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Investigation of the Impact of CNC-Technology Adoption on Productivity of Roda Machine Manufacturing Industry

BY: ENDESHAW SHANKO

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Investigation of the Impact of CNC-Technology Adoption on Productivity of Roda Machine Manufacturing Industry

By: Endeshaw Shanko

Advisor: Gezahegn Tesfaye (PhD)

Co-Advisor: Sewnet Alemu (PhD Candidate)

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This is to certify that the thesis prepared by: Endeshaw Shanko, entitled: "**Investigation of the Impact of CNC-Technology Adoption on Productivity of Roda Machine Manufacturing Industry"** and submitted in partial fulfillments of the requirements of the degree of Master of Science in Industrial Engineering.

Approved by Board Examiners:

Chairman, Dept. Graduate Committee Signature__________ Date_____________

Internal Examiner: Ameha Mulugeta (PhD) Signature__________ Date_____________

External Examiner: Ephrem Gidey (PhD) Signature__________ Date_____________

Advisor: Gezahegn Tesfaye (PhD) Signature__________ Date_____________

Co-Advisor: Sewnet Alemu (PhD Candidate**)** Signature__________ Date_____________

School dean: Areaya Abera (PhD**)** Signature__________ Date_____________

DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree in this or any other university and all sources of materials used for this thesis have been duly acknowledged.

Endeshaw Shanko	______________________	______________________
(Candidate)	Signature	Date

This is to citify that the above declaration made by the candidate is correct to the best of my knowledge.

Gezahegn T. (PhD)	___________________	______________________
(Thesis Advisor)	Signature	Date
Sewnet Alemu (PhD Candidate)	_____________________	____________________
(Co-Advisor)	Signature	Date

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I feel blessed to have reached the end of this important period of finalize my research. Without faith in God and his mother the Virgin MARRY things would have been more difficult.

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Abstract

Productivity is basic issue on which a business organization focuses for existence and being competitive in the market and making a profit while satisfying customer requirements. To create profit a business system has to be efficient in optimal uses of input resources to enhance productivity and reduce cost. The production inputs namely labor, materials, energy technological capability with organizational system setups are responsible for productivity among which technological capability is supreme.

Ethiopia has been importing manufacturing machines, since many years ago from different countries of the world. On the other hand there are local machine manufacturing industries which are believed to significantly contribute to economic development through providing machines and import substitution in line with the country's industrialization policy. Roda machine manufacturing industry is one of Ethiopian machine manufacturing industry. It is established for production of spare parts, molds, dies and machines of agriculture, construction, agro-processing and other manufacturing industries. Molds, dies and machine components production capacity is directly correlated with technological capacity which is association with updated technology adoption decision of the industry. However Roda is equipped with obsolescent machine tools, which are limited to produce mold, die and precious & complex parts to achieve its objective. This constrain with technological capacity impacts productivity and product quality of the industry. Hence the research is focused on investigation of impact of CNC-technology adoption on the productivity of Roda machine manufacturing industry and proposing appropriate improvement solutions.

A structured questionnaire, interview and physical work examination were employed for collecting primary data. Whereas for secondary data review of industry reports, profiles as well as records review were conducted. The questionnaire was distributed to representative sample of 87 drawn from the target population, from which 81 (93%) of them were filled correctly and responded. To analyze and presented the data, bar graphs, tables, fishbone diagrams and vensim software for system modeling and simulation were used. Understanding the benefits of technological capacity for productivity improvement limited and they believed that their source of technology is internally focused. To increase technological capacity of the industry CNC-technology adoption modeling is developed that facilitates productivity improvement.

Keywords: Productivity, computer numerical control (CNC), Technology, adoption, machine manufacturing industry.

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List of Acronyms

AMT-Advanced Manufacturing Technology

CNC- Computer Numerical Control

CIF- Cost, Insurance and Freight

Dmnl- Dimensionless

EC- Ethiopian Calendar

EDM- Electrical Discharge Machining

FDI- Foreign Direct Investment

GC- Gregorian Calendar

GDP- Gross Domestic Product

GTP- Growth and Transformation Plan

ICT- Information and Communications Technology

IT- Information Technology

LCD- Causal Loop Diagram

MCU- Machine Control Unit

MEPI- Measurement, Evaluation, Planning and Improvement

MIDI- Metal Industry Development Institute

MSE- Micro and Small Enterprises

PLC- Private Limited Company

R&D- Research and Development

TAM- Technology Acceptance Model

TVET- Technical and Vocational Education and Training

TPB- Theory of Planned Behaviour

TOE- Technology-Organization-Environment

TRA- Theory of Reasoned Action

UNCTAD- United Nations Conference on Trade and Development

UTAUT- Unified Theory of Acceptance and Use of Technology

CHAPTER ONE

INTRODUCTION AND RESEARCH BACKGROUND

1.1. Introduction

The objective of a business firm is to make a profit while satisfying customers' requirement. Productivity is a fundamental issue on which a business firm focuses for existence and competitive in the market. To make profit a business system has to be efficient to optimal uses of input resources to increase productivity and reduce production costs. Since production costs and productivity are inversely proportional i.e. increase in productivity has decrease impact on a decrease on the production cost while increases profit. The industry's inputs such as labor, materials, machines, and equipment with organizational system setups are responsible for productivity (Tadiyos, 2018).

Ethiopia has been importing technologies mainly machines, since many years ago from different countries of the world. For the last few decades onwards the paramount objective of technology importation is adoption with the main consideration of local resources' optimal utilization and maximum value addition to benefiting the people as well as supporting the country's economy. The technology adoption plan has focused on import substitution in general however, the achievement is limited. To adopt technology the government develops various strategies and institutional frameworks (Ethiopian Industry Development Strategic Plan, 2013-2025).

The machine manufacturing industry is one of the Ethiopian metal and engineering manufacturing industries. Its contributions to economic development are believed to be significant. Although the manufacturing sector will emerge as the main driver for industrial growth, machine is the prime mover of the manufacturing industries which needs prior attention (Ethiopian GTP-2). "Machinery and Equipment is an important subsector but local technological and workforce capacity cannot currently compete on the global stage": (Manufacturing Industry White Paper, 2020-2030 GC, p.35)

Ethiopian machine manufacturing industry has been growing in number, type, and scale of products. Roda machine manufacturing industry is one of Ethiopian machine manufacturing industry. It is established for production of spare parts, molds, dies and machines of agriculture, construction, agro-processing and other manufacturing industries. Molds, dies and machine components production capacity is directly correlated with technological capacity which is association with updated technology adoption decision of the industry. The industry's profile revealed that, it is using machine tools/conventional machines for production, which are limited to produce mold, die and precious & complex parts to achieve its objective. Machine tools/conventional machines are low in productivity, manufacturing flexibility, product quality, labor dependent, and limited for production of product variety, as a result, the machining cost is significantly high (Radhakishnan et al., 2011). On the other hand machine manufacturing firms have adopted Computer numerical control (CNC) as a strategy to tackle cost factors, increased market competition, improves product quality and productivity (Mohammed et al., 2015). Since CNC provides the enabling environment to increase flexibility of manufacturing and expand consumer market. CNC as an aspect of advanced manufacturing technology can impact performance through improved quality and output of product, reduction of time spent in manufacturing, improved accuracy and precision and increase in efficiency and profitability. Therefore adopting advanced manufacturing technology are enabling penetrate market earlier, prompt response to market needs, flexibility, high quality and reliability of products (Jani & Salleh, 2010).

Commonly used machine tools in the machine manufacturing industry are milling, lathe, grinding, shaper, and drilling machines. Among which the most common are milling and lathes machines. Therefore they are highly responsible for productivity, quality as well as effective production performance of the industry. Thus using technological support (automatic/advanced versions of those machines) provide a competitive advantage. However, analyzing comparative advantage especially the cost of those technologies over the conventional machine is significant. Detail machine specification on annex-1

Hence this research focuses on investigation of the impact of CNC-technology adoption on Roda machine manufacturing industry productivity improvements. Analyzing technological capacity and productivity performance is significantly important to deal with optimal utilization of the input resource. Based on these research findings a CNC-technology adoption model and productivity improvement method has been developed which lead to sustainable improvement and competitiveness of the industry.

1.2. Background

In today's competitive business world to survive and be competitive business firms must improve their productivity. Productivity declares optimum utilization of accessible resources with organized systems. Generally, it is doing the right things better in an exceedingly process so on reduces the cost per unit, increases profit, and ends up in economic growth. Therefore making sure individuals and firms grow in productivity requires adopting efficient technology and techniques. Baldwin et al. (1994) cited in, John and Brent (1995) small and medium-sized enterprises' success is related to the adoption of technology-based innovation strategy. But as Tessema et al. (2016) argued, developing countries technology adoption rate is low; consequently a large number of studies were conducted to identify the reason. Where advanced manufacturing technologies are computer-assisted technologies accustomed to controlling and monitoring manufacturing activities, for more flexible, to reduce production cycles, rapid responses to market changes and improve precision (José and Silvia, 2021). Machine manufacturing is among the manufacturing industries which are the most drivers for industrial growth, especially in technological improvement. Engineering machines can be categorized into two based on the intervention of human operators which are conventional/manually operated and automatic basically of computer numerical control (CNC).

Computer numerical control (CNC) machine is fundamental to advanced manufacturing technology (AMT) which is a major part of machine tools in advanced countries (Radhakishnan et al., 2011).

According to Collin et al. (2011), the adoption of CNC machines by manufacturers is the replacement of conventional machines by CNC machines in machine shops. CNC is used to create enabling environment for more flexibility in producing, improving quality, and expanding market opportunities (Mohammed et al., 2015). Consequently, most of the machine tools manufacturers switched to the use of CNC machine tools. CNC machine tools are required for the speed of production, machining quality and precision, and scalability of products ranging from automobiles to airplanes, warships to medical devices, and mobile phones to mining equipment. Annually tens of billions of folks US dollars are spent on purchasing new CNC machine tools which creates much larger effects on the economy (Taylor & Lunenburg, 2020). In order to technology adoption deficiency of resources, absence of customer requirement, environmental changing, improving technological accessibility, advanced manufacturing technology adoption consideration are few influencing factors (Jani & Salleh, 2010). Besides the factors, companies should consider such as the vision, commitment of top management, involvement of employees and business firm growth.

1.3. Problem Statement

Roda machine manufacturing is one of the Ethiopian machine manufacturing industries. Its contribution to the development of the economy is believed to be significantly important. However, the industry has been facing low-capacity utilization and a lack of meeting performance targets. According to the industry's annual reports, the last seven (2015-2021) years of production capacity performance and capacity utilization have been summarized in the table-1.1 below.

Table-1. 1: Roda machine manufacturing Industry Production Capacity utilization

Industry Description	Annual Capacity Utilization **(%)**						
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Roda Machine Manufacturing Industries	79.56	56.37	45.16	23.65	22.42	18.21	12.05

Table-1.1 indicates production capacity utilization of the Roda machine manufacturing industry is declined for consecutive years. The implication of under-capacity operation means high overhead cost, high cost of average production, and hence less competitiveness in the market.

Generally, Roda machine manufacturing industry's performance is weak. According to the industry as well as MIDI's reports the major challenges attributed to the weak performance effects are:

1. The industry is heavily dependent on imported semi-finished machine components as well as finished products which require advanced manufacturing technology mainly CNC machine tools.
2. Low capacity utilization to generate optimum value addition to substitute semi-finished and finished machine components
3. Low product quality, limitation to complex part production, and comparatively higher product price

The challenges are primarily sourced from the industry's technological capability. Roda's production machines are conventional machine tools (MIDI, Industries profile). Therefore the productivity and product quality are low whereas the price is higher than imported same products. From the industry's profile (sourced from MIDI), the adoption and the uses of modern and advanced manufacturing technology in the industry is poor. However many literatures are show impact of advanced manufacturing technologies on performance of industries. Hence the imported machine manufacturing industries replaced machine tools with CNC technology to be more flexible, shorter production cycles, improved quality, better precision, and complex part production, maximize value addition, tackle cost factors and improve competitiveness (Collin et al, 2011). Depending on the above statements studying the productivity impact of CNC-technology adoption on Roda machine manufacturing industries is very essential. Therefore based on a survey of the industry the study investigate key driving factors of CNC-technology adoption, develop a model and propose appropriate techniques that can effectively improve the productivity of Roda machine manufacturing industries.

1.4. Research Questions

The questions raised on the processes of the research are.

1. What is existing technological capability of Roda machine manufacturing industry?
2. What are productivity problems and contributions of technological capacity?
3. What is the impact of CNC technology on productivity, capacity utilization, and product quality?
4. What appropriate techniques can be used to adopt CNC technology to improve productivity?

1.5. Objectives of the Study

1.5.1. General Objective

Investigation of the impact of CNC-technology adoption towards productivity improvement of Roda machine manufacturing industry and propose adoption & improvement framework.

1.5.2. Specific Objectives

The research has subsequent specific objectives.

1. Analyze existing technological capacity and productivity of Roda machine manufacturing industry
2. Investigate the impact of technological capacity on productivity performance.
3. Assess the experience of Roda machine manufacturing industry’s technology adoption to improve productivity
4. Identify the existing technologies Roda has been using that need the adoption of CNC technology to improve productivity.
5. Identify key factors to adopt CNC technology which will enhance productivity
6. Develop appropriate techniques and propose to adopt CNC-technology

1.6. Significance of the Study

According to Metal Industry Development Institute and GTP-II reports the number and diversity of machine manufacturing industries are significantly growing. However, the industries including Roda machine manufacturing industry last seven years (2015-2021) report statistics shows that production performance and capacity utilization consciously decreased. This under-capacity operation causes high overhead costs and high costs of production which are associated with low productivity performance and result in less competitiveness even in the local market with imported machines. This research contributes to optimal work designing, planning, and execution opportunities for Roda machine manufacturing industry to revise technological capability, work procedures, and production systems through CNC-technology adoption to ensure productivity improvement. Since adoption is the integration of new technology into existing practice and is usually preceded by a period of trying and some degree of adaptation, hence it is important to have the full information about the technology and it's potential. Moreover, the recommendations forwarded and the developed adoption model will benefit Roda machine manufacturing industry as well as sector industries to enhance technological capacity to improve productivity. Finally the research will contributes data and information toward theory for better understanding of the impact of CNC technology on machine manufacturing industries' productivity to extend the existing knowledge.

1.7. Scope of the Research

The scope of this research is focused on Investigation of the Impact of CNC-Technology Adoption on Productivity of Roda Machine Manufacturing Industry in which the industry has a low level of productivity. The research is limited only on detailed technological capacity and productivity performance assessment, review, and analysis of Roda machine manufacturing industry. Beside the research the study was focused on the CNC technology adoption, industries as well as employees within the production systems knowledge absorption capacity and adoption process impacting factors. It was accomplished via reviewing previous studies on the field of the research, considering their weak point and developing enhancement solution to bridge the gaps. Because it is educational research having limited resources, it does not consider other machine manufacturing industries in details as well.

1.8. Limitations of the Study

The growing numbers and diversity of the local machine manufacturing industries and the geographical area where the industries located were limited for the overview assessment of the high or low performance of productivity and related issues. Roda machine manufacturing industry employees' different levels of understanding of perceive use and adoption process of CNC technology were challenging to get accurate data. Since the study was conducted on Roda machine manufacturing industry, it does not consider the details so that the findings may not be impact in same way to other machine manufacturing industry.

1.9. Organization of Documentation

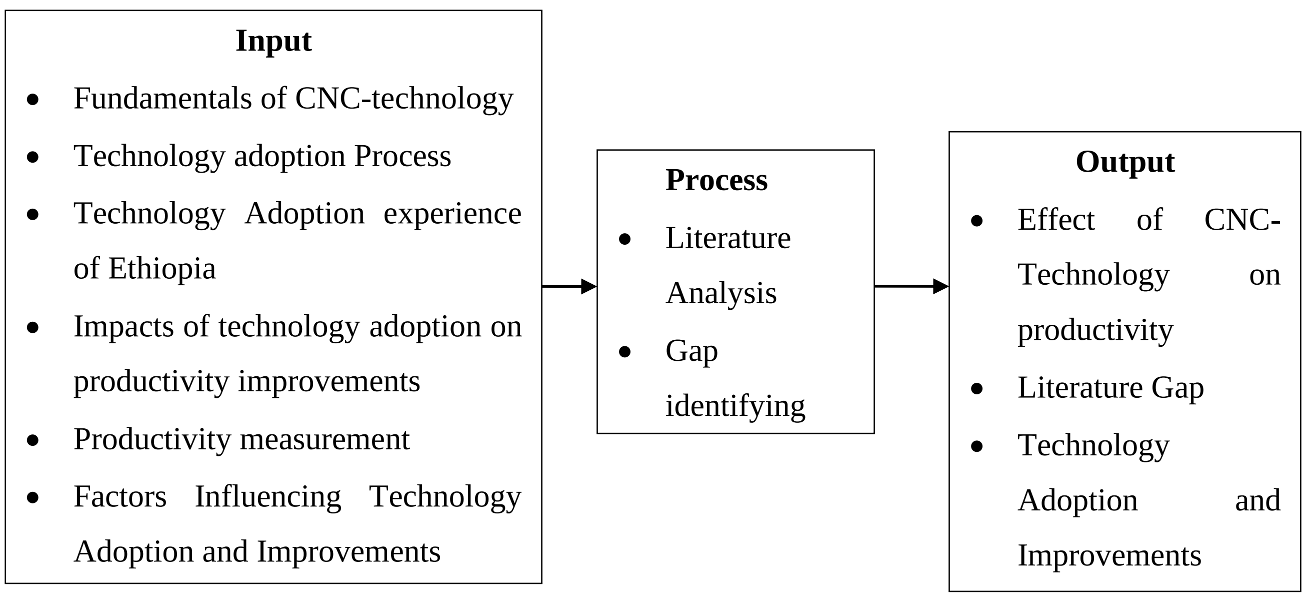
This research documentation has been organized into six chapters. First chapter covers Introduction, background, problem statement, objectives, significance of the study, scope, and limitations of the study. Chapter two presents a literature review concerning the concept of CNC technology adoption's impact on productivity. Chapter three discusses the research methodology, including the research design, method of data collection, and sources of data, study population, tools for data collection, data presentation method, and analysis. Chapter four deals with data analysis and interpretation of gathered data, presentation, and analysis using a system dynamic tool based on the survey questionnaire. Chapter five solution proposals present the proposed improvement system while last describes conclusion, recommendation and contribution.

CHAPTER-TWO

LITERATURE REVIEW

The research seeks investigating the impact of CNC-technology adoption on the productivity of Roda machine manufacturing industry. To do so relevant literatures were reviewed. Therefore the following literature review discusses the fundamentals of CNC technology, technology adoption of the machine manufacturing industry, the impact of CNC-technology adoption on productivity improvements, productivity measurement, and productivity impact of CNC-technology.

Literature Review Conceptual Framework



2.1. Fundamentals of CNC-Technology

According to Mohammad (2020) Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by employing a prepared program containing coded alphanumeric (letters, symbols, and numbers) data. It can control the motions of the workpiece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning the spindle on/off and turning coolant on/off. CNC consists of three main parts;

1. Machine- perform the operation
2. Control-Controlling machine engines.
3. Computer- on which the program is dedicated to the machine and saves the programs.

According to Kelley and Brooks (1991), compared to conventional machines, CNC significantly improve labor productivity, since time spent repositioning workpiece for separate passes are greatly reduced, has better product quality and ability to machine complicated parts than a skilled operator be able. In addition CNC offers faster set-ups than dedicated conventional equipment. CNC is widely used for machining processes such as lathe, drill press, milling machines, grinding units, laser, sheet metal press working machines, etc. (Supriya et al., 2016).

2.1.1. Features of CNC

According to Groover (2013) computer numerical control (CNC) systems which are standard on most CNC include the following:

- *More than one part program sorage*. It has sufficient capacity to store multiple programs. Controller manufacturers commonly offer one or more memory expansions as options to the machine control unit.
- *Various forms of programing input*. CNC controller possesses multiple data entries.
- *Program editing at the machine tool*. CNC allows a part program to be edited while it exits in the MCU computer memory. Hence, a program can be tested and corrected entirely at the machine site. In addition to part program corrections, editing also allows cutting conditions in the machining cycle to be optimized. After the program has been corrected and optimized, the revised version can be put away for future use.
- *Fixed cycles and programming subroutines*. The multiple memory capacity and the ability to program the control computer provide the opportunity to store frequently used machining programs as macros. Instead of writing the full instructions for the particular cycle into every program, a programmer includes a call statement in the part program to indicate that the macro cycle should be executed.
- *Interpolation*. The interpolation schemes such as linear, circular, helical, parabolic and cubic are normally executed only on a CNC system because of the computational requirements.
- *Positioning features for setup*. Setting up the machine tool for a given work part involves installing and aligning a fixture on the machine tool table. This must be accomplished so that the machine axes are established with respect to the work part. The alignment task can be facilitated using certain features made possible by software options in a CNC system.

- *Cutter length and size compensation*. For style controls, cutter dimensions had to be set very precisely to coincide with the tool path defined in the part program. Alternative methods for ensuring accurate tool path definition have been incorporated in to CNC controls.
- *Acceleration and deceleration calculations*. This feature is applicable when the cutter moves at high feed rates. It is designed to avoid tool marks on the work surface that would be generated due to machine tool dynamics when the cutter path changes abruptly. Instead, the feed rate is smoothly decelerated.
- *Interface ccommunication*. Most modern computer numerical controllers are inculcated with a standard RS-232 or other communicating interface to link the machine to computers and computer-driven devices. This is helpful for numerous applications, including downloading operation programs from a central data file, gathering operational data of works and interfacing with equipment, such as robots used to load and unload parts.
- *Diagnostics*. Most CNC systems take control of diagnostics that supervise specific aspects of the machine tool to detect malfunctions to diagnose system breakdowns.

2.1.2. Advantages of CNC-Technology on Productivity

The advantages of CNC systems outweigh the disadvantages considerably hence CNC machines have been widely accepted by the manufacturing industries. CNC controls are used to control various types of machine tools. Regardless of which type of machine tool is controlled, it always has a slide table and a spindle to control position and speed.

CNC is being used in drilling, lathe & turning boring, milling, and grinding machines. In addition to metal removal operations, wire-cutting, Electrical discharge machining (EDM), and many other areas. Some of the advantages of CNC machine tools are, simulated virtually manufacturing process without making a prototype or a model, reduces human efforts, manufacture several components to the required accuracy without any fatigue as in the case of manually operated, have high accuracy in manufacturing and short production time, save power, reduced inspection time due to the CNC machine's ability to produce parts with superior accuracy and repeatability however only spot-checking of critical areas is necessary without loss of machine time (Adithan & Pabla, 2015). In general the advantages are longer life, less frictional resistance, lower torque required, more precise positioning of slides, where backlash is almost completely eliminated (Katungi, 2007).

2.2. Concept of Technology Adoption

Lavison (2013) defines technology as "it is the knowledge/information that permits some tasks to be accomplished more easily, some service to be rendered, or the manufacture of a product". Likewise, different scholars defined adoption as it is the integration of new technology into existing practice and is usually preceded by a period of trying and some degree of adaptation (Loevinsohn et al., 2013). Rogers (2003) defined adoption as the "full use of an innovation as the best course of action available" and rejection is a decision "not to adopt an innovation" (p. 177). It is the mental process an individual passes from first hearing about an innovation to final adoption. While Feder et al. (1982) defined adoption as at the individual level the degree to which new technology is used in long-run equilibrium when the adopter has full information about the technology and it's potential. Meanwhile technology adoption is defined as "The choice to acquire and use a new invention or innovation" (Bronwyn H. H. and Beethika K., 2002). Once a new technology becomes available, it usually takes some time before it will be fully implemented. However various indigenous factors are attributed to the rate of adoption such as differences in skills, risk hate and prior beliefs (Katungi, 2007).

2.3. Technology Adoption Process

Once a new technology is innovated and becomes available, it will take time before it is fully adopted. The adoption period can be characterized by a time lag between awareness of the technology and adoption. New technology adoption and diffusion studies have used various stage models, includes a three-stage model of initiation, adoption, and implementation (Thompson, 1965), a six-stage model of initiation, adoption, adaptation, acceptance, routinization, and infusion (Cooper & Zmud, 1990), and a two-stage model of initiation and implementation (Zaltman et al., 1973). Finally, Rogers (2003), has proposed a five-stage model of new technology adoption and implementation. Furthermore, he has defined the adoption process as "the process through which an adopter unit passes first knowledge of an innovation, to forming an attitude regarding the innovation, to a decision to adopt or reject, to implementation of the new idea, and confirmation of this decision."

