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# TECHNOLOGICAL CAPABILITY ASSESMENT IN METAL MANUFACTURING AND ENGINEERING INDUSTRIES

**(ETHIOPIA)**

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***A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the Degree of Masters of Science in Mechanical Engineering (Industrial Engineering Stream)***


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## Abstract

Resource-based theory views a firm as a unique resource and capabilities providing the potential for competitive advantage in rapidly changing and unpredictable environments which then leads to superior performance. If firms' resources and capabilities are valuable, then they yield superior economic rents. Hence, firm's distinctive resources and capabilities already have the essence of competitive advantage and performance implications.

Technological capability has been regarded as an important strategic resource enabling firms to achieve sustainable competitive advantage when firms face a changing environment. Firms with more technological capabilities can perform better in more turbulent environments as compared with firms with lesser levels of technological capabilities

The metal manufacturing and engineering industries has been found to be the base in most developed and progressive economies and made the platform for the emerging of various theories about the significance of unique resources and capabilities on formation of competitive advantages by the firms. Such capabilities accrued through innovation or technology development are called technological capabilities, and the evaluation & measurement of which has made effort to create and maintain a progress.

## Acknowledgement

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## List of Acronyms

| | |
|---|---|
| EBMEI | Ethiopian metal manufacturing and engineering industries |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization |
| TC | Technological capability |
| OECD | Organization for Economic Cooperation and Development |
| LMSE | Large and Medium Size Enterprises |
| R&D | Research and Development |
| SME’s | Small and Medium Scale Enterprises |
| VAC | Value Chain Analysis |
| SWOT | Strength, Weaknesses, Opportunities and threats |

- The term **innovation** is used in this paper with a meaning of technology development process

# 1. INTRODUCTION

## 1.1. Background of the study

There are a lot of growing studies regarding how a firm can develop and maintain their sustainable competitive advantage in rapidly changing and unpredictable environments [13]. Resource-based theory views a firm as a unique resource and capabilities providing the potential for competitive advantage in rapidly changing and unpredictable environments which then leads to superior performance. If firms' resources and capabilities are valuable, then they yield superior economic rents. Hence, firm's distinctive resources and capabilities already have the essence of competitive advantage and performance implications.

Technological capability has been regarded as an important strategic resource enabling firms to achieve sustainable competitive advantage when firms face a changing environment. Firms with more technological capabilities can perform better in more turbulent environments as compared with firms with lesser levels of technological capabilities [14]

The metal manufacturing and engineering industries has been found to be the base in most developed and progressive economies and made the platform for the emerging of various theories about the significance of unique resources and capabilities on formation of competitive advantages by the firms. Such capabilities accrued through innovation or technology development are called technological capabilities, and the evaluation & measurement of which has made effort to create and maintain a progress. In this respect the infant metal manufacturing and engineering industry of Ethiopia lucking positive records expected to confront big challenges to overcome and maintain a sustainable pace of progress.

This thesis work attempts to explore the already available technological capabilities of the Basic metals manufacturing and Engineering industries of Ethiopia with an aim to identify the existing situations and prepare a document followed by developing alternative ways for improving performance. The paper is organized in five main chapters. One is the introductory part of the paper. Chapter two presents the surveyed literature and chapter three, deals about the description of the assessment in the scope from data collection to presentation of findings, where the gap analysis were conducted showing the level of technological capability of EBMEI, the capability statement of the sector prepared is also presented followed by a

SWOT analysis. Chapter four overviews about the newly established Metals and Engineering Corporation and its implication towards changing in Technological Capability of the nation and chapter five is about the development of strategic approaches for betterment of the sector and finally chapter Six winds the paper with conclusion and some recommendations.

## 1.2. Statement of the problem

The Basic metals and metallic product Industry sector in Ethiopia is still weak. The main industrial sub-sectors are food, textile and garment, leather and leather products, construction, and some light manufacturing and agro-processing industries. All of which have numerous potentials but their operation and contribution to the economy in both the local and export potential is disappointing. Most industrial facilities are private with some state owned facilities on privatization processes are decelerating in their performance and lacking bright futures. Furthermore the sector is manifesting a number and type of weaknesses and problems like:

- ❖ A Self-contained Data's Couldn't be found on the existing state of the technological capability of the sector
- ❖ The strategy and method being practiced on improving the technological capabilities of the sector are not following scientific procedures and not productive.
- ❖ The level of installed technology and its utilization strategy are not promising
- ❖ Variation in performance among industries in similar nature of operations following type of ownerships like: private, public, foreign owned etc…
- ❖ The existing industrial economic policy could also affect the degree to which the industries absorb new technological capabilities.

## 1.3. Research objective

The objective of this paper is mainly to assess the existing state of the technological capabilities of Basic metals and metallic product Industries and devise/set a direction for improvement.

**Specific objectives**

- Asses the state of the technological capabilities of manufacturing industries.
- Asses and identify the industrial and technological capabilities needed to cope up with the newly emerging FDI/Foreign direct investment/business.
- To answer questions like why industrial technological capabilities particularly the ability to select, assimilate, disseminate and improve transferred or imported technologies are poor in our context.
- Identify improvement opportunities to assist for betterment of their performance
- Recommend for simplified and productive strategic/technology alternatives to bridge the gap in performance and competitiveness.

## 1.4. Delineation of the Research

To make more clear, what this study is looking for and what is not considered in the study are shown below.

- Basic metal and engineering industries located out of the major industrial zone, Addis Ababa, are not considered in this study.

# 2. LITERATURE REVIEW

## 2.1. Technological Capability

### 2.1.1. Definition

Technological capability is defined as the knowledge and skills required to choose, install, operate, maintain, adapt, improve and develop technologies mostly by firms [1]. According to the World Intellectual Property Organization (WIPO) technology is defined as “the systematic knowledge for product manufacture and service provision in industry, farming and commercial fields,” and knowledge is reflected in inventions, utility models, designs, and in data forms. Knowledge is also shown in industrial plants, design, installation, operation, and maintenance of equipment, management of industrial & commercial corporations, and the technical skill & experience of experts for those activities. In this definition, it must be noted that technology comes from knowledge. However, not all knowledge is included. That is, it must be able to be transferred and it must be systematic knowledge that can satisfy needs & problems that arise in special fields of human activity including industry, farming, and commerce. So, there are 3 standards in the definition of technology.

First, knowledge must be systematic. This means that it must be organized in terms of providing solutions to problems.

Second, knowledge must exist in certain places like in someone’s head or in documents, and must be able to be presented, so no matter what it means it must be able to be transferred from one person to another.

Third, it must have purpose-orientation, so that it can be utilized for useful purposes in industry, farming, and commercial fields.

Science and Technology which are commonly discussed as if they were same is wrong, because there are essential differences, and those differences must be recognized (JETRO). Science is comparatively easy to transfer to other cultures because it is a systematic knowledge explainable in language, while technology is not. Hence technology is "the totality of scientific principles that enter, consciously or unconsciously, into the production, distribution, and consumption of goods, services, and information.” Technology is bound up with social relations and natural circumstances. Although synchronic and cross-cultural in principle, technology in its specific mode differs according to the country and region to which it is adopted.

And also Technology is a process; As per (UNESCO, 1985) it is:"...the know-how and creative processes that may assist people to utilize tools, resources and systems to solve problems and to enhance control over the natural and made environment in an endeavor to improve the human condition.". Thus technology in this statement involves the purposeful application of knowledge, experience and resources to create processes and products that meet human needs. The need to acquire this capability has necessitated purposive efforts aimed at assimilating, adapting and modifying existing technologies and/or developing new technologies called *Technological capability*. Firms that are adept at this are called learning organizations, because they are skilled at creating, acquiring and transferring knowledge, as well as at modifying their behavior to reflect new knowledge and insights [2].

The definition of technological capability is varied in perspective, depending on the aims of the researchers. Lall (1990: 17) defined technological capability broadly as "the entire complex of human skills (entrepreneurial, managerial and technical) needed to set up and operate industries efficiently over time". He defined TC in narrow sense as the capability to execute all the technical functions entailed in operating, improving and modernizing the firm's productive facilities. It is categorized to the investment TC, the production TC, and linkages TC according to the functions. Kim (1997: 4) pointed out that in the developing countries 'technological capability' could be used interchangeably with 'absorptive capacity' absorbing existing knowledge, assimilating it, and in turn generating new knowledge. In this paper, we use technological capability as the capability to make effective use of the technical knowledge and skills, not only in effort to improve and develop the products and processes, but also to improve the existing technology and to generate new knowledge and skills, in response to the competitive business environment.

Common terms used in Technological Capability:

- Technology transfer**:**

  Commonly referred to as technology transfer; the process of arranging for the commercialization of technology-based inventions or innovations originating in research universities, government or non-profit laboratories or large corporations. Technology transfer involves the organization responsible for originating the technology negotiating the transfer of the commercialization rights to that technology to a commercial entity (typically a for-profit company) via a licensing agreement. The business arrangements associated with tech transfer agreements can vary widely, but typically involve the company receiving the commercialization rights paying the owner of the intellectual property or IP (the inventing organization) some combination of up-front license fees, royalties (variable payments calculated as a percentage of future sales), and/or partial equity ownership (stock) in the commercializing company as per "The Company Crafters Entrepreneur's Dictionary”. In general “thefreedictionary.com” Defines and classify Technology transfer as:-

1. Applying the results of research to a practical application.
2. Sharing technical information by means of education and training.
3. Using a technical concept or hardware or software product to solve a problem in an industry that is entirely different from the one the technology was developed for.

Transferability of technology depends upon factors of adaptability to local situations. After a technology is transplanted from a foreign country, development occurs in stages: (1) proper operation, (2) proper maintenance, (3) partial improvements, (4) total improvement in design (new invention), and (5) manufacture of plant and equipment to produce the newly invented process or product. When native technicians and engineers attain one of the stages totally on their own, the next stage becomes, logically, easier to reach.

- Technology diffusion**:**

Technology diffusion involves the dissemination of technical information and know-how and the subsequent adoption of new technologies and techniques by users. In this context, technology includes "hard" technologies (such as computer-controlled machine tools) and "soft" technologies (for example, improved manufacturing, quality, or training methods). Diffused technologies can be embodied in products and processes. Although classic models of technological development suggest a straightforward linear path from basic research and development to technology commercialization and adoption, in practice technology diffusion is more often a complex and iterative process. Technology can diffuse in multiple ways and with significant variations, depending on the particular technology, across time, over space, and between different industries and enterprise types. Moreover, the effective use of diffused technologies by firms frequently requires organizational, workforce, and follow-on technical changes.

Technology diffusion can be contrasted with technological innovation, which emphasizes the development of new knowledge, products, or processes, and government-oriented technology transfer, which frequently seeks to shift advanced technology out of laboratories into commercial use. In many cases, diffused technologies are neither new nor necessarily advanced (although they are often new to the user), and they may be acquired from a variety of sources, including private vendors, customers, consultants, and peer firms, as well as public technology centers, government laboratories, and universities. Technology also diffuses through the internal "catch-up" efforts of firms, the transfer and mobility of skilled labor, the activities of professional societies and the trade and scientific press, varied forms of informal knowledge trading, and such practices as reverse engineering.

- Technology innovation**:**

The manifestation of something new in constructive human activity, an expression of human creative capabilities, and in technology, it's an improvement to something already existing. Innovation plays an important part in strengthening the ties between science and production, and it presupposes the active application of all theoretical and practical knowledge developed in any given field and in all related fields. Innovation provides the material from which new theoretical knowledge is worked out and promotes the development of science, technology, and production.

- Technology spillover**:**

Technology spillovers have been used to explain the increased rate of innovation that is found in technological clusters. In essence spillovers are the unintentional transmission or transfer of technology/knowledge to others beyond the intended boundary. At every possible interaction, there is a potential for knowledge exchange. If knowledge is exchanged with the intended people or organizations, it is “knowledge transfer”, any knowledge that is exchanged outside the intended boundary is spillover.

The unintended “use” of exchanged knowledge is called “Knowledge Externality”. When a person makes the decision to share his/her tacit knowledge there is usually a motivation behind this sharing. People share knowledge for different reasons, for example, to get feedback from other people, or to receive acknowledgment of ones ideas, this acknowledgment could be materialistic or simply recognition between peers for the work done. Once this knowledge is out there it can be used in any way to benefit other peoples’ work and could lead to other discoveries. Hence sharing knowledge could result in spillovers and other knowledge externalities. Reverse engineering is a good example of knowledge externality. When a company invests in research and development to introduce a new innovative product to the market, the motivation behind that act is to profit from the innovation. However, there is an associated risk that a competitor might reverse engineer that product and make use of the externalized knowledge materialized in the innovative product. Companies guard against spillovers and unintended use for a period of time by patenting their inventions.

- Technology adaptation**:**

Adaptation defined as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm and exploits beneficial opportunities” or “Any application of equipment, techniques, practical knowledge or skills that would allow natural or human systems to adjust to actual or expected climatic stimuli or their effects, by moderating harm or exploiting beneficial opportunities” (Rawleston Moore; June 29 2005)

### 2.1.2. Concept of Technological capability

As we noted above, the concept for Technological Capability is broad and starts by choice of technologies and make a loop through improving and development with an ultimate aim of improving human conditions. The use and assimilation of new technologies presuppose the existence of a minimum of technological capabilities in developing countries like Ethiopia to choose, acquire, generate, and apply technologies that are suited to their development objectives. Such capabilities would determine the rates and patterns of development and industrialization. Though the concept is somewhat elusive, it is clear that capabilities cannot be acquired overnight and that they will vary over time and space, technological capabilities can also vary between sectors. In the industrial sector, the elements of technology capability: production engineering, manufacture of capital goods, and research and development, etc. is different from those essential for the services sector. Technological capabilities may exist in both large and small industrial sectors [2]. As Jean-Jacques Salomon and Francisco R. Sagasti of the United Nations University; summarized Technological capabilities, whether considered in macro terms or in terms of elements, would depend on factors such as:

- ✓ Adequate number and quality of human resources with practical experience, skills, and aptitude;
- ✓ Useful technological information on sources and conditions of technology transfer;
- ✓ Institutions for education and training, for research and development, and for engineering design and consultancy;
- ✓ Favorable natural environment and factor endowments, attitudes and customs, etc [2].

