Chapter 1 - Technology Management

Course Contents: Introduction to Technology Management, TM activities and tools, The TM frame-work, TM activities behind technological capabilities, TM tools, Cases illustrating different TM system configurations.

Contents

Introduction

In the past, the value of a company was assessed largely on the basis of its capital and physical assets such as land, buildings, equipment, and inventory. Today, the real value of a company is much more than the value of its physical assets or its revenue. Technology adds value to the assets of a company.

The role of technology in fostering economic growth of nations and enhancing their industrial competitiveness has been widely recognized, through its domineering influence over industrial productivity. Further, technology has emerged as the most important resource that contributes directly to socio-economic development. Hence, technology is viewed from various perspectives: as an 'engine for economic development', as a 'strategic resource', and as a 'competitive weapon'.

Technological development is becoming very important to all firms competing in global highly competitive environment. The increasing of customer needs, demand, and expectations and with the accelerated rates of technological change and development, business owners are becoming more conscious of the strategic importance of technology in delivering value to their companies and networks in which they operate. However, adopting new technologies should be aligned with organization's vision and strategic goals, and it should support the company's sustainable development and enhance its performance.

The word 'technology' has a wider connotation and refers to the collection of production possibilities, techniques, methods and processes by which resources are actually transformed by humans to meet their wants. For example, Ferré (1988) has defined technology as "practical implementations of intelligence". However, Gendron (1977) has provided a more comprehensive definition: "A technology is any systematized practical knowledge, based on experimentation and/or scientific theory, which is embodied in productive skills, organization, or machinery". Technology can also mean skills to apply proper techniques (Hakkarainen, 2006) or practical application of knowledge (Webster 2010). 'Technology' is also defined by (Steele, 1989) as 'knowledge of how to do things', or 'capabilities that an enterprise needs in order to provide its customers with the goods and services it proposes to offer, both now and in the future'. (Burgelman, 2001) defines technology as "technology refers to theoretical and practical knowledge, skills and artifacts that can be used to develop products and services as well their production and delivery systems. (Floyd 1997; Steele 1989;Whipp 1991) describe the technology as applied knowledge focusing on the "know-how" of the organization. In many different bodies, one can recognize technology such as equipment, human resources, raw materials, as well as cognitive and physical processes.

Just to conclude, we can say that technology can be defined as all the knowledge, products, processes, tools, methods and systems employed in the creation of goods or in providing services. It is common to think of technology in terms of hardware, such as machines computers, or highly advanced electronic gadgets. However, technology embraces a lot more than just machines. It has three interdependent and equally important components.

1. **Hardware:** The physical configuration and logical design of the equipment or machinery, which is tangible, that is to be used to carry out the required task.
2. **Software:** The knowledge which is intangible used for the functioning of hardware in order to carry out the required tasks.
3. **Brain ware:** Analyzing the functionality of the technology with causality.
4. **Know-how:** Knowledge of how to do things or tasks effectively which is a result of experience or by technology transfer.

Classification of Technology

New technology: A technology which is newly introduced which can have its influence on the products of an organization.

Emerging Technology: A technology that is not yet fully commercialized, but has the potential to become so within about five years. It usually has high levels of research expenditure

Low technology: the technologies that have permeated large segments of human society. Low technologies are utilized by a wide variety of industries having the following characteristics:

- They employ people with relatively low levels of education or skill.
- They use manual or semiautomatic operations.
- They have low levels of research expenditure.
- The technology base is stable with little change.
- The products produced are mostly of the type that satisfies basic human needs such as food, shelter, clothing and basic human services.

Medium technology: the term medium technology comprises a wide set of technologies that fall between high and low technologies.

