Master's Thesis
Computer Science
Informatics

EVALUATING THE INFLUENCE OF INFORMATION TECHNOLOGY ON 3D PRINTING FOR PRODUCT DEVELOPMENT IN LAGOS, NIGERIA

Onyeche Ikechukwu Henry

Faculty of Computing
Blekinge Institute of Technology
SE-371 79 Karlskrona Sweden

This thesis is submitted to the Faculty of Computing at Blekinge Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science (120 credits) in Computer Science with a specialization in Informatics. The thesis is equivalent to 20 weeks of full time studies.

Contact Information:
Author:
Ikechukwu Henry Onyeche
E-mail: henrion4@yahoo.com

University supervisor: Hans Kyhlbäck

Faculty of Computing
Blekinge Institute of Technology
SE-371 79 Karlskrona, Sweden

Internet : www.bth.se
Phone : +46 455 38 50 00
Fax : +46 455 38 50 57

ABSTRACT

Context: Today, many organizations in global market now frequently scan and assess their environment as consumers' taste and preference became the sole target. Consumers' preferred product of yesterday might unexpectedly devalue or be perceived staled the next day, due to the varieties, quality options and advancement in information technology from other firms. 3D printing technology describes a series of digital manufacturing technologies, which produce component parts layer-by-layer through the additional use of materials. 3D printing technology consists of three core phases that is, the modelling, the printing and the finishing of the product. In the modelling, 3D printing technology could proffer additional improvements depending on the engaged manufacturing method.

Objectives: This research seeks to critically evaluate the influence of information technology on 3D printing for product development in Lagos, Nigeria. In this project, variables such as product design tools, decision support systems and file transfer protocol were categorized into three phases, namely; discovery, development and commercialization as the major sub-construct measuring the independent variable (Information Technology) on the dependent variable (3D printing and product development).

Methods: The research was purely quantitative as questionnaires were used as the major evaluating instrument under descriptive and cross sectional research design (survey methods). The population consisted of seven selected printing press companies in Lagos, Nigeria. The survey was used to generate responses related to the research questions and objectives.

Results: The result of the study reveals that product design tools in the discovery and development phase, the decision support system in the development and commercialization phase, and the file transfer protocols in the discovery, development and commercialization phase have significant influence on 3D printing for product development. Also, it was found that product design tools in the commercialization phase and in the discovery phase of decision support system do not have significant influence on 3D printing for product development.

Conclusions: The study concludes that product design tools in the discovery and development phase, the decision support system in the development and commercialization phase, and the file transfer protocols in the discovery, development and commercialization phase have significant influence on 3D printing for product development. Thus, the study recommends that there is need for more innovations, there is need to standardise packages for loan applications, which will act as a decision support system for the employees in order to make consistent applications for loans, credit analysis, etc. Finally, more research work can be devoted through the use of other related textbooks and journals.

Keywords: Information Technology, discovery, development, commercialization, product development.

CONTENTS

1 INTRODUCTION

1.1 Background to the Study

The continuous changes in the environment and increase in the global rate of market competition have shown trending in organisational innovations and product development. Most organisations in global market now frequently scan and assess their environment as consumers' taste and preference became the sole target. Consumers' preferred product of yesterday might unexpectedly devalue or be perceived as staled the next day, due to the varieties and quality options from other firms. The "effective product development rests on a product's design's ability to create a positive product experience" (Clarke & Fujimoto, 1991) as "product innovations performance has been seen as an important driver for firm growth particularly the combination of product and processes while innovations significantly improving firm growth" (Goedhuys & Veugelers, 2008).

Optimum growth rates in sales and raising of funds for business, see for instance the study conducted by Haeussler, Patzelt and Zahra (2012) under which it was posited that "new product development is important for new firm's successful performance, though they also attest that developing new products is costly and time consuming with at times uncertain outcomes". Ansoff (1987) coined and developed the concept of product development which he defines "as the focus on the needs of the current customers and the wider customer markets". Cooper, Edgett and Kleinschmidt (2004) added that "product developments are increasingly emerging in many competitive firms "as the key to corporate success in the marketplace".

Therefore, product development today must provide customers with values by designing products that fit customers' needs and contribute to gaining higher customer satisfaction and corporate profits.

However, for an effective product design and development, information technology (IT) is needed as a tool towards the implementation and achievement of organisation objective. In business context, the Information Technology Association of America (ITAA) defines IT as "the study, design, development, application, implementation, support or management of computer-based information systems". Despite all the stress and efforts of suppliers to design quality IT software, research suggests that "companies are fairly immature in their use of IT for product development" (Adams-Bigelow, 2004; Barczak & Sultan 2006). For instance, Adams-Bigelow (2004) narrated that "the recent Comparative Performance Assessment Study (CPAS) by the Product Development & Management Association (PDMA) found that less than 20% of the 'Best' firms used web-based market research tools and product portfolio management software while less than 40% used groupware software to support their project teams". According to Soludo (2005) "IT came to assume a new role in organizations, which is a strategic weapon, and IT revolution can be seen to have been affecting competition in the market settings under three important ways, firstly, it changes the industry structures, thereby altering the rules of competition, secondly, it created the opportunity for competitive advantage by producing new ways to perform better than similar competitors in the industry, and thirdly, it spawns a whole new business often from within a company's existing operation".

This continuous research and improvement on IT as well as development of products specifically in printing brought about the introduction of 3D design and technology. In a study of Reeves & Mendis (2015), "3D printing technology describes a range of

digital manufacturing technologies, which produce component parts layer-by-layer through the additional use of materials". This technology was developed in 1984 by Charles W. Hull from 3D Systems Corporation and has become more and more useful, while their price points lowered, thus becoming more affordable. Nowadays, rapid prototyping has a wide range of applications in various fields of human activity: research, engineering, medical industry, military, construction, architecture, fashion, education, computer industry and many others.

According to Pirjan and Petrosanu (2014), "3D printing technology consists of three main phases - the modelling, the printing and the finishing of the product. Under the modelling, 3D printing technology could offer additional improvements depending on the employed manufacturing technique. In the printing process, multiple materials or multiple colours can be used in manufacturing different parts of the same object. Lastly, if necessary when printing the objects, certain supports can be applied to be removed or dissolved when finishing the product".

However, "product development is a very accurate process, as 3D printing technology assumes a level of precision that in the early-stages is not available" (Santos, 2014). It is now the knowledge of most people in the developed countries that 3D printing as an IT instrument "met this accuracy by exploring processes that can create a better initial framing of the problem, which afterward require fewer prototypes and as a consequence remove a number of options from the solution space" (Fixson & Marion, 2012). Therefore, "companies can do their production using 3D printing technology without a physical prototype, or fewer prototypes and therefore the cost of rejecting a style (in terms of material, labour, and time) is significantly lowered and consequently the risk of the development process is also lowered" (Clarke & Wilhelm, 2011).

1.2 Statement of Problem

A central problem for managers today is the management of change and complexity arising from new technology and organization's interaction with the turbulent external environment. However, it is imperative for managers today, to be profoundly sensitive to on-going changes specifically on information technology (IT) in their environment. Therefore, it is essential that managers, executives, business research officers and other employees of an organization gain good understanding of how the business environment is changing. An alertness and sensitivity to the environment is very essential ingredient of business success, survival and longevity, because of the firm's dependence on it for resources inputs and services outputs.

However, many organizations erroneously attribute all increase in product quality and development to technology without paying attention to human resources as the main source of organizational strategy. In spite of the changing conditions that characterize the work place of the 21st century, man's domination in the society and organizational settings remain the same. IT has only expanded man's minds and intellect but has not replaced him. The effectiveness of an information system is therefore dependent not on the technology itself, rather its human effort or its cumulative knowledge that further promotes technology innovation to enable organization to cope with change.

Also, although the computer is perhaps the greatest invention that has influenced organizations, nations and human interactions in nearly all facets of life, nevertheless its performance and usefulness depend upon the knowledge, discrimination, intelligence and value of those who create it and make use of it. Technologies can only increase productivity or improve performance when combined effectively with other resources.

Given the importance of IT in creating business value through the development of new products and services, this study seeks to identify factors that influence IT usage in connection with product development. Evidence and conceptual studies indicate that the usage of IT tools for New Product Development (NPD) can shorten time to market, improve product quality, and increase productivity. However, empirical substantiation of this impact is mostly non-existent. The current study investigates the relationship between the influence of information technology on 3D for product development, speed to market and market performance. When it comes to additive manufacturing three main questions asked are regarding materials, scale and application. These will be discussed and investigated with the help of finite element analysis and 3D modelling/printing. Hence, a key problem to be analyzed is what the foreseeable application of 3D printing in the printing industry is. The main inspiration behind this research project (or also a further break-down of the key issues surrounding 3D) are the digital 'intelligence' of printers, bio-mimicry, efficiency of structures, use of materials, the future scale and development of rapid prototyping from both technological and social point of view.