### 2.1.3. Importance of Technological Capability

Technological capability is an important strategic resource that enabling firms to achieve sustainable competitive advantage, when firms face a changing environment. Firms with more technological capabilities can perform better in more turbulent environments as compared with firms with lesser levels of technological capabilities. Since superior technological capability can help firms to receive greater efficiency gains by pioneering process innovations, and to achieve higher differentiation by innovating products in response to the changing market environment. Moreover, superior technological capability can accelerate the development of new product developments in order to reap the pioneer advantages. As a result, technological capability can help a firm to create more value than its competitors and can receive a greater economic return above the industry average [1].

The competitive advantage of firms not only depends on the exploitation of current capabilities which involves the refinement of existing resources and capability that are currently available, they also need the exploration of new capability which involves the acquisition of new knowledge and the improvement of future performance. From dynamic capability perspective, a firm’s capability to reconfigure its asset structure plays a significant role in its sustainable competitive advantage. That is to say, firms have to renovate and enhance their technological capability in order to compete with others in future environment. A firm can acquire its sustainable competitive advantage performance by accumulating its technological capability [3].

Therefore the availability of such Technological capability for Ethiopian Basic Metal Manufacturers and Engineering Industries is very crucial and execution of the following practices such as;

- exploitation of current capabilities that involve the refinement of existing resources and available capability;
- exploration of new capability which involves the acquisition of new knowledge and the improvement of future performance; and
- From dynamic capability perspective it needs to renovate and enhance their technological capabilities.

Would help the sector to achieve the strategic and competitive advantages that Technological capability, would provide as a strategic resource, which are helping the firms: - to achieve sustainable competitive advantage, to a creation of more values than competitors as a result to accrue greater economic return and, to operate better under turbulent environments

Furthermore studies show that the economic importance of Technological Capability via Innovation for the last decades has got an increasing acceptance among policy makers, of the idea that diffusion produces most of the economic benefits of new technology. It is “not the creation of technological leadership in itself that affords a nation’s competitive advantage, but the rate and level of diffusion of the technology into economic use”. In a series of US case studies, it have shown adopters of even minor technological improvements attaining a median return on investment of 55%, compared with 22% for the companies which innovated these same improvements. The more significant the innovation, the larger the gap between returns to innovation and diffusion will be. In summary:-

- ✓ Technology development and diffusion are clearly of considerable potential economic importance, with diffusion offering particularly large benefits
- ✓ Technology diffusion involves far more than the simple introduction of new machinery into the firm. Additional measures, such as internal reorganization of both production and management processes and upgrading of skills, may be essential to capturing economic value from investment in new technology
- ✓ Whereas it may not be necessary to produce technology to reap its benefits, diffusion is essential to maximize potential national economic returns. However, realizing the benefits of diffusion may depend critically on broader social and institutional changes, which may, in fact, represent the most important obstacles of all

From what we seen above, presumably it is wise to focus on diffusion for EBMEI's to ease and make fast the progress to better technological capabilities through creating the economic ground and to proceed for innovative or technology development options.

#### 2.1.4. Economic Theory and Technological Capability

The way in which economic theory treats the firm is necessarily idealized. Nonetheless, it provides insight into the ways that rational and efficient firms would operate. Recent years have seen an important change in the way economists deal with innovation, and therefore also in the theory of the firm.

There are four themes which taken together are having a major impact on the way that scholars approach the study of innovation. These themes are bounded rationality, organizational capability, cognitive technological structures, i.e. paradigms, and technological systems. Together they lead us to an epistemological view of the firm as a creative experimental organization embedded in a wider network of knowledge-generating relationships. It is what it believes it is and it does what it does. It can only innovate by changing what it believes and knows [4].This resource-based approach to capabilities also highlights important characteristics of the innovating firm. From this perspective, business enterprise can be understood in terms of learning, path dependencies, technological rajectories and opportunities, complementary assets, technology and transaction costs.

Performance is a function of intangible assets, skills and the ability to develop new capabilities over time [5].

The upshot of this revolution in the theory of the firm is that companies are now seen as containing people, with specific histories, habits, skills and behaviors'. They have capabilities, and they are capable of learning. Table-1 briefly contrasts this modern view with the neoclassical one, considering: information; rationality; technological choices; technological progress; and firm behavior. It is well understood that, in practice, information flows in a very patchy way within the economy. Often, it makes sense to keep information (for example, about prices) secret. In other cases, such as patents, information is available, but it can only be used at a price. In a society where Information Technology is widespread, problems increasingly focus on intelligently filtering out the majority of irrelevant information. Information cannot be exploited or filtered - without having the ability to understand it and act on it, nor can it be used without devoting effort, and thereby incurring opportunity costs.

Firms do not always act as rationally as the neoclassical model would suggest. This may be because they lack the skills or the time to analyze incoming information effectively, or because that information is inadequate to their needs. (For example, they may know the prices in the local market, but be unaware that a new competitor in another country has developed a cheaper production technique, and can therefore attack their market unless they, too, change their production technology.)

**Table-2.1: Neoclassical and Contemporary Views of the Innovating Firm**

| Neoclassical View | Contemporary View |
|---|---|
| **Information**<br>Information about prices and technologies are available to the firm at no cost, and there are no restrictions on how the firm uses this information | Information may be costly to acquire, inaccurate and hard to understand. Exploiting it costs money and may require complementary assets, including internal technological capabilities |
| **Rationality**<br>The firm understands the information it receives and acts rationally to maximize its profits, based on that information | The firm's rationality is 'bounded'. Decisions are based on past experience. Actions may be strategic, sacrificing short run profits in order to reach long run goals |
| **Technological choices**<br>To produce any given good, there is an effectively infinite set of technologies (defined as the proportions in which factors of production may be combined) available. The firm can move smoothly between technologies, incurring investment costs but not other costs (such as opportunity or learning costs) | Technological choice is limited by the state of knowledge - both outside and inside the firm. Change is costly and risky |
| **Technological progress**<br>Technological progress is 'exogenous'. That is, it is not in the hands of the firm but just 'happens,' changing the 'production-possibility frontier' and allowing the firm to produce more efficiently. However, because there is perfect information, the entire set of new possibilities is immediately available to the industry as a whole so it is not possible to monopolize the benefits | Technological progress occurs both 'exogenously' and 'endogenously,' within the firm. Taking advantage of it requires that the firm have technological capability - including the 'absorptive capacity' needed to evaluate and exploit ideas from the outside |
| **Behavior**<br>The firm is a kind of economic robot, reacting to circumstances using a small set of fixed rules | The firm searches for opportunities, learns and changes its own competences and behavior over time |

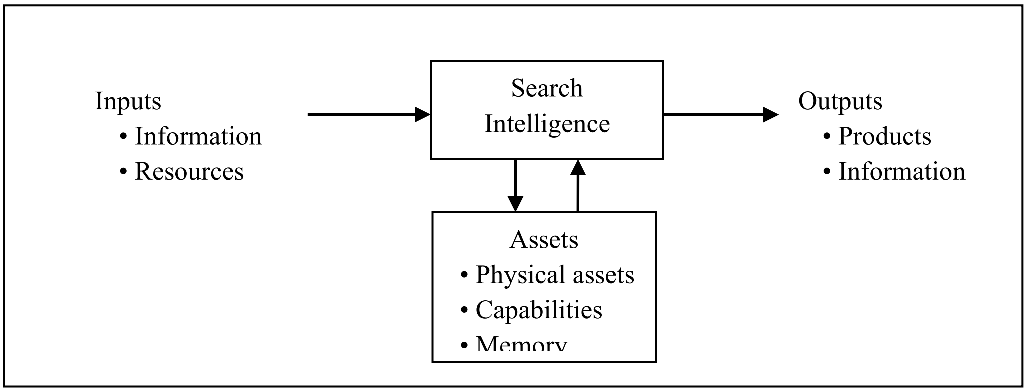
(Source: Erik Arnold & Ben Thuriaux; June 1997)

There are, indeed, many technologies available to firms. However, some will be proprietary. Adopting any of them will involve opportunity costs. Changing between them may involve overcoming institutional rigidities such as organization, skills, market focus and partnerships (for example use of distributors). It is easier to move between some technologies and others. Technological progress is, of course, not external but, to a very large extent - internal to firms and to the networks of relationships within which companies operate. Real firms are not at all homogeneous. They vary dramatically, both in size and in what they are capable of doing. In contrast, all neoclassical producers act in the same, predictable way. (Historically, this is because the theory was developed by considering the production of staple agricultural goods -

the 'corn' of the textbooks - and their sale on organized exchanges. The neoclassical model of firm is thus a pretty poor description of the real thing. While economists disagree about the wisdom of building a superstructure of economic theory on a model which is easily refuted, the neoclassical assumptions do at least make it possible to make calculations about the behavior of firms and markets. This is much more difficult with the less predictive contemporary models of the firm. Paradoxically, while neoclassical economics treats 'perfect competition' among small producers in homogeneous markets as the ideal state, real companies generally have to be large before they are capable of behavior which resembles that of the neoclassical firm. Crucial gaps between the theoretical model and reality are due to with the capabilities which theory supposes that firms possess. Policymakers talk about 'market failures' and the resulting need for intervention to support SMEs and other firms. These 'failures' are often caused by the inability of firms to live up to the neoclassical ideal, so the failures are actually in the theory, not in the market. But they are failures however. Correcting them as far as necessary is an important objective of innovation policy.

### 2.1.5. Competences and Capability

**Fig-2.1: Evolutionary Model of a Firm**




(Source: Erik Arnold & Ben Thuriaux; June 1997)

Modern, evolutionary economics sees the firm as a searching, learning mechanism. It survives and improves by continually reinventing itself. The firm consists of two elements as shown in Fig-2.1, above:

• A pool of assets, including both physical assets and intangible ones such as capabilities

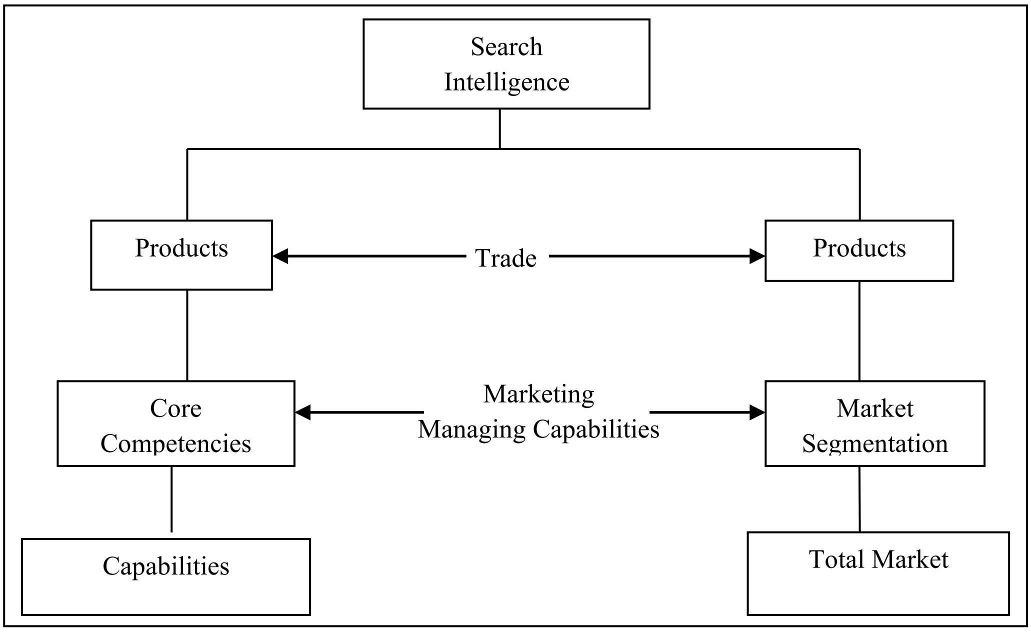
• Intelligence, which learns from the environment and modifies the resources.

Each of these elements can be broken down much further. An important attribute of the firm's 'memory' is that it comprises a mixture of knowledge (tacit as well as codified) and of the configuration of assets: namely, organization, characteristics of the capital stock, relationships, and so on.

The idea of 'core competencies' is an attempt to understand how companies marshal their capabilities. Teece, Pisano and Shuen define core competence as "a set of differentiated skills, complementary assets and routines that provide the basis for a firm's competitive capacities and sustainable advantage in a particular business" [6]. They go on to explain that core competences are unpredictable because they are competitively determined. From our perspective, they are possible to identify ex post, but are not so general that they form a useful basis for making policy.

Core competencies are, however, built up using the more generic capabilities which concern us here in Fig-2.2. Core competencies define how firms meet - and create - particular market circumstances. They are key parts of the corporate 'memory' and are defined in relation to the needs of the market segments in which the firm operates. Since market segmentation is to a significant extent the imposition of structure by the firm onto the demand side, the matching and modification of competences with market segments is one of the central aspects of firm's intelligence or entrepreneurship. Individual products and services are then 'instances' of this matching process.