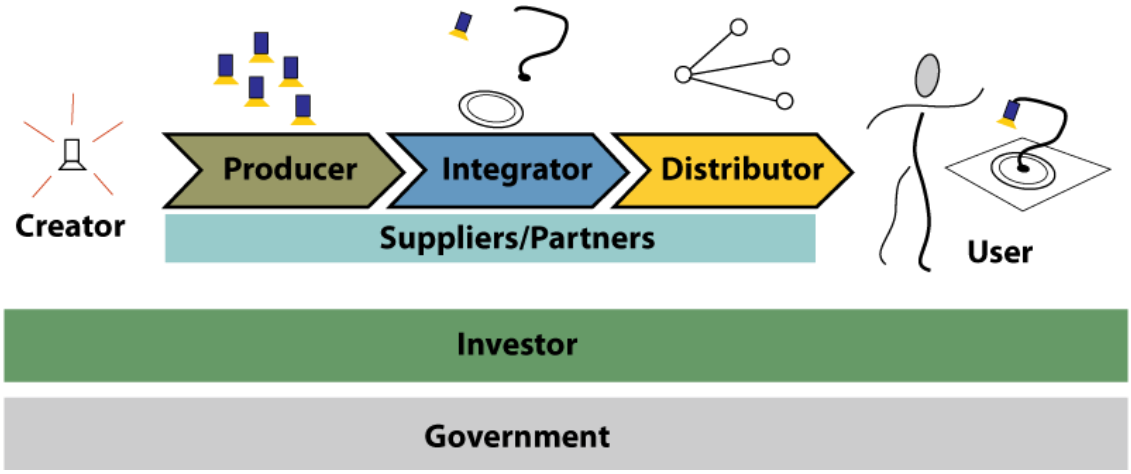
Appropriate Technology: The term appropriate technology is used to indicate a good match between the technology utilized and resources required for its optimal use.

Tacit technology: Tacit technology is non-articulated knowledge. There is no uniformity in the way it is presented or expressed to a large group of people. It is

usually based on experience and therefore remains within the minds of developers. The technology developers are the ones who have the know-how in question.

Codified technology: Codified technology, on the other hand, allows people to know how technology works but not necessarily why it works in a certain way. The brain ware may be part of the tacit knowledge kept in minds of developers and shaped by their experiences during the development process.

Roles Relative to Technology



Technological Change

Technological change has been broadly defined as: "the process by which economies change over time in respect of the products and services they produce and the processes used to produce them". More specifically, it has been termed as: "Alteration in physical processes, materials, machinery or equipment, which has impact on the way work is performed or on the efficiency or effectiveness of the enterprise". Technological change may involve a change in the output, raw materials, work organization or management techniques - but in all cases it affects the relationship between labor, capital and other factors of production. While the policies to stimulate technological progress and productivity growth - at both national and firm levels - must be formulated in a broad socio-economic context, their focus ought to be on the internal dynamics of technological change. It has been suggested that the knowledge pertaining to technological change in the less developed countries would be a crucial input to the understanding of the phenomenon in industrialized nations.

Measurement of Technological Change

Measurement of technological change depends on various factors. Two of the most important factors are:

1. **Economic Indices:** Arithmetic indices are derived based on price variations in capital and labor in relation to the industrial output. Technological change is measured as the weighted average of the change in factor prices, holding inputs constant. Solow derived a geometric index based on the premise that technological change is equal to the change in output not accounted for by the changes in labor and capital.
2. **Patents:** Patent statistics have been used as indicators of technological change. They have also been used to analyze the diffusion of technology across firms or industries or countries. Patent studies are also concerned with the analysis of the innovation process itself in order to assess and evaluate the output of research activity.

Rate of Improvement of Technology

A figure of merit for each functional capability of a technology is to be identified. For a product it could be travel speed per unit time (transport vehicles), or lumens per watt (lighting fixtures), or instruction execution rate per second (computers). For a process, it could be the efficiency of fuel utilization or reduction in waste generation. S-shaped growth curves are formulated to form a system of curves depicting advancement of technologies.

