the researcher presents themselves and their research to the chosen companies and provides all the needed documentation to ensure comfort and cooperation.

An initial visiting date is set to pilot the interview, and everything thus far is reviewed and re-reviewed. Next, the interview date and time (1.5 hours) is set, the company (InnoTech/Atom Labs) is informed that the data will only be stored for a year, and the interview commences. A self-memo or diary is used to notate the interview and collect data, after which the data is coded and analyzed using content analysis, suitable for qualitative data.

The researcher planned the interview questions by focusing on the research problem and research questions. Some of the types of interview questions about the use of 3D technology, the benefit of using 3D printing technologies, requirements for implement 3D printing technologies, challenges faced in implementing 3D printing technology, knowledge needed for an employee to work with 3D printing, best practices in implementing 3D technology, competitor(s) in the market, the benefit of 3D technology in the prosthetics departments, and role of 3D technology during the Covid-19 pandemic, etc. The participants have the facility to provide the answer directly to the researcher and the researcher will record the information during the time of the interview process.

❖ Survey

Conducting the survey begins by collecting the necessary background information, both about the technology and the hospital and then reaching out to the responsible authority to schedule a meeting. After an initial visit has been agreed upon, contact information is exchanged, and the focal point of discussion is set.

This is followed by preparing and submitting the required documents and forms, such as the ethical document and the research proposal via the hospital, and waiting for their administration's approval.

The sample size and technique are then chosen, cluster sampling in this case, wherein the researcher takes a whole sample with similar characteristics (being the employees of the orthopedic and prosthetics department in Khoula Hospital. Next, the survey questions are prepared with approval from the researcher's supervisor, in this case, the questionnaire will be made using Microsoft Forms, and will contain varied (multiple choice, ranking, and rating) close-ended questions to enrich the data collected.

After the data has been coded, the survey is sent to employees (6), and upon their completion, the survey is to be adjusted given their feedback. The pilot study helps to evaluate the time needed and make sure all questions are appropriately worded.

After which the modified survey is sent back to the focal point via the department head for distribution, and given 1 week to complete.

The researcher is looking forward to the collection of a valid answer for the research questions and makes the research strong and efficient. The researcher is focused on the provision of the survey questionnaire by proving the questionnaire which is related to the research problem and research questions. The survey questions are forwarded on the internet and most of the participants provided the answer. Moreover, the researcher made the survey questions that are easily answered by the participants.

There are Likert scale questions are made by the researcher and it consists of five options for the participants and easy to give the answer.

The collected data will be organized in an Excel sheet and copied to PSPP and will be coded (for example, Male = 1 and female = 2).

The charts and tables will be used to represent the response of the participants in each survey question. There will be changes for each participant towards their answering and the chart will highlight the differences. Moreover, the collected data will be supportive to identify the answer to the research problem and research question.

❖ Ethical considerations

The participants will be informed of the purpose of the study, and there is no type of harm, pressure, coercion caused to the participants. Nobody will be forced to participate and they can withdraw at any time. No personal data will be collected. All data will remain confidential and coded. Only the researcher has access to it.

The findings will be shared with the participants. The results will give us an indication of the participants' knowledge about 3D technology; and the benefits and requirements for applying such technology, and how they will apply knowledge from previous experience.

3.5 Conclusion

This chapter is a road map for the entire work. It explains every layer in onion research (philosophy, approach, strategies, methodological choices, time horizon, and data collection and analysis). The next chapter will be about project management.

CHAPTER 4: PROJECT MANAGEMENT

4.1 Introduction

The purpose of this research is to analyze the impact of the further industrial revolution by applying 3D printing technology at Khoula Hospital. The starting stage of this research described the introduction part of the research topic along with the rationale and objectives of the research. Similarly, the literature review about the topic of 3D printing technology and its benefits as well as challenges were discussed in the second chapter. Dissertations, like any other project, need a project management plan. Project management plans help achieve goals, minimize risks, avoid delays, and deliver work of high quality. This chapter describes the phases of project management which can be used to manage research in its entirety.

There are five phases in the project management plan and the researcher should follow it in this research.

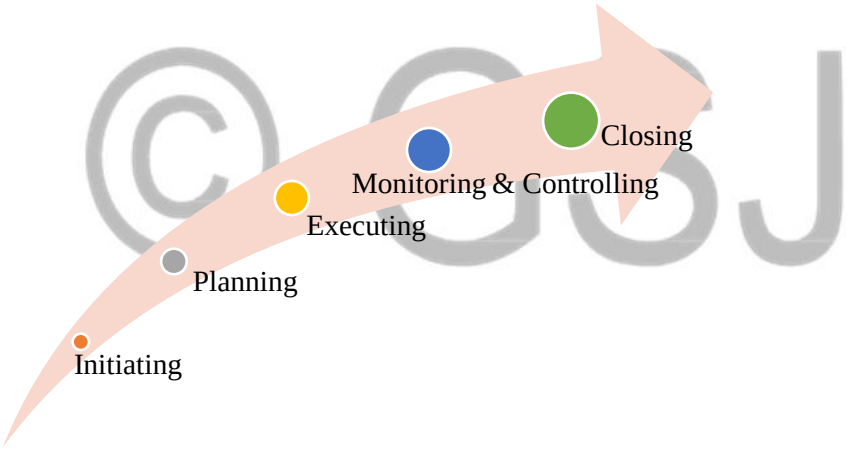


Figure 4.1 (project management life cycle)

4.2 Project Management phases

4.2.1 Initiating

In the first stage, the researcher begins thinking about their interests and which field they wish to conduct his research. First, they begin by reading about the topic of 3D printing technology that they choose and search Khoula Hospital for them to conduct the research. Secondly, to prepare to present the idea of the impact of the further industrial revolution by applying 3D printing technology at Khoula Hospital. After that, the researcher sends the title of the research to the supervisor for approval.

Thirdly, start work on the proposal on the impact of the further industrial revolution by applying 3D printing technology at Khoula Hospital, a brief explanation around the subject and the desired objectives as well as the methods and locations of research. After that, the researcher focused on the reasons behind the researcher's interest in the topic of 3D printing technology and collects and analyzes the data for the research. Once the proposal is ready the researcher needs to submit it through the Module on the college website by the due date towards the proceeding of the next stage of the research project.