**Fig-2.2**: **An Extended View of Core Competencies**




(Source: Nagy Hanna, Ken Guy and Erik Arnold, 1995)

OECD has listed major elements of producers' overall capabilities (including, but not only, technological capability) as:

- The knowledge and skills required for the process of production, where shop-floor experience and 'learning-by-doing' plays an important role
- The knowledge and skills required for investment, i.e. the establishment of new production facilities and the expansion and/or modernization of existing ones
- The vast area of adaptive engineering and organizational adaptations required for the continuous and incremental upgrading of product design and performance features and of process technology
- And, finally, the knowledge required for the creation of new technology, i.e. major changes in the design and core features of products and production processes.

The particular concern here is role of capabilities needed for innovation. While many observations about aspects of technological capability in literatures and number of discussion papers about how these develop, there appear to be almost no attempts to provide an overall view. We need this overview both to ensure that the description of technological capability is reasonably comprehensive and in order to understand companies' technological capabilities as systems, where individual components are related to each other.Table-4: shows how they respectively characterize technological capability. Both recognize that the ability to use and develop technology is deeply embedded in the 'soft' factors which surround the hardware, consistent with the broad definition of 'technology' so far defined.

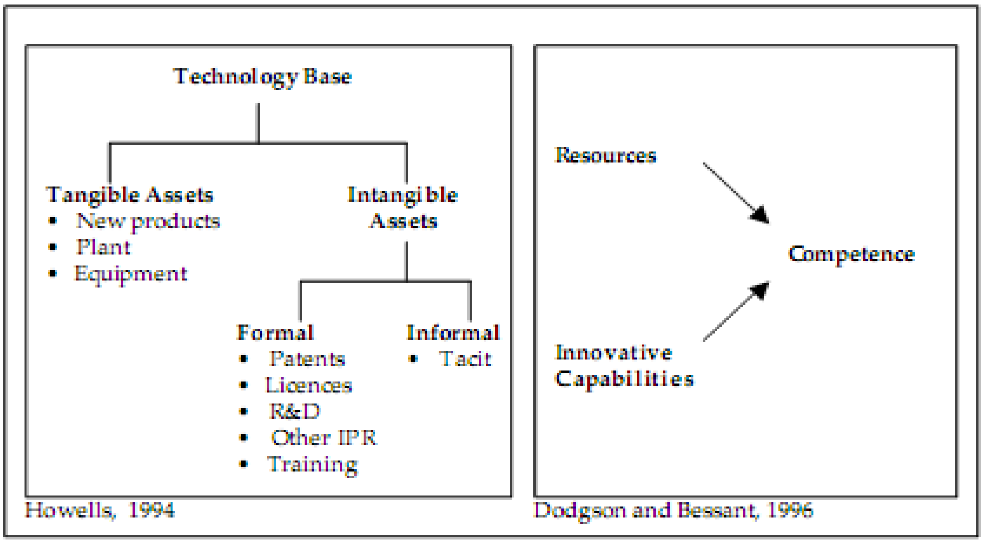



**Table-2.2: Approaches to Technology Capability**

As shown in table above, Howells' description is a static one. His concern is to show the interdependence of tangible and intangible assets in underpinning firms' competitiveness. He therefore makes the distinction between these two kinds of assets central to his model and treats tacit knowledge as a particularly special category of intangible assets.

Bessant and Dodgson's approach is dynamic. They define their terms as:

- **Resources:** All the assets in the firm which enable firms to operate, including tangible and intangible assets, skills, knowledge, organization, links with other firms
- **Innovative Capabilities:** Features of firms and their management which enable them to define and develop competences to create competitive advantage
- **Competences:** That focused combination of resources which enables firms to differentiate themselves from their competitors.

These three elements interact through learning, which is a purposive search for competitive advantage. If the analysis of technological capability is to be consistent with the neo-Schumpeterian or evolutionary view of the firm, it needs to involve this combination of resources and intelligence. Capability is much more than ... individual assets. If it were not, the firm would be no more than a bundle of bilateral contracts between owner and employee, and rent could not exceed the differences between current and next-best use value. One thing this tells us is that the organization must possess a memory, or a tradition of practice, so that losses in personnel can be matched with new employees who can be trained in the firm's routines [7].

The need for a memory drives progressive companies to accumulate tacit knowledge, to identify its components and to try to codify it as intellectual capital. Few are as explicit about the process as Skandia Insurance which some years ago appointed a Director of Intellectual Capital whose business is to codify Skandia's businesses processes [6]. Once codified, they can be analyzed, optimized and reproduced - for example when diversifying into new markets. Nonetheless, the same thing happens in many companies through, for example, engineering and reengineering, computer systems development and the articulation of processes and company standards. Creating intellectual capital - technology in the older sense of "a discourse or treatise on an art" - in this way is intended to improve the firm's effectiveness. But it also tends to lock the company into specific products, markets and technological trajectories, promoting 'path-dependency'. The problems can in principle be reduced if the corporate memory can forget as well as learn [6].

In Table-5, a simple way to think about technological capabilities is laid, which captures both this need for a corporate memory and the need to connect it with the market. It is based on the literature survey and shows three kinds of capabilities: internal; external; and strategic. These are interlinked and interdependent, because they are involved in a dynamic learning process.

**Table-2.3: Key Elements of Technological Capability**

**Strategic Capabilities**

- Search for market opportunities
- Understand and manage the fit between the firm's capabilities and market needs

**Internal Capabilities**

**Manage tangible technology base**
- Products
- R&D facilities
- Appropriate plant and equipment

**Develop and manage appropriate intangible resources**
- Codified intellectual capital
- Qualification and skills profile adapted to the needs of the firm
- Tacit knowledge

**Create needed organization**
- Technology management Capabilities
- Change-management capabilities
- Coordination among internal 'owners' of capabilities

**External Capabilities (Networking)**

**Access external knowledge**
- Science
- Technology, techniques
- Artifacts, practices
- Know-how, tacit knowledge
- Information resources

**Manage producer/user relations**

**Access partners with needed Complementary assets**
- Complementary knowledge
- Complementary production
- Complementary supply-chain role

(Source: Erik Arnold & Ben Thuriaux; June 1997)

The strategic level provides the intelligence or control mechanism which allows the firm to manage its capabilities and exploit them via the market. This meta-level involves the entrepreneur in deliberately stepping outside the accustomed circular flow of daily economic life, trying to understand what knowledge makes the business succeed and using this knowledge about knowledge to increase performance.

In modern industrial practice, the strategic function does not have a monopoly of learning, but ensures that it takes place at all levels of the firm, for example through Continuous Improvement groups. Intelligence is thus distributed through the firm, rather than belonging solely to a 'heroic' Schumpeterian entrepreneur.

The second category has to do with the **internal capabilities** of the firm: its management's ability to

- ✓ Identify and invest in the right physical infrastructure to meet the competitive requirements of the firm
- ✓ Analyze its situation, identify and put in place the needed skills
- ✓ Organize appropriately, and have the vision to understand when organization needs to change

Inevitably, the right levels of attainment here are competitively determined - even though it may be convenient in the support system to think about absolute levels of performance (such as conformity with the ISO 9000 quality standard).

The third group of capabilities is external or, more precisely, concerned with managing the relationship between the firm and the outside resources which it needs. These are largely the issues addressed by the current discussions of 'networking' in the innovation literature. If contemporary writers are correct that networking is central to the innovation process, then the ability to network must itself be a crucial capability. This means, then, making use of external knowledge, using partners to access complementary assets and managing the producer/user relations which have consistently been identified in the innovation literature as key to innovative success.

Both **internal** capabilities and **external** linkages generally included under the catch-all term 'networks' are clearly important. Cross-sector studies have found that external sources contribute around one third of all knowledge used in innovation, with more being obtained from other companies than [public sector research] institutions...Of the two-third that are obtained internally, half is knowledge which is personally held [8].Tacit knowledge is therefore an extremely significant part of technological capability, though its role does vary greatly between sectors. It is a key part of the distributed intelligence of the firm. Provided technological capabilities are strong, it is possible for real firms to move towards the ideal or norm of firm behavior anticipated in the neoclassical model (Table-1)

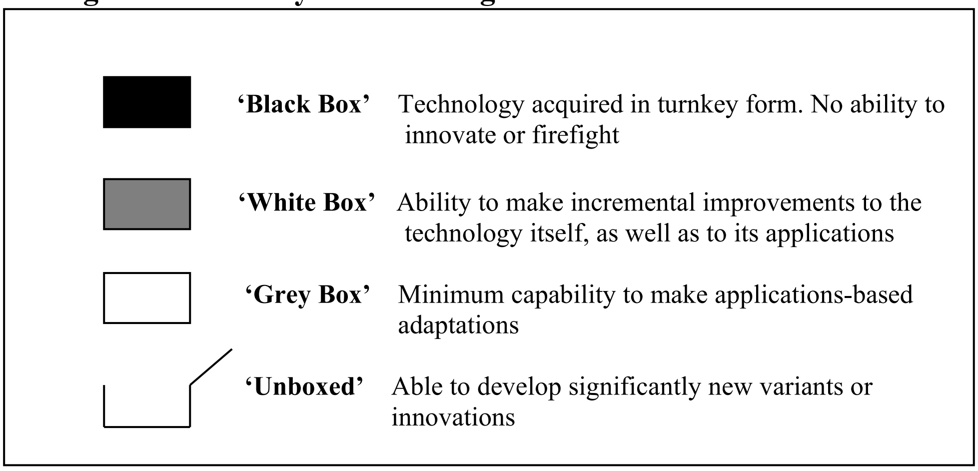
- ✓ Networking and the capability within the firm to search for and understand external signals puts it in a position to make better informed decisions
- ✓ Strategic and learning capabilities in the firm keep decisions rational and relevant to changing circumstances
- ✓ Strong capabilities provide firms with the greatest possible freedom in choice of technology, within the constraints of natural laws
- ✓ They enable innovation as well as imitation or incremental development of others' technologies

Innovation policies which encourage capability development and exploitation will therefore tend to promote efficient markets as well as industrial competitiveness.

### 2.1.6. Hierarchies of Technological Capability

What does technological capability allow firms to do? Trying to answer this question makes it clear that there are hierarchies or levels of ability. At its simplest, this hierarchical thinking is embedded in Fig-2.3, which suggests that technologies can be understood at different levels.

**Fig-2.3: Degrees of Mastery of Technologies**




(Source: Erik Arnold & Ben Thuriaux; June 1997)

For many technologies, a 'black box' understanding is perfectly adequate. Few companies, for example, would benefit from a deep understanding of the computer or telephone equipment they use every day. On the other hand, the business' core technologies generally need to be quite well understood. Whether they are acquired through internal development or by transfer, the aim will generally be to move as far towards an 'unboxed' understanding as is needed to generate and sustain competitive advantage.

Bell has set out a more detailed scheme, oriented to the inward transfer of technology to developing countries and the creation of local technological capability: Table-2.4 [9]. He spells out in a level of detail that appears unparalleled in the literature what it should be possible to do at different levels of technological development. His levels correspond closely to those we sketched in the previous Table-6, but takes on board the wider questions of the type of engineering skill needed to make investments, build machinery, develop products and link the firm with outside sources of technology.

Therefore from the various observations in literatures and number of discussion papers so far reviewed about aspects and levels of technological capabilities, it is found to be difficult to show Technological capability as overall view and hence table-2.4 is adapted to better help on describing and analyzing of those capabilities in EBMEI. The table presents detailed elements of the capability features at comprehensive and generic level that resemble the nature and practice of the metal manufacturing and engineering industries prospective in Ethiopia.

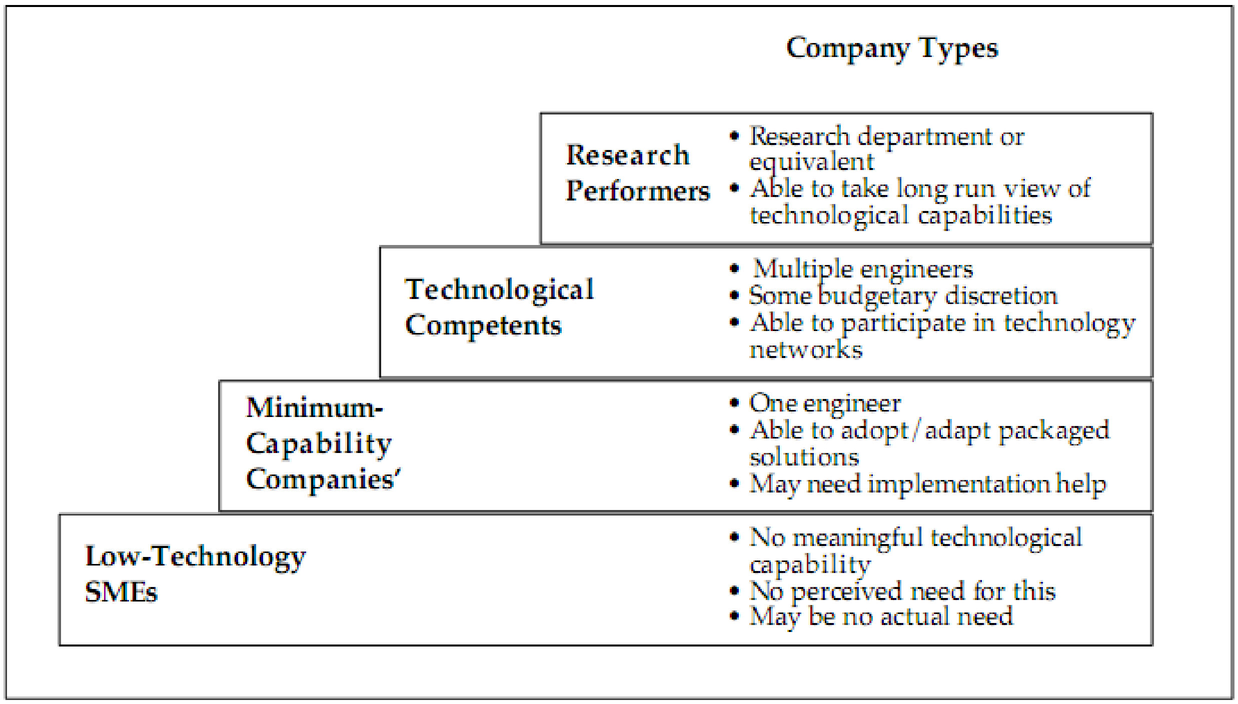
**Table-2.4: Industrial Technological Capabilities: An Illustrative Framework**