Rate of Substitution of Technology

It is determined on the basis of relative changes in the market shares of two technologies or two sets of technologies. Cumulative pattern of gain in market share by a technology exhibits S-shaped growth.

Rate of Diffusion of Technology

It represents the cumulative number of adopters of a new product, material or process. This follows an S-shaped curve.

Technological Change Theories

In literature various theories related to technological change have been introduced. Some of them are summeriezed in the following paragraphs (Saren, 1991; Sharif, 1986; Stoneman, 1983; Saviotti, 1985).

Neo-Classical Theory

The basic tool for the study of technological change is the notion of a production function which specifies a quantitative relation between inputs and outputs. The most common inputs are capital and labor, which are called factors of production. The production function can be represented as a series of isoquants - curves corresponding to the constant output obtainable by the infinite number of available

combinations of the factors of production. At any given time there is a given level of technology which determines the techniques available for production.

According to this theory technological change takes place in the form of shifts of the production function towards the origin.

Some of the major limitations of neo-classical theory are:

- Only labor and capital are incorporated as factors of production. The inclusion of more factors, however, makes the application of the production function analytically more complicated.
- The presence of infinite techniques at a given level of technology is rather unrealistic. Real life situations often imply a choice between a restricted number of options.
- Only cost-reducing improvements can be described by the production function. Improvements in performance or the appearance of new services find no place in this theory.

- Though an efficient tool for equilibrium analysis of economic life, it is ill at ease when dealing with dynamic problems.

Marxist Theory

Karl Marx perceived technology as not self generating, but as a process directed by willful, conscious, active people and molded by historical forces. He held that technological change - the development of the productive forces - was the prime mover of history. The individual entrepreneur invests and innovates because it is rational for profit maximization or necessary for survival. Marx seemed to be under the spell that innovations simply must be labor-saving.

Major limitations of the Marxist theory are:

- Undermining of capital-saving innovations.
- Underemphasizing the concept of productivity.
- Controversy involved in the theory of the falling rate of profit.

Schumpeter's theory

This theory views innovation as the engine of economic development and as a disequilibrium phenomenon. Innovation is defined as the carrying out of new combinations of means of production, which include a wide variety of cases such as:

- the introduction of a new good or of a new quality of a good, or of a new method of production,
- the opening of a new market,
- the conquest of a new source of supply of raw materials,

- the carrying out of a new organization of any industry.

The emphasis is laid on the notion that technological change is to be understood as a case of innovation more generally and not as another piece of routine economic behavior. Schumpeter's formulation of production function differed from neo-classical theory in that capital was excluded and only labor and land were included as inputs.

Major limitations of this theory are:

- Psychology of the entrepreneur (the embodied aspect of innovation) is an elusive phenomenon.
- No explicit attention is paid to the process by which innovation is generated.
- Lack of empirical evidence.

Evolutionary Theory

This suggests a biological analogy to explain technological change. The Darwinian two-state process of mutation (invention) and selection (innovation) has been employed to understand the evolution of technology. Biological evolution appears to have a certain correspondence with the interpretation of technological changes in industrial sectors - from a state of flux when product innovation prevails in the search for a successful design, to a maturity phase where incremental process innovation prevails.

Major limitations of the evolutionary theory are:

- Dearth of quantitative models.
- Many propositions need to be validated.

Market-Pull Theory

Markets govern the innovation process. The market constitutes a communication channel through which political, economic, social and ecological forces influence buyers in their demand for technological products. Continuous changes in these forces have an impact on the response provided by technology with respect to the type, capabilities, performance, safeguards, solutions, etc. These messages are transmitted and communicated through the market where buyer's requirements (themselves influenced by external forces) are matched with technological changes and where future demands can be detected by the producers of technology.

Major limitations of this theory are:

- The logical and practical difficulties in interpreting the innovation process.
- Difficulties of defining demand functions as determined by utility functions.
- The incapability of defining the 'why', 'when' and 'where' of certain technological developments instead of others.