4.2.2 Planning

In this phase, the researcher needs to submit their mid-term report to get feedback from their supervisor. In addition, the researcher needs to submit their 2nd phase plan with expected deliverable dates and get approval from the faculty to continue working on the next phase of actual research. The researcher must also make sure to meet ethical research standards because it will be needed when collecting data.

4.2.3 Executing

In this phase and after receiving feedback, the researcher will start to collect their information in order to finish their literature review chapter. That grants a better understanding of the subject and helps decide which methodology will be adopted (questionnaire/interview). At the same time continue to write and gather data for the remaining chapters. The executing phase is also when to contact companies to gather data and distribute the survey to its participants.

4.2.4 Control and Monitoring

In the control and monitoring stage, the researcher monitors their schedule to ensure the completion of each stage in the specified time. Also, the researcher remains in constant contact with the supervisor to receive notes about their work and solve any issue or problems that the researcher could face that might affect the execution of the project.

4.2.5 Closing

After writing the dissertation, it must be reviewed by a specialized linguist to check it linguistically and correct any spelling or grammar mistakes. Secondly, the dissertation must be coordinated according to the university guidelines. Lastly, upload it through MEC Moodle to check the similarity before the final submission.

4.3 Project scheduling

Research scheduling helps achieve tasks on a set timeframe and order. Each task has a start and an end; and to finish it successfully we need to plan well. Scheduling helps to adjust the late tasks and perform any needed changes.

Define the research activities and estimate the needed time to finish each task, and assign the right resources to help complete the work.

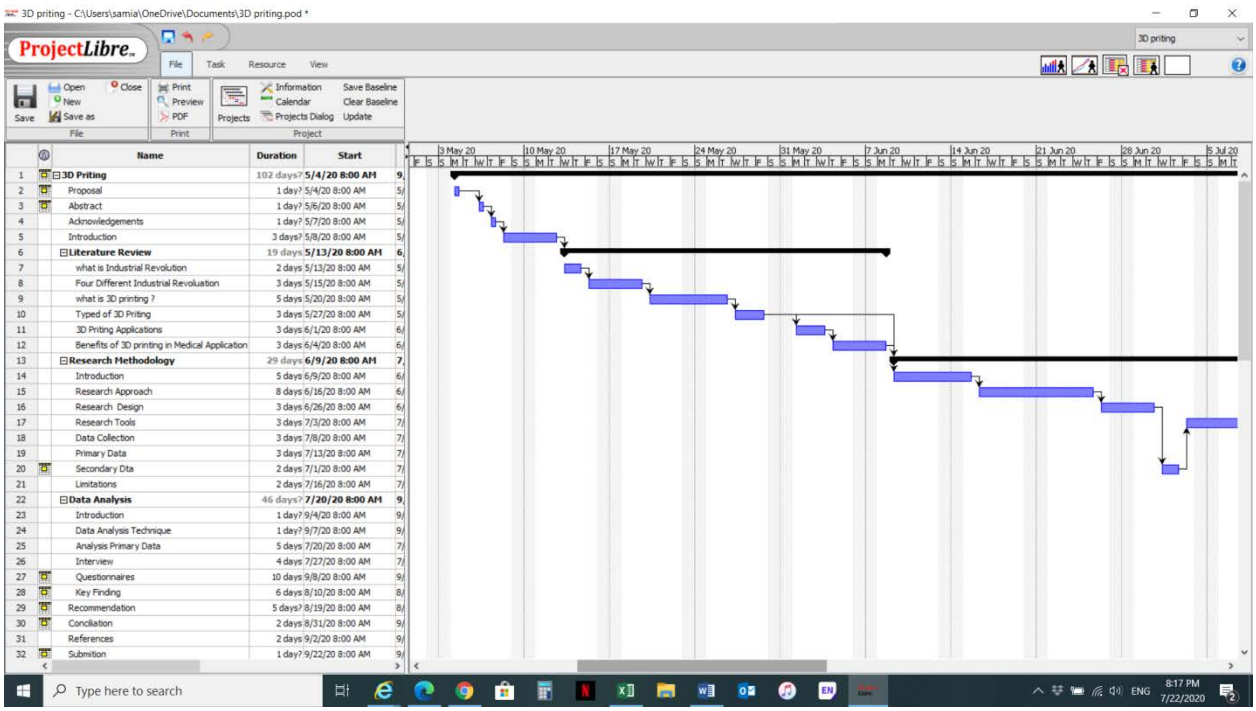


Figure 4.2 (Project scheduling)

4.4 Project Risk Management

The risk could appear during the research project, the researcher should not panic but analyze the case, what is the problem? How has it occurred and what is the solution? If the researcher could not solve the problem, they need to arrange a meeting with their supervisor and take their recommendations. The researcher also needs to show the examiners how they overcame these problems. That gives them credibility in the work they do and help future researchers overcome the risk.

Figure 4.3 (Risk management process)

One of the most important elements in project management is considered as risks. There are different types of risks are involved in a research project and the researcher must aware of these risks and its consequences on the completion of the research. Hence, it is required that the researcher must take the relevant immediate steps to mitigate the risks and make the research successful. Also, the researcher should avoid the steps which will lead the risk in the project. So, the awareness and taking the actions on time is effective to identify the risks in the project and mitigate the risks on time. All the risks were mentioned in the last chapter.

4.5 Conclusion

In this chapter, the project schedule was created using Projectile software and project management phases were explained to conduct the work efficiently on time. In addition to that, study all risks which could happen and provide a solution.

CHAPTER FIVE: ANALYSIS AND FINDING

5.1 Introduction

Collected data is close to meaningless without proper analysis. Thus, obtaining meaningful results and stimulating change first requires the data to be analyzed. This chapter presents the findings on 3D printing technology and its possible benefits if implemented in the hospital. It also analyzes the data collected (qualitative and quantitative) via survey and interview, showing all findings to address all research questions.

5.2 Data collection

5.2.1 Quantitative analysis

The survey objectives are: To evaluate the traditional way of prosthetics production, increase awareness about 3D printing technology, better the understanding of the challenges that could stop its implementation, and how Khoula Hospital prefers to learn about 3D technology.