| | INVESTMENT ACTIVITIES | | CAPITAL GOODS SUPPLY | PRODUCTION ACTIVITIES | | LINKAGE ACTIVITIES |
|---|---|---|---|---|---|---|
| | **Facility User's Decision-making and Control** | **Project Preparation and Implementation** | | **Process and Production Organization** | **Product-centered** | |
| **BASIC PRODUCTION CAPABILITIES** Capabilities to use existing production techniques | • Engage prime contractor<br>• Securing and disbursing finance<br>• Officiating at opening ceremony | • Preparation of initial project outline<br>• Construction of basic civil works<br>• Simple plant erection | • Replication of unchanging items of plant and machinery | • Routine operation and basic maintenance of 'given' facilities<br>• Efficiency improvement from experience in existing tasks | • Replication of fixed specifications and designs<br>• Routine QC to maintain existing standards and specifications | • Procurement of available inputs from existing suppliers<br>• Sale of 'given' products to existing and new customers |
| **TECHNOLOGICAL CAPABILITIES (CAPABILITIES TO GENERATE AND MANAGE TECHNICAL CHANGE)** | | | | | | |
| **BASIC** | • Active monitoring and control of:-<br>- feasibility studies<br>- technology choice/sourcing<br>-project scheduling | • Feasibility studies<br>• Outline planning<br>• Standard equipment procurement<br>• Simple ancillaries engineering | • Copying new types of plant and machinery<br>• Simple adaptation of existing designs and specifications | • Commissioning and de-bugging<br>• Improved layout, scheduling, and maintenance<br>• Minor adaptation | • Minor adaptation to market needs, and incremental improvement in product quality | • Searching and absorbing new information from suppliers, customers and local institutions |
| **INTERMEDIATE** | • Search, evaluation and selection of technology/sources<br>• Tenders/negotiation<br>• Overall project management | • Detailed engineering<br>• Plant procurement<br>• Environment assessment<br>• Project scheduling and management<br>• Commissioning<br>• Training/recruitment | • Incrementally innovative reverse engineering and original design of plant and machinery | • Process improvement and 'stretching'<br>• Licensing new technology<br>• Introducing organizational changes (JIT, etc.) | • Licensing new product technology and/or reverse engineering<br>• Incremental new product design | • Technology Transfer to suppliers and customers to raise efficiency, quality and local sourcing |
| **ADVANCED** | • Developing new production systems and components | • Basic process design and related R&D | • R&D for designs and specifications of new plant and machinery | • Process innovation and related R&D<br>• Radical innovation in organization | • Product innovation and related R&D | • Collaboration in technology development |

(Source: Martin Bell et al, 1995)

Inherently, behind these hierarchies of abilities must lie a hierarchy of capabilities. Fig-2.4 shows a simple hypothesis about a useful way to segment companies according to their level of research and engineering capability. It is far from perfect, and at present we have no empirical basis for mapping it across to the hierarchies of abilities just described. (This may, in fact, only be possible at the sector or firm level.)

**Fig-2.4: Simple Hierarchy of Company Types**




(**Source**: Erik Arnold & Ben Thuriaux; June 1997)

The segmentation suggests that there are four reasonably distinct levels in the development of firms' engineering and research capabilities. At the bottom level, there is no meaningful capability and there will tend to be a presumption that none is needed. At the next level up, the 'minimum capability' level, the firm acquires at least one person able to speak the language of technology, to monitor and understand the significance of technological changes happening outside the firm. These bottom two levels of firm rarely have much contact with universities. They do not share a common language or interest with them. The professors are likely to be interested in things which are longer-term than they can consider.

In OECD countries, many larger firms belong to the third level of 'technological competent', where there is enough capability to do fairly serious development work and where there tends to be a specialized innovation or development function. The highest level firms - 'research performers' - are of two types. Some correspond to the ideal of the very large company with capabilities in research as well as development and the strength and vision to work for the long term as well as the immediate future. Others are new, technology-based firms such as university or other research spinoffs, many of which exist primarily to do research and will be absorbed by larger companies if their work is successful. These highest-level firms' research departments communicate easily with universities. Third level firms often have difficulties in doing so.

These hierarchical ways of describing technological capabilities provide useful clues about the need to segment and to build hierarchy into policies aimed at developing company capabilities more generally. What we lack is some equivalent hierarchy of the 'soft' capabilities needed to move from technological change to innovation. A static view of these capabilities is built into Table-5, but a hierarchical or dynamic view would be more useful for policy formulation.

### 2.1.7. Elements of Technological Capability

In this section, we elaborate further on individual aspects of technological capability, raising issues for support infrastructures.Table-5 does not differentiate between different sizes of firm or stages of development. Rather, it represents an ideal of capabilities that are needed for innovative and competitive success. The extent to which companies actually possess these capabilities tends to increase with firm size. This seems mainly to be because increasing size brings increasing division of labor, allowing the firm to develop and devote the specialists skills required for the various dimensions of technological capability. Small, technology-based firms are the major systematic exception: they tend to have strong information and technology networking skills, but are not always as good at business skills. Many of the tasks of the support system in increasing technological capabilities involve helping SMEs act as if they were bigger than they actually are. In the best case, this becomes a kind of self-fulfilling prophecy, where SMEs grow to become large firms [6].

### Strategic Capabilities

In addition to providing a key part of the 'search intelligence' needed to develop and manage technological capabilities, the strategic functions are the major interface with the firm's business capabilities. In particular, this is where the understanding of customer needs and desires, technological opportunities and the company's own capabilities need to be matched together. This defines the core competencies of the firm. Product strategy needs to be hammered out here, based on inputs from the three areas mentioned.

We have not extended our review to cover the huge literature on general business management. The salient point from an innovation perspective is that the ability to wrap technological issues into business strategy - and vice versa - is an important capability. This requires an awareness of business and technology issues that is often not found in the same person: a problem, especially in small owner-managed companies. Increasingly, this fact is being reflected in education, awareness and support programs aimed at capability development.

### Internal Capabilities

In the model, internal capabilities have three main elements

- ✓ Managing the tangible technology base
- ✓ Developing and managing intangible resources
- ✓ Creating the organization needed to make effective use of these assets in pursuit of the company's business mission

The tangible basis of companies' internal technological capabilities is their products and the design and production facilities employed, which need to be adequate to meet competitive needs. Choice, maintenance and renewal of these are based on design and engineering skills. In the smallest firms, these often belong to the people who are also the owners and managers. Very small firms are typically dominated by a single manager - often the owner. The capabilities of this single individual therefore have a dramatic impact on firm performance. Small enterprises which use new production technologies typically have an owner/director who is well educated or a graduate, or have supervisory staff with higher education. These people use more sophisticated management practices, including 'technology watch' to monitor relevant events in technology [10].

Generally, it seems those small firms under, say, 60 employees conduct research in a very sporadic way, unlike in big companies where a regular budget can be allocated. However, the SMEs which commercialize inventions tend to produce more radical leaps than their larger counterparts. Small innovating firms spend a greater proportion of their innovation investments than large firms on non-R&D activities. Further, "... there is a clear tendency for the share of firms who acquire outside technology to rise across size classes. Given that it is usually believed that SMEs have a greater need for external technology inputs than large firms, this suggests a role for policy."[10]

Tacit knowledge is, almost by definition, hard to manage. Codifying this knowledge, in order systematically to improve it, is an important objective of technologists. Codification may be understood as a process of generalizing what is a specific and translating message into a common and shared language. It involves the establishment of technical standards and of basing technical development on general scientific principles. A special aspect relates to the design of the innovation process itself where information technology makes it possible to pursue development work on computers through virtual experiments rather than through real tests in real laboratories.... This new step in the codification of knowledge is important because it moves the border between tacit and codified knowledge. But it does not necessarily reduce the relative importance of skills, competencies and other elements of tacit knowledge, however. The easier and less expensive access to information makes skills and competencies relating to the selection and use of information even more crucial than before. In general, skills related to handling codified knowledge become more important in the labor markets.... The most fundamental aspect of learning is perhaps the transformation of tacit into codified knowledge and the movement back into practice, where new kinds of knowledge are developed.... At any point of time a certain amount of knowledge is in the pipeline being in the process of codification. While some engineers and scientists are involved in producing innovations and inventions, a much bigger proportion is engaged in standardization and in codifying and generalizing knowledge [10].

Codification results in the production of operating procedures, manuals (including quality manuals), standards, norms and even innovations in machinery. But continuing dependence on tacit knowledge for innovation arises from

- ✓ The tendency for advances in knowledge and techniques to be associated with new tacit knowledge
- ✓ Adherence to previously successful practice
- ✓ Lack of scientific or technological expertise within certain firms or sectors
- ✓ Systems complexity, which makes it hard to provide a comprehensive codification

Because tacit knowledge is person-embodied, it follows that managing it is linked to both engineering and personnel policy. It can be transferred internally through co-work or externally via interpersonal networking. Broader workforce skills are clearly a key aspect of firm capability. Industrial training systems have long been forced to tackle the task of defining the technological capabilities required by different categories of individuals. The UK's recent and rather belated attempt to relaunch the idea of technological training through a system of National Vocational Qualifications (NVQs) is typical in trying to define "units of competence" which can be taught and tested. While undoubtedly important, a weakness of this 'bottom-up' approach to defining and implementing competences is its lack of connection to company strategy and the specific needs of the firm. A dynamic mechanism needs to be in place for reviewing needs and updating the required definitions of competence. This is a natural function of the personnel and training department in a large company, but is more difficult to accomplish in smaller firms, which may need help from the support system.

The various aspects of technological capability need to be coordinated in order to pursue the company's interests, so good internal communications between research, development, production and marketing are also necessary for successful innovation. In management terms this means there has to be a good match between business and technology strategies, as well as means to opretionalize this match.

<u>External Capabilities (Networking)</u>

External or networking technological capabilities involve

- ✓ Accessing external knowledge
- ✓ Managing the producer/user relationship which is central to successful innovation
- ✓ Accessing other partners who have useful complementary assets and capabilities

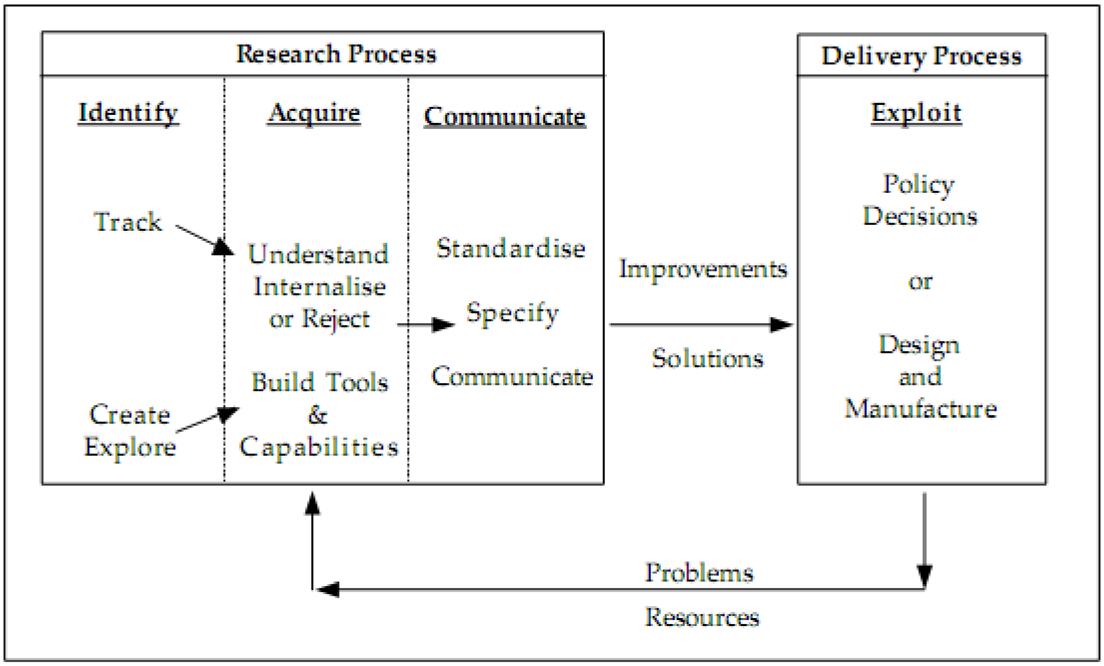
While it is tempting to dismiss as mere fashion the current tendency to describe almost any external relationship of a firm as ‘networking’, the role of such external relations in successful innovation and in learning is extremely important.
Learning is a social process. It is seldom done individually, without the support of, or isolated from, interpersonal interactions.... Innovation may accordingly be viewed as a collective activity; an outcome of communication and interaction between people.