2.3.1. Technology Adoption Theories and Models

Technology adoption is explained by different authors' developed theories and models such as the innovation diffusion theory, the theory of reasoned action (TRA), the Theory of Planned

Behaviour (TPB), Rajesh and Rajhans (2014). Some of the theories and models that have evolved for explaining the adoption of technology are summarized as follows:

Table-2. 1: Summary of Technology Adoption Theories and Models

Theory /Model	Author	Definition	Constructs	Moderators
Innovation Diffusion Theory	Rogers (1962)	Describe as the innovation decision process	1. Relative advantage 2. Ease of use 3. Result demonstrability 4. Tribality 5. Visibility 6. Image 7. Compatibility 8. Voluntariness of use	Experience
Theory of Reasoned Action	Fishbein and Ajzen (1975)	Describe as adaptable behavioral theory and model the attitude behaviour relationships	1. Attitude toward behaviour 2. Subjective norm	1. Experience 2. Voluntariness
Social Cognitive Theory	Bandura (1989)	A learning theory derived from the idea that people learn by observing others.	1. Eciprocal determinism 2. Behavioural ability 3. Bservational learning 4. Reinforcements 5. Expectations	None
Technology Acceptance Model	Davis (1989)	A model that involves psychological factors affecting technology acceptance.	1. Perceived usefulness 2. Perceived ease of use	1. Gender 2. Experience
Extended Technology Acceptance Model 2	Venkatesh and Davis (2000)	TAM2 includes two theoretical processes that cover social influence processes and cognitive instrumental processes to explain the effects of the various determinants on perceived usefulness and	1. Perceived usefulness 2. Perceived ease of use 3. Subjective norm	1. Experience 2. Voluntariness

		behavioural intention.		
Theory of Planned Behaviour	Ajzen (1991)	This theory is to foretell an individual's purpose to seize in the behaviour at a particular time and place.	1. Attitude toward behaviour 2. Subjective norm 3. Perceived behavioural control	1. Gender 2. Experience 3. Age
Motivational Model	Davis, Bagozzi and Warshaw (1992)	This model is widely used by researchers in psychology.	1. Extrinsic motivation 2. Intrinsic motivation	None
Combined TAM and TPB	Taylor and Todd (1995)	This model is determining of influence of social and control factors that are not in TAM but exits in TPB.	1. attitude toward behaviour 2. Subjective norm 3. Perceived behavioural 4. control 5. Perceived Usefulness	Experience
Unified Theory of Acceptance and Use of Technology	Venkatesh, Morris, Davis and Davis (2003)	Aims to explain the intentions of the user to use an information system and the subsequent behaviour of users.	1. Performance expectancy 2. Effort expectancy 3. Social influence 4. Facilitating conditions	1. Gender 2. Age 3. Experience 4. Voluntariness
Unified Theory of Acceptance and Use of Technology 2	Venkatesh, Thong and Xu (2012)	UTAUT2 extends the UTAUT with the main objective the new constructs could give a better explanation in new emerging technologies and consume ruse	1. Performance expectancy 2. Effort expectancy. 3. Social influence 4. Facilitating conditions	1. Gender 2. Age 3. Experience 4. Voluntariness

Source: Rajesh S. and Rajhans M., 2014.

2.3.2. Innovation-Decision Process

Rogers (2003, p12) “An innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption”. Although innovation may be invented a long time ago, if individuals perceive it as new, then it may still be an innovation for them.

Rogers’s model of the innovation-decision process goes through time phases of knowledge, persuasion, decision, implementation, and confirmation. Rogers (2003) used the word “technology” and “innovation” as synonyms. Hence the researcher had taken Rogers innovation decision model because it goes through time phases of knowledge, persuasion, decision, implementation, and confirmation which is used for technology adoption and implementation.

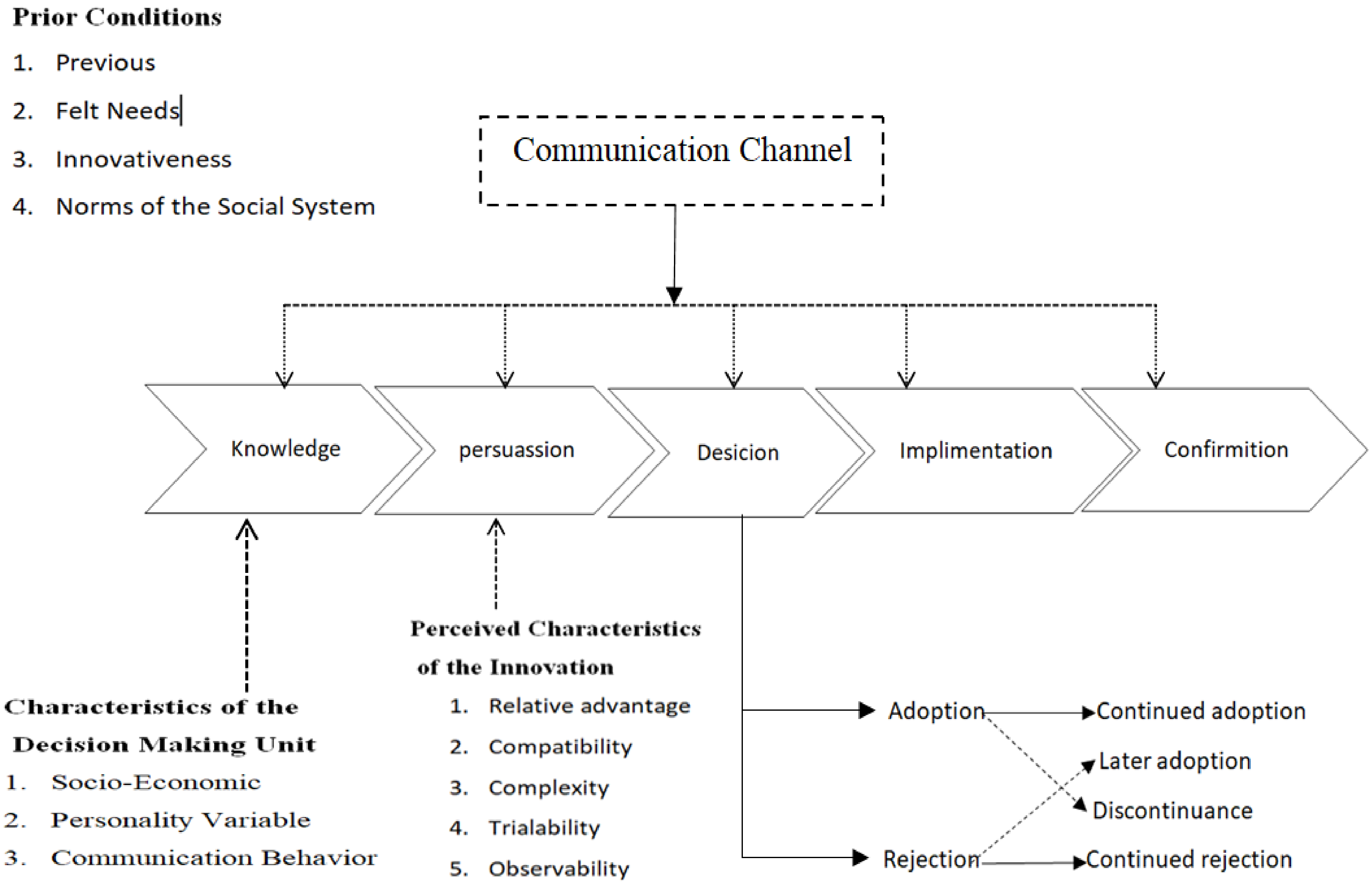


Figure-2. 1: Model of the Innovation-Decision Process (Third Edition, Everett M. Rogers, 2003, p.165)

From figure 2.1 the innovation-decision process starts with the knowledge phase. In this phase, an individual seeks information about the innovation. In this phase, the individual attempts to determine “what the innovation is and how and why it works” (Rogers, 2003, p. 21). According to Ismail (2002), the questions form three types of knowledge:

1. *Awareness-knowledge*- represents the knowledge of the innovation’s existence, can motivate the individual to learn more about the innovation and, to adopt it.
2. *How-to-knowledge*- comprises information about how to use an innovation correctly. Rogers saw this knowledge as an essential variable in the innovation-decision process.
3. *Principles-knowledge*- includes the functioning principles describing how and why an innovation works. An innovation adopted without this knowledge, but the misuse of the innovation may cause its discontinuance.

According to the model, potential adopters of an innovation:

1. Learn about the innovation
2. Are persuaded as to the merits of the innovation
3. Decide to adopt the innovation
4. Implement the innovation
5. Confirm (reaffirm or reject) the decision to adopt the innovation.

Table-2. 2: Summary of Rogers’ Adoption Stages

Stages of Adoption	
Awareness	The individual is exposed to the innovation but lacks complete information about it
Interest	The individual becomes interest in the new idea and seeks additional information about it
Evaluation	Individual mentally applies the innovation to his present and anticipated future situation, and then decides whether or not to try it
Trial	The individual makes full use of the innovation
Adoption	The individual decides to continue the full use of the innovation

2.3.3. Innovation Decisions

Rogers classifies four main types of innovation-decisions based on a social system. These represent the various ways decisions are accepted by the individual.

- *Optional innovation decisions*, the choices made by individuals are independent of others
- *Collective innovation decisions*, the choices are decided by consensus and then adopted by all in that consensus
- *Authority innovation decisions*, choices made by a few with power and are then adopted by the whole (usually by some form of directive)
- *Contingent innovation-decisions*, choices made by one or more of the above, but only after a prior innovation-decision.

2.3.4. Category of adopter

Rogers (1995) categorized adopters into five based on the time order of being adoption; these being the innovators, early adopters, early majority, late majority and laggards based on boundaries of integral standard deviations. The categories and adopter characteristics are grouped and described on Figure 2-5 Categories and table 2-2 below.

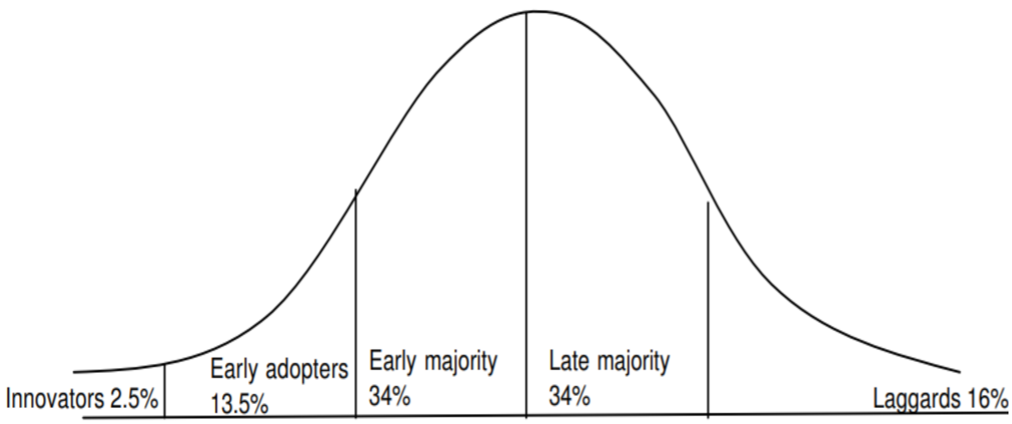


Figure-2. 2: Categories of Adopters (Roger, 1995)

Table-2. 3 :Rogers adopter characteristics

Category	**In general**
Innovators (2.5%)	**Venturesome** Will take risks and will take the setbacks. These are not usually highly respected in the social system but are cosmopolitan in communication channels, and act as gatekeepers of new ideas into the system.
Early adopters (13.5%)	**Respect** More integrated into social system and act as opinion leaders. Help reduce the uncertainty in the social system.
Early majority (34%)	**Deliberate** These deliberate for some time before adopting new ideas. Although seldom holding positions of opinion leadership in the system, they provide a link in the communication to the later adopters.
Late majority (34%)	**Sceptical** The pressure of peers is needed to motivate adoption. Innovations are approached with scepticism and caution, and the weight of system norms must definitely favour an innovation before they are convinced. Most of the uncertainty about a new idea has to be removed before they feel it is safe to adopt.
Laggards (16%)	Traditional Their point of reference is in the past, their decisions being made in terms of what has been done previously. They may be isolates in the social network.

Frontier technologies are designed to increase productivity, hence the adoption of new technologies by firms will impact their performance, their employment levels, and their skills needs since it is always linked with process innovation, which is coming up with new products (United Nations Conference on Trade and Development, 2022). As stated by United Nations (2022), new technology adoption most obviously contributes to process and product upgrading, and value chain participation might conceivably due to the knowledge acquired from technically advanced clients or due to developing countries firm's requirements for improvement in productivity and product quality to meet international market requirements. As a result of Michele et al. (2020) the adoption of new technology is the main driver of firm performance both productivity improvement & innovation and economic development.

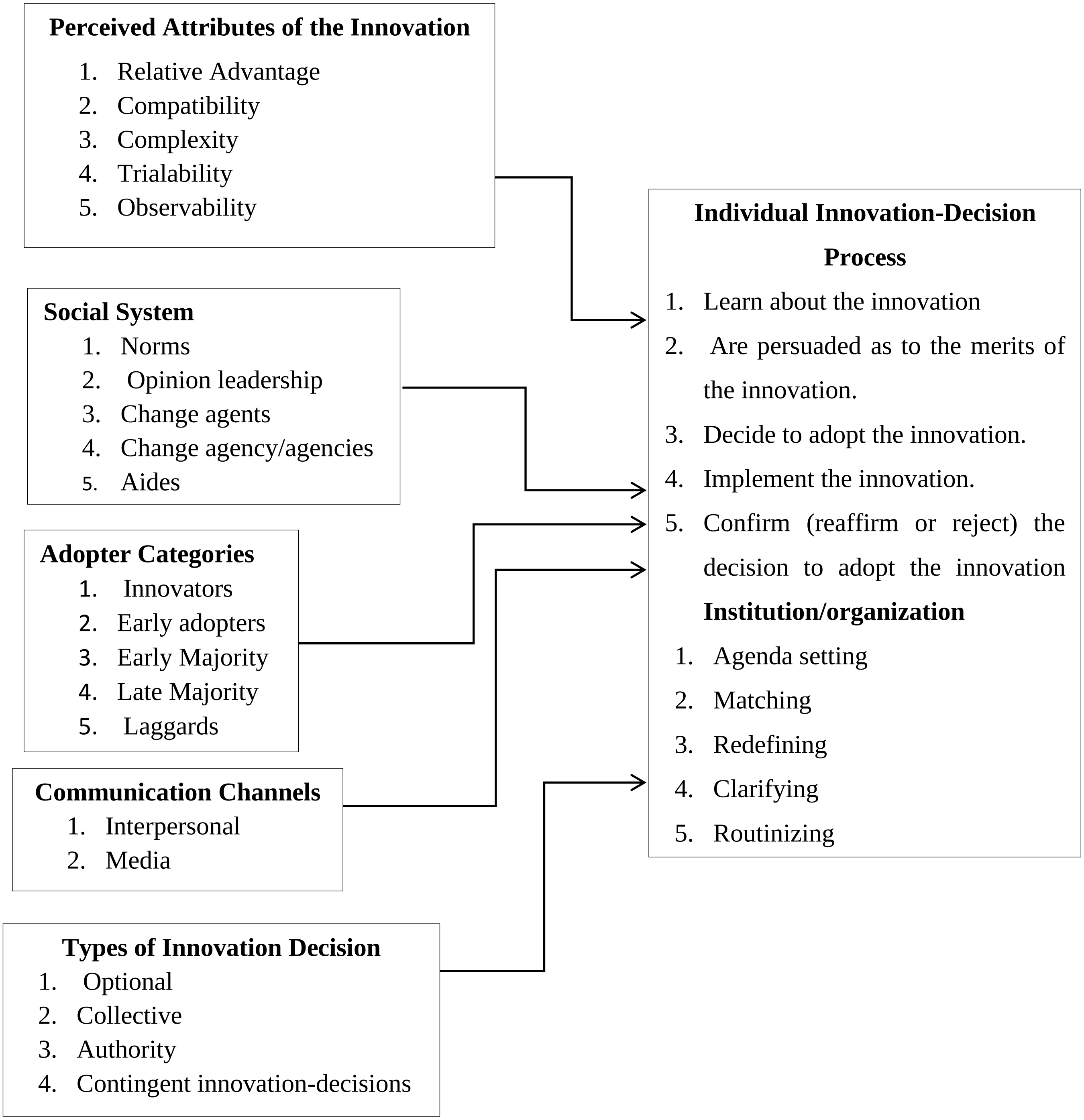


Figure-2. 3: Summary of Rogers Theory of Diffusion of Innovations, showing the main constructs influencing the adoption process.

Source: Enhancing Effective Implementation and Adoption of Web Information System Applications based on Adoption Theories, Stephen Hansen, 2006, p.48

2.4. Technology Adoption experience of Developing Countries

According to Organisation for Economic Co-operation and Development (OECD) (2001), The innovation adoption process consists of an integration of personal, cultural, social, and institutional factors, including the five stages of awareness, further information and knowledge, evaluation, trial, and adoption, while simplicity, visibility of results, usefulness and low capital investment promote its eventual adoption and should be considered when transferring any technology. Sanjaya (2001) suggested that, in developing countries, technological effort is essential to using technologies efficiently, even in ‘followers’ is informal – learning, incremental improvements, adaptations, and copying – rather than formal research and development (R&D). What is more in developing countries, social learning possibly complements knowledge dissemination and facilitates the technology adoption process where the impact of public agricultural extension systems is limited (Tessema et al., 2016). Moreover, Edward and Michael (2003) argued that technology adoption is influenced by contact with earlier adopters is not sufficient to distinguish learning and imitation. However, theories of social learning suggest that, when technologies are new, there is higher uncertainty about their expected returns and risks as well as the best practices (Kazushi et al., 2019). Mamudu et al. (2012) in Ghana's low adoption of modern agricultural technologies is identified as one of the main reasons for the low agricultural productivity. Furthermore, Michele et al. (2020) reported that the manufacturing firms’ adoption of different generations of technology in Ghana, Vietnam, and Thailand remains extremely limited. In other way Technology, adoption decisions require investment by adopters at two or more points in time; the first investment is typically associated with the reception and the second implementation of the technology (Alain et al., 2016). Solomon (2020) argued that improved technologies adoption is the tool for boosting production and productivity of the agricultural sector, poverty reduction, and ensuring food security in developing countries, whereas due to numerous determining factors in most developing countries, the rate of adoption of improved agricultural technologies is still low. Likewise, Hyuk (2021) stated that the positive association of internal R&D intensity with the likelihood of technology adoption in the manufacturing sector reflects the capability of industry technological innovation. Although Azmawani and David's (2009) study revealed that, in the process of technology adoption the users are challenged with various problems that arise during the implementation process as many firms learn by doing, Nicholas et al. (2010) ambiguity-aversion significantly reduces both the probability and intensity of new technology adoption.

2.5. Technology Adoption experience of Ethiopia

Manufacturing Industry White Paper 2020-2030 GC (2021) revealed that "Ethiopian industrial firms continue to lag in the adoption of leading technologies. Across subsectors, firms use outdated technologies, demonstrate low innovation potential, and exhibit outsized reliance on imported technologies" (p. 66). Moreover Manufacturing Industry White Paper 2020-2030 GC (2021) stated that machinery is an important subsector while local technological and workforce capacity cannot currently compete on the global stage. Hence according to Ethiopian industrial development roadmap (2014), in the period (2013-2025) the county has planned to develop and transform manufacturing industries through establishment of machinery and equipment for textile, agro-processing, leather and chemical industries as well as increasing the capability of industrial machinery for capital goods equipment. Human resource development and technological capability building are key driving force for the accomplishment of the plan. In order to human resource development and technological capability building the government develops various strategies and institutional frameworks. Science and technology universities admission policy 70% students' science and technology and the remaining 30% are in other fields of study, TVET Industry Extension Service Programs, industry development research institutes, technology transfer trough Foreign Direct Investment (FDI) and industry parks are the frameworks to adopt technology, knowledge dissemination and human resource development. On the contrary, according to United Nations Conference On Trade And Development/UNCTAD/ (2020) technological supports provided to operators of micro and small enterprises (MSE) are very low, paucity of highly qualified human resource, there has been a small number of Foreign Direct Investment (FDI) thus the room for technology adoption is very limited and most of the country industry park jobs of foreigners firms have not been skill-intensive and do not require high level qualifications.

According to Belay (2017) study of improved wheat technology adoption with a random selection of 120 households as a total sample size only 59 (49.2%) were adopters while 61 (50.8%) were non-adopters. As of the researcher argument, the less number of adopter is resulted from mainly of farmer's awareness and inadequate extension service. Moreover adoption of new technology involves various risks and uncertainty about its productivity which gives those rural livelihoods in Ethiopia causes substantial risk and uncertainties due to unfavorable weather conditions (Dercon & Christiaensen 2011). Placing farm households in a multidimensional adoption decision, improves agricultural productivity that requires multiple inputs and technologies (Kibrom et al., 2016).

The driving forces of farmer's decisions to adopt agricultural technologies and the fundamental impact of adoption integrate into output market. Data obtained from a random cross-section sample of 700 farmers in Ethiopia.

According to the study of adoption of chickpea from a sample data of 700 farm households of which about 32% are adopters that is planted at least one of the improved chickpea varieties (Solomon et al., 2010). Likewise several technologies (mainly of agricultural and information technology) have been introduced in Ethiopia over the past years. However the impact, process, constrains and related issues of the adoption of these technologies has not been comprehensively assessed in the country at a national level.

Gezehagn et.al (2001) concluded that, technology adoption involves a dynamic process of gathering information, learning and experience play vital roles. Moreover characteristics of adopter and the technology are important in explaining adoption process. Numerous factors may significantly influence decisions to acquire knowledge about the technology being adopted and then to use it continuously or reject.

2.6. Impact of Technology Adoption

2.6.1. Productivity

Technological changes and innovations are fundamental sources of productivity and sustainable growth (Van et al., 2008). A firm's successful technology adoption significantly affects its competitive advantage, especially its performance (Kotler and Keller, 2006).

As Yohanes et al., (2011) argued, in a competitive market world, firms should compete through manufacturing capabilities in competitive dimensions of manufacturing; cost, quality, dependability, and flexibility.

The European Productivity Agency (2003) defined productivity as an attitude of mind. It is attitude of progress, of the constant improvement of that which exists. It is the belief of being able to do better today than yesterday and continuously. It is the continuous adaptation of economic and social life to changing conditions.

Productivity is a fundamental issue on which a business firm focuses for existence and being competitive in the market. The objective of a business firm is to make a profit while satisfying customer requirements. To make a profit a business system has to be efficient to optimal uses of input resources to increase productivity and reduce production costs. Since costs and productivity is inversely proportional i.e. growth in productivity means a decrease cost of production while increases profit. On the other hand it is the efficiency of how well a country, business organizations, and industry convert inputs resource into output. Therefore productivity, measures how efficiently use resources. In another way, it is the quality that indicates how well input resources are utilized (Kendrick & Creamer, 1965). These and other inputs together with organizational system setups and other factors are responsible for productivity. Thus a firm has to focus on these inputs can improve productivity using its potential, resources, and appropriate methods. Machines and equipment may have a prominent role in productivity. They are required for the rate of production, machining quality and precision, and improvement of products ranging from automobiles to airplanes, warships to medical devices, and mobile phones to mining equipment (Taylor & Lunenburg, 2020). Consequently developed countries shift more toward knowledge-based economic activities, information, technology, and learning.

Achille et al. (2021) study reported that the impact of ICT-capital intensity on labor productivity in Sub-Saharan African countries is positive.

According to Tigist's (2017) study findings, a 1% increase in technology adoption leads to a 0.22% increase in productivity, and this influence is statistically significant at a one percent level.

Therefore as Craig and Xueda (2011), argued that the creation and diffusion of new and more advanced knowledge and technologies have long been recognized as a major contributor to productivity and economic growth. However, United Nations Conference On Trade and Development (2021) reported that developing countries face several challenges, including demographic change, the lack of capacity, shortage of finance, lower technological and innovation capacities, slow diversification, and intellectual property rights and technology transfer.