Since the study revolves around Khoula hospital (Orthotics and Prosthetics Department) the survey was for all 30 employees (all employees were required as a sample to have statistical meaning). Of which, 26 chose to participate.

Survey questions are close-ended and were in different formats, like ranking and multiple-choice questions, allowing the participant's flexibility to gather more accurate data. All the answers were mandatory, it was conducted online and given one week to fill out. Privacy policies were provided and no personal data was asked or taken. Pilot testing was with 3 employees and their feedback was taken. Besides, the proper channels are followed to conduct the survey questionnaire and interview by taking permission from the authority. Moreover, the collected data will not be used for any commercial purpose and it should be destroyed after a few months. Also, there is data security for the participants and no data will be shared with a third party. All ethical considerations to issue a nonobjective letter from the hospital are attached in appendix L.

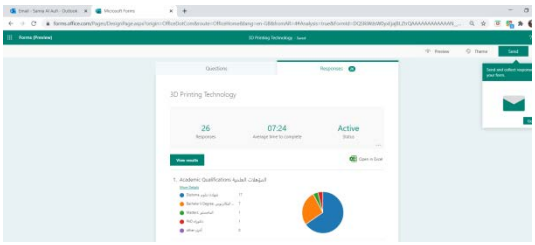


Figure 5.1: Microsoft Forms

As figure 5.1 shows that the survey was designed using Microsoft Forms and only 26 out of 30 participants filled the survey, taking 7.24 minutes on average to complete. After a week, the survey was deactivated, and its data imported into a raw excel sheet, to be used in PSPP for analysis with all the labels and label values to create visual displays. The survey will address Q1, Q2, Q3, Q4and the data will be stored for one year only. Appendix (D) contains the survey questions.

❖ Results

Q1: What are the weaknesses that the hospital faces in its current situation?

When any organization needs to replace one technology with another, the first thing to do is to evaluate the current situation and compare it with the proposed one. So the first question in the study was to identify the weaknesses that the hospital has in its current situation. Within the scope of this question, the survey asked questions about time, cost, quality, and how many patients they treat.

The response of the participants is the majority of the participants responded on the point weakness of Khoula Hospital face in their current situation is there are issues with time, cost, and product quality as well as treating their patients.

➢ Academic Qualifications/ knowledge level regarding 3D Printing

This demographic question helps to understand whether skilled laborers or employees with a higher level of education are needed. And whether the current employees can deal with the new technology easily or will need to be replaced with specialists from the medical staff.

Frequency analysis was used in this question and it shows how many times (frequency) the event occurs or is repeated in the same category.

The data collected shows that most employees have a university diploma at a percentage rate of 65.38% and a frequency of 17 out of 26.26.92% goes to Bachelors' Degrees, and 3.85% goes to Masters and PhDseach.

Diplomas represented the majority as the hospital needs skilled technicians, and the higher cost of employing more academically qualified individuals can yield diminishing returns.

The results show that all employees are educated well and it should be relatively easy to transition to working with new technology due to all of them having a Diploma or above. Check appendix J.1.

By using the histogram, we can tell that most participants have heard about 3D printing, followed by adequate knowledge in frequency. This result may be because the technology is new and is still being researched, especially in the medical field. Only a handful of organizations around the world are using it. See appendix J.2.

- period of using the same technology/satisfaction with the current technology

The chart in appendix J.4 shows that most of the employees have between 1-10 years of experience, and a majority are satisfied with the current technology. That indicates there is no relationship between the period of employment and desire for switching technology, and that could create a rejection challenge for implementation.

If deeper analysis is needed, crosstabs analysis can be used, which itself is typically used for categorical data, getting the relationship between multiple variables and how correlations change from one group of variables to another as in appendix J.5.

For example, if we are targeting Khoula hospital and we would like to have an idea about the period of work category (1-10) and its relation to satisfaction, we can easily categorize it as shown in the figure below.

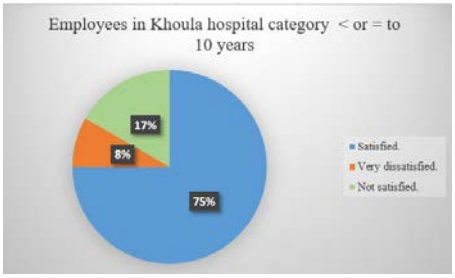


Figure (5.2) Employees satisfaction in Khoula hospital in the category of <= to 10 years of experiences

- Patients number / Employees number

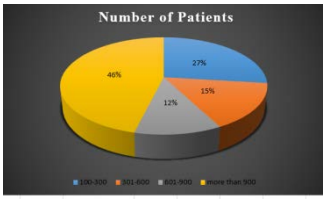


Figure (5.3) Number of patients

In this question, the survey tried to figure out the number of patients treated, and to check the percentage between the prosthetics and orthotics patients (since this study about the prosthetics only). Resulting in 300 prosthetics with the rest being orthotic, according to the head of the department. This indicates that the percentage of prosthetic patients is not small combining both manufacturing technologies is beneficial. (check interview analysis).

The number of employees is 30 in total and this number can be reduced by using 3D technology or shifting them to another department.

- Cost / /time / quality

The most important elements to study are how much device production costs, how much time it takes, and how is the quality? Those are very important because it will be compared with the new technology.

1- Cost

In appendix J.6 most participants see that the cost of production is suitable, this may be because the material they use is basic and cheap and the machines that they use for manufacture are cheaper when compared to 3D printing. Also, the number of prostheses

patients are fewer compared to orthotics patients (Khoula Hospital only can produce prosthetics).

3D might save costs in other ways than material and machine (in which it is more expensive). It can reduce the number of employees needed, as skilled hand labor is not needed, it can reduce waste due to the rapid prototyping made possible by 3D printing, reduce the time needed/wasted, and enable the hospital to work on orthotics as well as prosthetics.

2- Time

How long does the patients need to wait until they get their device on average?

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Less than 7 days	1	3	11.54	11.54	11.54
Between 7 daya and 14 days	2	10	38.46	38.46	50.00
Between 14 days and 1 month	3	9	34.62	34.62	84.62
More than 1 month.	4	4	15.38	15.38	100.00
	Total	26	100.0	100.0	

How long does the patients need to wait until they get their device on average?