Technology-Push theory

Technology is defined as an autonomous or quasi-autonomous factor. It assumes a one-way causal determination approach, i.e., from science to technology to the economy. It proposes that technological developments occur exogenously through discoveries, theories, ideas and R & D work, which may or may not then create (or be matched with latent) demand for their output.

Major limitations of this theory are:

- Failure to take into account the intuitive importance of economic factor in shaping the direction of technological change.
- Lack of understanding of the complex structure of feedbacks between the economic environment and the directions of technological change.

Technology Management

Fredmund Malik defines management as "the transformation of resources into utility." Management can be an art and to some extent a technology. As a field, it has a knowledge base and guiding principles which provide the means by which the desired goals of an enterprise are achieved. It encompasses various functions, including planning, organizing, staffing, motivating and controlling activities of the organization. Now-a-days, majority of these functions are managed or performed through technology.

The successful use of technology can offer many competitive advantages; so organizations have become more conscious of the value of technology when it is applied in their businesses. In today's rapidly changing environment with increasing cost, complexity, competition and rate of technological changes, the needs for technology management has become an urgent issue for every company and organization (Steele, 1989). It also necessitates effective management of technology - at both national and firm levels. As a result, Technology Management has now occupied the centre stage of decision-making.

Technology Management is a set of disciplines that allows organizations or a nation to manage their *technological* fundamentals to create competitive advantage through planning and developing its technological capabilities. Management of technology links engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of organization. It allows organizations to manage their technological fundamentals to create competitive advantage trough addressing several interconnected issues such as:

- technology policy;
- technological forecasting and assessment;
- technology strategy;
- technology transfer;
- technology project management;
- technology research and development;

- human resource management in terms of innovative capabilities, flexibility and contribution
- continuing improvement of process and product technology.

In literature, various definitions of Technology Management (TM) have been produced. Some of them are reported here:

- NRC/National Research Council (1987) describes TM as "a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization."

- The U.S National Research council report (1987) on management of technology defined it as "an interdisciplinary field concerned with the planning, development and implementation of technological capabilities to shape and accomplish the operational and strategic objectives of an organization".

- The Association of Technology, Management and Applied Engineering defines "Technology management as the field of study that impacts skills and knowledge, designed to improve the entire process of technological change and from systems planning and design, to introduction, to evaluation of effectiveness".

According to Gaynor (1989), managing technology is a method of operation that leverages human resources, technology and other business assets by optimizing the relationships between the technology functions of the business enterprise. It is the process of integrating science, engineering and managing with research, development and manufacturing in order to meet the operational goals of the business unit effectively, efficiently and economically. It includes managing the totality of the technology operations from concept through commercialization. In this regard, Tschirky has identified three levels of management tasks:

1. Normative level: This level deals with the company's major decisions, that vividly demonstrate its associated culture and policy
2. Strategic level: a comprehensive technology strategy, with a dominant principle of effectiveness is translated into the company's policy
3. Operative level: this changes the businesses strategies into practice over the short term, with efficiency as the primary principle.

Types of Technology Management

TM has become an organized and systematic discipline. As TM embraces several inter-connected issues ranging from policy planning at the national level to strategic planning at the firm level, it calls for decisions and result-oriented actions at the macro-as well as micro-levels and an effective macro-micro linkage.

Macro technology management commonly refers to technology management at the national level. It includes:

- Planning for the development of technological capabilities at the national level.
- Identification of key sectoral technology and related fields to be developed.
- Determining ‘make’ or ‘buy’ decisions, i.e., whether importation or self-development is to be pursued.
- Establishment of institutional mechanisms for directing and coordinating the development of national technological capabilities.
- Design of policy measures for controls.

Micro technology management concerns technology management at the firm or project level. It includes:

- Responding to competitors who are using technology as a strategic weapon.
- Integrating technology strategy into the overall corporate strategy.
- Identifying and evaluating technological options and innovations and the factors relating to their success and failure.
- Directing research and development itself, including determination and definition of project feasibility.
- Monitoring and planning technological obsolescence and replacement.