Networking is not independent of other capabilities. A firm’s ability to forge effective external linkages depend so no small extent on its in-house skills, typically in the form of qualified scientists and engineers. “Personal relationships of trust and confidence (and sometimes fear and obligation) are important both at the formal and informal level.” [10] They reduce transaction costs because the parties involved are known to each other. They make additional transactions between the partners more likely by reducing the amount of search effort needed before making a transaction and by providing channels through which ideas and opportunities are fed to the firm. Freeman distinguishes ten types of network that are important in innovation

1. Joint ventures and research corporations
2. Joint R&D agreements
3. Technology exchange agreements
4. Direct investments (minority holdings) motivated by technology
5. Licensing and second-sourcing agreements
6. Sub-contracting, production sharing and supplier networks
7. Research Associations
8. Government-sponsored joint research programs
9. Computerized data banks and value-added networks for technical and scientific interchange
10. Other networks, including informal networks [11]

Companies increasingly take care that they locate in places where there is an adequate scientific and technical infrastructure. Some companies do, in fact, make considerable use of external information about technology. Generically, the activities involved in accessing external knowledge, integrating it with internal research and absorbing it into the company look rather like those shown in Fig-2.5.

**Fig-2.5: A Systems View of the Role of Research**

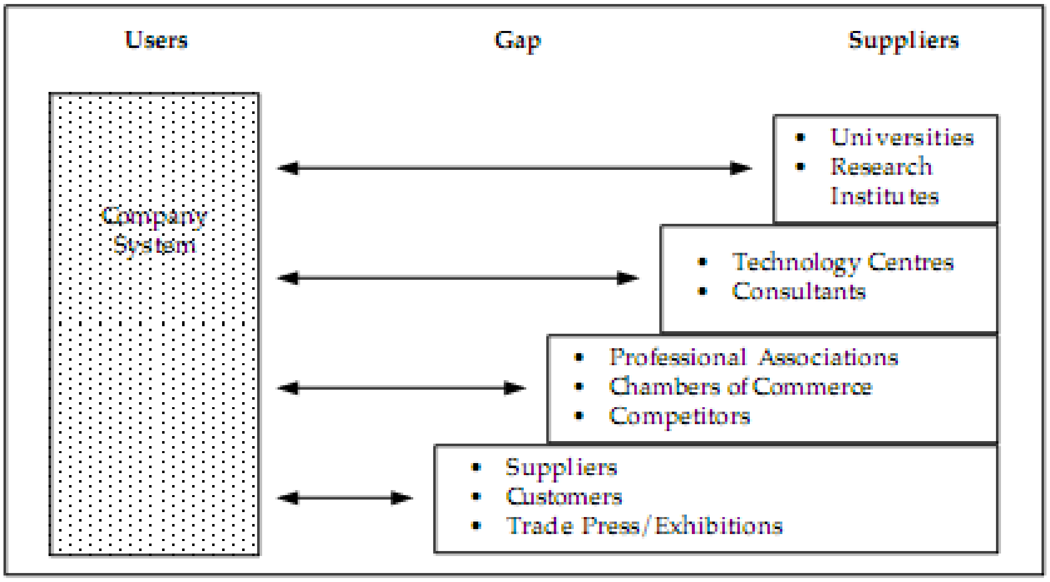



(**Source**: Roy Roth well, 1991)

Firms identify opportunities by tracking changes in knowledge and practice or (probably less frequently) by doing research which creates new opportunities. This takes effort, because information flows are imperfect. It also takes skills: both formal skills, represented by qualifications; and informal skills or experience. They must then test the opportunities, build any tools needed to understand and internalize them and communicate the results internally to those responsible for design and production.

As the table implies, doing all this involves many processes and, usually, quite a number of people. Few SMEs can afford to do these activities in-house or in a formal way. Because they lack (SME's) the resources and desire to monitor and assimilate external technology in the way shown in Fig-2.4. In practice, policy systems often try to compensate for this lack. The 'gap' between companies and potential external sources of technology can be wide. Fig-2.6 illustrates the general experience of this gap. However, the actual width of the gap varies according to the capabilities of the companies involved, and to their level of engagement with the technology supplier. Notably, studies in France, Italy and the Netherlands have noted that the presence of one or more research centers in a region is not an important factor in the effective dissemination of information unless the centre was started or is controlled by the users [11].

**Fig-2.6: Generic Gaps between Users and Suppliers of Technology**




(**Source**: Roy Roth well, 1991)

## 2.2. Measurement of Technological Capabilities

The theory and method for measurement of Technological Capability both at firm and country level have been controversial for years, although they have many commonalities both interms of their understanding of technological change, and of the statistical methods applied. These assumptions are often implicit rather than explicit and this may generate the impression that the results produced are somehow "beauty contests" where the firms ranked play the role of competitors [12]. In fact, the various statistical measures are not devoted to explore causal connections between technology on the one hand and economic and social performance on the other. Some of them have taken into account also an indicator of performance such as competitiveness, but the aim here is to identify means to successfully measures technological capabilities. If valuable, they can be used to test different and even competing hypothesis. But in another sense, these attempts do not limit themselves to the production of new statistical sources. Since they share the view that knowledge has a heterogeneous nature, all of them try to account for this heterogeneity by taking into account a battery of indicators, and even by summing them.

When any two indicators are summed, subtracted, multiplied or divided, the outcome can be meaningful only when there is an underlying theory that justifies the algorithm. On the other hand, the selection of the ingredients depends heavily on the value judgment of Researchers as well as on the availability of the data.

But generally at first, a certain consensus emerges on the understanding of technological capabilities. Although the literature discussed here is aware that technological capabilities and production capacity are strictly interconnected, it broadly shares the view that the former is a stock of knowledge which should be kept conceptually separated from the latter [12]. The two phenomena are clearly interdependent since technological capabilities generate production capacity and vice versa. However, since one of the main purposes of the economics of technological change is to quantify and specify the nature of this linkage, it is useful and necessary to separate the two concepts and finding independent measurement tools for each of them. Second, the literature shares the view that technological capabilities are composed of heterogeneous elements, which can be summarized in the following three contrasts:

a) Embodied/Disembodied,
b) Codified /Tacit, and
c) Generation/Diffusion.

To expand:

**a)** <u>Embodied/Disembodied</u>: It is recognized that technological capabilities are embodied in capital goods, equipment, infrastructures, and in disembodied forms such as human skills and scientific and technical expertise. There is ongoing debate on the relative importance of capital goods and disembodied knowledge, but there is a shared belief that both types of capability contribute vitally to the technological base of a country.

**b)** <u>Codified/Tacit</u>: Likewise, it should be stressed that the codified component of knowledge represented by manuals, blueprints, patents, and scientific publications are as important as the tacit components associated with learning by doing and by using. While it is relatively easy to quantify codified sources of knowledge, it is much more difficult to finde reliable measures of tacit components: if they were easily quantifiable and measurable they would no longer be tacit! Yet, concentrating on the codified knowledge may overlook fundamental components of the knowledge used in production. One way of quantitatively capturing these capabilities is by looking at the qualifications of the labor force, under the assumption that better educated employees have a higher learning potential.

**c)** Generation/Diffusion: Last but not least, it has long been recognized that both the production of knowledge and its diffusion and imitation provide a valuable technological resource. Some countries can be heavy producers of new knowledge but may be slow to apply it to production, while other countries may benefit disproportionately from the knowledge generated elsewhere. This implies that technological capabilities should be measured according not only to indicators of the generation of inventions and innovations, but also indicators of their application and dissemination.

Depending on the literature above researchers have been employed various approaches and/or methodologies and theories to base up on to measure firm’s technological capabilities. For instance firms could be asked to describe recent innovations, positive adaptations or changes:-

- In the products they sell,
- In production techniques and processes, or
- In the way that their enterprise organizes its business (including the form of relationship with suppliers / buyers / contractors), they were then asked to rate the impact of these innovations or changes on their businesses, in order to get a sense of the “weight” of different changes cited. On the basis of collated responses, enterprises were categorized as having relatively low, medium or high technological capability (relative to each other).

It should be noted that this method of assessment involves a subjective decision (on the part of the interviewer) and it is therefore important that the same individual or a tightly knit research team makes comparisons. Also the results cannot be used to benchmark enterprises operating in different trades, whose “normal” rate of innovations may vary greatly. Its value lies in detecting and ranking the degree of adaptability of enterprises within a similar cohort.

In summery; the measurement and comparison of level of technological capabilities need to base and consider those heterogeneous elements and shall give equal ground not to overlook some while exaggerating others to reach at a self-contained and meaningful results that could indicate the level and characteristic of technological capabilities available in firms, therefore this paper uses the classification and details industrial technological capabilities shown on table-2.4 as a base to develop questioners for accomplishing its objective of assessing the technological capabilities of EBMEI's. And the questioners and description of the assessment are presented in the next chapter.

Furthermore the paper carried an assessment on specific activities performed by firms to define areas of technological capability strength and weaknesses to be addressed by suitably devised strategic approaches. Hence it is found necessary to identify these activities and the value chain concept, developed by Porter becomes a useful tool for identifying the activities performed by the firm. For a firm in the metal manufacturing and Engineering industries sector, all the technological activities performed by it can be of two types. First, activities which result in long term competitive advantage may be considered as comprising the primary value addition activities. Second, activities that support the primary value addition activities are called support value addition activities. To elaborate:-

Technological capabilities corresponding to primary value adding activities:-

- ✓ Creation capability
- ✓ Design and engineering capability
- ✓ Marketing and selling capability
- ✓ Servicing capability

Technological capabilities on supportive value adding activities:-

- ✓ Acquisition capability
- ✓ Human resource development capability
- ✓ Information technology capability
- ✓ Strategic planning capability

# 3. DESCRIPTION OF THE ASSESSMENT AND DATA ANALYSIS

## 3.1 Background of Industries and methodology

This research paper attempts to assess the technological capabilities as per the detailed descriptions in table-7 of the previous chapter and is for the Basic Metal and Engineering Industries (BMEI) of Ethiopia, located around the major industrial zone, the capital Addis Ababa. The paper seeks to investigate the current situation and asses the technological capability of Ethiopian Basic Metal and Engineering Industries with an aim to identify and address potential challenges and indicate policy measures to be employed in order to augment the capabilities of the sector to enable it coping up with the global treats.

The scope of industries covered under this study is the large and medium size (LMSE) public and private industries located around Addis Ababa. Establishments of BMEI considered for the study are those industries which were operating at least for the last five years in organized and structured manners. According to the survey conducted by central Statistical Agency of Ethiopia (CSA, 2009), the total number of LMSE under the BMEI sub-sector in the country's different regional states and around Addis Ababa are 135 and 72 respectively. The numbers of industries under this study are those industries which lies around the capital Addis Ababa are shown in the table below.

**Table 3.1:** Summery of LMSE public and private BMEI, around Addis Ababa (2007/2008). (Source: CSA, 2009)

| S/No | Major BMEI | # of BMEI in Addis Ababa |
|---|---|---|
| 1 | Manufacture of Basic Iron and Steel | 10 |
| 2 | Manufacturing of fabricated Metal Products Except Machinery and Equipment | 48 |
| 3 | Manufacture of Machinery and Equipment N.E.C. ( Not elsewhere contend) | 3 |
| 4 | Manufacture of Motor Vehicles, Trailers & Semi-Trailers | 11 |
| Total # of BMEI | | 72 |

Those who recognize themselves as progressive companies in the metal manufacturing and engineering sector and organized an association and registered as a member in the Ethiopian Association of Basic metals and engineering industries (EABMEI) are 28 in number.

To asses and present the technological capabilities of EBMEI four sources of data's are used. each of this data sources planned to gives a ground on current situation, achievement, and future aim/vision on improving the technological capability of the Metal Manufacturing and Engineering industries at both a firm and country level. The source of data's used are:-

- Data from Survey questions
- Structured interview and direct observation of industries
- Surveying other country experiences and secondary sources

### 3.1.1 Survey questionnaires

Since the assessment shall reflect real capabilities of the industry in EBMEI's sector, as much self contained indicators or potential factors as possible were identified and structured in to questioners. Then the questionnaire was pilot-tested in order to refine before distribution and personal visits as well as phone calls were used to increase response rate.

The type of questionnaire designed to collect data is presented in Appendix-1; and the assessment questionnaire contains 29 questions requiring mainly two types of answers:

4. The first type requires objective answers and data's
5. The second type uses an ordinal scale, strongly disagree, disagree, agree, and strongly agree.

The questionnaire in this assessment is categorized into 10 sections depending on the activities in Ethiopian Metal Manufacturing and Engineering industries. The first category of questions (1to5) of part-I, is designed to collect objective data's about the firms profile.

The second category of questions (1 & 2) of part-II is related to the ability of senior management to recognize the role of technology in competitiveness and the dangers of 'standing still' in today's highly competitive environment and its aim is to evaluate the level of awareness.

The third category questions (3&4) the forth category questions (5&6) and the fifth category questions (7 to 9) were designed to assess searching capability of external technology events and trends, building of core technological competence, and capability of formulating a technology strategy respectively.

The sixth, seventh and eighth category questions (10&11), (12&13), and (14&15) are prepared to evaluate the capability to assess and select technology, acquisition capability, and technology absorbing and Implementation capabilities respectively.

The last two category of questions (16 to 18) and (19 to 24) are dealing with learning which is important part of building technological competencies, and Exploiting external linkages and incentives respectively. The objective by the later is to indicate how well-developed is the external support system for technology development by the firm.

#### 3.1.2 Structured Interviews

The design of the interviews was based on the research objectives. Interviews were conducted with top management member and concerned personals of the industries. The interviews were used to cross check the response to the questionnaire and to further investigate the performance level of specific activities as per Appendix-2.

#### 3.1.3 Direct Observation

In this research direct observation is used to assess the technical status and the production processes as a means to compare and cohere it with the collected data and information's.