2.6.2. Human resource development

According to the World Bank (2019), on account of frequently raised concerns about how the gains from new technologies share through their impact on employment, past many major innovations have been accompanied by the threat of job losses. On the contrary, recent concerns are highest around the automation of manufacturing jobs.

New technologies can be both substitute and a complement for labor, and therefore can boost job opportunities as well as reduce them (Autor, 2015).

As stated by economic theory, technological change allows producing the same amount of output with a lower amount of production inputs of capital and laboring (Vivarelli, 2012).

Although technology will cause some job displacement, it will cause some change and will create additional jobs for trained workers to use the new technology. Some past researches show that such displacement effects are temporary if accompanied by a capacity enhancement due to increased demand driven by economic factors. Therefore, the overall impact of new technology on employment is usually positive (NRC, 1994).

Mario and Hacer (2017) argued that the development and introduction of information technology is a recent example of new technology's impact on employment. Mario and Hacer (2017) concluded that overall growth in living standards productivity and employment are the results of the introduction of new technological developments.

2.7. Productivity Measurement

Productivity measurement is the ratio of the total output amount to a measure of input used in the production of goods and services (Jenny, 2015). Productivity indices, econometric models, and linear programming are common productivity-measuring techniques (Czumanskia & Löddinga, 2012). The goal of a business firm’s productivity measurement is productivity improvement from a combination of increased effectiveness and better use of input resources to produce desired output through technology, efficiency, real cost savings, living standards, and benchmarking production processes. With the intent of a quantified monitoring index productivity has been defined as the correlation of quantity of output and amount of input resources utilized for production, while productivity is a broad concept and has a great deal of controversy among scholars (Gboyega & Oyeranti, 2015). The net gain to the agent from the adoption of new technology is an important determinant of adoption. Thus quantity of results is predetermining factor for evaluating that firms are responsive to the use of technologies (Andrew & Mark, 2010). However, Productivity is the efficiency of how well input resources transform into output. Hence it measures how efficiently use resources. Kendrick and Creamer (1965) also discussed that productivity guides the management of business and success measures. Consequently, productivity management aims to develop continuous process plans for productivity programs, which are based on the productivity cycle of four stages including measurement, evaluation, planning, and improvement (MEPI). A productivity program is a continuous process. Therefore, productivity improvement has to be preceded by measurement, evaluation, and planning (Mahassan & Mostafaa, 2011).

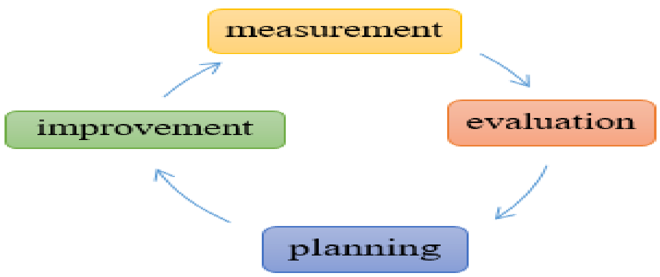


Figure-2. 4: Productivity Cycle [Source: Mahassan & Mostafaa, 2011]

Productivity evaluation is productivity indices calculated in productivity measurement stage and it is treated as a complementary part of productivity measurement. Whereas productivity planning requires forecasting future total productivity based on past performance of organization. There are various productivity measurements but selection can be based on the objectives and availability of measure data.

There are three major types of productivity measures, (i) single factor productivity measures (relating a measure of output to a single measure of input) (ii) multifactor productivity measures (relating a measure of output to a bundle of inputs) and (iii) total productivity measures (relating a measure of total output to sum of all input factors). Among the three measures total productivity measure is a basic and a set of five partial productivity measures: labor, material, energy, capital and other expenses measures (Mahassan & Mostafaa, 2011).

2.8. Factors Influencing Technology Adoption and Improvements

Referring to Lena (2002), technology adoption and implementation demand that companies change the organizational culture and system as well as the human resource management. As a result, the companies may face business competition by making various changes within the company. There are numerous internal and external factors that drive companies to adopt technology. The external factors include 1) global competition; 2) increasing customer demand for quality products; 3) the changing economic conditions that cannot be predicted; 4) higher market pressure; 5) environmental sustainability; 6) the degree of competition in the local market, and 7) media coverage. Of these seven factors, global competition and the customer demand for quality are the major ones. While Internal factors include: 1) implementing technology strategy; 2) increasing material costs of production; 3) increasing operational costs; 4) increasing business costs; 5) obsolescent plants and equipment; 6) increasing labor cost; 7) decreasing profits; 8) decreasing quality of products, and 9) high labor turn over. Two major internal factors driving technology adoption are the need to implement a technology strategy and the increasing material cost (Lena, 2002). However, the success of technology adoption, implementation, and empowerment as a competitive advantage depends on the technology management of the organization. According to Lena (2002), besides research and development (R&D), product and process effective technology management links engineering, science, and management disciplines to address the issues involved in the planning, development, and implementation of technological capabilities to accomplish the objectives of the organization. According to Salem (2012), many researchers have identified several factors that affect the diffusion of innovations, such as innovation characteristics, organizational characteristics, and environmental characteristics. Different scholars and researchers developed a different theory on factors influencing technology adoption, among the most prominent are reviewed as follow. Rogers (2003), has suggested five comprehensive sets of characteristics of innovations that are as mutually exclusive and as universally relevant as possible. These are summarized in the table below.

Table-2. 4: Summary of Rogers' characteristics of innovations

Factor	Definition
Relative Advantage	The degree to which an innovation is perceived as being better than the idea it supersedes i.e. improvement over the previous generation
Compatibility	The degree to which an innovation is consistent with existing business processes, practices and value systems. How well an innovation assimilates into an individual's life.
Complexity	The degree to which an innovation is difficult to use. Ease of use of an innovation by an individual
Trialability	The degree to which an innovation may be experimented with. Ease of experimentation on the innovation. (able to test an innovation)
Observability	The degree to which the results of an innovation are visible to others.

Likewise, Fishbein and Ajzens's (1975) theory of reasoned action (TRA) introduces two new affecting factors which are related to behavioral and normative beliefs of adopters: attitude toward behavior (an individual's positive and negative feelings (evaluative affect) about performing the target behavior) and subjective norm (the person's perception that most people who are important to him think he should or should not perform the behavior in question). As suggested by V. Venkatesh (2000), training, education, and technical support can affect an individual's perception-decision of the use of technology. On the other hand, Davis (1989) introduced two influencing factors of adoption: perceived usefulness and perceived ease of use. According to Majharul (2012), study analysis of individual factors such as perceived usefulness, personal innovativeness, prior experience, image, and enjoyment of innovation have a stronger influence on an individual's adoption of innovation tied with organizational policies, approaches, and actions.

2.9. Knowledge Absorptive Capacity and Realization

Cohen and Levinthal (1990) defined absorptive capacity as the ability to identify, assimilate and exploit knowledge from the environment. The premise of absorptive capacity is that the organization needs prior related knowledge to assimilate and use new knowledge. Absorptive capacity is a relevant, as well as valid concept in emerging economies as firms, tend to be engaged in innovation and therefore must undergo technological overtake processes to stay competitive (Petti et al., 2019).

The absorptive capacity of an organization provides both opportunities and constraints to improve upon the basis of its accumulated store of knowledge (Giuliani & Bell, 2005). The absorptive capacity of an organization will depend on the absorptive capacities of its individuals. To the development of an organization's absorptive capacity will build on prior investment in the development of its individual absorptive capacities, and, like individuals' absorptive capacities, organizational absorptive capacity will tend to develop cumulatively. According to Zahra and George (2002) and Anderson and Sun (2010), the absorptive capacity of organizational learning processes is presented in four dimensions:

- Knowledge acquisition – intuition and interpretation (individual and group learning);
- Knowledge assimilation – interpretation (group learning);
- Knowledge transformation – integration (group and organizational learning);
- Knowledge exploitation – institutionalization (organizational learning).

The first two of which refer to potential absorptive capacity and the next two refer to realized absorptive capacity.

According to van den Bosch et al. (1999), the organizational absorbing capacity depends on the number of organizational combinative capabilities factors such as (1) System capabilities- which includes directions, policies, procedures, and manuals that are used to integrate knowledge, they reflect the degree to which rules, procedures, instructions, and communications are laid down in a formal system. (2) Coordination capabilities- that manage knowledge and the processing rules and formalized procedures, coordination capabilities shape knowledge absorption by employing information linkages between individual members of the organization. (3) Socialization capabilities- the ability of firms to produce an ideology that offers members an identity as well as a collective interpretation of reality.

Knowledge exploitation (organizational learning) is a change in organizational knowledge and it results from three possibilities of enhancement, transformation, or reduction in organizational knowledge (Schulz & Baum, 2001). Organizational learning includes comprehensive perspectives of management and identifies various variables such as the organizational absorptive capacity, problem-solving skills, employee involvement, and learning environment Wang and Ahmed (2007). Therefore according to Irina V. Popova-Nowak1 and Maria Cseh

(2015), organizational learning is a practice of learning within organizations that involves individual interaction and inter-organizational levels of analysis with the ultimately intent of achieving the goals of an organization. However, there are factors affecting absorptive capacity, which are categorized into internal factors including organizational structure, size, strategy, prior knowledge base, and organizational responsiveness, and external factors, such as external knowledge environment and a firm’s position in knowledge networks.

2.10. Literature Review Summary

The literature review presents the research theoretical foundations underlying the technology adoption process, theory, and modeling. The technology adoption processes, theoretical frameworks, and models have implementation aspects at the individual as well as organizational levels while adopting innovation or technology.

The literature review mainly of the technology adoption process focused on Rogers's theory of Diffusion of Innovations with a detailed description of its encompassing theoretical framework covering the attributes of innovation, the process of adoption both for individuals and for organizations, the social channel and social context and aspects of the characteristics of the adopters. In addition to Rogers's theory other theories such theory of reasoned action (TRA), and Davis's theory are used.

The current research addresses the adoption of CNC technology by the machine manufacturing industries. The Rogers model is used as an approach to identify gaps in previous research used in review mainly on the technology adoption process.

2.11. Literatures Gap

Many pieces of literature on the fields of study in general and developing countries as well as Ethiopia particularly are reviewed from different sources to have sufficient data and the full understanding of the gap. Moreover, reviewed literatures are analyzed and summarized to identify gaps. The literature review major gaps drawn from past researches are summarized into two major parts Annex- 6. First limitation identified was the researches have been made on agricultural technology adoption in Ethiopian case. There are researches including Ethiopia that are reviewed sectorial or companies related to specific technology adoptions are conducted. Although those researches were not all-inclusive, consider one or two parts of agricultural technology adoption, seed access constraints and commercialization (Solomon et al., 2011, Gezahegn et al., 2001, Assefa & Gezahegn, 2009, Tigist, 2017, Mamudu et al., 2012, Nicholas et al., 2010, Miss & Mohammed, 2016, Margaret & Samuel, 2015). They are focused on regulating services (external factors), and lack of interlink between influencing factors, adoption process & explicitly point impacts. However, in order to implement technological adoption to get an integrated improvement solution fixing and examine the practices, problems, associated factors & their impact in a holistic way is significantly important.

Second overlooked has been on technology adoption in manufacturing firms that most of the articles, comprehensively focused on parts such as describing the important role of technology, to examines determinants and propensity for adopting and developing the technology revolution, the role of ambiguity-aversion on adoption of new technologies, effect of technology adoption on operational competitiveness, to provide knowledge on the adoption which neglecting the adoption factors, knowledge absorption capacity and decision process Azmawani A. and David (2009); Hyuk Chung (2021); Subodh, et, al. (2008); Iti and Meenu (2019); Kristianto, et al. (2011); Won-Sik & Ho-Sung (2021); Hui Li, et al., (2019).

Therefore the literature analysis highlighted the existence of gaps in the literature including paucity of sample size & research methods, limited geographical areas, focus on regulating services (external factors only), and lack of interlink between influencing factors, adoption process & impacts, and limitation linking data and methodology. To the best of my research review, there is no research has been conducted on the impact of CNC- technology adoption on the productivity of machine manufacturing industries.

Hence this research investigates the detailed productivity impact of the adoption of CNC technology under the study to understand the optimal importance which is not addressed in other research.

CHAPTER-THREE
RESEARCH METHODOLOGY

3.1. Research Design

This research intends to investigate the impact of CNC-technology adoption on the productivity of Roda machine manufacturing industry and propose appropriate improvement solutions. It will be achieved by the industries' survey data analysis of CNC-technology adoption and its impact on productivity improvement. Both qualitative and quantitative data will be used for analysis.

The data source strategies were literature review, primary data and secondary data. The past and present situation of the industry's CNC-technology adoption and its impact on productivity improvement has been collected from primary data collection through manufacturing technology and engineering industry research and development center former metal industry development institute (MIDI). Thus to meet the research objective the following methods are used.

3.2. Literature Review

Both theoretical and empirical literature review has been conducted relating to the research topic from sources such as academic, related articles, books and journals, government and non-government studies as well as reports to get core concepts, arguments, advancements and productivity improvement activities with a prior focus on the problems and improvement practices of manufacturing. The search strategy of the literature survey has done through an electronic database. The search considered all publication data without any limitation of dates of publication and location of the study but that mainly reflects CNC-technology adoption and its impact on productivity improvement.

3.3. Primary Data

Primary information/data has been collected from the sector supporting the institute of manufacturing technology and engineering industry research and development canter experts & leaders, Roda machine manufacturing industry, and sector association.

I. ***Key informant interviews***: This includes discussions with the management of Roda machine manufacturing industry. Key information interview mainly focuses on production capacity, capacity utilization, efficiencies, effectiveness, technology adoption, and future expansion plan of the industry. Furthermore, the level of support required from the government and provided concerning CNC technology and/or other technology adoption and its impact on productivity improvement as well as the industry's productivity performance.

II. ***Survey questionnaire***: A questionnaire containing several questions regarding the research objective is prepared and manufacturing technology and engineering industry research and development center experts & leaders, Roda machine manufacturing industry, and sector association. It was categorized to four parts with information about the firms, productivity concept, technology adoption affecting factors, and CNC-Technology Perceived usefulness and Perceived ease of use.

III. ***Observation***: physical observation is held on Roda machine manufacturing industry. The observation was mainly focused on the industry manufacturing workshop arrangement, technological capability and manufacturing (product, production, routing & machine) flexibility, productivity, and quality management system.

3.4. Secondary Data

All documents or records that are related to the Ethiopian, as well as Roda machine manufacturing industries' capacity, performance, and other related, were reviewed. Quantitative data regarding the trend of capacity, capacity utilization, and volume of production of machine manufacturing industries during the last six years are gathered from the industries report and manufacturing technology and engineering industry research and development center annual report. In addition, other vital documents were reviewed to have an in-depth understanding of the sector's industrial policies & strategies and other documents written by scholars on the sector.

3.5. Data Analysis and Presentation

Primary and secondary collected data were analysed and presented to answer the research questions and to achieve the objective of the study. To analyse the collected data has presented with bar-graphs and cause and effect diagrams. These analysis tools are used to analyze productivity performance impacting factors, production capacity, capacity utilization, the impact of CNC-technology adoption, and productivity improvement. The surveyed data was analysed in the supporting institution of manufacturing technology and engineering industry research and development center response analysis level and Roda machine manufacturing industry.

Secondly, Vensim simulation software was used for the analysis and developing of the technology adoption techniques model. Descriptive methods of tables, mean and percentage are also used to organize and interpret data gathered. The analysis was done to discuss, and identify major productivity activities, improvement methods and adoption of CNC-technology for a continuous improvement of Roda machine manufacturing industry was propose.

3.6. Population and sample Size

The definition of boundaries allows the researcher to clearly identify subpopulations, such as the target population, sample, and to ensure alignment between these groups within the research (Salkind, 2010). A population source list has been comprehensive, correct, reliable and appropriate to the study. It is very important for the source list to be as representative of the population as possible. Hence the population of the study are Roda machinery manufacturing industry employees, total number is 74 manufacturing technology and Engineering industry research and development center former metal industry development institute (MIDI) with concerned employees of 134. Hence total Population of the study is 208.

According to Kothari (2004) sample size of population should be optimum, neither be extremely large nor too narrower. To have representative and reasonable sample size that provide the research findings, below equations are used that developed by Johnson et.al (2009) and Freedman et al. (2007). Equation (1) computes the initial sample size. Due to the population is finite (less than 50,000) while equation (2) compute the new sample size.

$$n_f = \frac{n_0}{1+\frac{n_{0-1}}{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$n_0 = \frac{z^2 * p(1-p)}{c^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: n_o = Initial sample, n_f = target sample

Z = confidence levels are (Z=1.645 for 90% confidence level, 1.96 for 95% confidence level and 2.576 for 99% confidence level respectively)

p = percentage expressed as decimal 0.5 used for sample size needed

c = confidence interval, expressed as decimal; 0.08, proportion being estimated (the error that researcher willing to accept)

N = Population = 208 workers

$$n_o = \frac{1.96^2 * 0.5(1-0.5)}{0.08^2} = 150.063$$

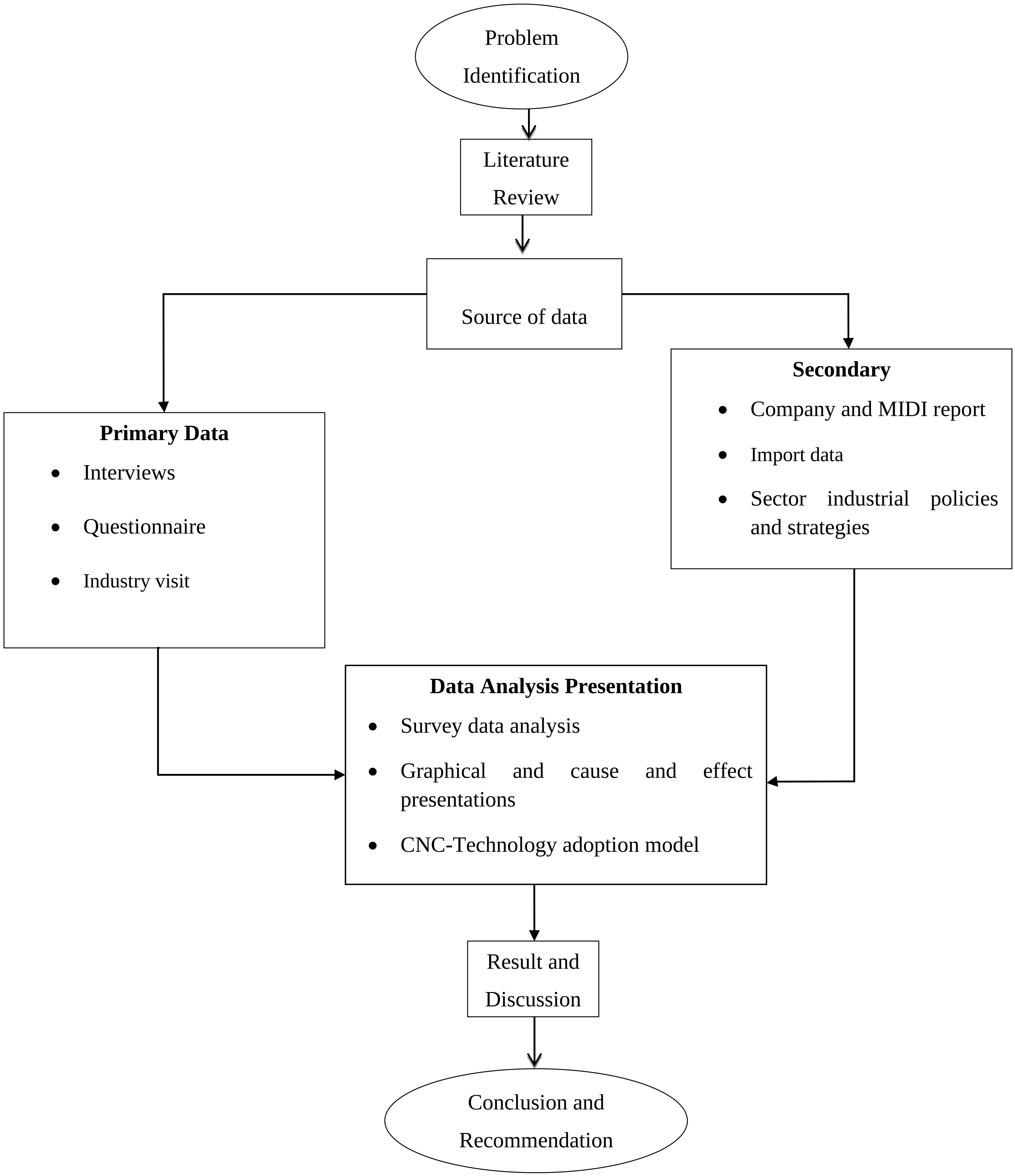
$$1 + \frac{no-1}{N} = 1 + \frac{150.063-1}{208} = 1.717$$

$$n_f = \frac{150.063}{1.717} = 87.39 \approx \underline{\mathbf{87}}$$

Table-3. 1: Total Number of respondents in specified department of MIDI and Roda

S.No	Department/Team	Total Number of Workers	Sample Size
1	Production/ Machine Shop	82	82x(87/208) = 34
2	Metal Part Fabrication Shop (welding, rolling, bending, shearing etc.)	26	26x(87/208) = 11
3	Maintenance team/After sales service	14	14x(87/208) = 6
4	Assembly Shop	6	6x(87/208) = 3
5	Quality	13	13x(87/208) = 5
6	Foundry Shop	20	20x(87/208) = 8
7	Research and Development	25	25x(87/208) = 11
8	Directors, Production head, Supervisors and Team leader.	22	22x(87/209) = 9
		Total	**87**

3.7. Research Framework



CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1. Introduction

This chapter presents analyses and interpret both primary and secondary data collected from Roda machine manufacturing industry and supporting institute of manufacturing technology and Engineering industry research and development center (former MIDI). Primary data was gathered by means of physical observations, questionnaires and structured interview to address the research objective, using several tools such as graphics, tables, etc. for illustration.

Manufacturing has both an upstream supply chain that includes networks of researchers and engineers, material suppliers, machinery, equipment, transportation, and other service providers plus a downstream sales chain that includes logistics and a global assortment of wholesalers and retailers.

Because machine manufacturing has so many substantial links with other manufacturing sectors throughout the manufacturing economy, its output stimulates more economic activity across society. That's a major reason machine manufacturing industries play such a critical role in economic growth. It also spurs growth in services such as finance and transportation. Thus it is it is understandable that machine is fundamental for manufacturing sectors in the economy a nation. So that it is vital to provide reinforcement to existing industries toward improvement of productivity and being competitive at the world market.

The chapter starts with information about the respondent profile, followed by tests of reliability and correlation.

4.2. Respondents profile

4.2.1. Response Rate

As determined by sample size computation the target sample size is 87 and the same number of respondents were administered from which 81 (93.10%) responded. All 81 collected responses are properly filled in so that it was used in the study.

Table-4. 1: Respondents Summary

Respondent's Firm/company Name	Questionnaires distributed	Questionnaires collected	Response rate (%)
Manufacturing Technology And Engineering Industry Research And Development Center	50	47	94.0
Roda machine manufacturing industry	31	29	93.55

4.2.2. Respondents Demographic Descriptive Data

In this section response rate, respondent gender, age, educational level, occupations, work experience, ownership, and business owner data were collected. To analyze the demographical data, a frequency table and histogram are used.

4.2.3. Respondents Educational Level

Respondents participated from different levels of educational backgrounds. To know the respondents' views of CNC-technology adoption's impact on productivity improvement, respondents were asked to indicate their educational background.