Both macro and micro-technology management seek to raise economic efficiency. Micro TM is the basis for macro TM, while the latter provides guidelines and an environment for the former. Consistency among these two levels of management is essential, but institutional mechanisms will largely determine whether they are effectively combined. While macro-support could catalyze changes, the real actions have to take place at the industry level.

In order to maintain technology and update the technology with the current changes, there are certain activities (like Innovation, Protection, Identification, Selection, Acquisition, Exploitation, Transfer, Learning including Diffusion & Absorption,) and functions (like Planning and Forecasting, Decision Making, Organizing, and Leading Technical People) that every organization has to understand. In addition the technology management community has developed some tools for effective technology management, like S–curve, Patent Analysis, Portfolio Management, Roadmapping, and Value Analysis/Value Innovation. These activities, functions and tools are the building blocks of Technology Management.

Technological Innovation

Typically it is thought of as a new product development. It refers to the process in which a new idea is embodied in tools, devices, or procedures that are of practical value to society. Technological innovations often involve tools and procedures, products and processes, interacting in new ways. Technological innovation can also be an improvement in instruments or methods of making or doing innovation (Kline and Rosenberg, 1986). For example, it may be a new process of production; a substitution of a cheaper material, newly developed for a given task, in an essentially unaltered product; or the reorganization of production, internal functions, or distribution arrangements, leading to increased efficiency, better support for a given product, or lower costs.

Technological innovation has been described often as a linear process of distinct stages or phases:

- innovation begins with scientific discovery,
- proceeds through development of practical applications of this discovery, and
- finally achieves success as dissemination and implementation at the hands of users.

This linear model is overly simplified. In fact, the innovation process may be quite non-linear, drawing repeatedly on basic knowledge, responding to newly perceived needs, and modifying earlier concepts of the tool, device, or procedure that eventually evolves (Tornatzky et al. 1990). Nevertheless, the progress of innovation requires, first, understanding of the basic principles and processes that permit manipulation of the physical environment, and then the interaction of often complex social forces through which this understanding is to be put to use.

In fact, the process of technological innovation is a complex set of activities that transforms ideas and scientific knowledge into physical reality and real world application. There are eight stages in the process of technological innovation.

1. ***Basic research:*** It for the sake of increasing our general understanding of laws of nature. It is a process of generating knowledge over a long period of time. It may or may not result in specific application.
2. ***Applied research:*** It is directed toward solving one or more of society's problems. Basic and applied research advance sciences by systematically building knowledge on previous knowledge. Successful applied research results in technology development and implementation.
3. ***Collaboration*** *Teamwork is essential to getting things done. In today's global and digital 24/7 world, challenges are more complex; it's becoming increasingly important to bring more, diverse minds to the table and to break down silos.* Collaborative process is more than working together. It means the ability to think together and to act on complex projects. A successful collaboration is mainly based on:

- **Listen and explore**—What can we do together?
- **Learn and adjust**—How will we learn together?
- **Focus and align**—What should we do together?
- **Link and leverage**—What will we do together?

4. ***Technology development:*** This is a human activity that converts knowledge and ideas into physical hardware, software, or service. It may involve demonstrating the feasibility of an idea, verifying a design concept, or building and testing a prototype.
5. ***Technology implementation:*** A step-by-step process or "roadmap" for technology Implementation, which outlines how to plan, implement, and sustain the use of technology in the target market.
6. ***Production*** Across all production environments, most manufacturing processes fit into one of five general categories:
    - Repetitive
    - Discrete
    - Job Shop
    - Process (batch), and
    - Process (continuous)

    To get single product out of the door, most companies use a combination of more than one of these environments.