### 3.2 Data collection and analysis

#### 3.2.1 Data results from questioners

The population considered under this study is Large and Medium Size Metal Manufacturing and Engineering industries under both the public and private ownership. These industries in turn are composed of four major categories as shown in Table 3.1. The population size is 72 and all of which are located around Addis Ababa, The variability regarding the nature of technology, size of the firm, business style and organizational structures are found to be low under same categories. Hence by taking this in to consideration a greatest care and attention is given to include enough and representative number of companies from each category.

The method employed follows two basic steps at (steep-1) calculates the Metal Manufacturing and Engineering industries current overall technology capability level and at (Step 2) identifies detailed strengths and weaknesses according to various important categories of the Technological Capability activities.

An overview for the overall technological capability level is assessed using the questioners below and compared between strongly disagree, Disagree somewhat, Agree somewhat, and strongly agree. On the basis of these comparisons, the following findings are summarized

**Table 3.2: Questioner data**

| No | Key Questions | Strongly Disagree | Disagree Some-what | Agree Some-what | Strongly Agree | N/A | Total |
|---|---|---|---|---|---|---|---|
| | **Assessment Score** | *1* | *2* | *3* | *4* | | |
| 1 | Technology plays an important part in my company's business strategy | | 2 | 13 | 25 | | 40 |
| 2 | My company is well aware of the technologies most important to its business | | 7 | 21 | 10 | | 37 |
| 3 | My firm is well equipped to assess technological opportunities | 2 | 23 | 12 | | 1 | 38 |
| 4 | My company can assess technology threats without difficulty | 3 | 16 | 18 | | | 37 |
| 5 | My company has special technological strengths which it is able to exploit | 25 | 10 | 3 | | | 38 |
| 6 | My company knows which technologies to outsource and which to develop internally | | 9 | 27 | | | 36 |
| 7 | Our management is skilled at formulating a technology strategy to meet business goals | 11 | 20 | 8 | 1 | | 40 |
| 8 | Our firm knows its main technology | | 12 | 24 | | | 36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | priorities | | | | | | |
| 9 | Our firm has a well developed technology ‘vision’ | | 2 | 32 | 3 | | 37 |
| 10 | Our firm knows how to select the technology needed for its business | | 7 | 30 | 1 | | 38 |
| 11 | Our company knows which are the best sources of technology | | 6 | 32 | | | 38 |
| 12 | Our company is effective at acquiring technology from external sources | | 11 | 25 | 2 | | 38 |
| 13 | Our company has good links with important external suppliers of technology | 11 | 14 | 12 | | | 37 |
| 14 | Our technology activities (e.g. engineering and R&D) are organized effectively within our company | 10 | 26 | 2 | | | 38 |
| 15 | We have clear processes for carrying out technology projects | 8 | 7 | 23 | | | 38 |
| 16 | Our company has a good system for assessing technology projects. | 8 | 24 | 2 | 2 | | 36 |
| 17 | Our firm carries out post-project reviews | 19 | 18 | | | | 37 |
| 18 | We are able to learn from one technology project to another | 9 | 3 | 6 | 18 | | 36 |
| 19 | Government policies encourage us to invest in technology | | 2 | 31 | 3 | | 36 |
| 20 | We use external organizations (e.g. consultancy firms) to assist us with technology assessment institutes in important technology projects | 3 | 9 | 26 | 2 | | 40 |
| 21 | We use outside bodies to help us develop technology | 12 | 20 | 7 | | | 39 |
| 22 | External organizations help us assess our technology performance | 15 | 19 | 5 | | | 39 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | We work with universities in key technology projects | 27 | 5 | | | | 32 |
| 24 | We work with government research | 32 | 4 | | | | 36 |

**<u>Step 1</u>: Assessing the overall technological capability level**

Here the overall Capability level of the Metal Manufacturing and Engineering industries are calculated by adding up the total scores (total possible score is 96) and entering in the analysis table below.

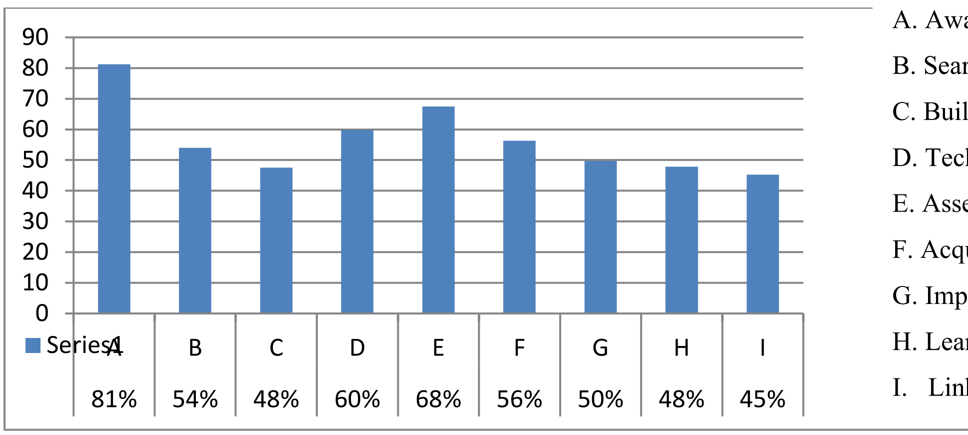
Table 3.3: Analysis

| Capability Level (1-4) | Your Score | Total Possible Score | Overall Audit Result |
|---|---|---|---|
| 1 | | 24 | Your company is weak and ill-prepared in all major areas of technology acquisition, use, development, strategy and so on; a major improvement program is urgently needed |
| 2 | | 25-48 | Your company has poorly developed capabilities in most areas of technology strategy, search, acquisition and capability building. However, there are some strengths upon which to build |
| 3 | 52.3 | 49-72 | Your company has strong in-house capabilities and takes a strategic approach to technology. In some areas, the firm is behind the international technology frontier but has many important strengths upon which to build |
| 4 | | 73-96 | Your company has a fully developed set of technological capabilities and is able to help define the international technology frontier. In many areas it takes a creative and pro-active approach to exploiting technology for competitive advantage. |

From data results of Table 3.3 the total score is found to be **52.3** and, the analysis indicates that the total score of the Metal Manufacturing and Engineering industries lie at the bottom line of "capability level-3". Hence, we can conclude that the Ethiopian Metal Manufacturing and Engineering Industries have strong in-house capabilities and take some strategic approach towards Technology. In some areas, the firm is behind the international technology frontier but has much important strength upon which to build its capability.

**Step 2**: **Assessing particular strengths and weaknesses**

At this step the results from Table 3.2 as classified in categories are further interpreted to indicate the level of the Metal Manufacturing and Engineering industries sectors of their capability of executing in those specific areas.




A. Awareness
B. Search
C. Building core competence
D. Technology strategy
E. Assessing and selecting
F. Acquiring technology
G. Implementing
H. Learning
I. Linking to external sources

Fig 3.1: level of technological capability traits

The analysis in the above chart shows the level of technological capability of metal manufacturing and engineering industries as compared to best practices. Hence the chart presented the level for each of the capability traits or elements shown at the right side of fig 3.1. According to the respondents the level of awareness about the role and importance of technology in competitiveness is found to be 81% and that is god for EBMEI sector showing the management group has at least the ability to recognizes the importance of technological capability and understand also the danger of 'standing still' in today's highly competitive environment.

Results from the second category question that was the searching ability of the firms to scan or monitor external technology events and trends has scored near to average i.e. 54% is low and paradoxical if compared to the previous result of awareness which can't be achieved without a proper searching and scanning ability in the area. The result may indicate that the sector could loss opportunities for growth or competitiveness. Large, advanced, companies often have a group of individuals permanently working on this task. In smaller companies, the managing director or a senior engineer may be responsible.

According to category three questions on building core technological competence respondents below average or 48% are agreed as their firms are on the right truck but the majorities 52% are not accepting that their firms are technologically competent. A firm with a strong technological competence will understand how its distinctive technological strengths differ from its competitors and how to further develop its skills and knowledge to remain competitive

The capability on formulation of technology strategy that is of category four questions, were the respondents result is 60% agreed for their firms are capable of formulating and the remaining 40% claims not. Today this technological strategy formulation capability is a key part of the overall business strategy of any leading firm, although firms luck this capability it is advisable to outsource for technology partners. Because it at least helps the process by which a proper visions, objectives and priorities are set and communicated within the company.

On the assessment and selection of technology results from respondents show that 68% are agreed of their firm's capability and the remaining 38% are on the opposite stand. Leading companies are able to gather information on the range of technological options available, chose quickly among competing solutions (e.g. different machines, approaches or suppliers) and identify the most appropriate source which 'fits' with their needs.

Technology acquisition, as reviewed in the literature once a new technology option is decided upon, a firm needs to deploy the resources to exploit it (e.g. by creating technology *via* in-house R&D, or by acquiring it through a joint venture or technology licensing etc.). In some cases, this may be a simple matter of buying off-the-shelf, or it may involve exploiting the results of research already carried out. In other cases it might require extensive search and research to acquire the technology. Most leading firms have well-developed skills in negotiating for the transfer of technology from external sources and for developing technology in-house. In this respect the capability of EBMEI's as per the respondents of category six questioners 56% are agreed as their firm is capable and the remaining 44% are saying their firm has not yet reached to that capability level.

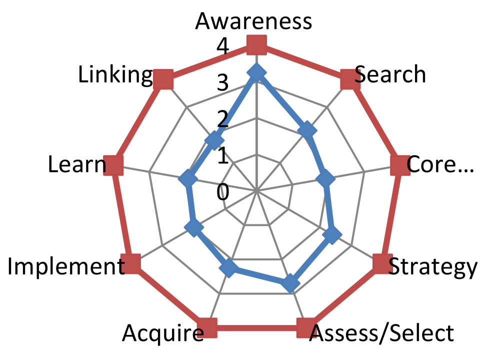
Concerning the Implementation and absorption capability the respondents on average (50%) are claiming their firms are not capable at this respect, while 50% of the respondents agreed as they lie at the right level. Implementation and absorption capability is not simple one in our context a firm in this process needs to implement the technology within the organization, which may involve various stages of further development to final launch, as in the case of a new product or service in the external market place, or a new manufacturing process or method within the organization. This often involves further innovation as the technology is adapted and reconfigured, and as well as in-house knowledge and skills, a leading firm will usually need well-developed project management capabilities to ensure implementation is effective and efficient. Hence those 50% of respondents claimed as having the capability is may be not well understood the questions or they made a random tick on the question box.

Learning which an important part is of building technological competencies, involves reflecting upon and reviewing technology projects and processes within the firm, as per the respondent of this category questions 48% are agreeing on having such capabilities by their firms and the remaining above average are rejected the availability. In leading firms this learning process can become conscious and formal, leading to continuous improvements in effectiveness, efficiency and strategy formulation. In order to learn how to manage the above technology processes better, a firm needs to systematically capture relevant knowledge from its own (and other firms') experience and act on this knowledge. Therefore EBMEI's sector is expected to work hard on the area.

According to this last category of the survey questioners on capability of Exploiting external linkages and incentives respondents below average (i.e. 45%) are agreed as their firm is capable but the majority (i.e. 55%) are rejected their capability on the practice.

In summery in each of the 8 key technology activities above, firms can and, in some cases, should make use of external suppliers of technology and related services. The final five questions (19-24) concern the different kinds of organizations which might supply the firm with services (e.g. consultancy companies, government research institutes or universities). As well as giving an indication as to the level of technological sophistication and openness of the firm, the answers can also give an indication of how well-developed is the external support system for technology development (sometimes called the 'national system of innovation').

Finally a radar plot is used to bring all results of analysis together. Thus it can help also to analyze and show further of the level of technological capability of EBMEI's sector in an integrated manner.




| | |
|---|---|
| Technology Weakness Areas | Linkage |
| | Core Competence |
| | Learn |
| Technology Strengths | Awareness |
| | Asses/Select |
| | Strategy |

Figure 3.1: Graphical Representation profile of Technological Capability of Ethiopian Metal sector

In Summery the sector needs to work hard for improving its inconsistency in performance and advised to use an integrative approach to accrue a better competitive advantage in general and to give a prior attention to those technologically weakened areas.

**<u>Step 3</u>: Ranking among sub sectors**

The sub sectors in the metal manufacturing and engineering industries namely: the Basic Iron and steel, Manufacturing of fabricated metals, and manufacturing of machinery, equipment, vehicle assembly and trailers. Are ranked to differentiate their relative technological capability levels depending on the above assessment, and the result indicates the manufacturing of fabricated metals is first by 86% of score. Following the manufacturing of machinery, equipment, vehicle assembly and trailers took the second 81%. And finally the Basic Iron and steel sub sector scored third by 78%.

### 3.2.2 Data results from interviews and direct observation

**Assessment for Specific Activities**

This assessment of specific activities for defining technological capability strength and weaknesses in EBMEI as the literature described requires accomplishing a three step procedure implementation. That is for identifying the technological capability needs and to develop indicators for technological capability assessment. The three steps in this procedure are elaborated below.

**Step 1: Identification of Value Addition Stages**

The first step of the technological capability assessment is the identification of the value addition stage(s) that the firm is involved in. Since Metal manufacturing industries execute the full range of activities and services required to bring a product or service from its conception to sale in its final markets, As per Porters Value Chain model as described above this activities are classified in to Primary and supportive activities. Therefore to elaborate our assessment of the technological capability level of the sector, a detailed/specific value adding stages are identified for both the primary and support activities as shown below:

Technological capabilities corresponding to primary value adding activities:-

- ✓ Creation capability
- ✓ Design and engineering capability
- ✓ Marketing and selling capability
- ✓ Servicing capability

Technological capabilities on supportive value adding activities:-

- ✓ Acquisition capability
- ✓ Human resource development capability
- ✓ Information technology capability
- ✓ Strategic planning capability

**Step 2: Definition of Needs**

Every activity that a firm performs requires some level of technological capability. Thus, by finding the specific activities in the value addition stages executed by the service provider, the technological capability needs can be defined.