N	Valid	26
	Missing	0
Mean		2.54
Std Dev		.90
Minimum		1.00
Maximum		4.00

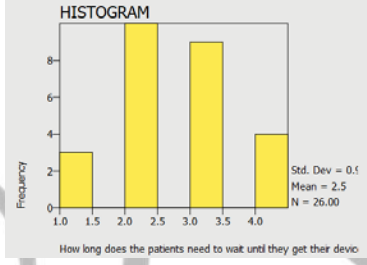


Figure (5.4) Time

The above table and charts show the response of the respondents and the findings show that 38.46% of patients receive their devices in one to two weeks and 34.62% between two weeks and one month. This indicates that the time here is still longer than the estimated time of 3 days when using 3d printing (according to both companies interviewed).

3- Quality

Patient safety depends on the consistency of the device and manufacturing quality. As in Appendix J.8 on average the patient returned one to two times to change or modify their device (57.69%) and with 30.77% of patients returning three or more times. A reason for which is the department deals with life-changing tools that need to perform daily, thus some testing and refining are only natural, but with almost a third of patients returning three or more times, streamlining the process of both manufacture and follow up can greatly benefit the patient, and reduce the workload of the department.

Note: The survey was only for employees not the patients and in future research, we advise to be conducted.

- 3D technology efficiency

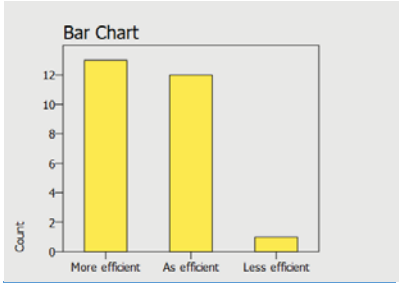


Figure (5.5): Comparison 3D technology with traditional

Despite the rate of satisfaction with the current technology (61.54%) most of the participants agreed that the new technology will be more efficient and it will help them to get better output in a shorter time. (check the literature review).

Q2: How will 3D printing benefit the hospital?

The main goal of changing from an old system to a new one is to benefit from it. All are discussed in the literature review. This question was meant to see how much they are wishing to improve their work and to give them good recommendations. In this question, the participant can choose more than one option. The highest percentage came as most of the participants want all the advantages that they can get from the new technology, and also demonstrates that all options given satisfy most of the participants.

Valid cases = 26; cases with missing value(s) = 0.

Variable	*N*	*Mean*	*Std Dev*	*Minimum*	*Maximum*
All Above	26	.62	.50	.00	1.00
Saving time and money	26	.04	.20	.00	1.00
Reducing the waiting list	26	.08	.27	.00	1.00
Higher quaility products and customization	26	.23	.43	.00	1.00
Imoroving medical staff' performance and reducing human errors	26	.08	.27	.00	1.00

Table (5.1): 3D advantages

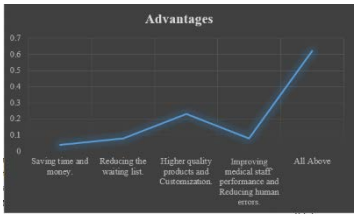


Figure (5.6): 3Dadvantages

Q3: What are the challenges that could stop the hospital from adopting 3D technology?

- Challenges

Every time any organization tries to radically change, it faces challenges. This question highlights the possible challenges that could stop the hospital from not implementing 3D technology.

The survey combined all challenges in one question and let the participant's rate each challenge from 1-5, being: (not challenging at all / slightly challenging / moderately challenging/ very challenging / extremely challenging) trying to know what challenges could stop the hospital from implementing this technology.

By using descriptive analysis, we calculate the mean for each variable to see which variable is the most challenging. Here, it is clear that the biggest challenge lies in the hospital's administration (3.38). Three variables come next, which are costs of the new technology, not commonly used and lack of technology labs here in Oman (3.35) came in second. The desire to continue with old technology and ignoring new technology was the least challenging, which means if the hospital can overcome the other challenges, the employees welcome the new technology. Check appendix J.9.

This question was also used to check the reliability of the data (Cronbach's alpha). If the score is reliable or not. This analysis is used when you measure multiple variables for the same assumption: so, for the challenges survey question, we have ten variables all asking different things, but at the end will measure the overall challenge.

Cronbach's alpha results is a number from 0-1 and the result could be: -

1- Negative numbers indicate that something is wrong with your data.
2- 0.70 and above is good,
3- 0.80 and above is better,
4- 0.90 and above is best. (Statistics Solutions 2020.)

The alpha value here equals 0.81 which means that items are reliable, but not the best. Check the table below.

RELIABILITY

RELIABILITY
/VARIABLES= Cost F.O.C L.HR L.E Ignorance Admin F.P N.C L.O.T.L O.Tech
/MODEL=ALPHA.

Scale: ANY

Case Processing Summary

		N	%
Cases	Valid	26	100.00
	Excluded	0	.00
	Total	26	100.00

Reliability Statistics

Cronbach's Alpha	N of Items
.81	10

Table (5.2): Reliability analysis

Q4: Which ways the employees prefer in helping them in implementing 3D printing? (previous experiences, training)?

The survey highlighted if the employees are interested in knowing about 3D technology, their favorite learning methods and if the hospital is ready to implement new technology.

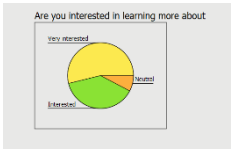


Figure (5.7): Interested in technology

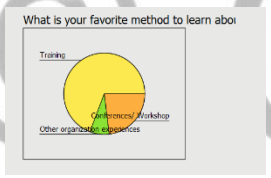


Figure (5.8): learning method

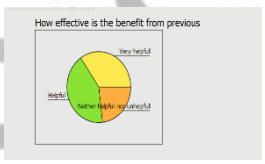


Figure (5.9): previous experiences

Figure (5.10): The readiness of the hospital

As we can see in the figures above, 53.85% are very interested, 38.46% are interested, and 7.69% are neutral, with none uninterested or very uninterested. That gives us an indicator that the employees really want to know more and are open to this technology. Additionally, since most employees gained their skills from training, they prefer training method to learn more about 3D technology. The employees also realize that previous experiences with 3D technology will be helpful for them to examine and try the technology before they adopt it.

Most employees do not know if the hospital is prepared and has a clear strategy to share knowledge with others or not.