7. ***Marketing/Commercialization*** is the process by which a new product or service is introduced into the general market. The process of commercialization is broken into phases, from the initial introduction of the product through its mass production and adoption. It takes into account the production, distribution, marketing, sales and customer support required to achieve commercial success.

    As a strategy, commercialization requires that a business develop a marketing plan, determine how the product will be supplied to the market and anticipate barriers to success. The process of commercialization is like a funnel. At the widest part are the many ideas that a company might have for launching a product. As the funnel narrows, the company weeds out ideas based on logistics and costs, consumer and economic trends, and feasibility. Commercialization is part of a larger feedback loop for a product, as the ultimate introduction of the product into the market may require adjustments to the process.

    For a potential product to be eligible for commercialization, it must have a level of public value that could result in overall profitability. These products may be developed within commercial businesses, government agencies, educational institutions or other entities involved in various forms of research and development.

8. ***Proliferation***
9. ***Technology enhancement.***

Innovation Management

Innovation, although not sufficient, is a necessary prerequisite for the continued survival and development of enterprises. The most direct way of business innovation is through technological innovation, disruptive innovation or social innovation. Management of innovation, however, plays a significant role in promoting technological and institutional innovation.

The goal of innovation management within a company is to cultivate a suitable environment to encourage innovation. The suitable environment would help the firms get more cooperation projects, even 'the take-off platform for business ventures'. Senior management's support is crucial to successful innovation; clear direction, endorsement, and support are essential to innovation pursuits.

Innovation management allows the organization to respond to external or internal opportunities, and use its creativity to introduce new ideas, processes or products. It is not relegated to R&D; it involves workers at every level in contributing creatively to a company's product development, manufacturing and marketing. It helps an organization grasp an opportunity and use it to create and introduce new ideas, processes, or products industriously. Creativity is the basis of innovation management; the end goal is a change in services or business process. Hence, the innovative management process can be viewed as an evolutionary integration of organization, technology, and market, by iterating series of activities: search, select, implement and capture.

Innovation management is based on two consecutive steps, *imitation* and *invention*, and a set of tools that allow managers and engineers to cooperate with a common understanding of processes and goals. By utilizing innovation management tools, management can trigger and deploy the creative capabilities of the work force for the continuous development of a company. Common tools include brainstorming, virtual prototyping, product lifecycle management, ideation, TRIZ, Phase–gate model, project management, product line planning and portfolio management.

Innovation processes can either be *pushed* or *pulled* through development. A *pushed* process is based on existing or newly invented technology that the organization has access to. The goal is to find profitable applications for the already-existing technology. A *pulled* process, by contrast, is based on finding areas where customers' needs are not met and finding solutions to those needs. To succeed with either method, an understanding of both the market and the technical problems are needed. By creating multi-functional development teams, containing engineers and marketers, both dimensions can be solved.