Table-4. 2: Respondents Educational Level

Respondent Firm	Respondents Educational Level					
	Below level-1	Level-1 to 4	Diploma	BSc	MSc	PhD
Manufacturing Technology And Engineering Industry Research And Development Center	7	22	1	14	3	0
Roda machine manufacturing industry	0	10	10	9	0	0

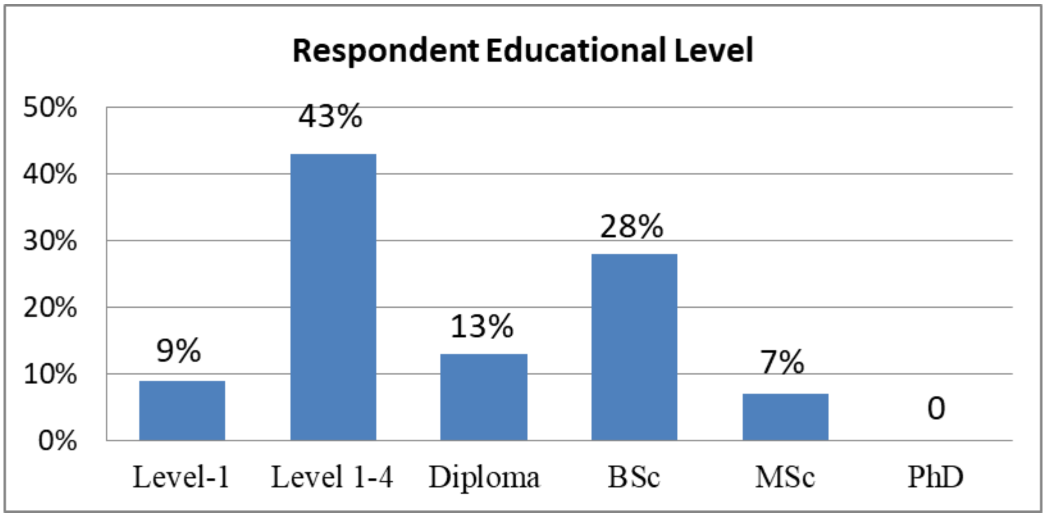


Figure-4. 1: Respondent's Educational Level

Figure-4.1. presents education levels of the respondents. The majority of the respondents are level 1-4 (43%), followed by BSc (28%), diploma (13%), level-1 (9%), MSc (7%).

4.2.4. Respondents Occupation

The respondents participating in the survey have various occupational levels as shown on the figure-4.2 including machinists, supervisors, quality control, Engineers, and managers/heads. The respondent level of occupation can indicate to identifying the impact of CNC-Technology and at the position of decision-making to adopt new technology or not.

Table-4. 3: Respondents Occupation

Respondent Firm	**6.1.1. Respondents Occupation**				
	Machinist	**Supervisor**	**Quality control**	**Engineer**	**Manager /head**
Manufacturing Technology And Engineering Industry Research And Development Center	19	8	3	16	1
Roda machine manufacturing industry	19	1	2	6	1

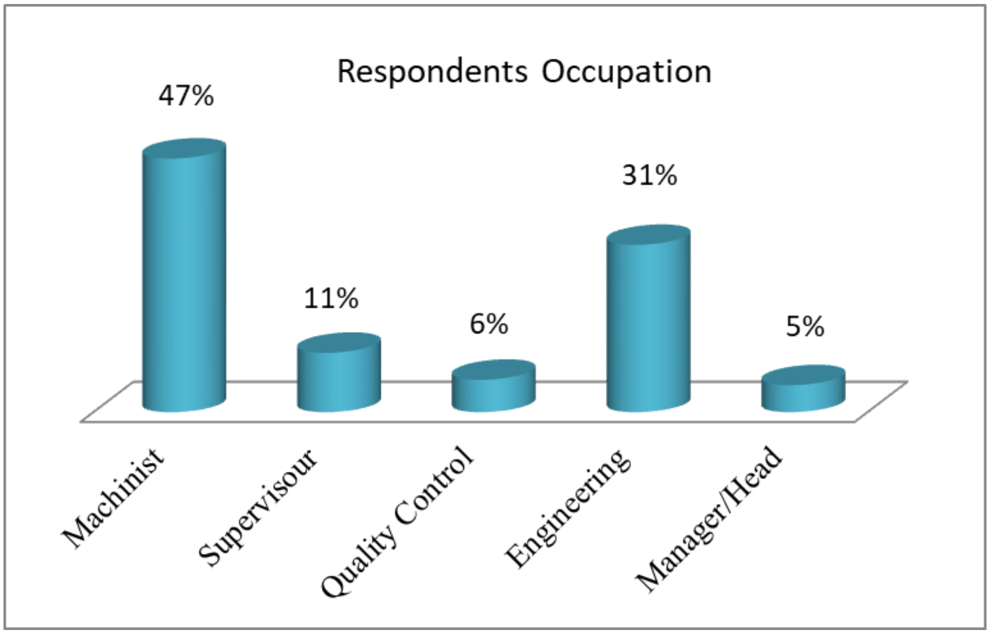


Figure-4. 2: Respondent’s Occupation

Figure-4.2 presents the occupational levels of the respondents. The majority of the respondents are machinists (47%), followed by Engineering (31%), supervisor (11%), quality control (6%), and Manager/head (5%). From figure-4.2 indicated the findings that the participant industries' major employees are machinists followed by Engineers.

4.2.5. Respondents Work Experience

Related organization’s employees with different work experiences were participated to respond questionnaire in the study to understand their views on technology adoption concerning the experience. For this purpose, respondents were asked to state their work experience. The majority of the respondents are 2-5 Years (38%), followed by 5-10 years (31%), 1-2 years (14%), 1 year (9%), and above 10 years (8%).

4.3. Supporting Institute Surveyed Data Analysis

Survey questionnaires were developed to assess the impact of the adoption of CNC technology to improve the productivity of Roda machine manufacturing industries. The survey was aimed to collect data to identify impacting factors, practices, and activities toward productivity improvement related to CNC-technology adoption. Data has been collected from Roda machine manufacturing industry; the manufacturing technology and Engineering industry research and development center, the former metal industry development institute (MIDI), and machine manufacturing industries associations.

There are a total of 38 questions (see Annex-3). All questionnaires are measured on a five-point Likert scale ranging from 1 to 5 (1= strongly disagree, 2 = Disagree, 3 = Indifferent 4 = Agree and 5= Strongly Agree). The questionnaire has four parts which comprise: part-I information about the respondent and industries, part II the industries' understanding of productivity (six items/questions are used to assess) and the factor impacting Productivity (five items/questions are used to assess), part-III Factors influencing CNC-technology adoption of the company (eighteen items/questions are used to assess) and part-IV is CNC-Technology Perceived usefulness (five items/questions are used to assess) and Perceived ease of use (four items/questions are used to assess). The questionnaire response total respondent number and meaning of the variables have been summarized as follows.

Table-4. 4: Summary of surveyed data analysis

S.No	**Variables**	**Mean**	**Number of respondent**				
			1	**2**	**3**	**4**	**5**
1	Understanding of Productivity in the Firm	4.60		9	37	133	307
2	Factor affecting Productivity	4.55			33	88	284
3	Factors influencing CNC-Technology adoption	4.68		44	120	260	710
4	External influencing factors of CNC-Technology adoption	4.57			38	76	210
5	CNC-Technology Perceived usefulness	4.72			24	132	249
6	CNC-Technology Perceived ease of use	4.48			29	105	190
		Total Score		**53**	**281**	**794**	**1950**
		Percentage (%)		**1.72**	**9.13**	**25.80**	**63.35**

Source: Researcher's questionnaire result, 2022

Table-4.4 indicates the total number of respondents, from the manufacturing technology and engineering industry research and development center, machine manufacturing industries association, and Roda's machine manufacturing industry. The total number of respondents is 81 and the total numbers of questionnaire items (questions) are 38. Consequently, the maximum number of response scores is (81*38) = 3078. From the total score, rating 2 is 53 with a percentage of 1.72, 3 is 281 with a percentage of 9.13, 4 is 794 with a percentage of 25.80, and 5 is 1950 with a percentage of 63.35 while 1 is null respectively. Moreover, the table reveals that of the respondents about 89.15% (agreed and strongly agreed) confirmed that the adoption of CNC technology positively impacts productivity improvement. The table also displayed the mean of all six variables of the questionnaire. Therefore the understanding of productivity in the industry has a mean of 4.60, factor affecting Productivity 4.55, factors influencing CNC-Technology adoption 4.68, influencing factors of CNC-Technology adoption 4.57, CNC-Technology Perceived usefulness 4.72 and CNC-Technology Perceived ease of use is 4.48 respectively. Although the mean value of the variables is high which is around the highest rating scale of 5(strongly agree) implies the adoption of CNC-Technology has a positive impact on the improvement of the machine manufacturing industry's productivity.

The findings are logical in that in a competitive business world technological capacity, R&D and innovations are fundamental for productivity improvement and staying competitive, thus industry’s successful technology adoption significantly impacts capacity utilization and competitive advantage.

4.3.1. Manufacturing Technology and Engineering Industry Research and Development Center Response Analysis

It is a governmental supporting institute of manufacturing technology and engineering industries mainly machine manufacturing industries. The objective of the center is to facilitate the development and transfer of engineering industries' technologies and to enable the industries to become competitive and get rapid development. To ensure the objective the center provides; technical consultancy services, technology selection, training programs, designing machines/spare parts & components, machine maintenance, market research, assistance and support concerning governmental programs and procedures, support to industry for securing different raw materials and consumables, facilitating market linkage in securing raw materials and marketing the end-products, facilitating the promotion of products for foreign market and product quality testing & quality assistance services to the industry (MIDI establishment proclamation No.182/2010, the role and responsibility). The role and responsibility of the center reveal that developing the industries in technology, human resource, and other inputs to be competitive in a world market. In order to realize its mission the center is organize according to the sector industries as shown in the Table-3.1 and the organizational chart of the center is show in annex-5. Hence technological support and capacity building are the major supports provided by the center so the researcher has collected data about the impact of CNC-technology adoption to improve the productivity of Roda machine manufacturing industry. There are a total of 47 respondents; the questionnaire response is summarized as follows.

Table-4. 5: Manufacturing Technology and Engineering Industry Research and Development Center Response Analysis

S.No	Variables	Number of respondents				
		1	2	3	4	5
1	Understanding of Productivity in the Firm		4	25	56	197
2	Factor affecting Productivity			12	38	185
3	Factors influencing CNC-Technology adoption		21	64	113	460
4	External influencing factors of CNC-Technology adoption			10	35	143
5	CNC-Technology Perceived usefulness			9	78	148
6	CNC-Technology Perceived ease of use			11	53	124
	Total Score		**26**	**130**	**373**	**1257**
	Percentage (%)	**0**	**1.51**	**7.27**	**20.87**	**70.34**

Table-4.5 shows questionnaire response is a summary of valid responses from 47 respondents. Total rated scale number 1(strongly disagree) is null while total rated scale numbers of (2 = Disagree 3 = Indifferent 4 = Agree 5= Strongly Agree) are 27(1.51%), 130(7.27%), 373(20.87) and 1257(70.34%) respectively. Therefore most of the supporting institute's respondents agreed that the adoption of CNC-Technology has a great impact on the improvement of productivity of Roda machine manufacturing industry.

4.4. Roda Surveyed Data Analysis

4.4.1. Roda Questionnaires Surveyed Data Analysis

The questionnaire was to assess the impact and factors of the successful technology adoption of CNC technology toward the improvement of Roda machine manufacturing industry productivity. According to the sample population computation, the total target sample size is 87 and the same number of respondents were administered of which 81 (93.10%) responded. Among the total 81 collected responses, 29 are from Roda machine manufacturing industry has been properly filled so that it is used in the study. Hence the respondents' demographic characteristics have been summarized in table Table-4.6.

Table-4. 6: Roda Respondents demographic characteristics

Variable	Characteristics	Frequency	Percentage	Variable	Characteristics	Frequency	Percentage
Gender	Female	20	68.97	Qualification	Level-1 to 4	10	34.48
	Male	9	31.03		Diploma	10	34.48
Age	21-30	11	31.03		BSc	9	31.03
	31-40	10	37.93		MSc		
	41-50	7	34.48		PhD		
	51-60	1	24.14				
	Above-60	0					
Occupation	Machinist	19	65.52	**Experience year**	Below 1	1	3.45
	Production Supervisor	1	3.45		1-2	4	13.79
	Quality Control	2	6.90		2-5	11	37.93
	Engineer	6	20.69		5-10	9	31.03
	Manager/Head	1	3.45		Above 10	4	13.79

Detail Roda's Surveyed data analysis according to each questionnaire has been summarized on the tables below.

Table-4. 7: Number of respondents rated items of "understanding of productivity in the firm"

S.No	Items of Understanding of Productivity in the Firm	Number of respondents				
		1	2	3	4	5
1	Improve capacity utilization			1	12	16
2	High production volume		1	2	12	14
3	Increased customer satisfaction				13	16
4	Reduce material waste and rework			4	11	14
5	Good quality		1		10	18

6	High profit		3	3	9	14
	Total Score		5	10	67	92
	Percentage (%)		**2.9**	**5.7**	**38.5**	**52.9**

As shown on table 4.7 the number of questionnaire items is 6 and the total number of respondents is 29 implying that at most each item would have a total of 29 responses. Therefore the maximum total number of responses will be (6*29) = 174. Moreover, it indicates that the total score of rating scale 2 is 5 with a percentage of 2.9 (5/174), 3 is 10 with a percentage of 5.7 (10/174), 4 is 67 with a percentage of 38.5 (67/174) and 5 is 92 with a percentage of 52.9 (92/174) while 1 is null. According to table-5.9 from total respondents 52.9% strongly agree, 38.5% agree, 5.7% are indifferent and 2.9% disagree respectively.

Table-4. 8: Number of respondents rated items of "Factor affecting Productivity"

S.No	**Items of Factor affecting Productivity in the firm**	**Number of Respondents**				
		1	**2**	**3**	**4**	**5**
1	Technological capability			2	6	21
2	Skilled man power			3	11	15
3	Availability of resources			5	8	16
4	Proper utilization of raw materials			4	7	18
5	Innovation and Research & Development			6	12	11
	Total Score			20	44	81
	Percentage (%)			**13.8**	**30.3**	**55.9**

Table-4.8 shows that the number of items is 5 and the total number of respondents is 29 implying that at most each item would have a total of 29 responses. Therefore the maximum total number of responses will be (5*29) = 145. Moreover, it indicates that the total score of rating scale 3 is 20 with a percentage of 13.8 (20/145), 4 is 44 with a percentage of 30.1 (44/145) and 5 is 81 with a percentage of 55.9 (81/145) while 1 and 2 are null. According to the table-4.8 from total respondents 55.9% strongly agree, 30.3% agree and 13.8% are indifferent respectively.

Table-4. 9: Number of respondents rated items of "Factors impacting CNC-Technology adoption"

S.No	Items of Internal Factors impacting CNC-Technology adoption in the firm	Number of respondent				
		1	**2**	**3**	**4**	**5**
1	To improve productivity				4	25
2	To improve product and process quality				7	22
3	Enhance competitive advantage			1	12	16
4	Product flexibility: To produce new (set of) products very economically and quickly.		1	2	12	14
5	Routing flexibility: To handle break-downs and to continue producing a given set of part types.			3	10	16
6	Production flexibility: The universe of part types that the manufacturing system can produce.			5	11	13
7	Machine flexibility: The ease of making changes required to produce a given set of part types.		3	4	9	13
8	To meet customer demand			3	11	15
9	New product development.			6	7	16
10	To extend the market.		3	3	11	12
11	Cost reduction and profit maximizing		4	4	7	14
12	Competitive price and survivals		3	2	10	14
13	To decrease material cost		4	8	8	9
14	To implement technology strategy		3	9	7	10
	Total Score		21	50	126	209
	Percentage (%)		**5.2**	**12.3**	**31.0**	**51.5**

Table-4.9 presents the total number of items of 14 while the number of respondents is 29 implying that at most each item would have a total of 29 responses. Therefore the maximum number of responses will be (14*29) = 409. Moreover, it indicates that the total score of rating scale 2 is 21 with a percentage of 5.2 (21/406), 3 is 50 with a percentage of 12.3 (50/406), 4 is 126 with a percentage of (126/406) and 5 is 209 with a percentage of 51.5 (209/406) and 1 is null. According to the table-4.9 from the total respondents 51.5 % strongly agree, 31.0% agree, 12.3% are indifferent and 5.2% disagree respectively.

Table-4.10: Number of respondents rated items of "CNC-Technology Perceived usefulness**"**

S.No	Items CNC-Technology Perceived usefulness	Number of respondent				
		1	**2**	**3**	**4**	**5**
1	Enables continual improvement of productivity				7	22
2	Improve quality of products			2	11	16
3	Product flexibility: To produce new products very economically and quickly			3	10	16
4	Increase efficiency of resource utilization			4	10	15
5	Improve innovation and Research & Development			6	13	10
	Total Score			**15**	**51**	**79**
	Percentage (%)			**10.3**	**37.2**	**54.5**

Table-4.10 show that the total numbers of items are 5 whereas the total numbers of respondents are 29 implies that at most each item would have a total of 81 responses. Hence the maximum number of responses will be (5*29) = 145. Additionally, it indicates the total score of rating 3 is 15 with a percentage of 10.3 (15/145), 4 with a percentage of 37.2 (51/145) and 5 is 79 with a percentage of 54.5 (79/145) with the other hand 1 and 2 are null. According to table-4.10 of the total respondents 54.5% strongly agree, 37.2% agree and 10.3% are indifferent respectively.

Table-4. 11: Number of respondents rated items of "CNC-Technology Perceived ease of use"

S.No	Items CNC-Technology Perceived ease of use	Number of respondent				
1	The interaction with CNC-Technology is clear and understandable.	**1**	**2**	**3**	**4**	**5**
				2	11	16
2	Learning to operate and use CNC-Technology is easy				10	19
3	I would find it easy to use CNC-Technology to make an adoption decision			7	9	13
4	Find it easy to get the technology to do what I want it to do			8	12	9
	Total Score			17	42	57
	Percentage (%)			**14.7**	**36.2**	**49.1**

Table-4.11 show that the total numbers of items are 5 whereas the total numbers of respondents are 29 implies that at most each item would have a total of 29 responses. Consequently, the maximum number of responses will be (4*29) = 116. Furthermore, it indicates the total score of rating 3 is 17 with a percentage of 14.7 (17/29), 4 with a percentage of 36.2 (42/116) and 5 is 57 with a percentage of 49.1 (57/116) on the other hand 1 and 2 are null. According to table-5.13 of the total respondents, 49.1% strongly agree, 36.2% agree and 14.7% are indifferent respectively.

The participants of the questionnaire respondents of Roda machine manufacturing industry are; 19 machinists, 6 Engineers, 1 supervisors, 2 quality control and 1 production manager.

Table-4. 12: Roda Machine Manufacturing Industry Respondents Rating Summary

S.No	Variables	Total Questions	Number of respondents				
			1	2	3	4	5
1	Understanding of Productivity in the Firm	6		5	10	67	92
2	Factor affecting Productivity	5			20	44	81
3	Factors influencing CNC-Technology adoption	14		21	50	126	209
4	External influencing factors of CNC-Technology adoption	4			27	36	53
5	CNC-Technology Perceived usefulness	5			15	51	79
6	CNC-Technology Perceived ease of use	4			17	42	57
		Total Score		**26**	**139**	**366**	**571**
		Percentage (%)		**2.4**	**12.6**	**33.2**	**51.8**

Table-4.12 Summary of Roda machine manufacturing industry respondents rating shows the total numbers of Roda's machine manufacturing industry respondents are 29. Whereas the total numbers of questionnaires are 38. Consequently, the maximum number of response scores will be (29*38) = 1102. From the total score of rating 2 (disagree) is 26 with a percentage of 2.4 (26/1102), rating 3 (indifferent) is 139 with a percentage of 12.6 (139/1102) rating of 4 (agree) is 366 with a percentage of 33.3 (366/1102) and rating 5 (strongly agree) is 571 with a percentage of 51.8 (571/1102) while 1 is null. On the other hand, it revealed that majority of the respondents around 85.1% (rating agreed and strongly agreed) confirmed that the adoption of CNC technology positively impacts productivity improvement in the industry.

The finding is that the employees are accepted and ensured that the adoption of CNC technology improves the productivity of Roda machine manufacturing industry.

4.4.2. Interview Data Analysis

Organizational technology management mainly focuses on the areas of customers, competitors, and technological evolution. Therefore the success of technology adoption, implementation, and empowerment as a competitive advantage depends on the technology management of the organization. Hence structured interview was prepared to discuss the management of Roda machine manufacturing industry about organizational technology management. The interview information focuses on production capacity, capacity utilization, technology adoption, and future expansion plan of the industry. Furthermore, the interview information involves the level of support required from the government and provided concerning CNC-technology and/or other technology adoption. The interview has held with the managing director/owner/ of the industry and the production head.

From the interview discussion data with the managing director, the industry was utilized only 10 to 25% of planned production capacity to ward 2018 fiscal year (Roda Production head). Furthermore planned annual revenue of the industry is birr 300,530,000, while in 2021 the achievement is around 36,063,600 birr which is 12% of the plan. The major reasons for the low production performances are using obsolescence machines, which are conventional/manual operated/, financial constraints and limited access to loan & lease financing of which using obsolescence machines is the most.

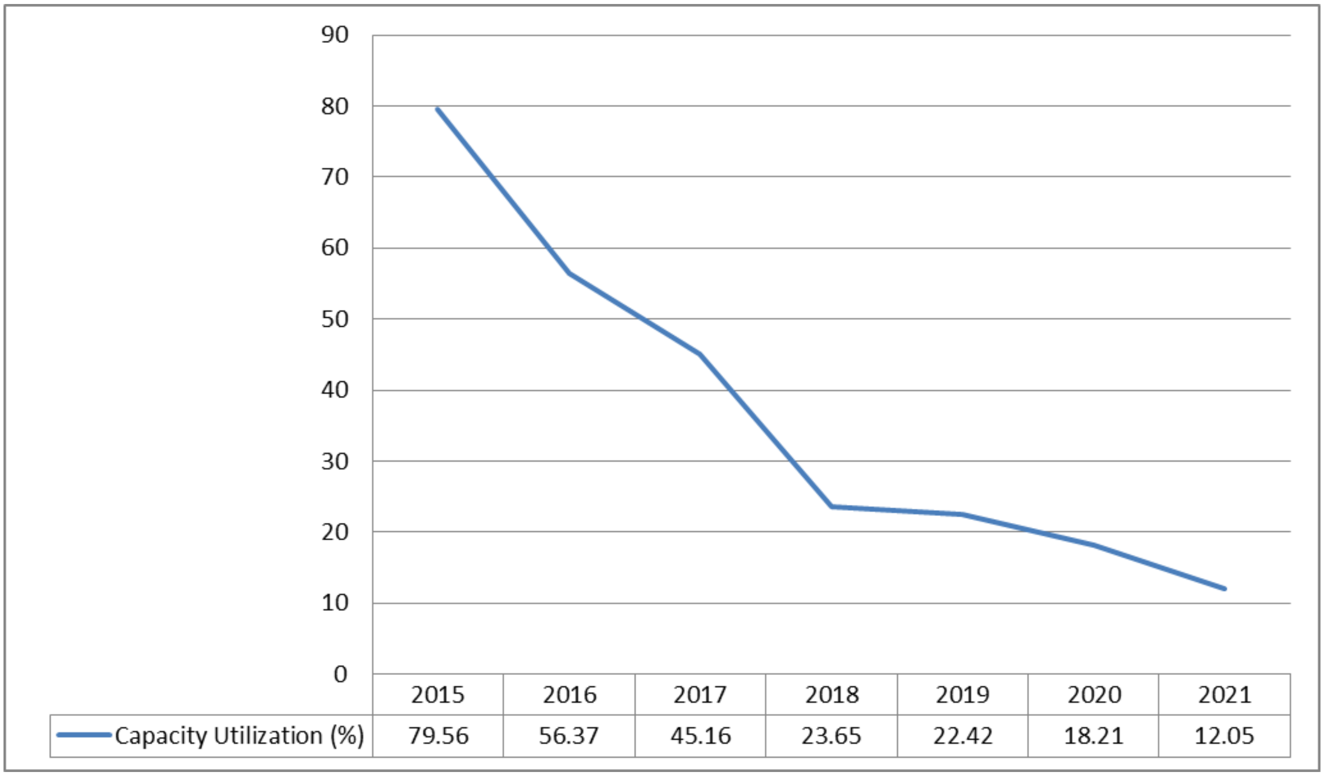


Figure-4. 3: Roda machine manufacturing industry capacity utilization

Source: Roda annual production performance and capacity utilization

The factors are not impacting only low production but also are the major factors for low productivity. To overtake the low productivity problem the industry has requested lease financing to replace the obsolescence machines. However, the country's finance sources are limited and the response from those sources also takes a long time sometimes found as a reason to reject the loan and lease financing request. The industry lease financing was requested by the Ethiopian development bank for expansion plants of (1) gearbox production, (2) Induction motor, welding, and transformer production, (3) Engine production, and (4) cutting tools and billet production industry. The industry-identified technologies for those products are CNC-gear hobbing, CNC-differential, CNC-bevel gear cutting, and CNC-chamfering machines. Using these CNC machines the industry has been scheduled to produce the machines and establish small-scale cement (100 to 300 quintals/day), sugar, oil (100 to 1000 litter/day), and bio-fuel production plants. The expansion plan of the industry is to substitute importing semi-finished and finished products. However, the industry has no plan to adopt advanced/CNC technology for replacing obsolescent technology to improve productivity, competitiveness, and product quality. Hence due to using obsolescence machines, financial constraints, and limited access to loan & lease financing the industry reduce/hire its Engineering employees from 29 to 8 among which only 3 are at work the remaining 5 are on long force leave. Moreover, the industry technical manpower plan was around 150 but only 38 workers are employed.