**Step 3: Indicators for Assessment**

At this step a set of indicators which can be used for the measurement of capability are identified. Considering the existence and interaction of many qualitative factors, a number of objective and subjective indicators may be used for the measurement of technological capability elements. The number of indicators needed may vary depending on the capability being assessed. To see the details in the Appendix A (Tables A-1 to A-4), a set of possible indicators for assessing the technological capability of the sector involved in all the value addition stages (creation, design and engineering, marketing and selling, servicing,) is given. For each element of technological capability several proxy measures are suggested to enable a more comprehensive assessment. The "low" (L), "medium" (M) and "high" (H) ratings in Tables A-1 to A-4 refer to indicator values and not to the level of the capability elements. While in most cases the ratings and levels will match, this is not true in all instances. It will be necessary to observe the capability level by examining the indicator values in the appropriate context. Not all the proposed indicators will be relevant for all metal manufacturing and engineering industries as well.

### 3.2.3 Case results from selected firms

More detailed assessment based on a schedule of questions to examine specific capability requirements is employed. Depending on proximity, their diverse nature of processes and size & structure five (5) firms are selected to apply the procedures suggested above. The information was then analyzed for comparison of technological capability with best practices and the findings of all capabilities are discussed in detail below.

**Creation Capability**

The five elements of the creation capability are assessed as shown in the following table below for all selected firms and an utmost care is given to assess the real phenomenon by close following up and discussion while completing the list.

**Data results from creation capability**

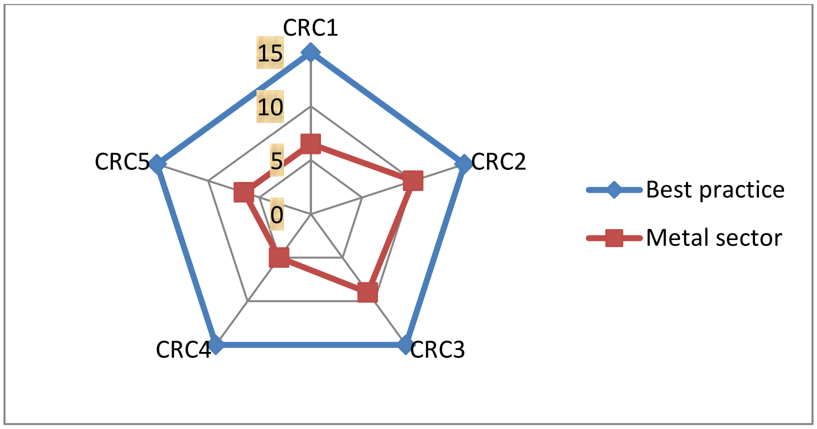
To distinguish the very crucial factors and take suitable measures for the case, data are collected and categorised as ‘Low’, ‘Medium’ and ‘high’. The extent respondents agreed for each option are shown in table.

**Table 3.4: Creation capability**

| Capability Elements | Indicators | Criteria for Evaluation | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| CRC1. Capability to adapt and modify existing process, applications, and service | R&D budget as a percent of annual turnover | 80% | 20% | |
| | Percent of research contracted to outside agencies in the total R&D budget | 100% | | |
| | Percent of R&D projects reaching completion out of total number of projects undertaken | 100% | | |
| CRC2. Capability to create new organizational structures. | Degree of dependence for undertaking major changes in the organization structure of the company during the last five years | | 100% | |
| CRC3. Capabilities to plan, monitor and control research and development projects | Percent of projects completed without cost and time overrun | 40% | 60% | |
| | Strength of linkage of R&D division with outside agencies | 100% | | |
| | Ratio of short term to long term R&D projects in terms of budgetary allocation | | | 100% |
| CRC4. Capability of managing joint venture partnerships | Increase in equity investment with partners during the last five years as the total contracts | 100% | | |
| | The outcome of the joint venture partnership | | | |
| CRC5. Capability of production process engineering | Internal defect rates | 60% | 40% | |
| | ISO 9001/2000 status | 60% | 40% | |
| | Maintenance awareness | 80% | 20% | |
| | Substitution of local raw materials | 80% | 20% | |

The level of Technological capability for one of the primary value adding stage i.e. creation capability of the sector as represented by the candidates are shown on the following graphical representation.

Figure 3.2: Graphical Representation of creation Capability




**Findings from creation capability**

The above graphical representation indicates the place where our creation capability lies in respect to international best practices and the details follow as per the indicators identified earlier:

The Capability to adapt and modify existing process, applications, and service: the assessed firms have no research and development centers and they did not carry out major work with respect to R&D. However, one of them (Akaki Spare Parts) was executing a product development work but currently some including the former have only a marketing research unit in their structure. Thus it could be stated that CRC1 is insignificant at present.

## 3.3 Technological Capability Statement

The Technological Capability overview of the Metal Manufacturing and Engineering industrial firms as a result from the assessment so far accomplished are presented here at generic level as shown below:-

- Manufacturing capability
  - In the Basic Iron and Steel Industries
    - ✓ Flat products /Billet manufacturing/
    - ✓ Steel Reinforcement Bars manufactured in various sizes

- ✓ Various Ferrous and Non-Ferrous casings
- In the Manufacturing of fabricated Metal Product Industries
  - ✓ Steel Profiles (Like: Angle irons, Flat iron, Round bars, U and I-Channels, LTZ's, Seco-profiles and sheets like corrugated and EGA)
  - ✓ Different Hollow-Sections: Square sections(SHS), Rectangular sections(RHS), Circular sections(CHS),
  - ✓ Various canes and cork manufacturing
- In the Manufacturing of Machinery and Equipment Industries
  - ✓ Spare Parts and Tool manufacturing
  - ✓ Manufacturing's of doors and windows, tankers, vehicle bodies, truck trailers, machinery like concrete mixers and vibrators

- Engineering Design & Analysis
  - Exercise AutoCAD for designing in-house assignments
  - Engineering analysis: is not Known and strange
- Innovation/Patent
  - No one firm has got a utility and/or Design patents.
- Partnerships
  - In practice it expected to have an extended network of partners specialized on various areas but the sector made no remarkable efforts beyond customer-supplier relationships.
- Engineering Services
  - Heat treatment and Electroplating
  - NDT and DT service
  - Part Manufacturing
  - Maintenance for vehicle engine parts

In summery the Ethiopian Metal Manufacturing and Engineering industry has the above detailed production capabilities which show the level and scope of the sector and its infancy to support the needs to downstream industries. A SWOT analysis is employed to investigate the pros and cons faced by the sector, so that a strategic improvement approach should be followed to trade the existing state and the Technological capability frontier.

## 3.4 SWOT Analysis

**Strengths**

- Availability of trained labor that could easily oriented to employ.
- Availability of a diverse market that could be accrued through a little value adding job
- The dynamic growth of downstream industries

**Weakness**

- Lack of strategic learning management (problem of Technological Capability development process)
- Except some SME's no large companies are working in some important categories. And those transferred or privatized a previously state owned companies are struggling to survive as like the colonized nations.
- Financial constraints are preventing private owners from channeling investments toward the machinery and equipment manufacturing sub-sector and also from getting in to various value adding product and services
- Extended failure of the sector from luck of strong governmental focus
- Rigidity of existing industrial policy focusing on agricultural lead industrialization
- The industry is highly concentrated on specific areas (i.e. manufacture of construction inputs)
- Lack of technology incubators and institution to support the Metal Manufacturing and Engineering industries

**Opportunities**

- The countries growing trend especially the construction sector has opened a diverse growing market.
- The establishments of diverse industries also are drivers to motivate the establishment for supporting industries
- Availability of a vast developing demand for spare parts etc...

**Threats**

- The main threat to the Metal Manufacturing and Engineering industries are coming from the newly establishments of the various industrial compounds by highly developing nations.
- Import market dominance in price delivery quality and quantity is also continued to be major treats to the local manufacturers.

## 4. THE NEW METALS AND ENGINEERING CORPORATION AND ITS IMPLICATION TOWARDS TECHNOLOGICAL CAPABILITY

The establishment of the Metals and Engineering Corporation (with establishment council of ministers Regulation No. 25/1992)taking the defence industries together with some state owned Engineering companies like (Akaki Spare Parts and Hand Tools SC, Ethiopia Plastic SC, and Nazareth Tractor Assembly Plant) has the following main objective of:-

- To design, manufacture, erect, and commission manufacturing Industries.
- To engage in maintenance and overhauling of manufacturing Industries
- To manufacture industrial machineries, capital goods and Industrial spare parts
- To expand and enhance engineering and technological capabilities through creating partnership for the integration and interfacing Industrial resources
- To undertake production, Manufacturing, maintenance, overhauling and upgrading of weapons, equipments and parts useful to defence and security forces for combat and war operations
- To sale its products of weapons equipments and parts to domestic and overseas buyers in conformity with the law
- To build technological capabilities of the countries defence force by identifying existing and potential needs and through research and development
- In line with directives and policy guidelines issued by the ministry of finance and economic development aimed at ensuring macroeconomic stability, to seal and pledge bonds and to negotiate and sign loan agreements with local and international finance sources
- To engage in any other related activities necessary for the attainment of its purposes.

Having the above purposes the newly established metal corporation signed an agreement with city bus for importing and assembly of 500 public buses in six month’s time. The corporation also announced its plan for manufacturing of small scale ploughing tractors for rural farmers.

Concerning the resource it entails is the best available resource/industries/ in their complexity, in addition to the nine industries which had been operated under ministry of defense it incorporated the above listed three companies which were under the Privatisation and Public Enterprises Agency (PPESA)

The nine industries which had been operated under ministry of defence and now joined to be MetEC are Dejen Aviation, Bishoftu Automotive and Locomotive, Hibret Machine Tools Engineering Complex, Homicho Ammunition Engineering Complex, Gafat Armament Engineering Complex, Power Engineering, Hitech Industry, Metal and Fabrication Industry, and Adama Garment Industry

Dejen Aviation:

Have potentials to produce: Prefabricated housing parts (Made of Fiberglass); private size plane assembling; small size boat assembling; large size fiberglass pipe Manufacturing; production of rubber parts-on preparation; Electronic Maintenance and precision parts manufacturing; etc…

Bishoftu Automotive and Locomotive:

Heavy vehicles (DAF Orals and Earthmoving types) Overhauling and assembly line; Electronic Maintenance; Electroplating lines;

Hibret Machine Tools Engineering Complex:

Heat treatment facilities; Precision parts manufacturing; various type of bullet manufacturing lines; Fabrication Units; Training facilities;

Homicho Ammunition Engineering Complex:

Ferrous and Non-Ferrous Casting (Green Sand casting); Heavy Press work section; Machining Centers; Potential:-

- Production of Machine gun bullets (for various arsenals and armored combat vehicles)
- Various Castings like Gear Box, Engine housing etc…
- Spear Parts Manufacturing for sugar and cement Industries
- For light, medium and heavy machine guns like 0.3 to 0.50-caliber

Gafat Armament Engineering Complex:

Manufacture and overhaul of hand held weapons like: Kalashnikov;

Potential:

- Precision Casting facilities (lost wax )
- Part Manufacturing and
- Dedicated hand held gun manufacturing facilities

Metal and Fabrication Industry

Manufacturing and maintenance of construction machineries

Potential:

- Fabrication facilities
- Part Manufacturing and
- Maintenance accessories

Adama Garment Industry: engaged in Production of military dress and related accessories; Power Engineering: for production and maintenance of electric power transmit ion equipment and diesel generators as well as manufacture electro and hydro mechanical equipment; and Hitech Industry: is working on Electronics engineering equipments manufacturing, research and development jobs.

In summery the assessment from the newly established metal engineering corporation signifies that the plans stipulated as per the objective above are strategically achievable with respect to the resource /technical status/ the corporation already has

The implication from the establishment of the metal and engineering corporation (MetEC) towards the technological capability development of the metal manufacturing and engineering industries of the country could be seen from different angles based on its mandates, institutional setup, and some of its recent proceedings as detailed below. It shall be noted that all the details following are opinions and/or assumptions based on the literature reviewed so far and information's gathered from various sources.

Using the mandates, if the corporation works in partnership with like SME's and if it establishes significant raw material and supply linkages in oversee, hence the medium and small sized firms may not have to face all the uncertainties, cost constraints and difficulties of creating linkages, opening new markets, hard currency shortage etc... Furthermore, if the corporation interfaces or gives access for using (providing service) its technical resource, for its stockholders (medium and small scale firms), then the establishment of the corporation will significantly improves the progress and/or development of the metal sectors Technological capability.

The other assumption relates to the institutional setup which centralized the significant resources of the nation, and the undertakings of simultaneous responsibilities by the established corporation for diffusing and development to be retained centrally. Looking from a historical pattern: In the former Soviet Union although they were used reverse engineering like Japan, but much of the responsibility for diffusion and development were rested in central institutions rather in large industrial firms like the case in Japan (10). Hence, where the recipient enterprises and countries gain little in terms of innovative capabilities and that was the ground which distinguished the developed Japan and the one who continually lagged behind Soviet Union/Russia until recent times.

# 5. RECOMMENDED TECHNOLOGICAL CAPABILITY DEVELOPMENT STRATEGY

## 5.1 The Development Process (Technological Capability)

To help for developing the current Ethiopian metal manufacturing and engineering sector it needs a well understanding of the subject matter: what and how to develop and that shall consider the empirical process employed by others to transform their situation. And then to analyze trends and prepare for catching-up, through a specific “window of opportunity” that could arise in the evolution of a technology system.