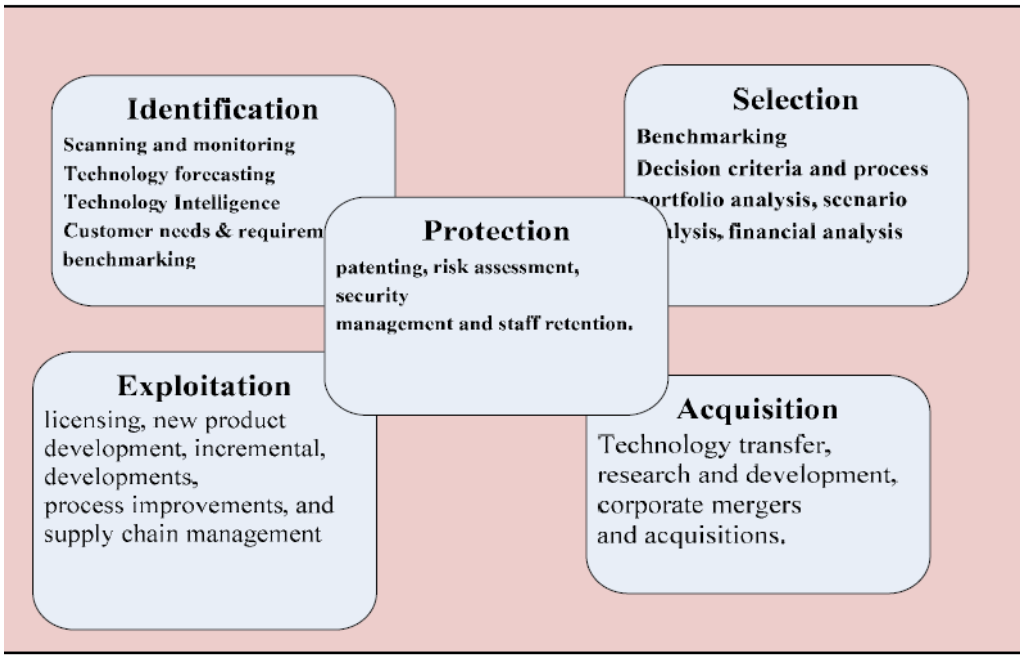
Technology Management Framework

A set of management definitions, concepts, activities, stages, and procedures Researchers have developed a range of concepts, stages,

procedures, activities and management definitions, all of which are directed towards forming and articulating a certain framework of technology management as the TM methodology.

In order to: explore the methods and techniques of technology management; identify and investigate the meaning of technology management; and to clarify its functions, various Technology Management models, frameworks, definitions, concepts, assumptions, and proposals have been articulated[1].

Gregory (1995) described technology management as a five step model which includes identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural), which in adherence to the company's objectives, are needed to uphold company performance and market position



1. **Identification:** The spine of the management process is seen to be the identification of technologies, crucial to the company's

[1] (Sarkis,J. 1995; Dey., 1996; Chan,S.L and Choi C.F, 1997; Lopes and Flavell, 1998; Haas and Kleingeld, 1999; Garshnek et al., 2000; Pretorius and Wet, 2000; Sharratt and Choong, 2002;).

strategic operations. Such identification processes include: scanning and monitoring, technology forecasting, customers orientation, technology intelligence, data collection and benchmarking. Such work will show how the business identifies the technologies it uses, how the company forecasts for success of new technology, how scanning and monitoring for the new technologies are performed, how the company identifies the customer needs and requirements, and what are the main factors that affect the identification process.

2. **Selection**: selection of those technologies that are chosen to support companies and organization. Such processes include: scenario analysis, portfolio analysis, expert judgment, decision criteria and financial analysis. Since technology selection requires one to make accurate decisions with regards to the correct technologies, it is crucial for the organization. This is especially so when decisions are made that require long term investments. Also, the business must concentrate on quantitative, qualitative, intangible and tangible criteria in the selection of its technology. This process is necessary so that the business adopts systematic procedure in its selection process.

3. **Acquisition** of technologies that have been selected. Example processes include internal research and development, Joint Ventures, Organizational Change, Project Management, Licensing, corporate mergers and acquisitions, technology transfer, technology insertion.
4. **Protection** of knowledge and expertise. Processes include patenting, contracts, risk assessment, copyrights, staff retention, security management.
5. **Exploitation** of technologies. Example processes include process improvements, licensing, new product development, and supply chain management.

Technology Management Capabilities

1. Have the capacity and ability to perform technology Identification
2. Have the capacity and ability to perform Selection
3. Have the capacity and ability to perform Acquisition
4. Have the capacity and ability to perform Exploitation
5. Have the capacity and ability to perform Protection

6. Have the capacity and ability to Learn about new technologies
7. Have the capacity and ability to perform Strategic Management
8. Have the capacity and ability to perform Innovation Management
9. Have the capacity and ability to perform Project Management
10. Have the capacity and ability to perform Knowledge Management
11. Have the capacity and ability to perform Technology Management