The industry wants government should give attention to all sorts of industries, encourage accelerated growth towards strongly substituting imports, and further generate export earnings. The machine is the prime mover of all manufacturing industries, hence giving prior attention will accelerate the realization of industrialization of the country. Thus the industry calls to the government for technical and financial support to adopt CNC technology.

4.4.3. Physical Observation Data Analysis of Roda Machine Manufacturing Industry

Physical observation was conducted on the industry in addition to questionnaires distributed and interviews for primary data collection. It was mainly focused on the industry manufacturing workshop arrangement, technological capacity and manufacturing (product, production, routing & machine) flexibility, productivity, and quality management system. According to the observation and discussion with the production head the industry is arranged with; a production machine shop, fabrication (welding) shop, chrome plating & galvanizing shop, foundry, assembly, and after-sales service. Besides, observed that the shops are equipped with; conventional lathe, milling machine, shaper, radial drill, band saw, press brake, sheet metal shear, sheet metal rolling machine, CNC plasma, oxyacetylene gas cutter, bending machine spot welding and other welding machines. The researcher proved that the industry is not using CNC technologies for production, but only CNC plasma and oxyacetylene gas cutters.

The major limitation observed in the industry is the lack of manufacturing flexibility (product, production, routing & machine). Flexibility is the most competitive factor in the manufacturing industry (Yohanes et al., 2012). Strategic flexibility consists of strategic leadership, dynamic core competencies, human capital, manufacturing resources, and information technology then manufacturing capabilities should be aligned with technology adoption (Hitt et al., 1988).

Second part of observation sees to machine tool precision and product quality. The machine tools of the industry especially lathe and milling machines lost their precision due to their long-time service and design of conventional origin. Since the product quality is not convenient, the machinists tremendously take measurements of the parts being machined. Consequently, the industry was engaged in the production of simple spare parts with some simple machine manufacturing that does not require precision. As a result, this is not suited for skilled manpower and caused them to leave the industry. However, the employees' experience with technical education qualifications is crucial to knowledge acquisition and continuous productivity improvement of the industry.

The third part of the observation was focused on research and development activities and practices of the industry. The industry has an R&D department only as an office but it has neither a department with assigned researchers nor an individual. Machine manufacturing is dynamic unless it is supported by research and development no longer competitive and sustainable.

According to, the organization for economic co-operation and development (1993), R&D is defined as comprising creative work undertaken systematically to increase the stock of knowledge and the use to devise new and improved products, processes, applications, and services that fill market needs”. Hence R&D supports enhancing the industry’s stay competitiveness. Machine manufacturing and the market are influenced by changes in global markets and competition, technological change, policy environments, and corporate management and organization as well as demand and supply. This shows that the changes related to production can have direct impacts on the machine manufacturing industry’s competitiveness as survivals.

4.4.4. Causes and Effect analysis

To minimize causes of low productivity determining the root causes is essential. Hence to analyze responsible factors of cause and effect used in low productivity includes man power, technological capacity, innovation and R&D, marketing and availability of resource.
Moreover from the productivity impacting factors technological capability is one of the most that affect productivity through product quality, production cost, delivery and manufacturing flexibility. Therefore the majors and other factors cause and effect relationship respective to technological capacity are presented on Figure 4-4 via fish bone diagram.

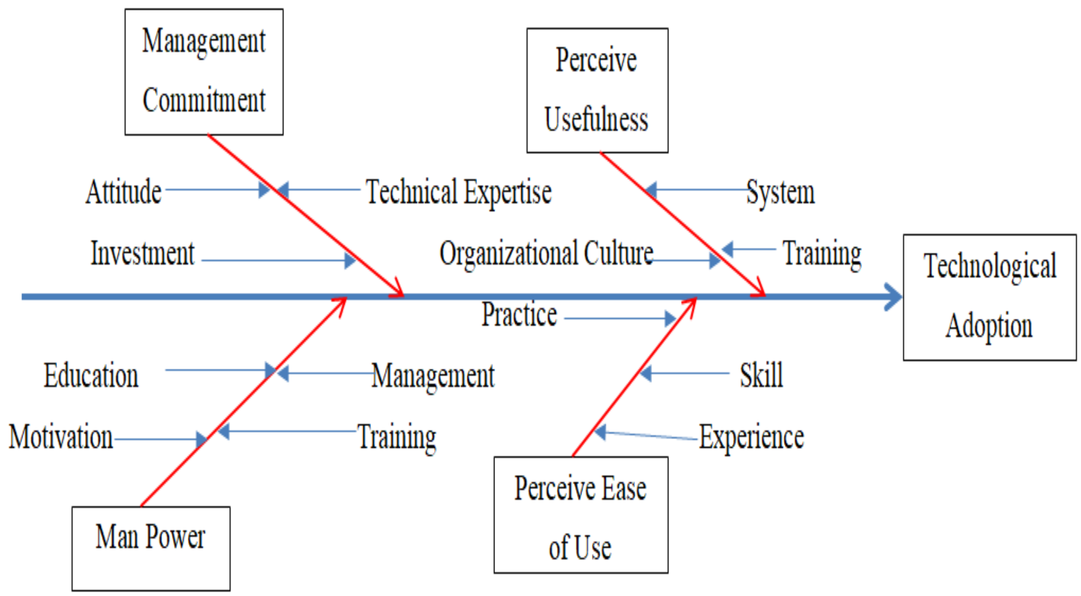


Figure-4. 4: Cause and effect diagram for technology adoption

4.5. Identified Findings

Generally, productivity-related problems of the industry are mainly technological capability, skilled manpower, lack of innovation and R&D, market, shortage of raw materials, and low-quality level of products. From the productivity impacting factors, technological capability is one impacting factor through product quality, production cost, delivery, and manufacturing flexibility. Hence findings from this study are;

- Top management's commitment is lack of strategy about prior technology adoption, rather believed that their sources of technology are internally focused; they are more concerned with short-term drivers of income.
- Understanding the benefits of technological capacity for capacity utilization, productivity improvement, and gaining competitive advantages is limited. This is the reason for the strategy of top management in idea generation, decision-making, and monitoring of the technology implementation.
- Low research & development and innovation cultures, participation, and involvement of employees are very low to create innovative culture and technology adoption.
- Limitations on developing technological capability, enhancing technological skills and capabilities of employees as well creating a culture that encourages technology advancement

CHAPTER-FIVE

CNC TECHNOLOGY ADOPTION AND PRODUCTIVITY IMPROVEMENT SOLUTION PROPOSAL

5.1. Introduction

To, develop a pertinent technology adoption strategy toward continuous improvement of Roda machine manufacturing industry productivity; first detail investigation of existing technological capacity, productivity performance and analyzing it according to theoretical frameworks. Second, summarizing and identifying the major limitations, productivity-related as well as CNC-technology adoption impacting factors. Finally the development of a CNC-technology adoption strategy based on the identified gaps and exciting performance to improve productivity as well as sustain efficient capacity utilization of Roda. Furthermore, in this part a summary of productivity related as well as CNC-technology adoption-impacting factors and then the development of an improvement solutions based on the findings.

5.2. Roda's Productivity Performance and Measurements

Based on the interview and physical observation of Roda machine manufacturing industry productivity measurement issues have been discussed. The industry conducts productivity measurement by comparison of production plan with actual product/output for strategic decision making. This is because of less understanding of measuring productivity and lack of skill. They use the result of the measurement just for increasing product selling price, decreasing workers number, and increasing their profit margins rather than working to optimal utilization of resources for continuous productivity improvement.

The machine tools of the industry especially the lathe and milling machines, which are the most used in the industry, and lost their precision due to the long time service and design of conventional origin. The industry, therefore, engaged in the production of spare parts with some simple machine manufacturing which does not require fine precision, while the machinist tremendously measures parts being manufactured on these machines since the product quality is not convenient. As a result, skilled man powers are not suited and caused to leave the industry.

Losing skilled manpower and efficient machines & equipment negatively impacts the industry's knowledge acquisition and continuous productivity improvement.

5.3. Roda Productivity improvement practices

As presented on the table-4.7 Roda's machine manufacturing industry understanding of productivity in the firm scores about 91.4% of respondents' results rating scores of strongly agree and agree. On the other hand, based on table-4.8 response results technological capability 21.6% impacts the productivity of the industry followed by skilled manpower 20.8%, Proper utilization of raw materials 20%, Innovation and Research & Development 18.4%, and availability of resources 17.6% respectively. Among which technological capability scores 21.6% is the highest impact on the productivity of the industry. Moreover, as stated in the interview section the annual revenue achievement is around 36,063,600 birr which is 12% of the plan. However, the industry has not planned to replace the obsolescent conventional/manual-operated machines with CNC machines to improve productivity, competitiveness, and product quality.

In the same way, based on physical observation the major limitation of the industry is the lack of manufacturing flexibility (product, production, routing & machine). Moreover, the industry has an R&D department only as an office but it has neither a department with assigned researchers nor an individual. Machine manufacturing is dynamic unless it is flexible and supported by research & development no productivity improvement accordingly to customer requirements, market behavior, and competitor competitive advantage. However, for productivity improvement, the industry gives job training and occasional pieces of training sponsored by other stakeholders or organizations such as MIDI on machining, welding, environmentally safe, and KAIZEN (5S). However, the industry does not provide scheduled capacity building based on identified workers' skill and knowledge survey analysis.

5.4. Improvement strategy

5.4.1. Knowledge Absorptive Capacity

The absorptive capacity of an organization will depend on the absorptive capacities of its individuals. Absorptive capacity is affected by an employee's qualifications which are dependent and built on the absorptive capacity of the employee. This indicates that employee involvement, practices of learning and skills are fundamental to achieving organizational goals.

From Roda's machine manufacturing industry physical visit observed that the industry machine tools are obsolesced and lost their precision which is not suited for skilled manpower and caused to leave the industry. However, skilled manpower is crucial to knowledge absorptive capacity and the management process of the industry. On the other hand, the industry has an R&D department only as an office but it has neither a department with assigned researchers nor an individual. Machine manufacturing is dynamic unless it is supported by research and development no longer competitive and sustainable. Whereas Roda's machine manufacturing industry survey data of the questionnaire CNC-Technology perceived usefulness response of the respondent employees revealed that 87.5% strongly agree and 10.34% agree respectively. This confirms the employees have knowledge about the adoption of CNC-Technology and believed that the use of technology can improve productivity. Likewise, the survey data of the questionnaire CNC-Technology perceived ease of use shows that 45.3% strongly agree and 33.6% agree indicates the employees proved that the use of technology will be free from effort, understandable, and learning to operate and use CNC-Technology is easy. Therefore Roda machine manufacturing Industry proposed knowledge absorptive capacity learning processes are modeled on the figure-6.1, using the 4I model i.e. intuiting, interpreting, integrating, and institutionalizing proposed by (Crossan et al., 1999).

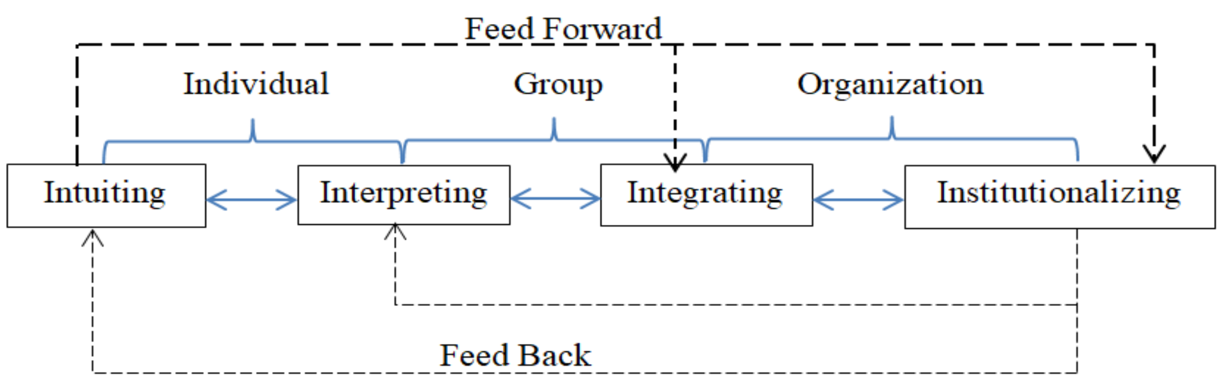


Figure-5. 1: Proposed model of Roda machine manufacturing Industry organizational learning processes (*modified & drawn based on the concept from Tracy A. Jenkin 2013)*

Factors impacting organizational learning comprise its employees' qualifications and the emphasis on training. The emphasis is on training as there is a need for all employees to have prior knowledge of absorptive capacity. Training boosts the absorptive capacities of individuals and ultimately it enhances the organizational learning capacity. Moreover, the proposed Roda machine manufacturing industry knowledge absorption capacity model has been constructed as presented in figure-6.2. The model has been developed by accommodating the five Cohen and Levinthal (1990) and Zahra and George (2002) absorption capacity process dimensions of (a) acquisition, (b) valuing (c) assimilation, (d) transformation, and (e) exploitation with the three relationships between absorptive capacity and technological innovations of external knowledge source, knowledge storage, and technology-innovation achievements.

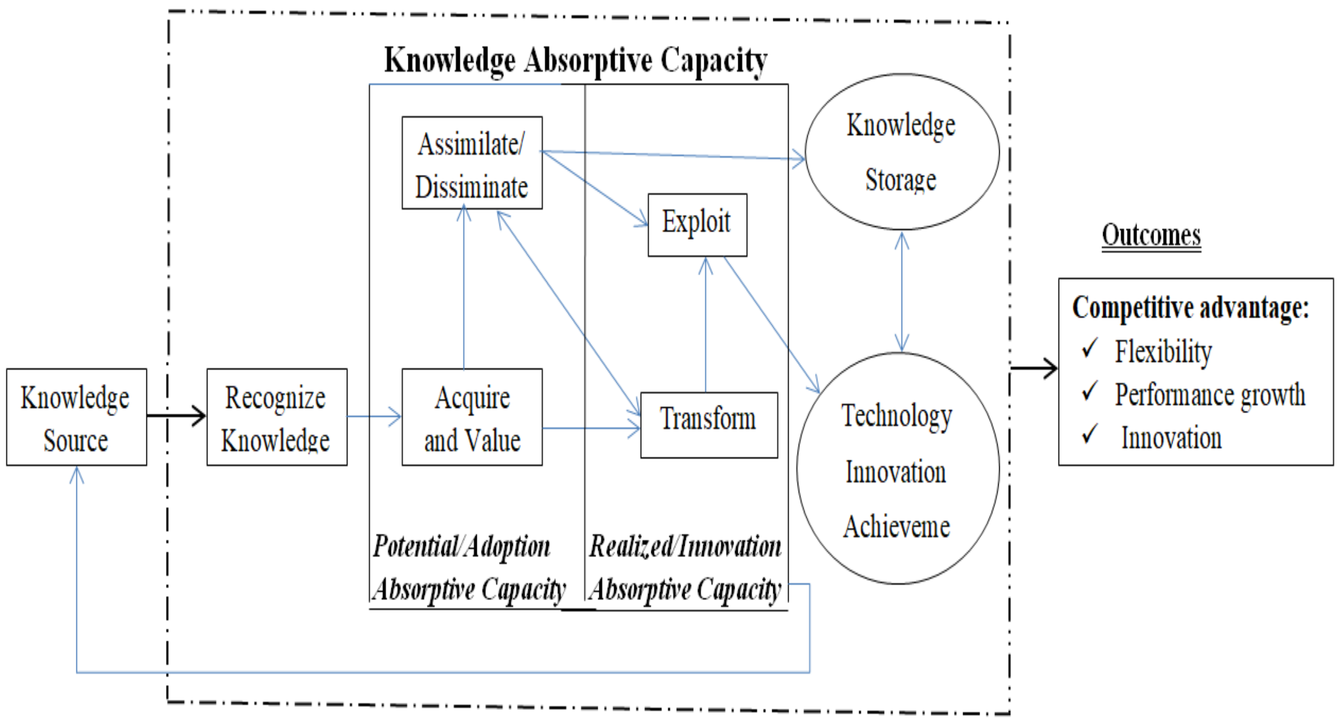


Figure-5. 2: Roda machine manufacturing industry knowledge absorption capacity process model

The outcomes from the implementation of the model are:

- To implement a technology strategy
- New product development
- Improve innovation and Research & Development
- Efficient utilization of capacity
- Enables continual improvement of productivity
- Improve product and process quality
- The flexibility of production, production, and process

- Market expansion
- Performance growth

5.4.2. Technology Adoption

Manufacturing Industry white paper 2020-2030 GC (2021) argued that Ethiopian industrial firms continue to lag in the adoption of leading technologies. Across subsectors, firms use outdated technologies, demonstrate low innovation potential, and exhibit outsized reliance on imported technologies. Roda machine manufacturing industry technology adoption indeed follows the same trend and experience of the country. That is why the industries are using obsolescent technologies which make the industries far distance lagging from industrialized countries and updated technologies as well. The country/government gives prior attention to machine manufacturing industries among the manufacturing industries to realize its industrialization policy. According to the manufacturing industry white Paper, 2020-2030 GC (2021) stated that the machine manufacturing industry is an important subsector while local technological and workforce capacity cannot currently compete on the global stage. The industries are expected to supply tools, dies, molds, and spare parts to all manufacturing industries as well as machines to substitute importing value-added products.

The country's manufacturing industries include textile, leather, cement & other construction input, sugar, agro-processing, basic metals, electrical-electronics, and automotive. So machine manufacturing industries are established to supply tools, dies, molds, spare parts, and machines to manufacturing industries to accomplish the objective of a self-reliant economy in the nation. To do so technological capacity and human development are fundamental for machine manufacturing industries. Technological capacity is the most significant because once an industry has built technological capacity; human development is automatically following the technology.

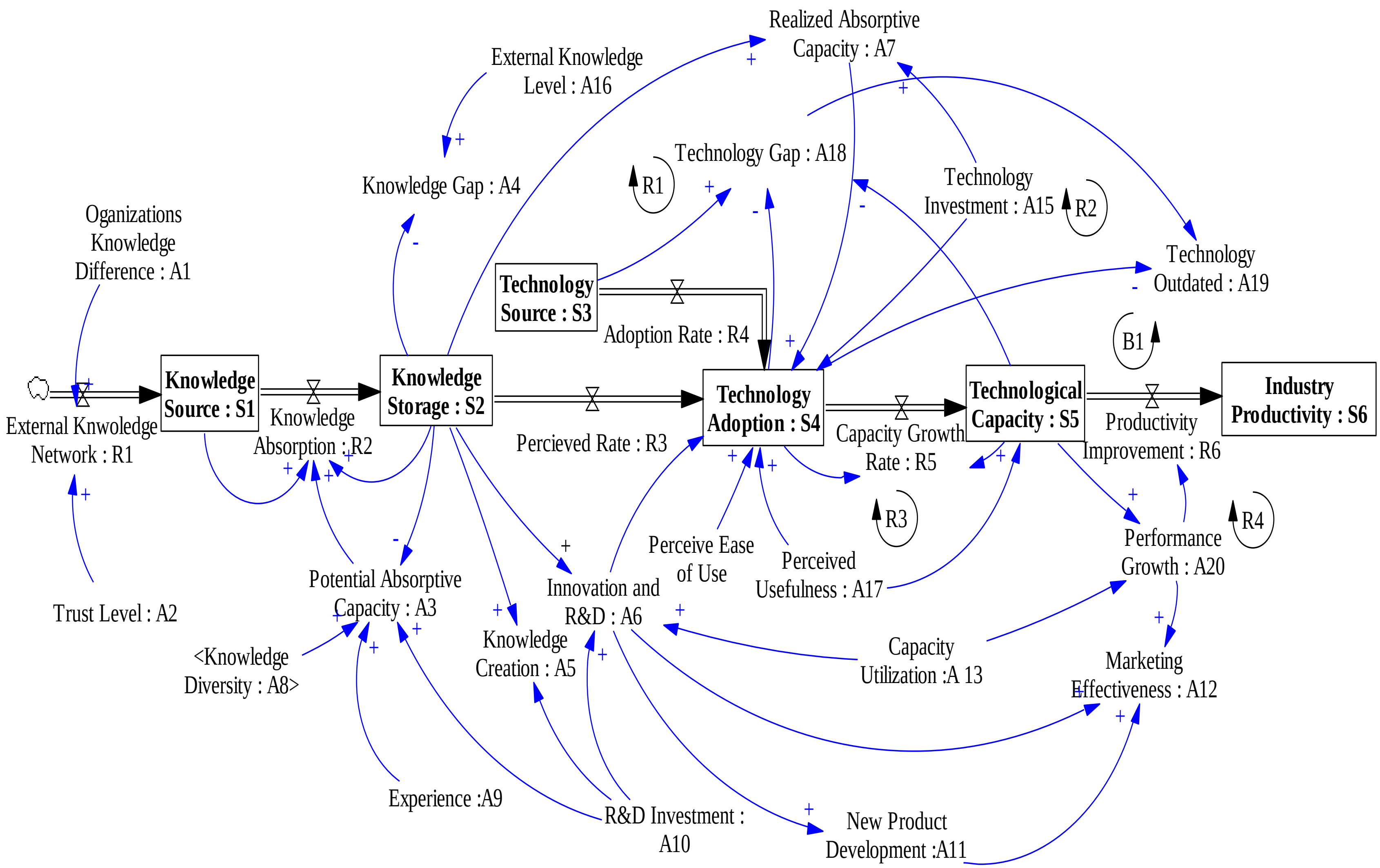
As presented in the overview of machine manufacturing industries, chapter four of this study, almost all are equipped with conventional machines which cannot enable the industries to deliver even a few of the manufacturing industry's needs. This is also true for Roda machine manufacturing industry. As per the survey data of this study, the technologies used by the industry are obsolescent which can’t make it possible for the industry to accomplish its objective as well as deliver the manufacturing needs of tools, dies, molds, spare parts, and machines as per requirement. Eventually, the industry adopted the technologies going to use while it is not adopting updated technologies to provide a product according to world market change, customer demand for quality, and change in economic conditions to satisfy customer requirements, improve productivity and enhance competitive advantage.

Therefore the proposed Roda machine manufacturing industry CNC-technology adoption process developed model has been shown in the figure-6.2.

5.4.3. Model Description

System dynamic (SD) is used as a modeling tool to analyze relationships between variables and in handling dynamic aspects of system behaviour (Quaddus & Intrapa, 2001). System dynamics models often have been used to understand the causal mechanisms underlying observed behaviors (Andre, 2018). Modeling the system is developed using stock and flow diagrams to quantify the causal diagram and run simulation iterations of CNC-technology adoption to analyze the output. The primary effect of CNC-technology adoption is increasing technological capacity of Roda machine manufacturing industry and consequently improves productivity. Therefore this section presents a detail description of the model. Figure-6.1 presents a system dynamic (SD) model about knowledge absorption and persuasion enables technology adoption that facilitates productivity improvement and indicates the relationships of its components.

The model has been developed with into consideration of (Rogers, 2003) innovation/technology decision processes (knowledge, persuasion, decision, implementation and confirmation). It is used to investigate the potential impact of Roda's CNC-technology adoption on productivity based on the current technology in accordance with product market demand. To realize the technology adoption, identify knowledge gap, acquires external knowledge by developing external knowledge sources, assimilate the knowledge, form the knowledge storage, transforms and utilizes the knowledge to achieve the productivity improvement. The model consists of key variables connected by arrows presenting the causal impacts among the variables and relationships can be shown by either positive (+) or negative (-) polarity to show the direction of change one variable cause to the other variable. A positive polarity represents a change in one variable causes a change in the same direction for another variable, while a negative polarity indicates that a change in one variable results a change in the opposite direction for another variable other factors are constant. Likewise the model is consist of loops which are indicated by a circular causal arrow links of either positive (reinforcing - R) or negative (balancing - B) feedback to show relationships among the elements of the model. Positive (reinforcing - R) feedback effect reinforces the original change and causes increase processes in a system, whereas negative (balancing - B) is opposes the original change and responsible for the stability and balance in a system.