5.2.2 Qualitative Analysis

The research questions could not be covered by the survey only, thus an email was sent to three companies working in the 3D printing business to conduct interviews. Of which, two companies agreed to partake. The interview contributed and maximized our understanding of the research questions, especially question number five. As ethics protocol, the letter from the college, and the copy from the ethics form was sent to them.

Two interviews with two companies were conducted by sending them an email introducing myself and giving them a brief idea about the study asking them for an appointment. They replied with the names and time available (interview protocol is attached in appendix I). Both interviews were in the companies' offices and were face to face.

The interview started on time and the questions were open-ended questions. It was a semi-structured interview with several topics. Notes were taken during the interview and took one and a half hour to two hours to complete. Many other questions appeared and provided additional information. In the end, they showed me their workshop and different types of printers. The data was written the word document with a password so no one can open it.

Q5. What are the requirements needed to implement 3D printing technology in the hospital?

After the interview, the document was arranged systematically and saved in a word document. Then notes were written after going through the entire document. After that, the document is reread line by line. At the analyzing stage, the codes were implemented and divided into themes and labels. The second step in coding was creating categories and placing relevant codes in one category. Then selecting which category we need and how all categories are connected to each other. In the end, the result was documented.

➢ Company name and code:

The first step is to refer to the answers from both companies as A (InnoTech company with code) and B (Atoms Lab company with code) without mentioning company names. See appendix (J.11)

➢ Name of Interviewee:

A- Project Manager

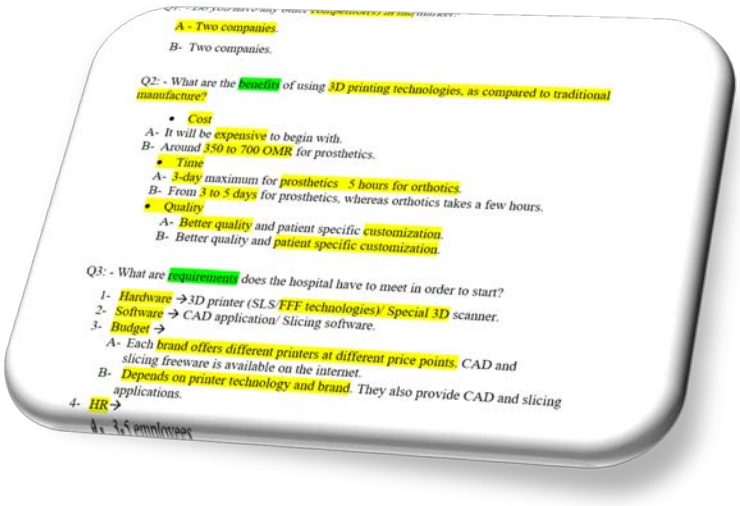
B- Chief Technology Officer

➢ Company background:

A- It is an Omani company established in 2013 and specializes in 3D printing, AI, and innovative learning techniques.

B- It was established in 2018 and specializes in 3D printing, assembly, and manufacturing solutions, as well as laser engraving and cutting technology. They further provide technical support services and training.

➢ Coding process


A - Two companies.

B- Two companies.

Q2: - What are the benefits of using 3D printing technologies, as compared to traditional manufacture?

- Cost

A- It will be expensive to begin with.

B- Around 350 to 700 OMR for prosthetics.

- Time

A- 3-day maximum for prosthetics 5 hours for orthotics.

B- From 3 to 5 days for prosthetics, whereas orthotics takes a few hours.

- Quality

A- Better quality and patient specific customization.

B- Better quality and patient specific customization.

Q3: - What are requirements does the hospital have to meet in order to start?

1- Hardware → 3D printer (SLS/FFF technologies)/ Special 3D scanner.

2- Software → CAD application/ Slicing software.

3- Budget →

A- Each brand offers different printers at different price points. CAD and slicing freeware is available on the internet.

B- Depends on printer technology and brand. They also provide CAD and slicing applications.

4- HR →

Figure (5.11): Interview Document

As we can see in figure (5.11) there are some words and sentences highlighted. This process is called coding and it has several steps.

The first step→ Read the whole interview document well.

The second step→ Any relevant sentences or words to the study subject were highlighted (labeled) using yellow color. It could be important, repeated, or information that has been in this study or previous studies. It could also be concepts, processes, or opinions.