1.3 Purpose of the Study

The major purpose of this research work is to critically evaluate the influence of information technology on 3D printing for product development in Lagos, Nigeria. Specifically, the study aims to achieve the following minor objectives:

i. To examine the use of product design tools in the discovery, development and commercialization phases on 3D printing for product development.
ii. To investigate the use of decision support systems (DSS) for project evaluation in the discovery, development and commercialization phases on 3D printing for product development.
iii. To determine the influence of file transfer protocols in the discovery, development and commercialization phases on 3D printing for product development.

1.4 Research Questions

The following questions are to be examined in the course of this study.

i. What is the influence of the use of product design tools in the discovery, development and commercialization phases on 3D printing for product development?
ii. What is the influence of decision support systems (DSS) for project evaluation in the discovery, development and commercialization phases on 3D printing for product development?
iii. What is the influence of file transfer protocols in the discovery, development and commercialization phases on 3D printing for product development?

1.5 Research Hypotheses

The following hypotheses will be tested and appropriate inferences drawn in the study:

$H_0$1: Product design tools in the discovery phase do not have significant influence on 3D printing for product development.
$H_0$2: Product design tools in the development phase do not have significant influence on 3D printing for product development.
$H_0$3: Product design tools in the commercialization phase do not have significant influence on 3D printing for product development.
$H_0$4: Decision support systems (DSS) in the discovery phase do not have significant influence on 3D printing for product development.

$H_0$5: Decision support systems (DSS) in the development phase do not have significant influence on 3D printing for product development.

$H_0$6: Decision support systems (DSS) in the commercialization phase do not have significant influence on 3D printing for product development.

$H_0$7: File transfer protocols in the discovery phase do not have significant influence on 3D printing for product development.

$H_0$8: File transfer protocols in the development phase do not have significant influence on 3D printing for product development.

$H_0$9: File transfer protocols in the commercialization phase do not have significant influence on 3D printing for product development

1.6 Significance of the Study

The findings that may be provided by this research are expected to benefit managers to guide them on how best they could channel their organization's resources when it comes to investing in information technology towards adoption of 3D printing technology and achieving optimum improvement in new product development effectiveness. Also, the aim is that the findings will be useful for other researchers who would like to do further research on the subject matter in the future. The aim is to contribute to knowledge development in the area of improving product effectiveness.

1.7 Restrictions of the Study and Targeted Audience

The scope of this study is to develop and demonstrate the use of an evaluation instrument in evaluating the influence of information technology on 3D printing for product development with reference to printing press companies in Lagos, Nigeria. However, due to the fact that not all the printing press companies in Lagos can be selected for evaluation, this study specifically looks at seven selected printing press companies in Lagos State, Nigeria, namely Alpha Press Limited, Philsprints, Printivo.com, Funseg Flourshingn ventures, Slite, Lifemangado and Current Grafix Prints.

In order to delimit the study to a manageable size, the researcher concentrated on staff and customers of these aforementioned printing press companies, regardless of their gender, age, marital status, religion, ethnicity, educational qualifications, and their experience concerning printing press business. A case study approach was applied concerning the seven printing press companies located in Lagos State, Nigeria and did not cover other printing press companies situated in other states in Nigeria. Hence, the result will not be generalized, but findings will be placed in the relevant context of printing improvement in Nigerian companies in Lagos which are utilizing 3D technology for product development.

2 RELATED WORK

2.0 Introduction

In this chapter, theories and definitions in this research are explored to explain what information technology is all about and how it influences all aspects of life. In conjunction with 3D printing for product development, topical issues that are discussed are the conceptual framework, taking into cognizance the concept of information technology, 3D printing technology including its advantages and disadvantages, product development as well as product development processes. A constructive model was depicted to explain the flows of relationship between these variables. Within the theoretical framework, the mathematical theory and diffusion of innovations theory are discussed based on their interconnectivity with the theories to explain the dependent and independent variables. For the empirical framework, recent related articles were reviewed for the purpose of the study.

2.1 Concept of Information Technology

Information Technology (IT) has been defined in various ways by different authors. Over the years, IT has been conceptualized and measured differently by different researchers. The majority of the authors, however, equate IT with computer systems. Heeks & Molla (2004) defined information technology (IT) as "an organization's computing and telecommunications hardware and software technologies that provide automatic means of handling and communicating information". It is a general term "that describes any technology that help to produce, manipulate, process, store, communicate, and/or disseminate information" (William &Sawyer, 2005).

Similarly, Shelly, Cashman, and Verment (2004) narrate that "IT includes hardware, software, databases, networks, and other related components which are used to build information systems". The proper utilization of IT design is a paramount component of competing in a turbulent environment and economy as a whole. Vasudevan (2003) postulated that IT is the major contributor to the progress of the developed countries.
Other researchers, such as Poku and Vlosky, (2002), similarly state that "IT is the technology that supports activities involving the creation, storage, manipulation and communication of information together with their related methods and management applications". Thus, 'IT 'or the 'Info Tech' concept as it is generally used today, has evolved from a merging of computer with telecommunications technologies.

In quest of improving efficiency and effectiveness, companies are making heavy investments in IT. These enduring magnitudes of investment in IT have attracted the attention of many researchers, managers and policy makers to the influence of IT on product development. The expectation is usually that increased investment in IT and product development would naturally lead to increased performance of the organization.

2.2 3D Printing Technology

3D printing is a term used to describe "a range of digital manufacturing technologies, which produce component parts layer-by-layer through the additional use of materials" (Weinberg, 2010). Historically, 3D printing concepts were first developed by Charles Hull in 1984. Hull went on to develop the first 3D printer

termed the 'Stereolithography Apparatus' which was patented in 1986. Since then, 3D printers have been developed and applied in many areas, including: manufacturing; printing prototypes of car and airplane parts, printing structural models by architects, fabricating medical implants with customised design, and there's an intriguing possibility that custom robots can be produced with the aid of 3D printing (Bogue, 2013). One of the key benefits of 3D printing is that its innovative technology has been proven to deliver products with high speed and with low operational cost (Dimitrov et al, 2006). 3D printing processes provide flexibility for individuals or industries to personalize product customization according to individual needs and requirements.

"There are many different types of 3D printing processes, which are all controlled using three-dimension digital data", according to Gross et al (2014). They add that "some processes build parts by extruding molten plastic through a nozzle and depositing this accurately onto a build platform, as other technologies use lasers to melt layers of powdered material, with other processes using ink-jet printing heads to deposit material into the shape of the desired component part" (Gross et al, 2014). Therefore, 3D printers can be used to print both edible and inedible products. According to Clarke and Wilhelm (2011) "companies can do their production using 3D printing without a physical prototype, or fewer prototypes and therefore the cost of rejecting a style (in terms of material, labour, and time) is significantly lowered and consequently the risk of the development process is also lowered". With 3D printing, objects can be turned into a real life creation from just a simple computer file. Other benefits of 3D printing highlighted by Campbell et al. (2011) include:

- Assembly lines and supply chains can be reduced or eliminated for many products
- Products could be printed on demand without the need to build up inventories of new products and spare parts.
- Manufacturing companies can print a huge range of types of products without retooling, and each printing could be customized without additional cost.
- Production and distribution of material products could begin to be de-globalized as production is brought closer to consumer.
- Manufacturing could be pulled away from 'manufacturing platforms' to the countries where the products are consumed, thereby reducing global economic imbalances as export countries' surpluses are reduced and importing countries reliance on imports shrink.
- Reduced need for labour in manufacturing
- The carbon footprint of manufacturing and transport as well as overall energy use in manufacturing could be reduced substantially.

2.3 Product Development

Product development, also called new product management, is a series of steps that includes the conceptualization, design, development and marketing of newly created or newly rebranded goods or services. But today, "leading-edge firms can exploit global asset configurations to customize existing products and services, and they also have the ability to combine their resources with an expanding knowledge base to create a continuous stream of new products and services" (Miles, Snow, & Miles, 2000). According to Johansen (2005) "product development is the process that covers product design, production system design and product introduction processes and start of production". Its objective is to cultivate, maintain and increase a company's market share by satisfying a consumer demand. "Product development (PD) is widely recognized as a key to corporate prosperity" (Lam, Chin, Yang, &