Key: S-Stock/Level Variable, R- Rate/Flow and A- Auxiliary variables

Figure-5. 3: Roda machine manufacturing industry CNC-technology adoption model stock and flow diagram

Table-5. 1 No table of figures entries found.**: CNC-technology adoption model's stock and auxiliary variables**

<table>
<tr><th>Stock/Level</th><th>Auxiliary Variable</th><th>Stock/Level</th><th>Auxiliary Variable</th></tr>
<tr><td>A. Knowledge Source</td><td>1. Organizational knowledge difference
2. External Knowledge Network
3. Trust level</td><td rowspan="3">B. Knowledge Storage</td><td rowspan="3">1. Knowledge absorption
2. Potential absorptive capacity
4. Knowledge diversity
5. Knowledge creation
6. Experience
7. R&D investment
8. External knowledge level
9. Innovation and R&D
10. Knowledge gap
11. Realized absorptive capacity</td></tr>
<tr><td>C. Technology Source</td><td>1. Adoption Rate
2. Technology gap</td></tr>
<tr><td rowspan="2">D. Technology Adoption</td><td>1. Perceived Rate
2. Innovation and R&D
3. Capacity utilization</td></tr>
<tr><td>4. Perceived ease of use
5. Perceived usefulness
6. Knowledge storage
7. Technology investment
8. Technology outdate
9. Capacity growth rate</td><td rowspan="2">E. Technological Capacity`</td><td rowspan="2">1. Capacity growth rate
2. Marketing Effectiveness
3. Perceived usefulness
4. Performance growth
5. Capacity utilization
6. New product development
7. Technological gap</td></tr>
<tr><td>F. Productivity</td><td>1. Productivity improvement
2. Marketing effectiveness
3. Capacity utilization
4. New product development
5. Performance growth</td></tr>
</table>

Note:

Stocks/Level - describing a condition of a given system and generating information for all decisions and actions.

Auxiliary variables- which link with one another using informational bonds allowing determining unambiguously the cause and effect direction in a system (Małgorzata, 2010)

The model comprises six stocks: (1) knowledge source, (2) knowledge storage, (3) technology source (4) technology adoption (5) technological capacity (6) industry productivity. Likewise, the mode contains auxiliary variables corresponding to each stock as indicated in figure 6.3 and table-6.1. In addition, the model involves five feedback loops of which four are reinforcement while the other is balancing arising from various cause-effect relationships between stock, auxiliary variables, and relative availability of charging points. The feedback loops are described as follow.

1. **Knowledge reinforcement (R1)**

It represents the knowledge absorptive potential of the company. It is primarily derived from the knowledge gap which is the knowledge gap between the industry's existing status and the knowledge demanded to adopt CNC technology. Knowledge is fundamental to innovation and adoption (Barta et al., 2016). It is impacted by the inflow of external knowledge sources, knowledge storage, institutional knowledge absorption capacity, and outflow rate of absorption, innovation, and R&D with constant values of individual experience and knowledge management of the industry. Potential absorptive capacity is a key factor for the industry to acquire and assimilate knowledge (Zahra and George 2002) that influences knowledge absorption.

2. **Adoption reinforcement (R2)**

It reflects the potential of CNC-technology perceived decisions of the industry. It is impacted by the inflow of knowledge absorption rate, innovation, R&D, realized absorption capacity, perceived usefulness and perceived ease of use, and outflow rate of technology innovation achievement with constant values of technology investment and organizational incentive system. The realized absorptive capacity enables the industry to transform and exploit knowledge to ensure technological capacity improvement performance (Zahra and George, 2002). Subsequently realized absorptive capacity positively impacts the technological capacity of the industry. Moreover, technology investment is also an important factor that impacts technology adoption. According to interviews in the industry is a lack of strategy about prior technology adoption rather believed that their sources of technology are internally focused; they are more concerned with short term drivers of income.

3. **Efficiency reinforcement (R3)**

The effect of CNC-technology adoption enhances the technological capacity. Technological capacity performance is the most important tangible outcome of knowledge absorptive capability as well as technology adoption and the result of technology-innovation achievements which shows the existing technology level of the industry. In Efficiency reinforcement (R3) the adoption rate of CNC technology positively impacts technology capacity thereby; capacity utilization, performance growth, and flexibility (production, product, machine, and routine) new product development then affects marketing effectiveness in return reduces outdated technology.

4. **Productivity reinforcement (R4)**

The return of technological capacity performance reflects the reinforcing effect on resource optimal utilization, reduces material waste and rework, improve product and process quality, innovation and research & development, in return increase customer satisfaction and enhance competitive advantage, finally confirms productivity improvement. Productivity improvement is influenced by the inflow rate of capacity growth, performance growth, marketing effectiveness, product & process flexibility with other variable values are constant.

5. **Technology balancing (B1)**

The effect of new technology adoption and enhancing technological capacity to improving productivity can cause replacement of outdated/obsolesce technology. Outdated technology is a specific technology that becomes less productive and gradually disappears from market. It is impacted by the inflow of technology capacity performance, technology investment and technology innovation achievement.

5.4.4. Analysis and Simulation Results of Stock Variables

The model simulation time unit is year and the total simulation time consists of 10 years. Hence the mathematical formula and simulation results for the six stock variables are analyzed below. The model Auxiliary Variables and rates mathematical formula are attached on Annex-2.

1. **Knowledge Source (S1)**

The major knowledge source of organization is from external sources, which are fundamental to innovation (Park, 2014). Hence the external knowledge source (S1) is influenced by the inflow rate of external knowledge (R1) and the outflow rate of Knowledge absorption (R2), with the initial value is zero. The mathematical equation is:

$$S1 = \int (R1 - R2)\,dt$$

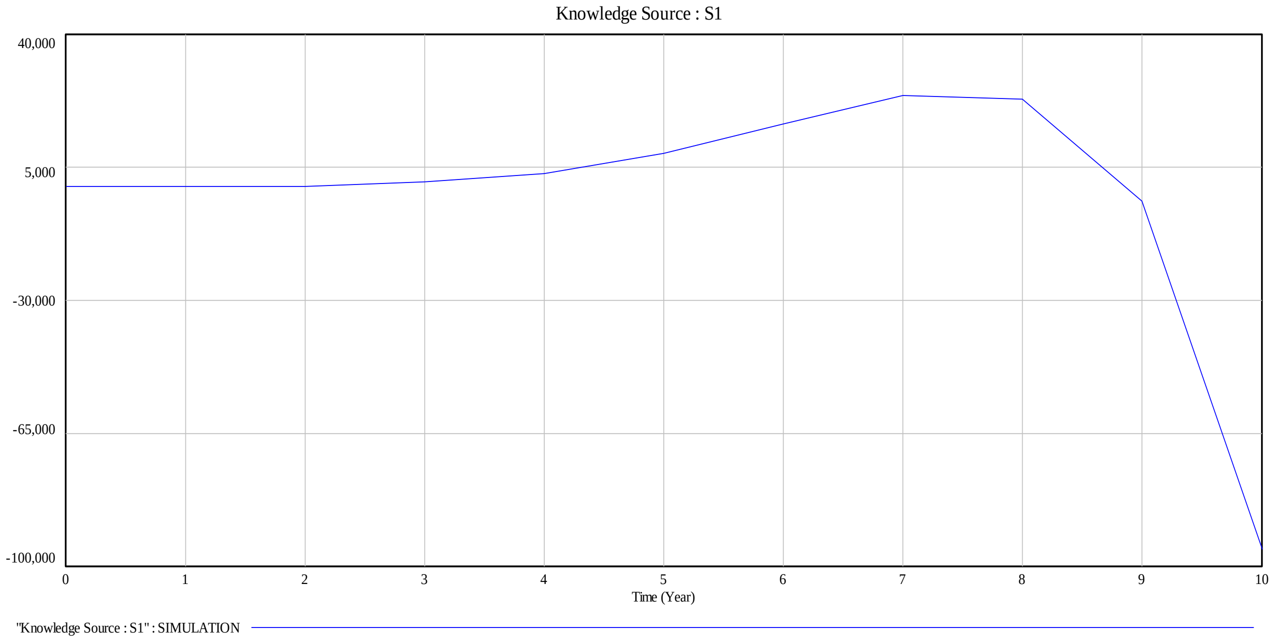


Figure-5. 4: System dynamic model graph of knowledge source

The simulation result graph shows that the curves of knowledge source at the starting time are high and continued increasing far to time of eight years. This indicates that at the time of start the industry is at low knowledge to improve its productivity. Therefore to improve the low productivity the industry acquired more external knowledge over a time interval of zero to eight years. However, after eight years the industry has established an internal knowledge source and achieved its productivity performance thus no external knowledge will be required.

2. Knowledge Storage (S2)

Knowledge storage is the amount of knowledge that an organization has in a store, which affects the organization's research and development (R&D) activities and potential ability to achieve technological innovation (Wanzenböck et al., 2013). More knowledge storage in an industry will cause build-up technology adoption achievements. It is impacted by the inflow rate of knowledge absorption (R2) and the outflow rate of technology perception (R3).

$$S2 = \int (R2 - R3)dt$$

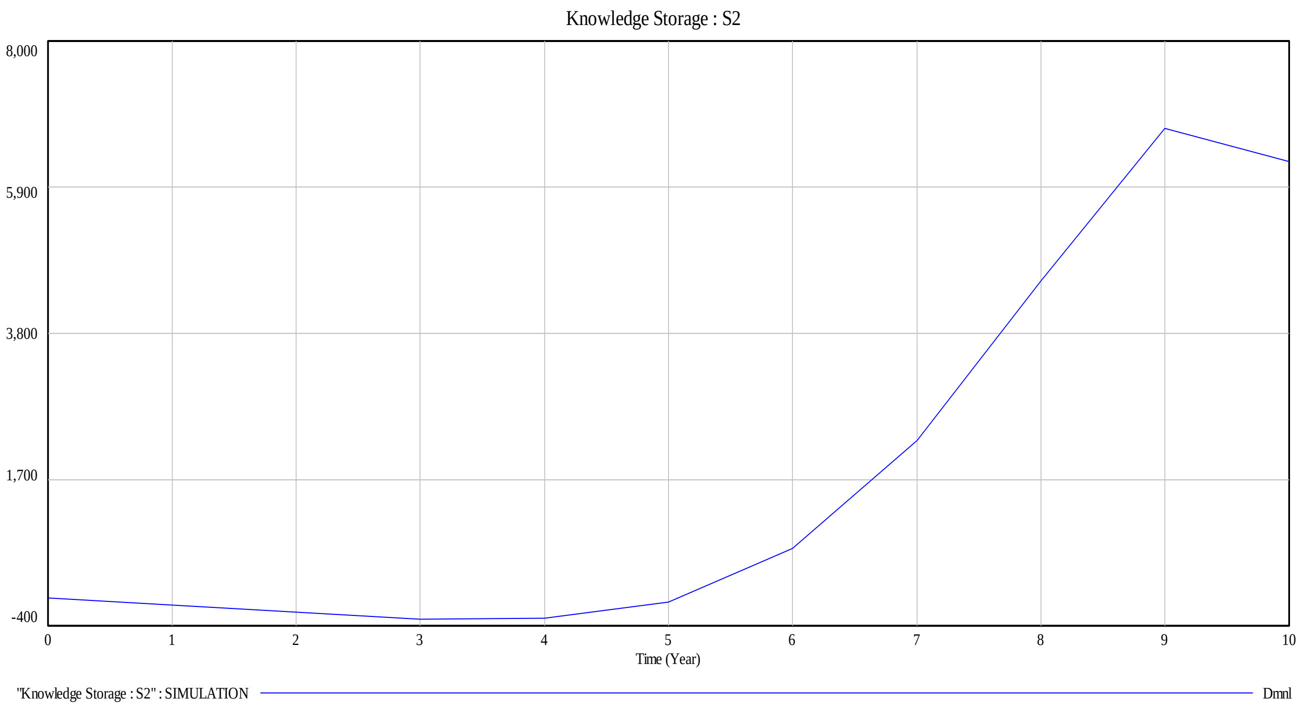


Figure-5. 5: System dynamic model graph of knowledge storage

The knowledge storage is low to time of four years, while increases rapidly to time of nine years. The low growth is due to the industry at time of start to four year is acquiring knowledge mainly comes from external knowledge sources.

3. Technology Source (S3)

Knowledge source is fundamental to innovation/technology (Park, 2014). Technology source (S3) is influenced by number international CNC-machine suppliers and the outflow rate of adoption rate (R4). The top five (N) international CNC-machine suppliers, which include Fanuc, Siemens, Sinumerk, Mitsubishi and Takumi-CNC, are taken for the model development.

S3 = $\int(N - R4)$ **dt,** Where N- number international CNC-machine supplier

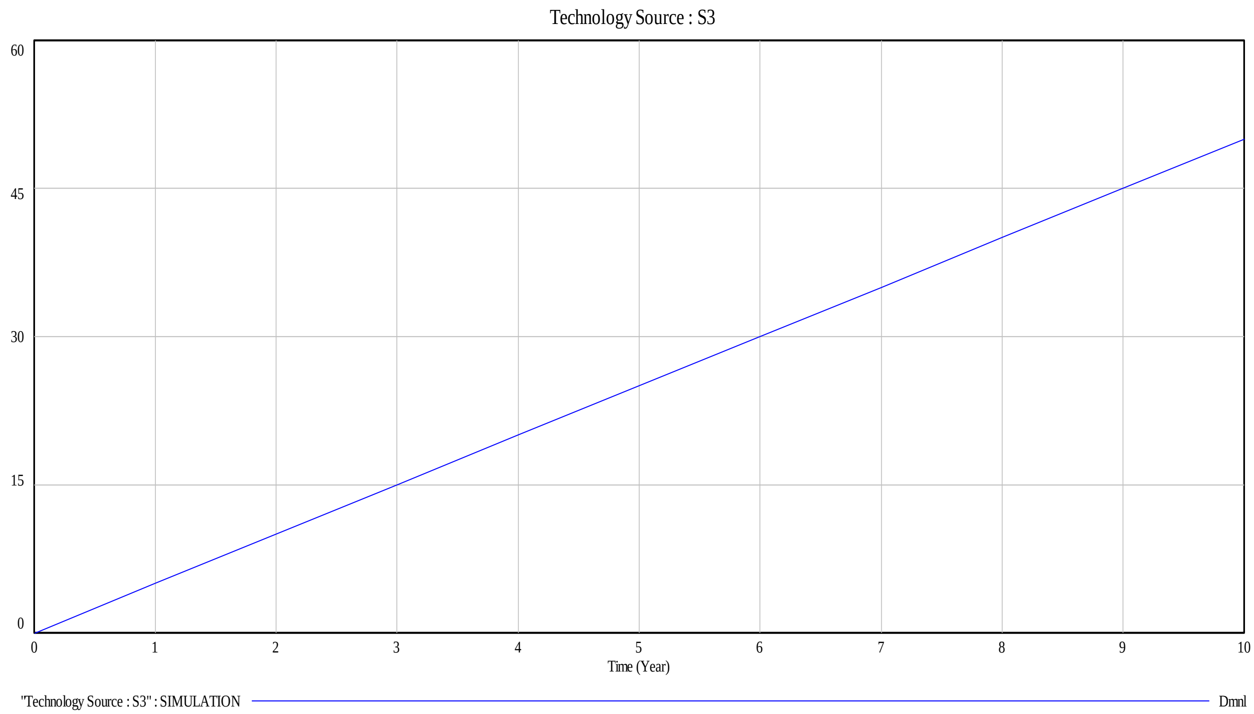


Figure-5. 6: System dynamic model graph of technology source

Technology source simulation graph shows that it is linearly increasing with increase of time.

4. Technology Adoption (S4)

The two major inter-organizational factors driving technology adoption are the need to implement a technology strategy and the increasing material cost (Lena, 2002). However, the success of technology adoption, implementation, and empowerment as a competitive advantage depends on the technology management of the organization. Technology management is related

to how the organization generates the technology internally, develops technology externally, and integrates the technology within the skilled and operational workers and other operational activities (Morone, 1989). According to Rogers, (2003) technology adoption can take into consideration of knowledge about the technology; perceive usefulness & ease of use, and decision to implement to improve technological capacity which impacts the industry productivity.

Therefore successful technology adoption significantly impacts the industry's competitive advantage. Technology Adoption (S4) is influenced by the inflow rate of knowledge perceived (R3) & technology adoption (R4) and the outflow rate of technological capacity (R5).

$$S4 = \int (R3 + R4 - R5) * A6 \, dt$$

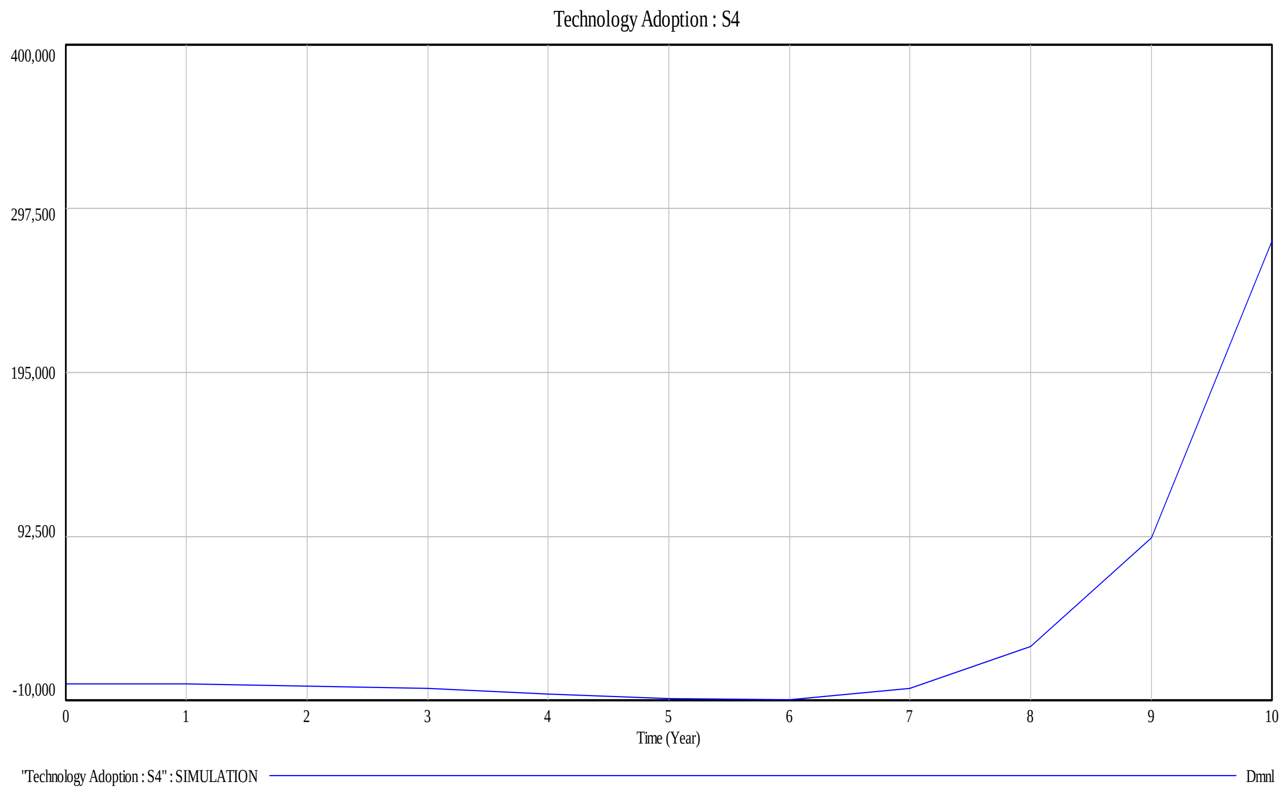


Figure-5. 7: System dynamic model of technology adoption

Organizations' successful technology adoption significantly affects their competitive advantage, especially their performance (Kotler & Keller, 2006). According to the simulation results, in the years from the start to six years technology adoption stay at a low level. As presented on the simulation graph of knowledge sources at time to six-year the industry was acquiring external knowledge. Hence the industry's potential to adopt a technology was weak. This indicates that knowledge absorption is of significant importance for technology adoption. According to Zahra and George (2002) before the exploitation of the acquired knowledge, it has to be interpreted and integrated among the group in the organization which takes time.

5. Technological Capacity (S5)

Szalavetz (2018) defines technological capacity, as the capability to change or develop products and processes more meaningfully than what routine production activities would entail. It is expressed as the capability of an organization in adopting and improving new technology. According to Nurul Afiqah Azman1, Nurazwa Ahmad (2020), technological capacity has been tested on its impact on operational functioning aspects of competitive priorities, customer satisfaction, innovativeness, strategic decisions, system efficiency, innovation performance, manufacturing or operational performance, and new product development performance.

Technological capacity can indicate the industry's competitiveness, customer satisfaction, innovation capacity, and efficiency. It is impacted by the inflow rate of technology adoption (R5) and the outflow of productivity (R6).

$$S5 = \int (R5 * R6) dt$$

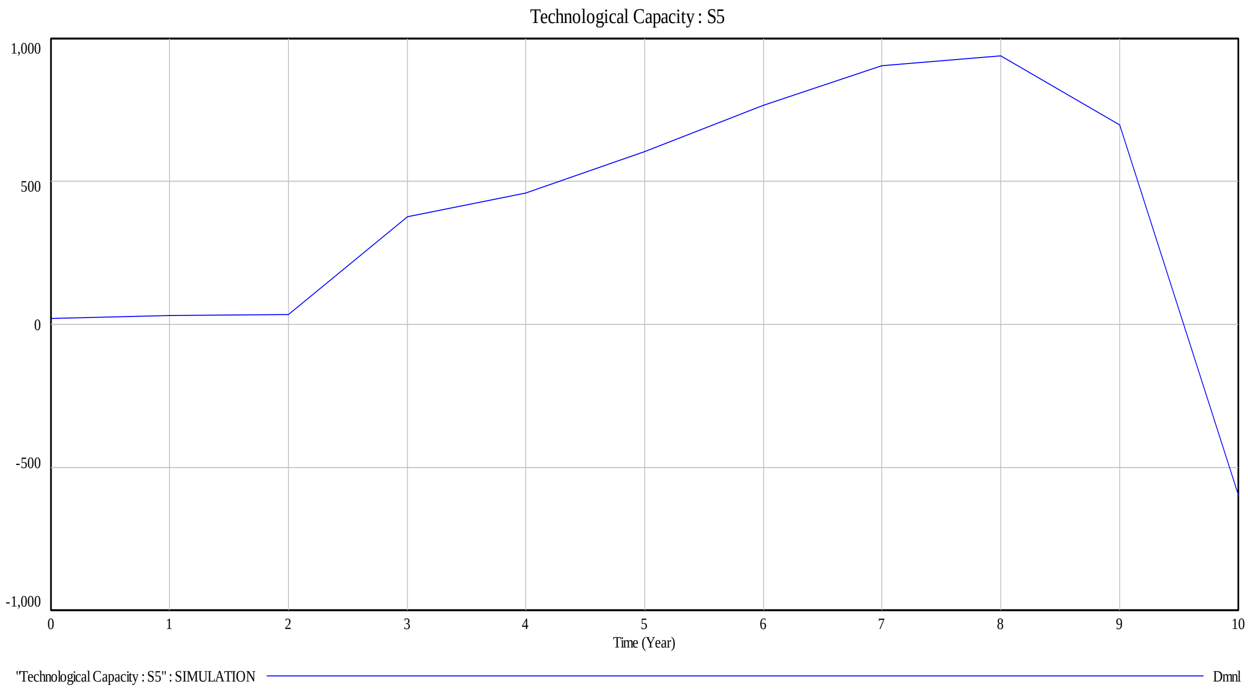


Figure-5. 8: System dynamic model graph of technology capacity

To achieve competitiveness, customer satisfaction, innovation capacity, and efficiency technological capacity are fundamental. The technological capacity simulation graph reveals at the time between the start (zero) and two years the industry's technological capacity is low because it is using obsolescence technologies/machines. However, after two years it grew rapidly and starts to decline at eight years. The knowledge source simulation graph presented that after eight-year similarly; the graph declined means that the industry did not need to acquire more external knowledge. Therefore, this will cause to decline in the technological capacity of the industry.