In the two interviews, we highlighted the following words: -

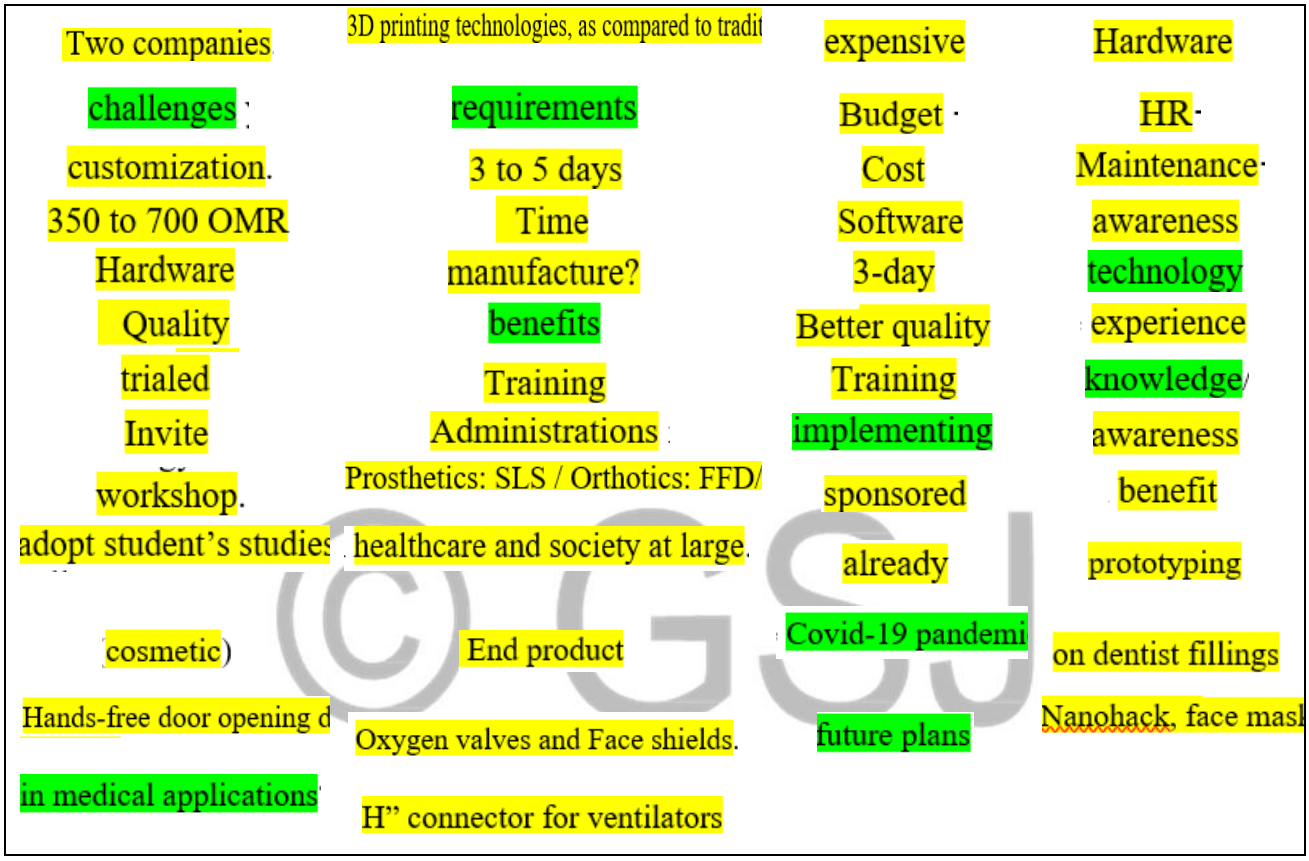
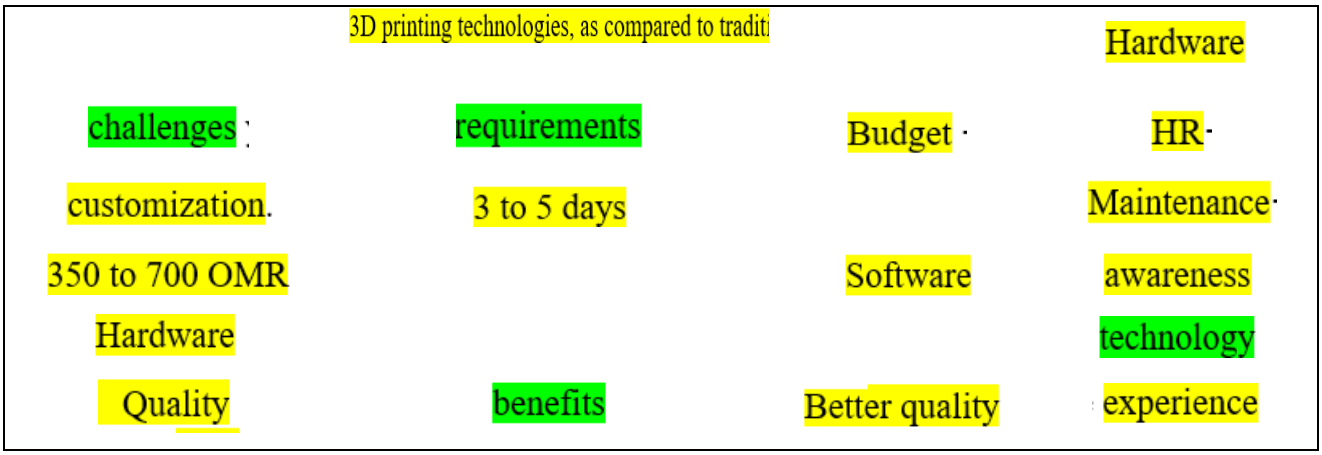


Figure (5.12) survey analysis A

The third step→ Initial codes could not all be used. Upon reviewing it again new codes are added, weak ones deleted and repeated ones combined.



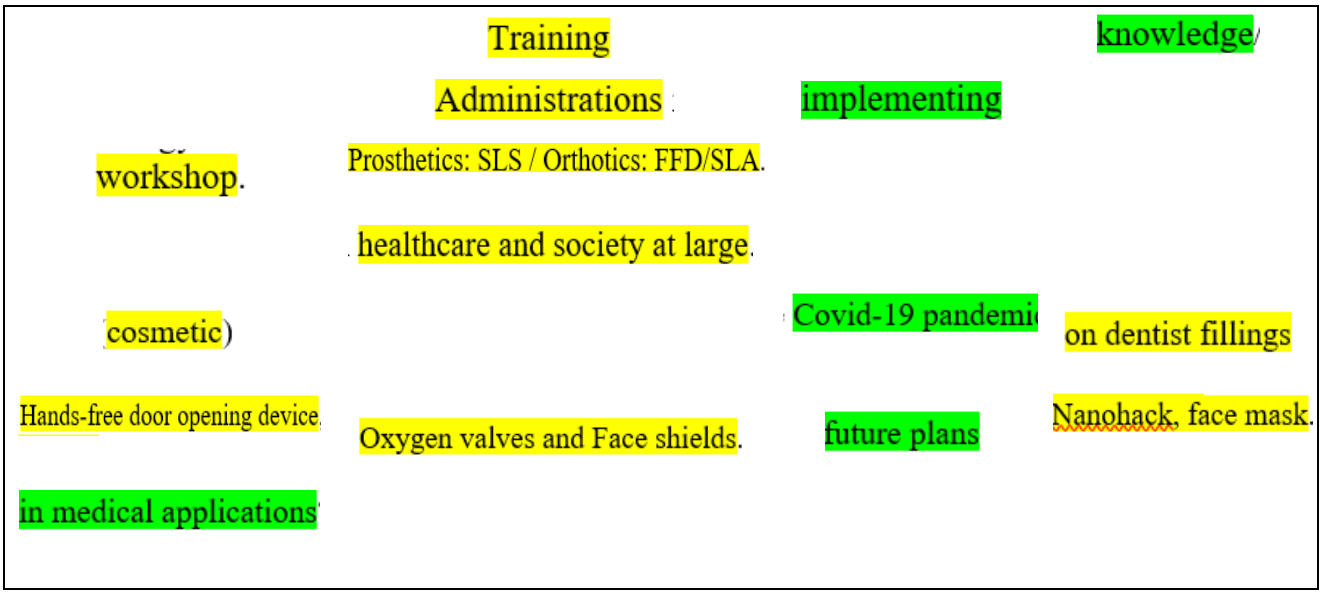


Figure (5.13) survey analysis B

The fourth step→ Categories were created by decided which codes are linked under the same category.