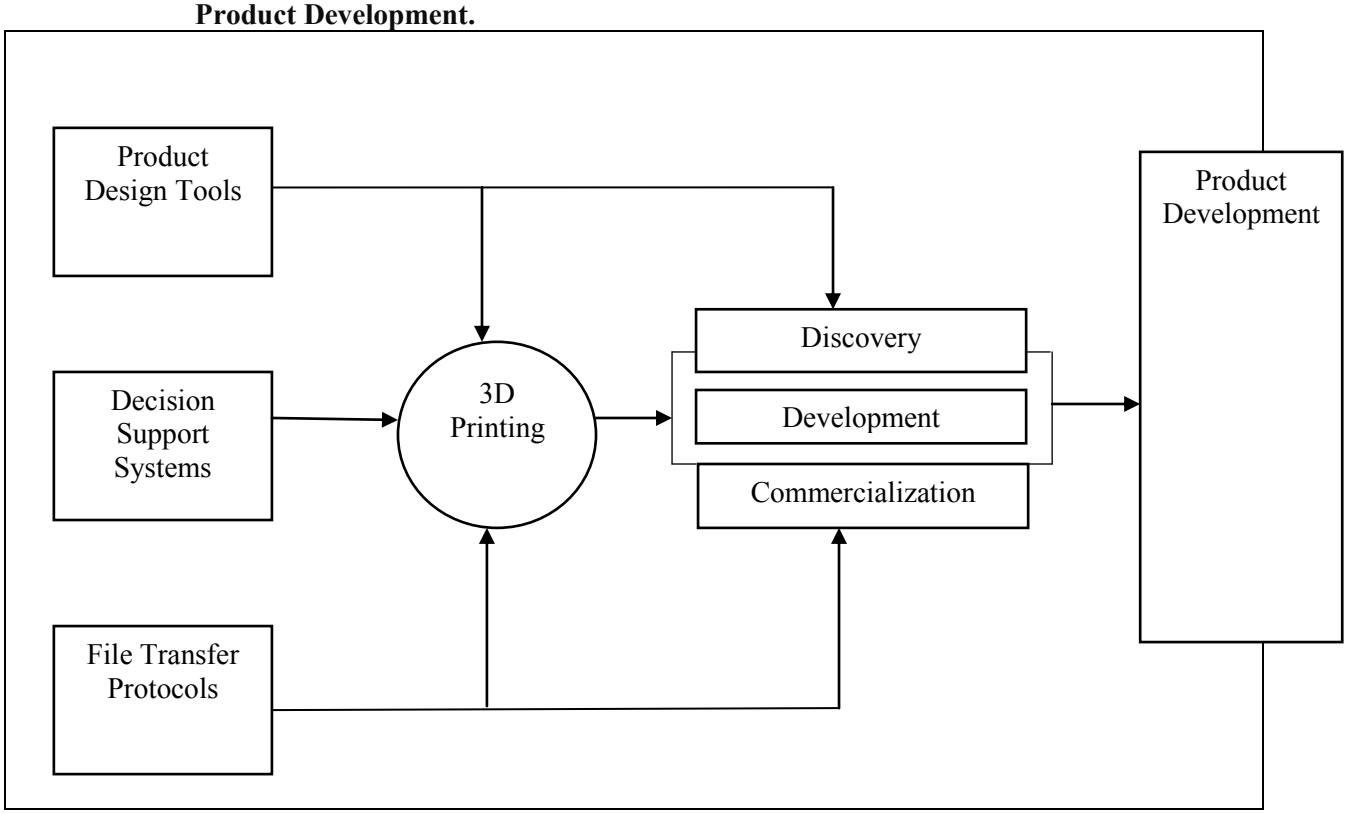
Liang, 2007). Not every product will appeal to every customer. Because of this the target market for a product is a critical component that must be de termined early in the product development process.

"With the needs to respond quickly to dynamic customer needs, increased complexity of product design and rapidly changing technologies, the selection of the right set of NPD is critical to a company's long-term success" (Chen et al, 2008). Also, "combination of factors such as ever changing market needs and expectations, rough competition and emerging technologies among others, challenges industrial companies to continuously increase the rate of new products to the market to fulfil all these requirements" (Sorli et al, 2006). Meanwhile, "the ultimate objective of all product development teams, is superior marketplace success of the new product" (Akgun et al, 2006). In light of this, product innovations came up, which are central in securing a firm's competitive advantage in international markets (Jeong, 2003). Therefore, product development "is vital and needs to be developed both innovatively and steadily" (Chen et al., 2008).

2.4 Conceptual Framework

Smith (2004) explains that "conceptual framework is structured from a set of broad ideas and theories that help a researcher to properly identify the problem under investigation", frame relevant questions and find suitable literature. Also, Mile and Huberman (1994) define conceptual framework "as a written or visual presentation that explains either graphically, or in narrative form, the main things to be studied, the key factors, concepts or variables and the presumed relationship among them". In light of the foregoing, the study uses the model below to provide further insight as to the web of relationships between information technology sub-constructs, 3D printing technology and product development.

Figure 1: Model of Information Technology, 3D Printing Technology and Product Development.



Source: *Conceptualized by researcher, 2016.*

Figure 1 above shows the relationship between the sub-constructs of information technology (IT), 3D printing and product development, as conceptualized by the researcher. The figure depicts a web of relationships which exist among these variables previously explained above, such as product design tools, decision support systems and file transfer protocols, in the discovery, development and commercialization phases of 3D printing for product development.

2.5 Theoretical Framework

Theory helps us to understand, analyze and interpret the phenomena aligned with either independent variables, dependent variables or both. This study is predicated on the following two theories:

i Mathematical Theory

ii Diffusion of Innovations Theory

2.5.1 Mathematical Theory

The mathematical theory of communication development by Shannon and Weaver, popularly called the Shannon-Weaver model, was developed in 1949 as a model in electronics communication. They considered the theory as strictly mathematical and it has been identified with technology and technical aspects of communication. It created an impact on such concept as measuring the units of the information transmitted over technical channel. Shannon was concerned with the technical problems of the transmitting signals from one point to another. He considered communication as a mechanistic system consisting of the following five basic elements:

i. Information: The source

ii. Transmitter: To convert a message into transmittable signals
iii. Channel: Medium or agency
iv. Receiver: Who reconstructs the message from the signals
v. Destination: The person or machine for which it is intended

Some of the components he introduced in the systems are the message, transmitted signals, received signals and noise source. The Shannon and Weaver model contains the essential elements for explaining the human communication processes, according to their mathematical theory.

This is applied to the study as information technology (IT) involves series of data arranged in an organization's database. This information according to Shannon and Weaver (1949) in mathematical theory "must pass through series of stages such as the information source, to transmitter, medium selective, the receiver and the destination". Information communicated in this manner was said to be effective. Also, this theory considered how meaning can be gained from information regardless of the language, medium and destination. Therefore, an information shared or saved in a database for future use, that can be easily transmitted to be read, deliver meaning and be understood, is considered to be effective.

2.5.2 Diffusion of Innovation Theory

Diffusion of innovation (DOI) is a theory of how, why, and at what rate new ideas and technology spread through cultures, operating at the individual and firm level. DOI theory "sees innovations as being communicated through certain channels over time and within a particular social system" (Rogers, 1995). "Individuals are seen as possessing different degrees of willingness to adopt innovations, and thus it is generally observed that the portion of the population adopting an innovation is approximately normally distributed over time" (Rogers 1995). "Breaking this normal distribution into segments leads to the segregation of individuals into the following five categories of individual innovativeness (from earliest to latest adopters): innovators, early adopters, early majority, late majority, laggards" (Rogers 1995). The innovation process in organizations is much more complex, as many stressed how the organisation product could be developed. However, the idea of product development in an organisation is in itself an innovation process for which this theory can be used to explain progress and potential challenges. Product development generally involves a number of individuals, perhaps including both supporters and opponents of the new idea, each of whom plays a role in the decisions being made and adhered to concerning product development.

Based on DOI theory at firm level (Rogers, 1995), "innovativeness is related to such independent variables as individual (leader) characteristics which describe the leader attitude toward change, internal organizational structural characteristics which include observations, and external characteristics of the organization". According to Rogers (1995), "centralization is the degree to which power and control in a system are concentrated in the hands of a relatively few individuals"; "complexity is the degree to which an organization's members possess a relatively high level of knowledge and expertise"; "formalization is the degree to which an organization emphasizes its members' following rules and procedures"; "interconnectedness is the degree to which the units in a social system are linked by interpersonal networks"; "organizational slack is the degree to which uncommitted resources are available to an organization"; "size is the number of employees of the organization".

2.6 Review of literature concerning empirical studies in this area

However, "out of several and heavy investment in research and development, few studies have examined how information technology (IT) is adopted, how design customization capability is built, and whether they reveal close associations with new product development (NPD) success". This according to Chen and Li (2010) in their study conducted to examine the "effect of information technology adoption and design customization on the success of new product development". Using the data from 172 sample high-tech manufacturers, the effects of IT adoption and design customization on NPD success were investigated. The results support the idea that "IT adoption and design customization have positive impacts on NPD success". Therefore, it was concluded that "the advancement of internet technology and customization capability set off research into their impacts on all business operations including NPD".
Also, Peng et al (2014) in their research conducted using "collaborative product development to assess the effect of project complexity on the use of information technology tools and new product development practices", tested their hypotheses using data from a sample of NPD projects in three manufacturing industries. The results showed that "IT tools are associated with collaboration to a greater extent when product size is relatively large". In contrast, "IT tools exhibit a smaller association with collaboration when project novelty or task interdependence is relatively high". NPD practices on the other hand are found to be more significantly associated with "NPD collaboration under the contingency of high project novelty or high task interdependence". Thus, it was concluded that the findings "provide insights about circumstances where several popular IT tools are more likely to facilitate collaboration, thus informing an NPD team's IT adoption and use decisions".