6. Industry Productivity

Productivity is fundamental issue on which a business firm focuses for existence and being competitive on market. Productivity is the efficiency how well a country, firms, organizations and industry convert inputs (labour, capital, and raw materials) into output (Kendrick & Creamer, 1965). It is impacted by the technological capacity, performance growth and other stock and auxiliary variables of the model.

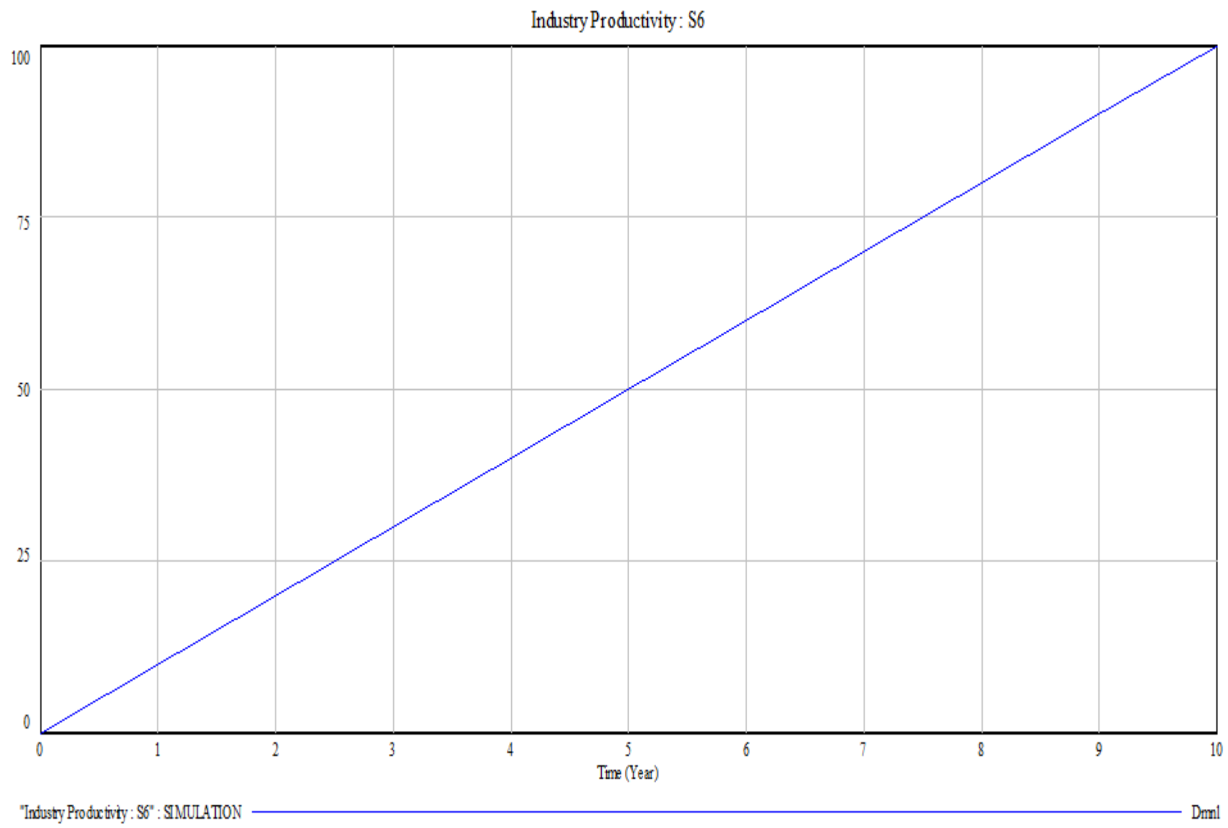


Figure-5. 9: System dynamic model graph of industry productivity

The industry productivity simulation graph shows that it is linearly increased with time. Productivity is the quality that indicates how well labor, capital, materials, and energy are utilized (Kendrick & Creamer, 1965). These and other inputs such as motivation, machines and equipment, organizational system setups, and other factors are responsible for a firm's productivity. The system dynamic model revealed influencing factor of productivity is technological capacity. The improvement in technological capacity based on knowledge absorption together with adoption significantly improves the industry productivity. Hence on the base of the result, the researcher concludes adopting CNC-technology can benefit a lot Roda machine manufacturing industry to improve productivity through efficient utilization of its resource to realize market competitiveness and sustainability.

5.4.5. Sensitivity Analysis

To test the model behaviors the researcher has conducted a sensitivity analysis of the model's variables. Sensitivity analysis is a critical tool in the evaluation of the reliability of model outputs to show confidence in the model outcomes. Decision-makers are interested in understanding the uncertainties of the models. Because only evaluating the nature of the system model cannot provide a realistic picture of the possible outcomes, since it is impossible to predict with certainty the result of each management decision. Most of the developed model variables are tested using the sensitivity analysis of Vensim. The analysis demonstrates numerical sensitivity in the sense that simulated results change in response to changes in a variety of variable values. Hence the researcher has chosen three stock variables (technology adoption, technological capacity, and industry productivity) and the two most impacting rate/flow (perceived rate and adoption rate) to analyze the change of the stock variable concerning the impact of inflow or outflow rate of technology perception and adoption. Hence the changes are measured under five scenarios of perceived rate and adoption rate values of 20%, 40%, 60%, 80%, and 100% respectively.

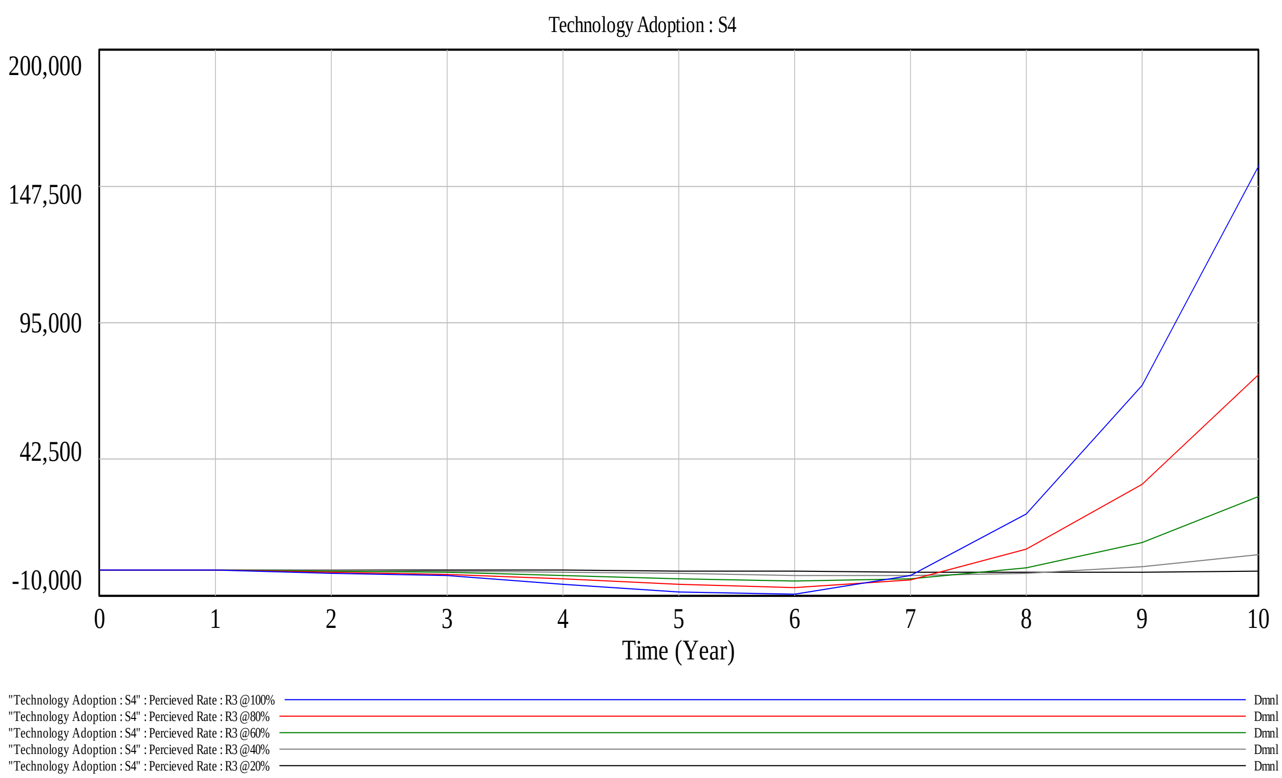


Figure-5. 10: Graph of technology adoption analysis with respect to perceived rate

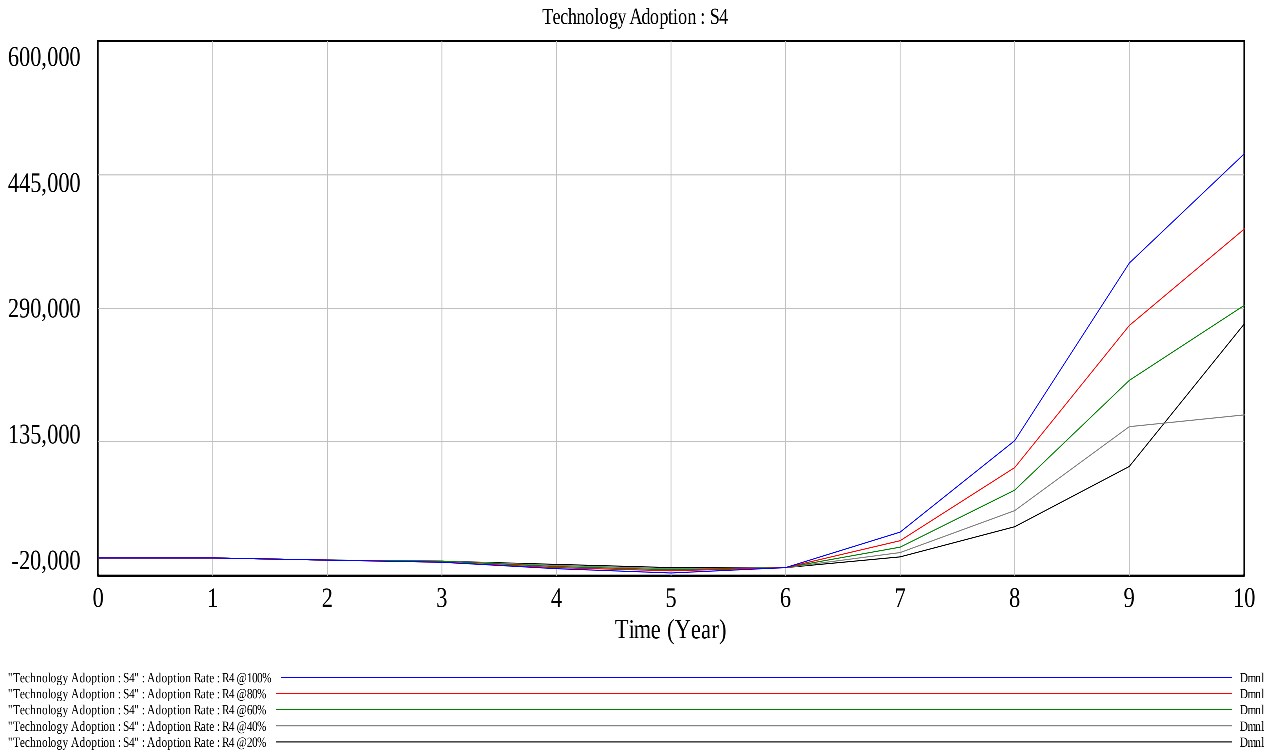


Figure-5. 11: Graph of technology adoption analysis with respect to adoption rate

Both the simulation graphs (Figure-10 and 11) of technology adoption indicate in the years from start to seven the industry's potential to adopt a technology was weak. During these periods the industry was seeking knowledge to improve the potential of technology adoption and decrease the technology gap. Therefore, knowledge absorption requires a longer time to identify, acquire, assimilate, and exploit that supports technology adoption which results in productivity improvement. Furthermore, observed from the graphs technology adoption increase with increased rates of perception and adoption.

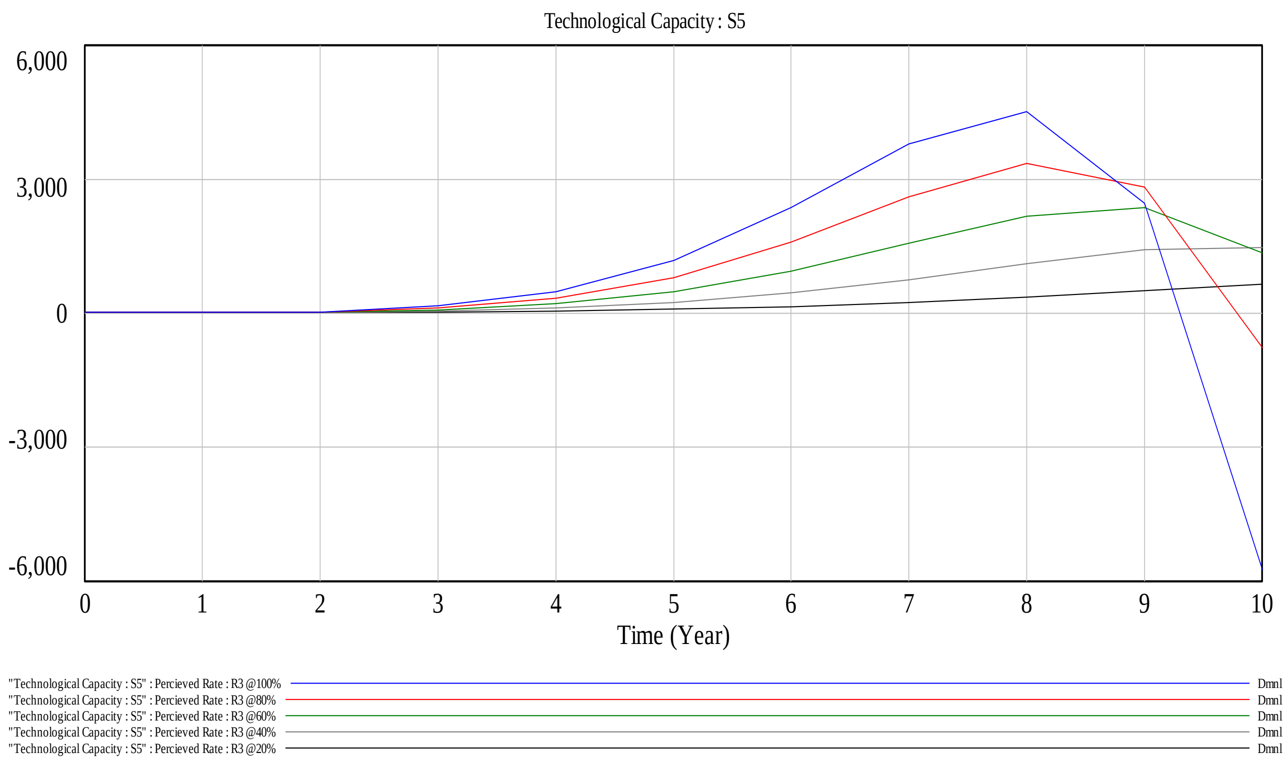


Figure-5. 12: Graph of technological capacity analysis with respect to perceived rate

Figure-6.12 represents a simulation graph of technological capacity concerning perceived rate. According to the graph, the technological capacity remains constant from the time of start (zero) to two years, which means that the perceived rate does not have an impact in this period. However, from the graphs that technology adoption increase with increased rates of perception and then tends to decrease.

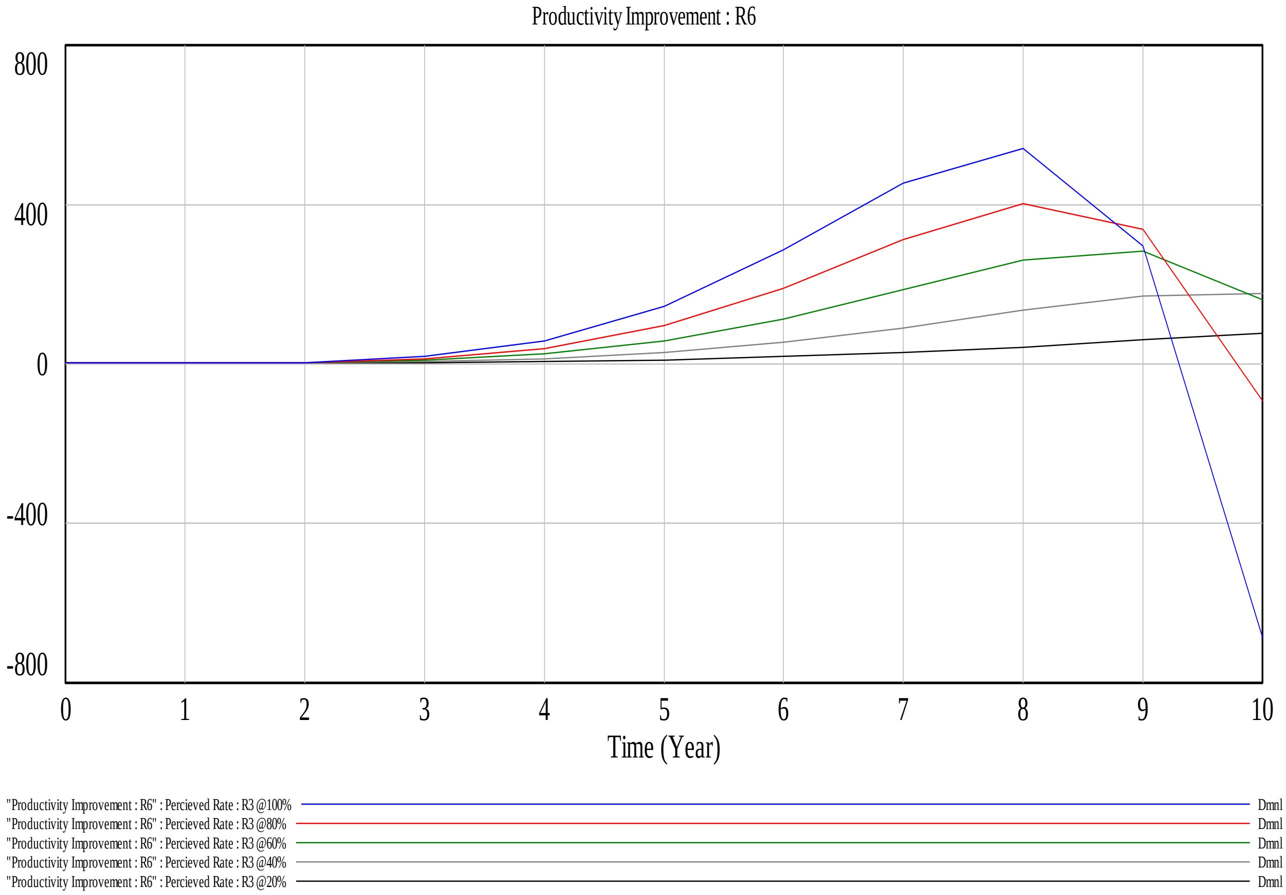


Figure-5. 13: Graph of productivity improvement analysis with respect to perceived rate

The productivity of the industry is impacted by all the variables of the model. From the simulation graph results of technological capacity (Figure-6.12) and productivity improvement (Figure-6.13) have similar Behaviours with the same value perceived rate. the finding is that with improving technological capacity the industry productivity will be improved accordingly. Therefore the industry establishes a CNC-technology knowledge source network within a short time, absorbs the knowledge, and adopts the technology that can improve the optimal utilization of capacity and the industry's productivity.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.2. Conclusion

This research comprehensively reviews impacts of CNC-technology adoption on the productivity improvement of Roda machine manufacturing industry. According to Rogers (2003), compatibility, observability, and trialability in the machine manufacturing industry increased the adoption of CNC technology. Adopting the technology enhances competitive advantages, improves product and process quality, manufacturing flexibility, optimal capacity utilization, and reduces material waste and rework, improving product and process quality which results in productivity improvement. Productivity is a fundamental issue on which a business organization focuses for existence and being competitive. To enhance productivity the production inputs like labor, materials, machines, and equipment within organizational system setups are responsible.

Roda machine manufacturing industry is functioning at lower productivity due to numerous internal and external problems. It has several problems for low productivity including raw materials, working capital, technological capability, skilled manpower, marketing, technology and innovation-related problems, product quality & high cost of production. However technological capability, the research focus area takes as prime movers.

The industry is using manual which are limited in manufacturing flexibility and obsolescence machines, which are major impacting factors for low productivity. Moreover, the industry still does not perceive the technological capacity to enable them to realize production capacity plans as well as annual revenue return. The industry continues to perceive its sources of technology are internally focused. This is due to a lack of commitment to adopt prior technology and a misunderstanding of the benefits of technological capacity for capacity utilization, productivity improvement, and gaining competitive advantages. As a result, the industry has limited manufacturing flexibility (product, production, routing & machine), and the machines are lost their precision which affects the product quality and lost research and development (R&D) culture. Therefore the industry shows;

- ✓ Decrease in capacity utilization
- ✓ Low market competitiveness
- ✓ Decrease annual production plan to 10 to 25%

- ✓ Low annual revenue plan achievement to 36,063,600 birr which is 12% of the plan on 2021.
- ✓ Reduce/hire its Engineering employees from 29 to 8 among which only 3 are at work the remaining 5 are on force leave.
- ✓ Skilled man powers are not suited and caused to leave the industry.

These identified problems will be causes and/or effects of low productivity in the industry. Therefore the problem has been addressed based on the proposed models of Roda machine manufacturing industry organizational learning, knowledge absorptive capacity, and Vensim system modeling.

6.3. Recommendation

Technology continues to be used as the basis of an enriched manufacturing industry. To be productive the improvement of technological capacity has become the norm, which has resulted in the manufacturing industry being better equipped to be competitive and deliver quality products. Therefore based on findings of the research and conclusion, following recommendations are forwarded to Roda machine manufacturing industry;

1. Productivity is the primary factor for the industry’s stay competitive in the business world and survival. Therefore, in order to ensure productivity and continue competitiveness the industry should be able to efficiently utilize and manage resources.
2. Should have a clear understanding, of measurement, analysis and improved methods of productivity.
3. Since organizational productivity is achieved with establishing programs of research and development (R&D) that connect research with business. It can develop a culture of participation and involvement of employees to create innovative ideas and technology adoption.
4. The industry still does not perceive the technological capacity to enable it to realize the production capacity plan, as well as annual revenue return and sources of technology, are internally focused. However, the industry should adopt CNC technology to have manufacturing flexibility (product, production, routing & machine), improve capacity utilization, reduce material waste and rework, improve product and process quality, improve productivity then enhance competitive advantage.

5. Since the machine manufacturing industry requires a high level of technical and engineering knowledge and skill, the industry should effectively use its employee's skills and knowledge to develop knowledge. Should recognize best performers for their outstanding contributions.
6. Finally, the government should give prior attention and provide support to realize its industrialization plan regarding CNC technology and/or other technology adoption, capacity building in order to alleviate low productivity to ensure competitiveness.

6.4. Contribution of the Research

6.4.1. Contribution for Practice

The contribution of the research is that it enables Roda machine manufacturing industry's management to apply optimal work designing, planning, work procedures, and production systems in line with CNC-technology adoption to ensure productivity improvement. As was demonstrated in the developed models of organizational learning, knowledge absorption capacity and CNC-technology adoption stock and flow diagram are good ways of adopting technology to improve productivity and competitiveness. For machine manufacturing industries regarding the model as a whole gives substance to the execution of the testing and validation of their technological capacity and guides to improve their current practices toward productivity as well as the competitiveness.

6.4.2. Contribution for Science

An important motive for this research was the low technological capacity of Roda machine manufacturing industry. It is one of the largest machine manufacturing industries in Ethiopia. But it is equipped with obsolescent conventional machine tools which are limited in productivity, product quality, and flexibility (product, production, and machine) and are the major challenges to utilizing production capacity and competitiveness.

During the research study, much literature has been reviewed on the fields of the study, it was hard to find relevant information on the impact of the CNC-technology machine manufacturing industry and the adoption model of CNC technology in the literature. Although the absence of a commonly used CNC-technology adoption model complicated to execute the adoption, it was underline the relevance of this research.