Category	Sub-category
requirements	Training Budget HR. Maintenance
benefits	customization. Quality 3 to 5 days Better quality
implementing	awareness experience workshop. healthcare and society at large.
challenges	350 to 700 OMR Administrations
in medical applications	cosmetic)
Covid-19 pandemic	Hands-free door opening device Oxygen valves and Face shields. Nanohack, face mask.
future plans	on dentist fillings
technology	Hardware Prosthetics: SLS / Orthotics: FFD/SLA. Software
knowledge	3D printing technologies, as compared to traditional

Figure (5.14) survey analysis C

The fifth step → check and describe any relevant relations between categories and how they are connected.

1- Technology and requirements categories are connected because technology is itself a requirement, of which the companies both offer consultation services.

2- Future plans and medical applications are connected because the companies draw on previous experience when embarking on new endeavors.
3- Knowledge and training are connected if the companies provide training because training leads to knowledge.
4- Implementation and challenges are connected because overcoming challenges precedes implementation.

The sixth step → determine which category will be focused on to aid in answering research Q5 of this study.

Requirements category

- Findings

Both interviews agreed that 3D printing technology will benefit the hospital by reducing cost (it will be expensive, to begin with, and the cost will be around 350 to 700 OMR for prosthetics) and time (3-day maximum for prosthetics and 5 hours for orthotics.) not to mention the better quality of the final product.

The project has many requirements. The two companies agreed on: hardware such as 3D printers (SLS/FFF technologies), special 3D scanner, software such as CAD and slicing applications, a budget which depend on hardware and software prices, HR with 3-5 employees, training which is part of the purchasing process and maintenance as a contract between the company and hospital. Check appendix (J.11) as an example of specifications.

The largest challenges in implementing this technology (as both companies said) are people's awareness of the technology and administrations in targeted organizations. To solve this problem, they have implemented strategies like:

- Raise awareness about technology via workshops, participation in internal and external exhibitions, a traveling exhibition to spread awareness, and online channels.
- Offer to produce some devices and allow them to be trialed on patients.
- Invite the private sector to participate in manufacturing devices as has happened when companies sponsored the production of assistive breathing devices.

- Raise awareness of 3D printing technology uses in healthcare and society at large.
- Invite the healthcare employees to a workshop.
- Invite the private sector to sponsor a 3D project in any hospital.
- Prepare a study about the benefits of using 3D technology in the health sector, or adopt student's studies according to high standards after contacting universities or colleges.

The best technology for the prosthetics and orthotics department are SLS (Prosthetics) and FFD/SLA (Orthotics). Both companies did well during the Covid-19 pandemic by manufacturing oxygen valves, face shields, hands-free door opening devices, H connectors for ventilators, and Nanohack face masks. Additionally, both companies are ready to cooperate with hospitals in the future and invest in the health sector.

5.3Conclusion

In view of the above points, the weakness of Khoula Hospital's face in their current situation is there are issues with time, cost, and product quality as well as treating their patients. There is no relationship between the period of employment and desire for switching technology, and that could create a rejection challenge for implementation. The cost of production is suitable because the material they use is basic and cheap and the machines that they use for manufacture are cheaper when compared to 3D printing. 3D might save costs in other ways than material and machine and it can reduce the number of employees needed. Also, 3D can avoid skilled hand labor, it can reduce waste due to the rapid prototyping made possible by 3D printing, reduce the time needed/wasted, and enable the hospital to work on orthotics as well as prosthetics.

3D is effective for streamlining the process of both manufacture and follow up can greatly benefit the patient, and reduce the workload of the department. Most of the participants agreed that the new technology will be more efficient and it will help them to get better output in a shorter time. The advantages of Khoula Hospital from the new technology of 3D printing are it can enhance the satisfaction of the patients and employees. The desire to continue with old technology and ignoring new technology was the least challenging, which

means if the hospital can overcome the other challenges, the employees welcome the new technology.

The survey highlighted employees are interested in knowing about 3D technology, their favorite learning methods once the hospital is ready to implement new technology. Moreover, the employees in Khoula Hospital want to know more and open to this 3D printing technology. Interviews show that 3D printing technology will benefit Khoula Hospital by reducing cost and time. The requirements for the implementation of 3D printing project hardware such as 3D printers, special 3D scanner, software such as CAD and slicing applications, a budget which depend on hardware and software prices, HR with 3-5 employees, training which is part of the purchasing process and maintenance as a contract between the company and hospital. The next chapter will discuss the recommendation, self-refection, and risk management.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter will discuss the conclusions and summary based on the results to come up with a recommendation to Khoula hospital to use 3D technology and improve their work. Student reflections and all risks faced during the research will also be highlighted in this chapter. The end will mention how this dissertation will help future investigators research in the same field.

6.2 Summary

Technology contributes to advancements in the medical field in many ways, like disease control, development of antibiotics, medical devices, performing complex and delicate surgeries, and drug-making technology. Technology and its advancement is a very important element of our lives and we need to use it, otherwise risking lagging behind other nations.

The research focused on the advantages of 3D printing technology, challenges in terms of implementation, determining the requirements for implementation in Khoula Hospital. For all the aforementioned reasons this study tried to study all current limitations, from awareness about 3D technology advantages to asking what the real challenges stopping implementation are. Also, the study highlighted the requirements and the employees' preference to gain knowledge about 3D technology and how it will help them to produce the prosthetic in a shorter time with less price and high quality.

6.3 Conclusion

Because of the above points, this research analyzed the impact of the industrial revolution by applying 3D printing technology at Khoula Hospital. To fulfill all research objectives, a survey and interview were conducted (primary data) and from previous sources (secondary data). Following the interview and survey protocols was very helpful in collecting data, using PSPP software to analyze it, and display the results as charts and tables. There

were many problems faced by Khoula Hospital due to the lack of advanced technology in their workplace like the usage of present running technology leads to wasting time, material, money, and efficiency of the product. The study has resulted that 3D printing technology will benefit the hospital by reducing costs and enhance the quality of work. All employees are educated well and it should be relatively easy to transition to working with new technology due to all of them having a Diploma or above.