Finally, Reeves and Mendis (2015) together conducted a study to assess the "current status and impact of 3D printing within the industrial sector, under the analysis of six case studies". These six case studies were arranged into three key themes such as, "replacement parts, customized goods and high value small status goods". The research was carried out using a qualitative software tool to interview leaders within the selected industries to identify 'existing intellectual property precedence in the UK' and 'EU relating to 3D printing, business drivers, constraints and benefits of transitioning to 3D printing rather than more traditional supply chains'. Also, focus groups were held with "artists, creative and technology users to further understand the opportunities and constraints presented by the manufacturing approach". The findings revealed that "there will be very little commercial impact on either the automotive or domestic appliance aftermarket within the next decade as a function of either consumer 3D printing or industrial additive manufacturing". Also, that "there is no evidence to suggest that file sharing of illicit material is rife, largely as the value proposition of the parts being printed is very small". Therefore, it was concluded that, the scope behind the findings was "primarily due to the low maturity of home 3D printing technology and the anticipated rate of development". "If the technology - including hardware, software and materials – reaches a point where a product can be printed easily and quickly and it will work in the appliance without having to modify the part through iteration, a wider consumer base may adopt the technology". In the long run, it was concluded, "it is unlikely to have a significant impact on the domestic appliance aftermarket".

3 METHODOLOGY

3.1 Introduction

The objective of this chapter is to elucidate how this project was carried out. It contains the processes and procedures employed in the implementation of the study which include the research design, sample size and sampling techniques, description of study population, instrumentation, data collection procedure and the nature of constraints faced by the researcher during the course of conducting this research, which were all employed to ascertain the influence of information technology on 3D printing for product development in some selected printing press companies in Lagos, Nigeria. Thus, this chapter is concerned with the methods and techniques used in the conduct of the study. It involves a detailed narration of the research instruments and description of the research design. In a nutshell, the chapter involves the processes, procedures and techniques that would be adopted in order to arrive at a reasonable conclusion and as well to meet with the objective of the study.

3.2 Research Design

Research design according to Fagbohungbe (1993) is "an action plan that allows a researcher to provide solution to the problem of who to study, what to study, when to study, where to study and how to generate and analyze data or information in the research situation". It involves the plan structure and strategy of investigation conceived to provide answers to research question and control variances. There are three basic research designs, namely: descriptive research design, causal or experimental research design and exploratory research design.

For the purpose of this study, a descriptive research design employing its variance in terms of cross sectional survey will be adopted for use. A descriptive research design involves field enquiries for collecting data, using questionnaire or interview from the target population at or during a period of time. Therefore, the design is the most appropriate for this study because the variables of the research are purely descriptive and can only be examined through primary data collection. The data generated will then be analyzed along with the research hypotheses leading to appropriate inferences and generalizations.

3.3 The Study Population

The population of this study comprises of customers and members of staff of some seven selected printing press companies in Lagos Metropolitan, Nigeria, namely Alpha Press Limited, Philsprints, Printivo.Com, Funseg Flourishing Ventures, Slite, Lifemangado Studios and Current Grafix Prints. The study will focus on the selected participants irrespective of their gender, marital status, religion affiliation, age, educational background, and ethnicity. Therefore, the total targeted population is 5,237 as the figures represent the total population of members of the staff of of the seven companies and their customers out of which a sample size will be drawn.

3.4 Determination of Sample size

It has been discussed in the literature that "the main determinants of sample size are the purpose of the study, population size, sampling error (the level of precision), the confidence level and the degree of variability in the main measured attributes"

(Israel, 2013). Therefore, having defined the population of interest, a sample of it can now be drawn for the purpose of the study.

A sample size of 371 respondents shall be adopted using the Yamane (1967) formula. The formula and selection procedure is given below:

$$n = \frac{N}{1 + N(e)^2}$$

Where: n = Overall Sample Size

N = The Total Population

e = Margin of Sampling Errors

Thus, using a sampling error of 0.05 and the population size being 5,237, the sample became:

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{5{,}237}{1 + 5{,}237\,(0.05)^2}$$

$$n = \frac{5{,}237}{1 + 5{,}237\,(0.0025)}$$

$$n = \frac{5{,}237}{1 + 13.0925}$$

$$n = \frac{5{,}237}{14.0925}$$

$$n = \mathbf{371}$$

Therefore, based on the result obtained above, the total sample size is 371, using convenience sampling techniques. The sample size chosen was to ensure fair representation of the respondents and allow for precision in the data analysis.

3.5 Research Instruments

According to Dixon-Ogbechi (2002) "research instrument is a device for collecting relevant data or measuring the variables which are used for answering research question and/or testing study hypothesis". Hence in this study, for data collection purposes, questionnaire will be adopted. The reason for employing questionnaire relate to its simplicity, ease of administration, consistency of answer, freedom of answers and unambiguity. The design of the questionnaire is highlighted below:

- **Section A:** This section introduces the topic and the purpose of the research to the respondents, which will be addressed in cover letter stating that the information provided will be used for academic exercise and the information will be treated with strict confidentiality.

- **Section B:** This section contains items that were constructed to elicit responses from the respondents regarding the three research questions postulated to guide the study. These items were scored using a five-point format of Likert scale of strongly agree = 5, agree = 4, undecided = 3, disagreed = 2 and strongly disagreed = 1.

- **Section C:** This section consists of the demographical information of the respondents under study. Specifically, the content in this section are the personal characteristics of the respondents.

The researcher will visit the designated area to obtain information to carry out the study. Other data that is used in this research is secondary data, that is, it consists of information from published works such as textbooks, journals, newspapers, amongst others.

3.6 Methods of Data Analysis

The data that will be generated from the field of study will be presented using frequency distribution and percentage to describe the aspect of the data, where all the data will be presented in forms of tabulation, frequency and percentages. For the purpose of the data analysis; both descriptive and inferential statistical techniques will be used. Percentage will be used for descriptive analysis to measure the statistical difference of one variable over others while multiple regression analysis will be the main statistical tool to measure the significant influence between the variables. These methods are selected because of the large amounts of data that were envisaged in the course of study. It is often useful to distribute the data into categories and to determine the number of individuals or cases belonging to each category.

4 RESULTS

This chapter discusses the data obtained from the questionnaires that were distributed and presented to the respondents. Their responses were presented in tabular form for easy analyses and interpretation. Analyses were centered on evaluating the influence of Information Technology on 3D printing for product development in Lagos, Nigeria. In addition, this chapter describes in detail the socio demographical variables of the respondents such as gender, age, marital status, educational qualifications and length of service. These analyses were carried out with the use of descriptive statistics (frequency counts and percentages) with the aid of SPSS Version 20.0 to produce tables and statistical data that was applied for the interpretation of the results.

However, due to the attitude of individuals towards research and time constraints, a total of 371 copies of a structured questionnaire were administered, out of which 356 questionnaires were returned and were validly completed for analysis and interpretation. Finally, regression analysis was used to test the hypotheses of the study.

4.1 Socio-demographic Characteristics of the Respondents

Characteristics	Frequency	Percent
Gender		
Male	224	62.9
Female	132	37.1
Total	356	100.0
Age (Years)		
20-29	70	19.7
30-39	163	45.8
40-49	63	17.7
50-59	41	11.5
60 and Above	19	5.3
Total	356	100.0
Marital Status		
Married	223	62.6
Single	123	34.6
Divorced	10	2.8
Total	356	100.0
Highest Educational Qualification		
O-level & below	46	12.9
OND/NCE	238	66.9
Bachelor's degree /HND	42	11.8
Master's Degree	30	8.4
Total	356	100.0
Length of Service (Years)		
0 – 4	89	25.0
5-9	162	45.5
10-14	60	16.9
15-19	24	6.7
20 and Above	21	5.9
Total	356	100.0

Source: *Survey, 2016*

The above table shows the social demographic characteristics of the respondents. The gender distribution reveals that the percentage of male respondents was 62.9% while that of the female was 37.1%. This shows that the study is gender friendly as it does not discriminate or form any bias against any gender. Also, the percentage indicates that more male gender responded to the questionnaire than female. Age of respondents varied from 20 years and above with age bracket of 30 to 39 years being the modal age. Marital status of the respondents includes single, married and divorced with majority of the respondents being married (62.6%). Respondents were asked to provide their educational background, among which 12.9% were holding O'level certificate and below, 66.9% were OND/NCE holders, 11.8% were identified with Bachelor's degree/HND while 8.4% were masters' degree holders. This shows that the respondents are well educated and can be expected to know the relevance and implication of the study. Finally, under the respondent's length of service in printing press business, 25% indicated to have spent below 4 years, 45.5% were between 5 to 9 years, 16.9% were between 10 to 14 years, 6.7% were between 15 to 19 years, while 5.9% were 20 years and above. This revealed that the majority of the respondents were having an experience between 5 to 9 years in printing press business.

4.2 Presentation and Analysis of Data According to Research Questions Using Descriptive Statistics

The decision rule is that, if mean is greater than 2.5, the respondents agree/are favourable and if mean is less than or equal to 2.5 the respondents disagree/ are unfavourable to the statement, as indicated by their answer on a five point Likert scale where strongly agree (SA) is 5, agree (A) is 4, undecided (U) is 3, disagree (D) is 2 and strongly disagree (SD) is 1.