Models were eventually developed by combining the steps of Rogers (2003) with literature on the innovation adoption process relevant to the knowledge absorption capacity (Zahra & George,

2002) and CNC-technology adoption (Zou et al., 2016) and literature on guidelines to organize CNC-technology adoption. Such models did not exist yet in the literature and can therefore be a great help for organizations that are experiencing problems with the adoption of innovation.

Generally, concluded that the research study contributes to filling a gap in the literature by establishing a theoretical model of CNC technology impact on the machine manufacturing industry and adoption model of the CNC-technology model to provide insight into how a theoretical model can be adjusted to fit and improve the innovation/new technology adoption practice of an organization.

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Annex-1: CNC-Machine major specification and unit price

Name of Machine	Specifications	Quantity	Unit	Price (USD)
TOOL ROOM TYPE CNC LATHE MACHINE	**Major Specifications** Swing Over Front Apron: 300 mm. Swing Over Cross Slide: 450 mm. Chuck size: 203 mm. Max Cutting Diameter: 406mm. Max Cutting Length (without work holding): 762 mm. X Axis travel: 203 mm. Z Axis travel: 762 mm. Max Rating of spindle: 7.5 Kw. Max Speed: 1800 rpm. Spindle nose: A2-6. Spindle bore: 76.2 mm.	01	No	18400
LATHE MACHINE (CONVIENTIONAL)	**Major Specifications:** Height of centres : 250 mm or more Swing over bed: 420mm or more Swing over cross slide : 260 mm or more Swing in gap: 620 mm or more Distance between centres: 1000 mm or more Spindle Nose/ Bore: MT5 / 50 mm Spindle Speed range: 8 Steps from 32-1220 forward or better 7 Steps from 45-1150 reverse	01	No	15845

TOOL ROOM TYPE CNC MILLING MACHINE: (SMALL)	<u>Major Technical Specifications</u> Table Size : 900x600 mm or more Axis traverses: X-Axis - 700 mm or more Y-Axis - 500 mm or more Z-Axis - 500 mm or more Load on table: 1500 Kg or more Variable spindle speed: 100-18000 rpm or higher (with ICS internal cooling system) Spindle Power: 11 Kw Rapid Traverse (X/Y/Z): 30 M/Min or more Positioning accuracy: 0.010 mm or better Repeatability: 0.005 mm or better Tool shank type: HSK 63A CNC Controller: latest version of Heidenhain with all types of standard cycles and 3D graphics simulation.	01	N0	20700

Milling Machine (CONVIENTIONAL)	Table size (Effective): 360x1320 mm or higher T-slots (Size:WxD)/ Numbers 16 x 65 mm / 03 Travel for XYZ: 1000 x300x400 mm TO BE SPECIFIED BY THE SUPPLIER Spindle speed (RPM):66-4500 RPM Quill travel: 127 mm Ram travel: 560 mm or more Quill feed (mm/rpm): 0.04 mm ~ 0.08 mm ~ 0.14 mm Head swivel (R & L): ± 45° Head tilt (up & down): ± 45°	01	No	18516

Annex-2: CNC-technology adoption Vensim model Rate and Auxiliary Variables_mathematical formula

1. Technology Adoption: S4"= INTEG (("perceived Rate : R3"+"Adoption Rate : R4"-"Capacity Growth Rate : R5")*"Innovation and R&D : A6",
2. Technological Capacity: S5"= INTEG ("Capacity Growth Rate: R5"*"Productivity Improvement: R6",
3. Absorptive Capacity= "Experience: A9"*"Potential Absorptive Capacity: A3"
4. Knowledge Storage = "Knowledge Creation: A5"+"Potential Absorptive Capacity: A3"
5. New Product Development: A11"= "Innovation and R&D: A6"
6. Adoption Rate: R4 = 1
7. Capacity Growth Rate: R5 = ("Technological Capacity: S5"-"Technology Adoption: S4")/"Technological Capacity: S5"
8. Capacity Utilization: A 13"= 0.12
9. Experience: A9"= 0.1
10. External Knowledge Level: A16"= 100
11. Perceived Rate: R3 = 100
12. External Knowledge Network: R1"= "Organizations Knowledge Difference: A1"*"Technology Gap: A18"*"Trust Level: A2"
13. Potential Absorptive Capacity: A3 = "Experience: A9"*"Knowledge Diversity: A8"*"Knowledge Storage: S2"
14. Industry Productivity: S6"= INTEG (+"Productivity Improvement: R6", 0)
15. Innovation and R&D: A6"= "Knowledge Storage: S2"*"Capacity Utilization: A 13"
16. Knowledge Absorption: R2"= ("Knowledge Source: S1"/"Knowledge Storage: S2")*"Potential Absorptive Capacity: A3"
17. Knowledge Creation: A5"= "Knowledge Storage: S2"*"R&D Investment: A10"
18. Knowledge Diversity: A8"= 1, [1, 10, 1]
19. Knowledge Gap: A4"= "External Knowledge Level: A16"-"Knowledge Storage: S2"
20. Knowledge Source: S1"= INTEG (+"External Knowledge Network: R1"-"Knowledge Absorption: R2", 0)
21. Knowledge Storage: S2"= INTEG ("Knowledge Absorption: R2"-"Percieved Rate: R3",1)

22. Marketing Effectiveness: A12"= "Innovation and R&D: A6"*"New Product Development: A11"*"Performance Growth: A20"
23. Trust Level: A2"= 0.1 [0.1, 1, 0.1]
24. Organizations Knowledge Difference: A1"= 10 [10, 100, 10]
25. Technology Gap: A18"= "Technology Source: S3"-("Technological Capacity: S5"+"Technology Adoption: S4)
26. Performance Growth: A20"= "Technological Capacity: S5"*"Capacity Utilization: A 13"
27. Technology Outdated: A19"= "Technology Gap: A18"-"Technology Adoption: S4"
28. Productivity Improvement: R6"= 10 Dmnl [10, 100, 10]
29. R&D Investment: A10"= (1/100)*3.0053e+008 Dmnl [0, 10, 1]
30. Technology Source: S3"= INTEG (5-"Adoption Rate: R4",0)
31. Technology Investment: A15"= (1/5)*3.0053e+008

Annex-3: Research questionnaire

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

QUESTIONNAIRE

I am a student of Addis Ababa University Institute of Technology school of Mechanical and Industrial engineering. Currently I am conducting a research for the fulfillment of MSc degree. The title of the research is “Investigate impact of CNC-technology adoption on productivity of Ethiopian Machine Manufacturing” in the case of Industries “Case of Roda Machine Manufacturing Industry. The main objective of the questionnaire is to assess impact of CNC-technology adoption and the key influencing factors of adoption in Ethiopian machine manufacturing industries to improve productivity. Therefore, your response to the questions is vital to the success of the study, what more the quality is and quantity of information you provide determines the ultimate reliability of the research thus I sincerely request you to fill the questionnaire carefully. All information will be used only for this research and treated in the highest confidentiality. For further information you can contact me through the addresses mentioned below.

Thank you in advance for your cooperation!!!

Kind regards,

ENDESHAW SHANKO:

Mobile: - +251946715262

E-mail:- endesh22696@gmail.com

Part-I: Respondents' profile Data

Please place [X] on appropriate box.

i. Gender: Male [ ] Female [ ]

ii. Age (year): 21-30 [ ] 31-40 [ ] 41-50 [ ] ı1-60 [ ] ɔove 61 [ ]

iii. Qualification level: Below level-1 [ ] level 1 to 4 [ ] Diploma [ ]

BSc/BA [ ] MSc/MA [ ] PhD [ ]

iv. Occupation: Machinist [ ] Production supervisor [ ] Quality Control [ ]

Engineer [ ] Manager/head [ ]

v. Your experience in this company: Below 1yr [ ] 1-2yrs. [ ] 2-5yrs. [ ]

5-10yrs. [ ] Above 10yrs. [ ]

vi. Ownership: Public [ ] Private [ ]

vii. Business owner: Local [ ] Venture [ ] Foreigner [ ]

Part-II: Understanding of Productivity in the Firm and the factor affecting Productivity

Please place an "X" in the appropriate box to rate the following items using Scales of 1-5

1= strongly disagree 2 = Disagree 3 = Indifferent 4 = Agree 5= Strongly Agree

S.No	Understanding of Productivity in the Firm	1	2	3	4	5
1	Improve capacity utilization					
2	High production volume					
3	Increased customer satisfaction					
4	Reduce material waste and rework					
5	Good quality					
6	High profit					
	Factor impacting Productivity					
7	Technological capability					
8	Skilled man power					
9	Availability of resources					
10	Proper utilization of raw materials					
11	Innovation and Research & Development					

Part-III: Factors influencing CNC-Technology Adoption of the company

Please place an "X" in the appropriate box to rate the following items regarding "factors affecting CNC-technology adoption", using Scales of 1-5

1= strongly disagree 2 = Disagree 3 = Indifferent 4 = Agree 5= Strongly Agree

S.No	A. Factors impacting CNC-Technology adoption	1	2	3	4	5
1	To improve productivity					
2	To improve product and process quality					
3	Enhance competitive advantage					
4	Product flexibility: To produce new (set of) products very economically and quickly.					
5	Routing flexibility: To handle break-downs and to continue					

	producing a given set of part types.					
6	Production flexibility: The universe of part types that the manufacturing system can produce.					
7	Machine flexibility: The ease of making changes required to produce a given set of part types.					
8	To meet customer demand					
9	New product development.					
10	To extend the market.					
11	Cost reduction and profit maximizing					
12	Competitive price and survivals					
13	To implement technology strategy					
14	Increasing material cost					
	B. External influencing factors of CNC-Technology adoption					
15	Global market competition					
16	Customer demand for quality					
17	Change in economic condition					
18	Competition in local market					

Organization technology management mainly focuses on three key areas surrounding business (1) customers- identify which existing technologies to satisfy the most important requests of potential customers. (2) Competitors- to know which technologies competitors are using and how these support their respective competitive advantages. (3) Technological evolution- gathers and analyzes information on available technologies that can be incorporated in the processes, products or services to promote competitive advantages. Therefore success of technology adoption, implementation and empowerment as competitive advantage depends on the technology management of the organization.

Part-IV: CNC-Technology Perceived usefulness and Perceived ease of use

Please place an “X” in the appropriate box to rate the following items regarding “Perceived usefulness”, using Scales of 1-5

1= strongly disagree 2 = Disagree 3 = Indifferent 4 = Agree 5= Strongly Agree

S.No	**A. CNC-Technology Perceived usefulness**	**1**	**2**	**3**	**4**	**5**
1	Enables continual improvement of productivity					
2	Improve quality of products					
3	Product flexibility: To produce new products very economically and quickly					
4	Increase efficiency of resource utilization					
5	Improve innovation and Research & Development					
	B. CNC-Technology Perceived ease of use					
6	The interaction with CNC-Technology is clear and understandable.					
7	Learning to operate and use CNC-Technology is easy					
8	I would find it easy to use CNC-Technology to make an adoption decision					
9	Find it easy to get the technology to do what I want it to do					

Annex-4: Research interview questions

ADDIS ABABA UNIVERSITY, INSTITUTE OF TECHNOLOGY SCHOOL OF MECHANICAL & INDUSTRIAL ENGINEERING GRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

Thesis Title: "Investigate the impact of CNC-technology adoption on productivity of Roda Machine Manufacturing Industry

INTERVIEW QUESTIONS

Prepared by: ENDESHAW SHANKO [+251-946715262, E-mail: endesh22696@gmail.com]

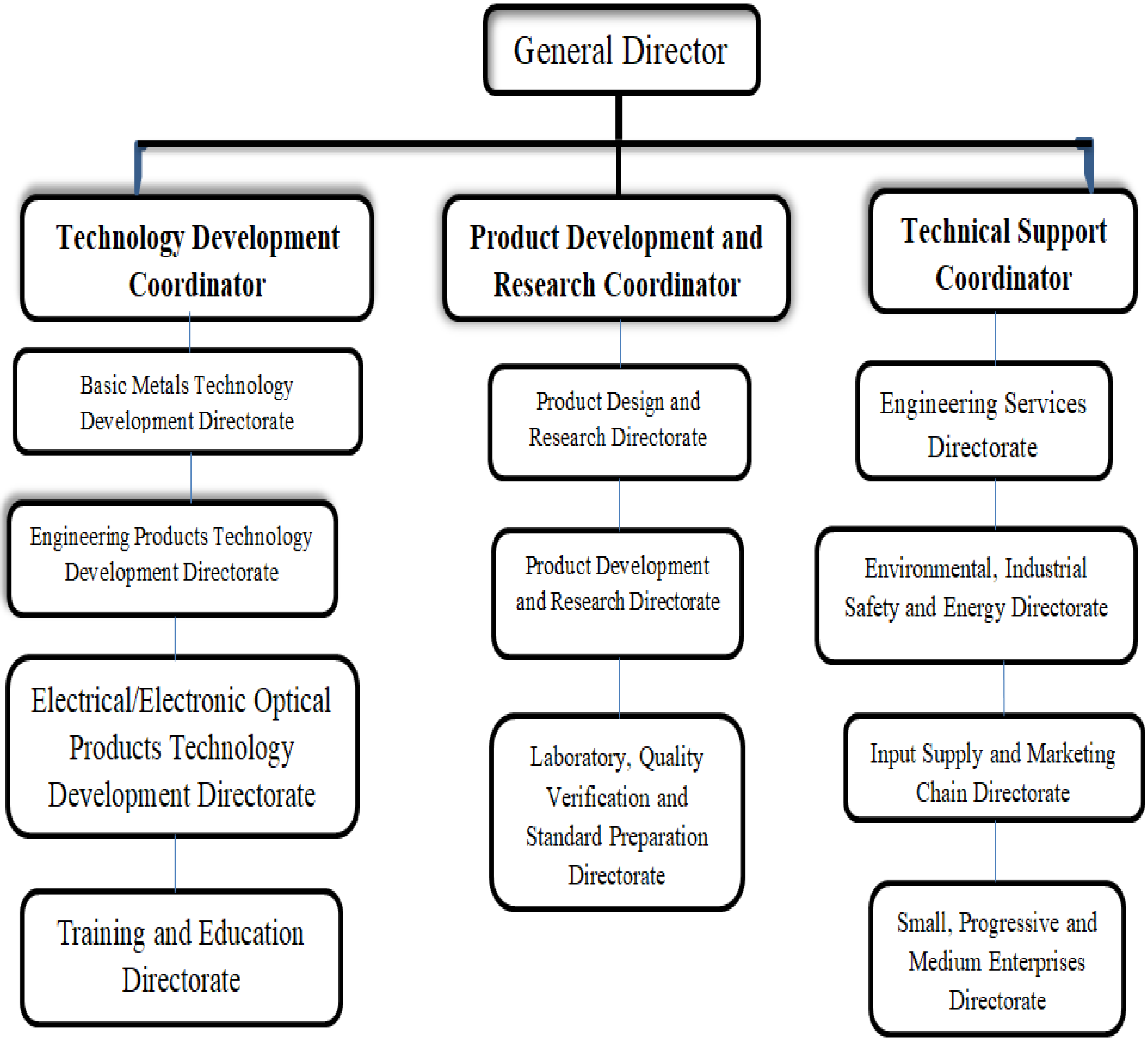
Interview Date: ______________________ Time: ____________________

Name: ____________________ Sex______ Position______________________

Qualification _________________ Experience ___________

1. Industry production capacity, capacity utilization and future expansion plan (when)?
2. What are the major problems responsible for the company low capacity utilization status?
3. How do you define, measure and analyze productivity of the firm?
4. What factor is the most influencing for your company's productivity (labour, capital, Technology, energy or other)?
5. What is the existing status of technology adoption to substitute importing semi-finished and finished product?
6. Which existing technologies need adoption of CNC-technology to improve productivity, competitiveness and product quality?
7. What are the major technology adoption activities so far in your company?
8. What kinds of supports do your company needs from the Government to adopt CNC-Technology to improve productivity?

Annex-5: Metals Industry Development Institute Organizational Chart



Annex-6: Summary of Literature Review Analysis, evaluation of works and identified gaps

S.No	Author/s	Title of Reference	Country, Sector & Year of publication	Aim of the study	Methodology or tools used	Result/Conclusion	The researcher's reflection of research gap
1	Solomon Asfaw, Bekele Shiferaw, Franklin Simtowe and Messia Hagos	Agricultural technology adoption, seed access constraints and commercialization in Ethiopia	Ethiopia, Agricultural Economics (2011)	To examines the driving forces behind farmers' decisions to adopt agricultural technologies and the causal impact of adoption on farmers' integration into output market using data obtained from a random cross-section sample of 700 farmers in Ethiopia.	Double-Hurdle model , treatment effect and propensity score methods	Findings from the research show that knowledge of existing varieties, perception about the attributes of improved varieties, household wealth (livestock and land) and availability of active labor force are major determinants for adoption of improved technologies. And concluded that adoption of	• From the five Rogers innovation-decision process, knowledge and perception are identified as adoption determinant, however they are not explicitly addressed • There are adopters, their adopter category, innovation decision (optional, collective or authority) and Innovation -Decision Process were not addressed

						improved agricultural technologies has a significant positive impact on farmers' integration into output market	• Sample size is not clearly defined.
2	Mamudu A, Emelia, G. & Samuel, K.	Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions?	Ghana, Agricultural Economics and Extension (2012)	Examine the factors that influence farm households' modern agricultural production technology adoption decisions in Ghana.	Logit model	The results showed that farm size, expected benefits from technology adoption, access to credit and extension services are the factors that significantly influence technology adoption decisions of farm households in the study area. And It was concluded that farm	It doesn't identify which technologies are going to be adopted the knowledge of society on innovation-decision process and who is most responsible, Institution or organisation. In addition not quantifies the effects of the influencing factors

						households' agricultural technology adoption decisions depends on their socio-economic circumstances and institutional effectiveness.	
3	Gezahegn A., Mohammad A. and Elias Z.	Diffusion and Adoption of Vertisols Technology Package in Highland Ethiopia	Ethiopia, Agricultural Economics 2001	Understand the process of generation, diffusion and adoption of technology, the possible pathways for adoption of a new technology, and in the specific case of BBM, the factors that may influence adoption	The data analyzed quantitatively by using frequency table	Technology adoption is not a one-off static decision rather it involves a dynamic process.	Perceived Attributes of the Innovation to the intended user is not addressed

				behaviour of potential adopters.			
4	Assefa A. and Gezahegn A.	Adoption of improved technology in Ethiopia	**Ethiopia,** Agricultural Economics 2009	To identify the factors, which exert significant influence on the adoption behaviour of farmers and the intensity of adoption from a nation survey	Logit and Probit models	The result shows that younger farmers, famers with larger land size, farmer living closer to market, and farmers who had closer contact with the extension system are more likely to adopt new technology and use it more.	It doesn't address the extent of these factors influence on adoption of technology. In addition not quantifies the effects of the influencing factors
5	Azmawani A. and David	Advanced Manufacturin g Technology Adoption in Developing Countries: The Role of	Malaysia, Manufacturin g technology, 2009	To describe the important role of buyer-supplier relationships (BSR) in the process of technology	structured equation modeling (SEM)	The majority of the firms reported improvements in their performance since the acquisition of advanced manufacturing	Not addressed firms Perceived Attributes of the Innovation, Innovation -Decision Process somewhat opportunities during the feed-back sessions

		Buyer-Supplier Relationships		selection, acquisition and implementation.		technology, closer investigation revealed that closer relationship with their suppliers are more likely to achieved higher levels of technology and implementation performance than those that do not.	at the end user.
6	Hyuk Chung	Adoption and Development of the Fourth Industrial Revolution Technology	Korea, Technology Development 2021	To examines determinants and propensity for adopting and developing the Fourth Industrial Revolution technology.	Probit model	In the manufacturing sector, internal R&D intensity, patent and trademark rights are positively associated with the propensity for adopting and developing technology	It doesn't address the extent of these factors influence on adopter. In addition it doesn't indicate Social system as well as Innovation - Decision Process
7	Nicholas Ross, Paulo	Risk, Ambiguity	Sydney, Agricultural	Investigate the role of ambiguity-	Self-specified/deve	Ambiguity-aversion, but not risk-	It doesn't indicate the impact of knowledge

	Santos and Tim Capon	and the Adoption of New Technologies	Economics 2010	aversion on adoption of new technologies.	loped linear (y=ax+b) model	aversion, significantly reduces both the probability and intensity of adoption.	or learning on adoption decisions.
8	Sanjaya Lall	National strategies for technology adoption in the industrial sector: Lessons of recent experience in the developing regions	England, biotechnology and information/communication technology 2001	Analyse the uneven spread of new technologies in the developing world, in terms of the success of different countries in using their potential to build viable and dynamic industrial sectors.	The data analyzed quantitatively by using frequency table and pie-Chart	The new technological paradigm affects all developing countries. It forces all productive activities to cope with emerging technologies, since they all have to compete by using new technologies in some form.	Technology adoption decision-process was investigated only against knowledge/learning, while other stages are not addressed.
9	Yohanes Kristianto, Mian Ajmal, Richard	A study of technology adoption in manufacturing	Finland, manufacturing technology, 2011	To study the effect of technology adoption on operational	The data analyzed quantitatively by using	The leadership role is a significant factor to motivate strategic flexibility and	The researcher shows the technology adoption factors (quality, cost, time and

	Addo Tenkorang and Matloub Hussain	firms		competitiveness by taking an example from international manufacturing companies	frequency table	generate higher benefit.	flexibility) affecting manufacturing companies competitiveness. But doesn't connect the finding/research result with the title
10	Won-Sik Hw ang and Ho-Sung Ki m	Does the adoption of emerging technologies improve technical efficiency? Evidence from Korean manufacturing SMEs	Korea, manufacturing technology, 2021	To examines the impact of employing core technologies of the 4-Industrial revolution (IR) on small and medium enterprises (SMEs).	analyzed quantitatively by using frequency table and pie-Chart	Adopting emerging technologies enhances SMEs' productivity	It doesn't clearly address the enhancement methods (resource utilization, quality improvement, cost minimization or other). Generalized that manufacturing SMEs can decide to make use of new technologies in their production process without any justification about knowledge and

							innovation-decision process
11	Miss Fatima and Mohammed Ziaul	Impact of Technology Adoption on Agricultural Productivity	Bangladesh, Agricultural Economics 2016	To examines the impact of technology adoption on agricultural productivity.	analyzed quantitatively by using frequency table and pie-Chart	Farmers are adopting high level of technology in seed variety and medium level of technology in land and low level of technology in weed control and harvesting	Not indicated that impacting factors of either high level or low adoption of technology.
12	Tigist Mekonnen (PhD)	Productivity and household welfare impact of technology adoption	Ethiopia, Agricultural Economics 2017	To evaluates the potential impact of improved agricultural technologies on smallholders' crop productivity and welfare.	analyzed quantitatively by using frequency table and pie-Chart	Result shows that modern agricultural technology adoption positively contributes to small holder's crop productivity and welfare of rural households in Ethiopia.	Researchers identified that adoption decision influencing factors but not justify the most and least factors to viewpoint of managing new technology.

13	Margaret Mwangi and Samuel Kariuki	Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries	Kenya, Agricultural Economics 2015	Shedding some light on the potential factors that influence agricultural technology adoption in developing countries	Quantitative description	Technological, economic, institutional factors and human specific factors are determinants of agricultural technology adoption.	It doesn't indicate the impact of knowledge or learning on adoption decisions
14	Hui Li, Diejun Huang , Qiuzhuo Ma, Wene Qi and Hua Li	Factors Influencing the Technology Adoption Behaviours of Litchi Farmers in China	China, farm technology 2019	To provide knowledge on the adoption of litchi top grafting by litchi farmers through identifying the internal and external factors that influence the uptake.	analyzed quantitatively by using frequency table and A logit analysis	The results of the study can help policy makers understand potential drivers of and barriers to the adoption of top grafting by litchi farmers.	Identified positively and negatively affecting factors. But not categorized the factors least and most influencing for prior action for continuous improvement.

15	Ketut Kariyasa and Yovita Anggita Dewi	Analysis of factors affecting adoption of integrated crop management farmer field school (ICM-FFS) in swampy areas	Indonesia, Agricultural Technology 2012	Analyzing factors influencing the adoption of integrated crop management farmer field school (ICM-FFS) at swampy lands	logistic regression model	The continuously effort to improve rice productivity should be taken into account as the priority to encourage more farmers to adopt ICM-FFS program.	Analyses adopters demographic as influencing affect, but not addressed adopter perception and knowledge /learning.