In Khoula Hospital, it takes care of prosthetics and orthotics; producing prosthesis devices and purchasing orthotic devices. They take a long time like 7-14 days than 3D technology like a maximum of 3 days. The cost is suitable for them because they use basic materials and treat a few patients. They have more than 13 specialists working the workshop which can be reduced to three with the support of 3D technology. Further, the process takes a long time to measure (check Appendix F) and it wastes many molds and prosthetics in the process. So compared to 3D technology they are wasting time, money, material, and product efficiency.

In Khoula Hospital, the employees welcome the new technology, and that they want to improve their work. In terms of Khoula Hospital, the administration is the most challenging part of this project. Employees prefer to get trained in how to use this technology and it will help them the most in learning about this technology. Hardware, software, training, budget, and place are required to implement this specified project in Khoula Hospital. The research concluded that 3D printing technology is most suitable and efficient for Khoula Hospital to increase their business activities by saving time, decreasing cost, enhance customer satisfaction, enhance product quality and improve the operational efficiency of Khoula Hospital and achieve the objective of this research.

6.4 Recommendation

This research analyzed the impact of the industrial revolution by applying 3D printing technology at Khoula Hospital. Based on that, it is highly recommended that Khoula Hospital must utilize the benefits of 3D printing technology to enhance their working efficiency and make the patients highly satisfied. The strategy of collecting more information and implementation processes from other experienced organizations will support Khoula Hospital

to implement 3D printing technology successfully. Moreover, the adoption of skilled staff and professional to implement 3D is effective for Khoula Hospital to increase the efficiency of their operational activities.

It is recommended that the project manager should identify the risks involved in each stage of the project and it would support to make the project process successful. The involvement of the project manager with the concerned authority people of Khoula Hospital will be effective to make the project successful. In addition, Khoula Hospital must focus on the successful implementation of 3D technology to increase their business efficiency and increasing financial stability by decreasing operational cost and improves product quality along with saving time. The provision of proper training and the availability of skilled staff will support Khoula Hospital to overcome the challenges involved in the 3D printing technology implementation process.

It is recommended that Khoula Hospital must encourage the process of 3D technology as part of the industrial revolution to achieve the objectives of Oman vision 2040. Also, Khoula Hospital must focus on 3D technology to enhance the patient's satisfaction by providing better treatment and facilities to the patients. Moreover, the implementation of 3D technology will support Khoula Hospital to reduce the employees' strength. Also, 3D technology is effective for Khoula Hospital to enhance the efficiency of diagnostic and provide better service to the patients. In addition, 3D printing technology implementation is highly recommending to Khoula Hospital, because it will produce the prosthetic in a shorter time with less price and high quality.

In addition to that most orthopedic devices are brought from outside Oman with the high cost and large quantities as the department needs more of them. So we recommend that they can use the same technology to produce prostheses and orthopedic devices, which will reduce the money spent on purchases.

6.5 Risk Management and Limitation

Every study has some limitations. It might be clear from the beginning or can arise during the study. Safety and health risks are the main risk involved in this project. The research preparation period was during the period of the Covid-19 pandemic and the necessity of social separation and distance. This led to difficulty in reaching the staff in the hospital. The solution was to follow the precautions and do the work. Running out of research resources and 3D technology is new in the medical sector and lack of many regional previous research studies on the topic, as well as restricted access to data. The solution was to try to contact outside organizations to gain a better understanding. Use e-library and research sites to reach the previous studies.

There were issues with the no-objection letter from the hospital. It took a long time to procure so we kept contact them every day and all forms needed from the hospital filled. The lack of experience for the students in the research field is another limitation of this study and the interaction with the supervisor helped to mitigate the issue efficiently. There are issues with data collection sites that can help gather information about 3D technology that is rare to find since this technology is still not common in Oman. Hence, the researcher focused on some of the online websites and books to collect relevant data.

Due to the Covid-19 impact, contacting people could also be difficult during this period especially as some people refuse in-person interviews. Hence, the researcher followed the strategy like email, zoom, or phone to contact with some of the participants. Lack of awareness of professional norms or procedures in the hospital is another issue and the solution was to visit the hospital from the beginning and try getting as detailed information as possible.

6.6 Future Investigation

Research needs to continue to expand knowledge, solve problems, and improve services. For future studies, taking two case studies and following them from the day of patient transfer to the department, ending with the final installation of the prosthesis. Comparing the two processes (traditional, 3D printing) from different aspects like functional safety, quality, manufacturing time, economic, ergonomic, aesthetic and life cycle to give us a more in-depth comparison by stating the advantages, and disadvantages of the two methods.

Future studies should involve the patient's opinions since this is what the devices are made for. More research also needs to be done on the connection between artificial intelligence systems and the new devices to help in the manufacture of prosthetics.

6.7 Student Reflection

If there is a will, there's a way, no pain no gain, and keep learning and exploring things because you will never know when you will need it.

I'm so lucky to go through this journey which gave me a chance to explore and learn something new and to improve myself in many ways.

There are a lot of things that I learned, first of all, is time-management and how I can manage my time between my family, work, and the dissertation; and how to divide the project into several stages with individual start and finish times. The literature review took the most time from me, but following my plan, and adjusting it when necessary, helped complete it and move on.

Primary and secondary data research skills, in this stage I learned the value of patience in collecting, organizing, and filtering the relevant data to my work. There are a lot of secondary sources of data (book, internet, magazine) that needed time and effort to read and select relevant and useful data to the research objectives. Skills were improved because of the new things that I learned, like designing the survey and analyzing it using software and using quantitative and qualitative research methods. Onion research was also new for me, as was selecting the sample size and how to analyze the interview data.

Self-Confidence and communication skills were improved by meeting new people, visiting different organizations, and throughout the entire data collection process in order to get the information from them.

Research experience contributed to appreciating the importance of data and information about 3D printing technology, how it works, its benefits and applications, etc. All that I gained through this dissertation will help me in both my professional and personal life.

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