Table 4.2.1: Product Design Tools

ITEMS	SA (%)	A (%)	U (%)	D (%)	SD (%)	Mean	Std Dev.
Discovery							
We are aware of new tools in designing our printing products.	136 (38.2)	140 (39.3)	71 (19.9)	3 (0.8)	6 (1.7)	4.1152	.86932
The expenses of our product design tools have been under control.	119 (33.4)	131 (36.8)	57 (16.0)	26 (7.3)	23 (6.5)	3.8343	1.15943
New product designs have been timely launched.	143 (40.2)	145 (40.7)	34 (9.6)	28 (7.9)	6 (1.7)	4.0983	.97801
Development							
We possess technical capabilities of product design (related to competition).	90 (25.3)	150 (42.1)	62 (17.4)	46 (12.9)	8 (2.2)	3.7528	1.04308
We have developed new products with financial success.	114 (32.0)	133 (37.4)	62 (17.4)	37 (10.4)	10 (2.8)	3.8539	1.06995
We are satisfied with our product design and development process	111 (31.2)	150 (42.1)	54 (15.2)	33 (9.3)	8 (2.2)	3.9073	1.01529
Commercialization							
We design new products to conform to customers'	116 (32.6)	154 (43.3)	45 (12.6)	36 (10.1)	5 (1.4)	3.9551	.99191

requirements.							
Customers became involved in 3D printing project only after the design was completed.	117 (32.9)	131 (36.8)	54 (15.2)	46 (12.9)	8 (2.2)	3.8511	1.08655
Customers were frequently consulted about the design of their products.	116 (32.6)	168 (47.2)	37 (10.4)	28 (7.9)	7 (2.0)	4.0056	.96120

Source: *Survey, 2016*

Items in table 4.2.1 sought to find out the influence of the use of product design tools in the discovery, development and commercialization phases on 3D printing for product development. The above result shows that majority of the respondent agreed under the three phases (discovery, development and commercialization) with the entire mean greater than 2.5 (i.e. the respondents agreed that they are aware of new tools in designing their printing products). Respondents that agreed were of the view that they are aware of new tools in designing the printing products, the expenses of the product design tools have been under control and that new product designs have been timely launched.

Also, according to mean score above, it was revealed that they possess technical capabilities of product design (related to competition) and have developed new products with financial success. They agreed that they are satisfied with the product design and development process. Respondents agreed that they design new products to conform to customers' requirements; customers became involved in 3D printing project only after the design was completed. Customers were frequently consulted about the design of their products. Thus, product design tool in the discovery phase has statistical considerable influence on 3D printing for product development.

Table 4.2.2: Decision Support System

ITEMS	**SA (%)**	**A (%)**	**U (%)**	**D (%)**	**SD (%)**	**Mean**	**Std Dev.**
Discovery							
Top managers are aware of recent IT development.	109 (30.6)	149 (41.9)	55 (15.4)	37 (10.4)	6 (1.7)	3.8933	1.00973
Top managers are aware of competitors' new movements in using IT.	123 (34.6)	163 (45.8)	40 (11.2)	25 (7.0)	5 (1.4)	4.0506	.93008
Top managers believe the use of IT is beneficial.	105 (29.5)	152 (42.7)	68 (19.1)	29 (8.1)	2 (0.6)	3.9242	.92683
Development							
Top managers encourage employees to be familiar with new IT applications.	116 (32.6)	155 (43.5)	56 (15.7)	25 (7.0)	4 (1.1)	3.9944	.93144
Top managers frequently ask subordinates to be aware of new IT development and trends.	102 (28.7)	154 (43.3)	63 (17.7)	33 (9.3)	4 (1.1)	3.8904	.96229
Top managers provide sufficient supports for IT investment.	97 (27.2)	156 (43.8)	57 (16.0)	40 (11.2)	6 (1.7)	3.8371	1.00499
Commercialization							
Top managers provide decision support system towards the use of new	93 (26.1)	142 (39.9)	69 (19.4)	45 (12.6)	7 (2.0)	3.7556	1.03969

technologies.							
Top managers have invested a lot on acquiring IT knowledge.	101 (28.4)	162 (45.5)	48 (13.5)	39 (11.0)	6 (1.7)	3.8792	.99832
Information technology has played a key role in changing the process of decision support system.	102 (28.7)	141 (39.6)	64 (18.0)	39 (11.0)	10 (2.8)	3.8034	1.05915

Source: *Survey, 2016*

Items in table 4.2.2 were presented to investigate the use of decision support systems (DSS) for project evaluation in the discovery, development and commercialization phases of 3D printing for product development. The above result reveals that a majority of the respondents agreed with the statements concerning the three phases (discovery, development and commercialization) with the entire mean greater than 2.5 (i.e. the respondents agreed that top managers are aware of recent IT development.).

It was revealed that the general perception among respondents is that top managers are aware of recent IT development; top managers are aware of competitors' new movements in using information technology; they agreed that top managers believe the use of information technology is beneficial; they were of the opinion that top managers encourage employees to be familiar with new IT applications. They agreed that top managers frequently ask subordinates to be aware of new IT development and trends and that top managers provide sufficient supports for IT investment.

Respondents were of the opinion that the top managers provide decision support system towards the use of new technologies; top managers have invested a lot on acquiring IT knowledge while a majority of the respondents were of the view that Information technology has played a key role in changing the process of decision support system. A majority of the respondents were of the view that decision support system in the development phase has significant influence on 3D printing for product development.

Table 4.2.3: File Transfer Protocols

ITEMS	**SA (%)**	**A (%)**	**U (%)**	**D (%)**	**SD (%)**	**Mean**	**Std Dev.**
Discovery							
We are aware of file sharing via network protocol.	81 (22.8)	146 (41.0)	58 (16.3)	47 (13.2)	24 (6.7)	3.5983	1.16952
File transfer protocol enables employees and customers to have access to information at their fingertips.	103 (28.9)	163 (45.8)	55 (15.4)	24 (6.7)	11 (3.1)	3.9073	.99285
File transfer protocol has made collation of information easier thereby reducing time taken to attend to clients.	104 (29.2)	151 (42.4)	62 (17.4)	27 (7.6)	12 (3.4)	3.8652	1.02851
Development							
Our information is stored and shared through computer networks.	63 (17.7)	159 (44.7)	32 (9.0)	60 (16.9)	42 (11.8)	3.3961	1.28167

We exchange information frequently through computer network connections.	126 (35.4)	156 (43.8)	41 (11.5)	23 (6.5)	10 (2.8)	4.0253	.99119
File transfer protocol improves transactions with customers.	125 (35.1)	173 (48.6)	35 (9.8)	21 (5.9)	2 (0.6)	4.1180	.85092
Commercialization							
Our database system is safe and under control.	150 (42.1)	150 (42.1)	31 (8.7)	22 (6.2)	3 (0.8)	4.1854	.89406
Our network is reliable in sharing data between the client and the server.	133 (37.4)	154 (43.3)	33 (9.3)	27 (7.6)	9 (2.5)	4.0534	.99857
Information technology has increased the interaction of the employees with customers through file transfer protocol.	121 (34.0)	182 (51.1)	23 (6.5)	25 (7.0)	5 (1.4)	4.0927	.89748

Source: *Survey, 2016*

Items in table 4.2.3 were presented in order to determine the influence of file transfer protocols in the discovery, development and commercialization phases on 3D printing for product development. The above result indicates that a majority of the respondents agreed with the statements concerning the three phases (discovery, development and commercialization) with the entire mean greater than 2.5 (i.e. the respondents agreed that they are aware of file sharing via network protocol).

Respondents were of the opinion that they are aware of file sharing via network protocol; they agreed that file transfer protocol enables employees and customers to have access to information at their fingertips; file transfer protocol has made collation of information easier thereby reducing time taken to attend to clients. They agreed that information is stored and shared through computer networks in the organization; they exchange information frequently through computer network connections; file transfer protocol improves transactions with customers. Highest percentage of the respondents agreed that their database system is safe and under control, they were of the view that network is reliable in sharing data between the client and the server. Information technology is perceived to have increased the interaction of the employees with customers through file transfer protocol.

The results also show that file transfer protocols in the discovery phase are perceived as having significant influence on 3D printing for product development. Similarly, file transfer protocols in the development phase is perceived as having significant influence on 3D printing for product development. Lastly, file transfer protocols in the commercialization phase is perceived as having significant influence on 3D printing for product development.

Table 4.2.4: 3D Printing for Product Development

ITEMS	**SA (%)**	**A (%)**	**U (%)**	**D (%)**	**SD (%)**	**Mean**	**Std Dev.**
We consulted customers early on 3D printing efforts for product development.	92 (25.8)	212 (59.6)	23 (6.5)	24 (6.7)	5 (1.4)	4.0169	.84902

We partnered with foreign companies on 3D design in developing our printing products.	100 (28.1)	207 (58.1)	19 (5.3)	24 (6.7)	6 (1.7)	4.0421	.86946
The customers prefer 3D printing technology in designing and developing their products than other digitals.	94 (26.4)	189 (53.1)	31 (8.7)	29 (8.1)	13 (3.7)	3.9045	.99965

Source: *Survey, 2016*

Items in table 4.2.4 above presented the respondents view on 3D printing for product development. The result shows that a majority of the respondents agreed, with the mean of 4.02, 4.04 and 3.90 respectively under each scale, that they consulted customers early on 3D printing efforts for product development, that they partnered with foreign companies on 3D design in developing printing products and that customers prefer 3D printing technology in designing and developing their products rather than other digitals.

4.3 Test of Hypotheses

Regression Analysis

To test each of the hypotheses formulated in the study, a multiple regression analysis was conducted to confirm (or disprove) the presence of a relationship between the constructs of the study. Regression analysis can be used to forecast the values of a dependent variable given value of one or more independent variables by calculation of a regression equation. The general model of the regression analysis is given below;

$$\mathbf{Y = a + \beta x}$$

$$\mathbf{Y = a + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5}$$

Where:

Y = Dependent Variable

a = Regression Constant

β = Beta coefficient or interception or slope (i.e. explains the actual effect of the independent variable on dependent variable).

X_n = The Changing Variables (i.e. x_1, x_2, x_3, x_4, x_5)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.980[a]	.960	.959	.18030

a. Predictors: (Constant), FTP Commercialization, DSS Commercialization, DSS Discovery, FTP Development, PDT Commercialization, FTP Discovery, PDT Discovery, DSS Development, PDT Development

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	271.255	9	30.139	927.160	.000[b]
	Residual	11.248	346	.033		
	Total	282.503	355			

a. Dependent Variable: 3D Printing for Product Development

b. Predictors: (Constant), FTP Commercialization, DSS Commercialization, DSS Discovery, FTP Development, PDT Commercialization, FTP Discovery, PDT Discovery, DSS Development, PDT Development

The regression model summary and ANOVA table above shows that the observed variance accounted for by all the predictors (product design tools (PDT), decision support system (DSS), and file transfer protocol (FTP)) is 96%. This connotes a strong and positive influence of information technology on 3D printing for product development. Also, the F-ratio is statistically significant as F (9, 346) = 927.160, P (0.000) < 0.05. This means that the three predictors (i.e PDT, DSS and FTP) jointly contribute to the observed change in the dependent variable (product development).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.169	.057		2.969	.003
	PDT Discovery	-.797	.073	-.871	-10.918	.000
	PDT Development	-.336	.096	-.387	-3.487	.001
	PDT Commercialization	.075	.080	.084	.937	.350
	DSS Discovery	-.050	.094	-.053	-.538	.591
	DSS Development	.299	.102	.319	2.942	.003
	DSS Commercialization	.547	.081	.625	6.733	.000
	FTP Discovery	.371	.069	.433	5.403	.000
	FTP Development	-.275	.069	-.308	-3.984	.000
	FTP Commercialization	1.122	.058	1.147	19.351	.000

a. Dependent Variable: 3D Printing for Product Development

The coefficient table shows all the predictors and their sub variables which contribute significantly to product development. It is evident from the table that the respondents in this study perceive that product design tools have significant influence on 3D printing for product development under the discovery phase and the development phase, but not significant influence under the commercialization phase. Also, respondents perceive that decision support system has significant influence on 3D printing for product development in the development and commercialization phase, but not in the discovery phase. Lastly, respondents perceive that file transfer protocol has significant influence on 3D printing for product development in all the three phases (i.e. discovery, development and commercialization). The outcome of the results of the survey concerning the rejection or acceptance of the hypotheses tested are presented in the table below

Decision

S/N	Hypotheses Statements (Null)	Decision
$H_0$1	Product design tool in the discovery phase does not have significant influence on 3D printing for product development.	Reject
$H_0$2	Product design tool in the development phase does not have significant influence on 3D printing for product development.	Reject
$H_0$3	Product design tool in the commercialization phase does not have significant influence on 3D printing for product development.	Accept
$H_0$4	Decision support system (DSS) in the discovery phase does not have significant influence on 3D printing for product development.	Accept
$H_0$5	Decision support system (DSS) in the development phase does not have	Reject

	significant influence on 3D printing for product development.	
$H_0$6	Decision support system (DSS) in the commercialization phase does not have significant influence on 3D printing for product development.	Reject
$H_0$7	File transfer protocol in the discovery phase does not have significant influence on 3D printing for product development.	Reject
$H_0$8	File transfer protocol in the development phase does not have significant influence on 3D printing for product development.	Reject
$H_0$9	File transfer protocol in the commercialization phase does not have significant influence on 3D printing for product development	Reject

4.3.1 The Validity of the Research Instrument

According to Asika (1991), validity is "about the research instrument measuring what it is designed to measure". Validity is a test of accuracy of the instrument in measuring variables of the research interest. Perfect validity requires that there be no measurement error. There are different ways in which validity can be assessed; content validity; criterion validity; face validity; homological validity; construct validity; convergent validity; and discriminate validity. For the purpose of this study, data collection instrument is subjected to content, construct and face validity. The adapted questionnaires were presented to professionals, lecturers, and doctoral degree students for perusal where all corrections were taken into consideration after due and careful deliberation with the supervisor. The corrections raised by experts and that of the supervisor forms the basis for testing validity of the research instrument. In the end, the process produced a questionnaire which was furthered subjected to a pilot study.

4.3.2 The Reliability of the Research Instrument

According to Zikmund (2000), "reliability is the degree to which measures are free from error and therefore yield consistent results". It is the test of consistency of the instrument in measuring variables of research interest. Reliability of instruments is measured to determine the level of its consistency and when the research results emanating from this instrument then it can be repeated" (Collis & Hussey, 2003). Malhotra (1999) concluded that "Cronbach's alpha is the most widely used measures of the reliability test of the instrument in social science". "It indicates the extent to which a set of test items can be treated as measuring a single latent variable" (Malhotra, 1999). It is expressed in terms of a reliability coefficient. Although, "there is no prescribed standard, but a scale that renders reliability coefficient of above 0.70 is usually regarded as a reliable instrument" (Nunnally & Bernstein, 1994).

Therefore, in order to determine the suitability of the instrument for data collections, it is subjected to reliability test through a mini pilot study. A pilot study is a standard scientific tool for soft research, allowing scientists to conduct a preliminary analysis before committing to a full-blown study or experiment. Table below shows the result of the reliability test (in variables) obtained from the SPSS following a pilot study.

Reliability Test of Variables

No	*Variables*	*N*	*Items*	*Cronbach Alpha*
	Product Design Tools			
1	Discovery	40	3	.801
2	Development	40	3	.704
3	Commercialization	40	3	.873

	Decision Support Systems			
4	Discovery	40	3	.751
5	Development	40	3	.871
6	Commercialization	40	3	.730
	File Transfer Protocols			
7	Discovery	40	3	.872
8	Development	40	3	.720
9	Commercialization	40	3	.831
	Dependent Variable			
10	3D Printing for Product Development	40	3	.811

Source: *Pilot Study, 2016*

The table above shows the results of the reliability test obtained from the Statistical Package for the Social Sciences (SPSS) following a pilot study. This was categorized in variables, under which product design tools as the first variable with three sub-variables (i.e. discovery, development and commercialization) and 3 items each reveals Cronbach alpha coefficient of 0.801 (N = 40) for the discovery, 0.704 (N = 40) for development and 0.873 (N = 40) for the commercialization. Also, under the decision support systems as the second variable with 3 items each, reveals Cronbach alpha coefficient of 0.751 (N = 40) for the discovery, 0.871 (N = 40) for development and 0.730 (N = 40) for the commercialization. Furthermore, under the file transfer protocols as the third variable with 3 items each, reveals Cronbach alpha coefficient of 0.872 (N = 40) for the discovery, 0.720 (N = 40) for development and 0.831 (N = 40) for the commercialization. And finally, regarding the dependent variable of the study 3D printing for product development, with 3 items, reveals Cronbach alpha coefficient of 0.811 (N = 40).

The study pilot survey revealed a *Cronbach Alpha Coefficients* of 0.704, 0.873, 0.751, 0.871, 0.730, 0.872, 0.831, 0.811, $p < 0.5$. The result of the Pilot study is an indication that the instruments are reliable. Thus a reliability coefficient of 0.704, 0.873, 0.751, 0.871, 0.730, 0.872, 0.831, 0.811 were considered for instrument on **Product Design Tools (**Discovery, Development and Commercialization), **Decision Support Systems (**Discovery, Development and Commercialization), **File Transfer Protocols (**Discovery, Development and Commercialization) as well as 3D Printing for Product Development meaning that the score that was obtained from the measuring instruments was 80 percent true reflection of the underlying trait measured.

As explained in the work of Pallant (2001), when a Cronbach alpha coefficient value is 0.7 and above, the scale is reliable with the sample and or has a reliable internal consistent, the scale items of the above variables are perceived as reliable and acceptable as their values were more than 0.7 and above.

4.3.3 Limitation of the Methodology

The limitations that can be identified in relation to this study include the following: The study may be constrained by time; a study of this nature requires a considerable period of time while also taking into consideration other employment commitments competing for the limited time. Substantial financial resources were required for this study to cover expenses such as printing of questionnaire, transportation and communication among others. The observable busy schedule of most prospective respondents may be another challenge of this study. Generally, the challenges that are likely to be encountered are time, fund, poor data bank in Nigeria and poor attitude to research by respondents.

In this study, no distinction was made between respondents who were customers and respondents who were professionals employed in the involved companies, nor was there any distinction made between answers concerning which company answers referred to.

5 ANALYSIS AND DISCUSSION

The purpose of this research is to evaluate the influence of information technology on 3D printing for product development in Lagos, Nigeria. Based on the findings of the study, the hypothesis one, which states that product design tool in the discovery phase does not have significant influence on 3D printing for product development, was disproved. The study indicated that product design tool in the discovery phase has significant influence on product development. Similarly, hypothesis two, which states that product design tool in the development phase does not have significant influence on 3D printing for product development, was disproved. The study indicated that product design tool in the development phase has significant influence on product development. This result is in accordance with the findings of Santos (2014) which reveal that the application of 3D is appearing in several industries beyond clothing, such as medicine, construction and automobile and emerging in different forms as 3D design and 3D printing, among others. However, the promises of all the types of 3D converge for rapid prototyping capabilities with the high-volume throughput of conventional manufacturing.

However, hypothesis three, which states that product design tool in the commercialization phase does not have significant influence on 3D printing for product development, was confirmed by the study, which indicated that product design tool in the commercialization phase has no significant influence on product development. This result is in line with the findings of Chen and Li (2010) , that only supportive idea and IT adoption and not design customization have positive impacts on new product development success.

Furthermore, as regard to hypothesis four, which states that decision support system in the discovery phase does not have significant influence on 3D printing for product development, this was confirmed by the study, which indicated that decision support system in the discovery phase has no significant influence on product development. This result is in line with the findings of Barczak, Sultan and Hultink (2006) which reveal that project risk, existence of a champion, and IT embeddedness positively affect the extent of IT usage for NPD. Additionally, IT usage positively and significantly influences the performance of the new product in the market place, but it does not have any impact on speed to market discovery and management support system.

Hypothesis five, on the other hand, which states that decision support system in the development phase does not have significant influence on 3D printing for product development, was disproved by the study. The study indicated that decision support system in the development phase has significant influence on product development. Similarly, hypothesis six, which states that decision support system in the commercialization phase does not have significant influence on 3D printing for product development, was disproved by the study. The study indicated that decision support system in the commercialization phase has significant influence on product development. This result corroborates with the findings of Silva, Mathrani and Jayamaha (2014) that the substantial increase in the recent use of information and communication technology in collaborative product development is evidenced, as a result of extended spans between collaborative partners and enhanced collaboration effectiveness. Since using information and communication technology is a highly cost intensive task, uncovering a detailed picture of the effect of information and communication technology usage on collaborative product development performance would be immensely useful for effective management information and communication technology in collaborative product development.

Regarding hypothesis seven, which states that file transfer protocols in the discovery phase does not have significant influence on 3D printing for product development, this hypothesis was also disproved by the study, which indicated that file transfer protocols in the discovery phase are perceived as having significant influence on product development. Similarly, hypothesis eight, which states that file transfer protocols in the development phase do not have significant influence on 3D printing for product development, was disproved by the studym which indicated that file transfer protocols in the development phase have significant influence on product development.

Finally, the last hypothesis state that file transfer protocols in the commercialization phase do not have significant influence on 3D printing for product development. This hypothesis was disproved by the study, which indicated that file transfer protocols in the commercialization phase have significant influence on product development. This result is in line with the findings of Farhanghi, Abbaspour and Ghassemi (2013) which indicated that information technology has a direct and indirect impact on file protocol, as operating system was found to have a direct effect on file protocols.

6 CONCLUSION AND FUTURE WORK

This chapter deals with the summary, conclusion and recommendation of the study. Findings were computed from the descriptive and inferential statistical data of the study. The study focused on evaluating the influence of information technology on 3D printing for product development in Lagos, Nigeria. The summary of findings from the analysis, the conclusion drawn from the study and recommendations were in line with the objectives of the study and were given based on the research findings.

Based on the findings, the following conclusions were made:

- Product design tool in the discovery phase has significant influence on 3D printing for product development.
- Also, product design tool in the development phase has significant influence on 3D printing for product development.
- Product design tool in the commercialisation phase does not have significant influence on 3D printing for product development.
- Furthermore, decision support system in the discovery phase does not have significant influence on 3D printing for product development.
- Decision support system in the development phase has significant influence on 3D printing for product development. The study discovered that decision support system in the development phase has significant influence on product development.
- Also, decision support system in the commercialisation phase has significant influence on 3D printing for product development.
- The study concludes that file transfer protocols in the discovery phase have significant influence on 3D printing for product development.
- Similarly, file transfer protocols in the development phase have significant influence on 3D printing for product development.
- Lastly, file transfer protocols in the commercialisation phase have significant influence on 3D printing for product development.

Recommendations

There is a general belief by many that the manufacturing industry is essential and crucial to the process of economic development. To be able to fulfill its role, the industry must not be found wanting in its capacity in terms of capital, product/services, mix, innovation, technology and well-motivated and skilled manpower (or human resources) in order to propel the economy.

As a panacea for the foregoing challenges the following recommendations are made with respect to the influence of information technology on 3D printing towards product development, sustaining the efficiency, profitability and growth of printing press companies in a dynamic and competitive business environment.

In spite of the success achieved by some selected printing companies in Lagos State on improved service delivery and quicker information processing through IT, there is need for more innovations.

There is need to standardize packages for loan applications, which will act as a decision support system for the employees in order to make consistent applications for loans, credit analysis, etc.

According to Bill Gate, "*The successful companies of the next decades will be the ones that use digital tools to reinvent the way they work"*, companies he says will

make decisions quickly, act efficiently and directly touch their customers in a positive way. Remarkable opportunities exist for the printing companies most especially in Nigeria and Africa as a whole, to embrace the current digital evolution so as to create and grow new products and service through e-Business solutions.

Suggestion for Future work

This research work was limited in study to only seven printing press companies in Lagos with no defined criteria in selecting the companies. The study can be expanded to capture more 3D printing companies geographically spread across the state and with data detailing status of product development before and after the deployment of 3D printing technology by the companies.

More research work can be devoted to this type of study through the use of other related textbooks and journals. A different statistical tool may also be used in testing hypotheses. The topic will also appreciate the review of the contributions of other professionals in this field. Particularly, more work can be done to understand consumer buying behavior with respect to product development using 3D printing technologies as against other traditional methods. This will give insight to reasons why consumers use or do not use 3D printing technologies.

Manufacturing industries, medical institutions, and other organizations can explore how the use of 3D printing would reduce production time, labor cost and cost associated with assembling tools traditionally used for product development.

REFERENCES

Adams-Bigelow, M. (2004). *First results from the 2003 comparative performance assessment study (CPAS) in the PDMA handbook of new product development* (2nd Edition), edited by Kenneth B. K., New Jersey, Hoboken: John Wiley and Sons, Inc., 546-566.

Akgun, A. E., Lynn, G. S., & Yilmaz, C. (2006). Learning process in new product development teams and effects on product success: A socio-cognitive perspective. *Industrial Marketing Management, 35(1)*, 210 – 224.

Ansoff, I. (1987). Conceptual underpinnings of systematic strategic management. *European Journal of Operational Research. 1(2),* 1-56.

Asika, N. (1991). *Research methodology in the behavioral sciences*. Lagos: Longman Press.

Barczak, G., & Sultan, F. (2006). Use IT or lose it. *Marketing management,* 15(2), 30-34.

Barczak, G., Sultan, F., & Hultink, E. J. (2006). Determinants of IT usage and new product performance, *Marketing Management, 15(2),* 30-34.

Bogue, R. (2013), 3D printing: the dawn of a new era in manufacturing, Assembly Automation, Vol. 33 Iss 4, pp 307-311

Campbell, T., Williams, C., Ivanova, O., and Garrett, B. (2011). Cloud 3D printing change the world? Technologies and implications of additive manufacturing, Atlantic Council, Washington DC/USA

Chen, H. H., Kang, Y. K., Xing, X., Lee, A. H. I., & Tong, Y. (2008). Developing new products with knowledge management methods and process development management in a network. *Computers in Industry, 59(1)*, 242–253.

Chen, J. S. & Li, E. Y. (2010). The effect of information technology adoption and design customization on the success of new product development. *International. Journal of Electronic Business*, 8(6), 550–578.

Clark, K. B., & Fujimoto, T. (1991). *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry.* Boston: Harvard Business School Press.

Clarke, P., & Wilhelm, W. (2011). *3D in apparel design: A revolution in the industry*, Retrieved on 27th of August, 2016 < http://www.walterwilhelmassoc.com/news/3D-in-Apparel-design---a-revolution-in-the-industry.cfm>

Collis, J., & Hussey, R. (2003). *Business research: A practical guide for undergraduate and postgraduate students.* Hampshire, Houndmills: Palgrave MacMillan.

Cooper, R.G., Edgett, S. J., & Kleinschmidt, E. J. (2004). Benchmarking best NPD practices. *Research Technology Management, 47(1)*, 31–43.

Dimitrov, K., Schreve, N., and Beer, De. (2006). Advances in three-dimensional printing-state of the art and future perspectives, Rapid Prototyping Journal, Vol. 12 Iss 3, pp136-147.

Dixon-Ogbechi, B. N. (2002). *Research methods and elementary statistic in practice.* Lagos: Philglad Nigeria Limited.

Fagbohungbe, O. B. (1993). *Research methods for Nigerian tertiary institutions*. Ojota Lagos: KOTLEB Publishers.

Farhanghi, A. A., Abbaspour, A. B., & Ghassemi, R. A. (2013). The effect of information technology on organizational structure and firm performance: An analysis of consultant engineer's firms (CEF) in Iran. *Procedia - Social and Behavioral Sciences,* 81(3), 644-649.

Fixson, S. K., & Marion, T. (2012). Back-loading: A potential side effect of employing digital design tools in new product development. *Journal of Product Innovation Management, 29(1)*, 140-156.

Goedhuys, M., & Veugelers, R. (2008). *Innovation strategies, process and product innovations and growth: Firm-level evidence from Brazil*. Brazil: Department of Managerial Economics, Strategy and Innovation (MSI)

Gross, B. C., Erkal, J. L., Lockwood, S. Y., Chen, C., & Spence, D. M. (2014). Evaluation of 3D printing and its potential impact on biotechnology and the chemical sciences. *American Chemical Society*, 2(1), 1-14.

Haeussler, C., Patzel, H., & Zahra, S. A. (2012). Strategic alliances and product development in high technology new firms: The moderating effect of technological capabilities. *Journal of Business Venturing, 1(2),* 1-14.

Heeks, R., &Molla, A. (2004). IDPM, University of Manchester, Adapted for MIS Classin University of Ghana by Richard, B. (2009) ICITD, Southern University and University of Ghana Business School.

Israel, G. D. (2013). *Determining sample size*. Florida: IFAS, University of Florida.

Jeong, I. (2003). A cross-national study of the relationship between international diversification and new product performance. *International Marketing Review, 20*(4), 353-376.

Johansen, K. (2005). *Collaborative product introduction within extended enterprises.* Sweden, Linköping: Linköpings Universitet.

Lam, P. K., Chin, K. S., Yang, J. B., & Liang, W. (2007). Self-assessment of conflict management in client-supplier collaborative new product development. *Industrial Management & Data Systems, 107*(5), 688 - 714.

Malhotra, N. K. (1999). *Marketing research*. UK, Harlow: Edinburgh Gate.

Miles, M. B. & Huberman, M. A. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd edition). Berverly Hills: Sage.

Miles, R. E., Snow, C. C., & Miles, G. (2000). The future.org. *Long Range Planning, 33*(3), 300-321.

Nunnally, J., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGraw-Hill.

Pallant, J. (2001). *SPSS survival manual.* Milton Keynes: Open University Press.

Peng, D. X., Heim, G. R., & Mallick, D. N. (2014). Collaborative product development: The effect of project complexity on the use of information technology tools and new product development practices. Retrieved on 3rd of August 2016 from <http://ssrn.com/abstract=2046708>

Pirjan, A., & Petrosanu, D. (2014). The impact of 3D printing technology on the society and economy. *Journal of Computer Science for Business Management, 1(2)*, 1-11.

Poku, K., &Vlosky, R. P. (2002). An exploratory study of internet adoption by primary wood products manufacturers in the western United State. *Forest Products Journal, 52(6)*, 1-35.

Reeves, P., & Mendis, D. (2015). The current status and impact of 3D printing within the industrial sector: An analysis of six case studies. *Research of Intellectual Property Office, 2(3)*, 1-86.

Reeves, P., & Mendis, D. (2015). The current status and impact of 3D printing within the industrial sector: An analysis of six case studies. *Research of Intellectual Property Office, 2(3)*, 1-86.

Rogers, E. M. (1995). *Diffusion of innovations*, Fourth Edition ed., New York: Free Press.

Santos, S. R. (2014). *Impact of 3D design on new product development process in the clothing industry: A case of Cordeiro Campos*. Dissertation of University of Catolica, Portugal.

Shannon, C. E., & Weaver, W. (1949).The mathematical theory of communication. Urbana, IL: University of Illinois Press.

Shelly, G. B., Cashman, T. J., & Verment, M. E. (2004). *Discovering computers: A gateway to information web enhanced*. U.K., Boston: Thomson Course Technology.

Silva, C., Mathrani, S., & Jayamaha, N. (2014). The role of information and communication technology ICT in collaborative product development: A conceptual model based on information processing theory. *International Journal of Innovation, Management and Technology, 5(2),* 1-7.

Smith, R. (2004). Exploring the usefulness of a conceptual framework as a research tool: A researcher's reflections. *Issues in Educational Research*, 14(2), 167-180

Soludo, C. C. (2005). *A keynote address delivered at the inauguration of the National payments system committee (NPSC).* Abuja: Central Bank of Nigeria Head Office.

Sorli, M., Stokic, D., Gorostiza, A., & Campos, A. (2006). Managing product/process knowledge in the concurrent/simultaneous enterprise environment. *Robotics and Computer-Integrated Manufacturing, 22(3)*, 399–408.

Vasudevan, A. (2003). Some perspectives on IT up gradation in the financial sectors. *Journal of Indian Institute of Bankers*, *74(1),* 36-38.

Weinberg, M. (2010). *It will be awesome if they don't screw it up: 3D printing, intellectual property, and the fight over the next great disruptive technology and public knowledge.* Retrieved on the 12th of August 2016 from <http://www.publicknowledge.org/it-will-be-awesome-if-they-dont-screw-it-up>

Williams, B. K., & Sawyer, S. C. (2005). *Using information technology: A practical introduction to computer communications*. Boston: McGraw Hill.

Yamane, T. (1967). *Statistics: An introductory analysis.* New York: Harper and Row.

Zirmund, W. G. (2000). *Business research methods*. Florida, Orlando: Dryden Press.

QUESTIONNAIRE

Instruction: Please tick as appropriate

SECTION A

Consider your view on *product design tools,* to what extent do you agree or disagree with the following statements? 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree						
Discovery		**1**	**2**	**3**	**4**	**5**
1	We are aware of new tools in designing the printing products.					
2	The expenses of the product design tools have been under control.					
3	New product designs have been timely launched.					
Development						
4	We possess technical capabilities of product design (related to competition).					
5	We have developed new products with financial success.					
6	We are satisfied with the product design and development process					
Commercialization						
7	We design new products to conform to customers' requirements.					
8	Customers became involved in 3D printing project only after the design was completed.					
9	Customers were frequently consulted about the design of their products.					
Consider your view on *decision support systems (DSS) for project evaluation*, to what extent do you agree or disagree with the following statements? 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree						
Discovery		**1**	**2**	**3**	**4**	**5**
10	Top managers are aware of recent IT development.					
11	Top managers are aware of competitors' new movements in using IT.					

12	Top managers believe the use of IT is beneficial.					
Development						
13	Top managers encourage employees to be familiar with new IT applications.					
14	Top manager frequently ask subordinates to be aware of new IT development and trends.					
15	Top managers provide sufficient supports for IT investment.					
Commercialization						
16	Top managers provide decision support system towards the use of new technologies.					
17	Top managers have invested a lot on acquiring IT knowledge.					
18	Information technology has played a key role in changing the process of decision support system.					
Consider your view on *file transfer protocols (FTP)*, to what extent do you agree or disagree with the following statements? 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree						
Discovery		**1**	**2**	**3**	**4**	**5**
19	We are aware of file sharing via network protocol.					
20	File transfer protocol enables employees and customers to have access to information at their fingertips.					
21	File transfer protocol has made collation of information easier thereby reducing time taken to attend to clients.					
Development						
22	Our information is stored and shared through computer networks.					
23	We exchange information frequently through computer network connections.					
24	File transfer protocol improves transactions with customers.					
Commercialization						
25	Our database system is safe and under control.					
26	Our network is reliable in sharing data between the client and the server.					
27	Information technology has increased the interaction of the employees with customers through file transfer protocol.					
Consider your view on *3D printing for product development*, to what extent do you agree or disagree with the following statements? 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree						
3D Printing for Product Development		**1**	**2**	**3**	**4**	**5**
28	We consulted customers' early on 3D printing efforts for product development.					
29	We partnered with foreign companies on 3D design in developing our printing products.					
30	Our customers prefer 3D printing technology in designing and developing their products than other digitals.					
Source: *Adapted scales of Chen & Li (2010); Peng, Heim, & Mallick (2014).*						

SECTION B

S/N	Socio-Demographic Characteristics	Categories
1	What is your gender?	[ ] Male [ ] Female
2	What is your age?	[ ] 20-29 years [ ] 30-39 years [ ] 40-49 years [ ] 50-59 years [ ] 60 years & above
3	What is your marital status?	[ ] Married [ ] Single [ ] Divorced [ ] Others
4	What is your highest educational qualification?	[ ] O-level & below [ ] OND/NCE [ ] Bachelor's degree /HND [ ] Master's degree [ ] Others
5	What is your length of service?	[ ] 0-4 years [ ] 5-9 years [ ] 10-14 years [ ] 15-19 years [ ] 20 years & above