Therefore on studying the process for development of this technological capability it’s better to focus on the TC development process of newly industrialized economies (NIEs):i.e. the eastern experience. Based on reviewing various literatures on the area the TC development process in NIEs found to be following the next three steps.

1. Domestic firms transfer maturing technology from multination companies (MNCs);
2. Then they absorb the transferred technology and diffuse the technology in the firm and in the industry, even in the whole economy;
3. Eventually, these firms then develop and innovate their own, new technology.[15]

In addition, they follow a three-stage model of acquisition, assimilation and improvement of technology. According to the experience, during the early stage of the TC development, firms in developing countries acquire mature (specific-state) foreign technology from MNCs since they lack adequate local production capability. Local firms develop production processes through the acquisition of these ‘packaged’ foreign technologies. Firms merely assemble foreign inputs to produce standardized, undifferentiated goods. However, once firms acquired the transferred technology, they make efforts to assimilate the transferred technology to manufacture more advanced and related, differentiated products. Firms repeat the process with higher-level technologies in the intermediate technology stage (growing technology). If successful in growing technology, firms may eventually accumulate indigenous TC to develop and generate the emerging technologies in their own right and compete on leading-edge innovation with firms in advanced countries.

The nature of R&D changes through the progress in the three stages. Technological activities in the acquisition stage emphasize duplicative imitation, producing knockoffs and clones of the mature technology, normally without improvement to the technology. In the assimilation stage, the technological emphasis is creative imitation, producing facsimile products but with new features. In the third stage, indigenous innovation is essential [Kim 1999]. More research in developing countries support the idea that firms make efforts to master the transferred mature technologies and practice them efficiently.

To summarize, the practice of TC development process in (NIEs) is as follows:

- ❖ In the developing countries, the state of technological capability develops from mature technology to growing technology and to the emerging technology.
- ❖ Most of the firms in these countries are at the stage of mature technology, few reach the emerging technology stage.
- ❖ There are clear and visible boundaries between the different three stages.
- ❖ The technological capability must develop from one stage to the next, step by step.
- ❖ The main R&D activities of the firms in the developing countries are acquisition and assimilation the transferred mature technologies, not development of the mature technology.

Finally :( Fig.5.1) in advanced economies, technology life cycles are long and relatively distinct (upper part of the figure). Firms in developing countries could acquire, and then assimilate, foreign technologies in order of maturity: first, technologies that are already in a phase of recession, then second, technologies that are mature, then third, technologies that are growing. In the fourth stage, domestic firms develop indigenous technologies themselves, as they have reached the international level of technological capability. Since they do not have to undertake much technology research by themselves to create those technologies, they can concurrently import and assimilate these technologies, hence their technology stages collapse and become interlaced.

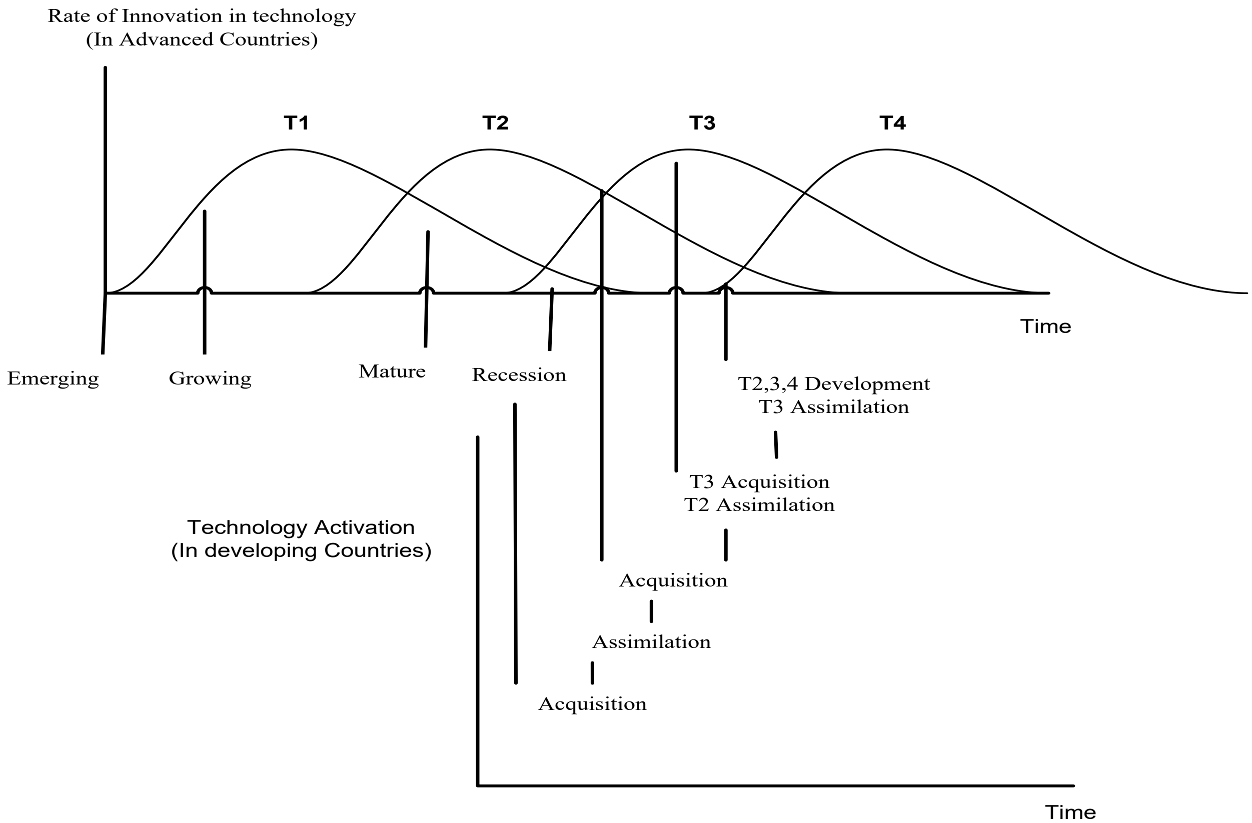



Figure 5.1: Four stages of TC Development

Therefore, the framework shown above is about the process of development that could help for fast caching-up of the TC which could enable our local Metal Manufacturing and Engineering Industries sector to operate at advanced, cost-effective and globally competitive manner. Hence to bring the system, having the appropriate process and stages being well understood, then it's advisable to follow the footsteps how they exercised, and benchmarking their practice will help to build/innovate a model which better fits ours context.

## 5.2 Benchmarked Best practice

The purpose of this benchmark is to identify the key features of other countries catch-up process so that to propose a model to catch-up for Ethiopian metal manufacturing and engineering industries, which considers key features of the current situation.

### 5.2.1 The practice of catching up in Japan and Korea

- They followed three stages from imitation to innovation.

- The first stage is to acquire mature technology from developed counties, the companies will learn some production technology from this, in Japan technology import and reverse engineering are very important for catching up for the first stage.

- In the second stage process development and product design technologies are acquired. They took incremental process innovation as their core competence to win the competition with companies in developed countries, that is a reversed innovation process rather product innovation coming first. In Japan reverse engineering and in-house R&D are their top priority in industrial enterprises to catch up; Japanese firms had a strong propensity to invest in production processes.
- In the third stage, companies will do R&D work and get the capability to product innovation.
- In all of the above cases, the role of government and other institutions are also cited. In Japan, the government, especially the Ministry of International Trade and Industry (MITI), was able to judge the direction of technological change and mobilize technological and capital resources to pursue national strategic goals in line with that change. The government helped industry to forecast the new technology trends and facilitated coordination among companies and with universities [13]. The educational system and enterprise training, in this sense, also supported the accumulation of necessary skills to support innovation activities. In Korea, the government also acted as a catalyst to promote innovation in Korean firms.

### 5.2.2 The chinese cutch-up Experiense

- The Chinese catching up is a process market-oriented innovation with global technology outsourcing. A kind of “outsourcing innovation”, which employs global networks of partners”, to cut costs and reduce the lead time for new product development.
- Modularity, globalization of technology and IT are the three key factors of new development paradigm for Chinese catching up.
- Leading Chinese companies now are more willing to merge technology division of multinationals to strength their R&D function.

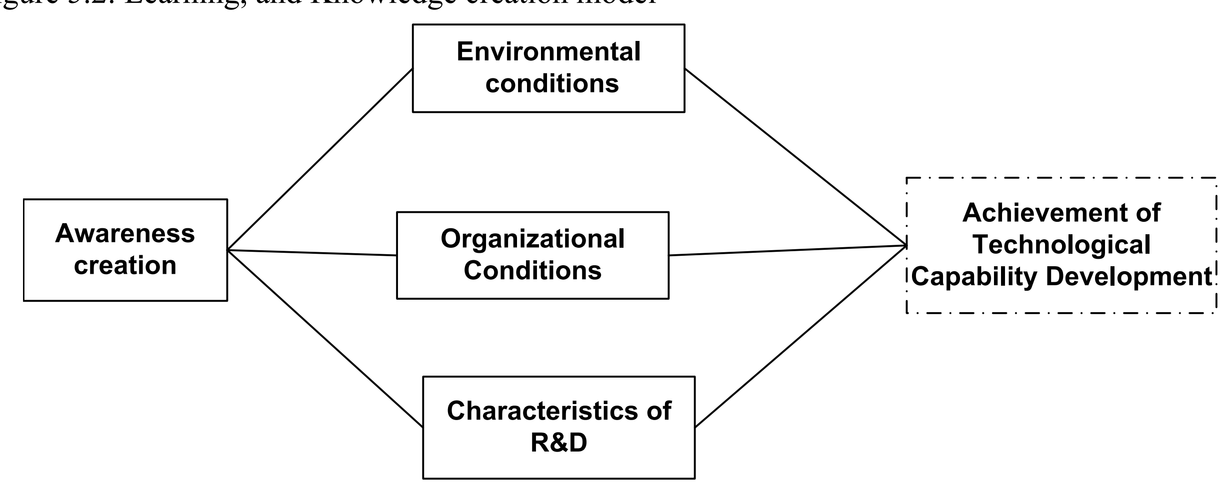
Technological capability doesn't come overnight, and are not seen as flowing freely across country (or organizational) boundaries as the early neoclassical growth model deals. Instead, technology and especially the innovative process from which it arises and applied are closely related to specific firms, networks and economic institutions. These technology and innovation are central to the catching-up process, and a country (or firm, for that matter) must be able to use a specific "window of opportunity" that may arise in the evolution of a technology system to catch-up. As the case with Japan since 1960's for consecutive decades then following by Korea and recently China were used such windows of opportunity but with own unique approaches at different situations as shown above (Benchmark of best practices). The other significant factor in building up these capabilities is Technological regime, which highly affects the nature and success of the innovative activities of those firms trying to catch up; having this I propose the following strategies to be followed for improving the status and level of technological capabilities of Ethiopian Metal manufacturing and Engineering industry sectors.

## 5.3 Technological Capability Development framework

**Awareness Creation**

In a strategy towards developing technological capability in our context, what has to come first is the need and understanding of the logic and concept of Technological Capability, then to sense the importance and the way others has been exercising (i.e. process of building TC) as shown above. Based on the findings so far I propose the following framework of Learning, Knowledge creation, and acquisition model for better understanding of the logic.

Figure 5.2: Learning, and Knowledge creation model



### 5.3.1 Awareness

This includes a process of social learning about the concept the importance and the effective way of technological capability development and furthermore the process of knowledge acquisition. It refers also the ability of managers to recognize the role of technology in competitiveness and the dangers of ‘standing still’ in today's highly competitive environment. This is because the essence of TCD is knowledge acquisition and it has a set of features, effective addressing of this features in R&D will help to make TCD more effective.

### 5.3.2 Organizational conditions

Organizational conditions are a set of conditions that influence a firm’s choice of how to develop its technological capabilities-to follow the “normal” way, or to develop key technology internally. The normal” way of technological capability development for firms in developing countries is to buy technology, absorb the technology, and then develop new technology.

### 5.3.3 Environmental conditions

Firms operate in certain environmental conditions, and different firms might face different environmental conditions that influence their technological capability development. Here the first condition for example is MNE’s (Multinational enterprises) policy of technology transfer. It’s possible that MNE’s might have different technology transfer policies some might be more willing to transfer their technology to firms in developing countries than others, depending on their gain or loss game. The other condition is also MNE’s policy of engagement in the local market, if they believe that localization is critical for its success in developing country it will be willing to have a deep engagement policy and localize its production, or even set up R&D organizations in the local market.

### 5.3.4 Characteristics of R&D

Technology can be understood as a set of knowledge and a lot of studies have shown that knowledge has the following features:

- Knowledge is cumulative
- Knowledge Acquisition is costly
- Knowledge Acquisition is a creative process
- Knowledge Acquisition is likely to cross firm boundary
- Different kinds of knowledge have different features of absorption and creation

**Recommended framework**

Having the above model Technological capability development is significantly affected by the way how those characteristics are being addressed in the firms R&D activities. With that respect the findings of the assessment from the metal and engineering industries indicate that R&D lies at a very infant and misconceived stage. Furthermore the Metal Manufacturing and Engineering Industries lack clear and guided approaches for practicing and/or studying and implementation for better achievement of the various stages of the technological capability levels. Because of that the following hieratical approach/Model/ (Table:5:1) for developing technological capability is recommended specially for companies already engaged in the Metal Manufacturing and Engineering Industry business. Hence the convenient way to looking up of the Table shall follow the following figure 5.3. [The model is developed based on the various assessment results and the literature reviewed particularly Table2.3 and Table2.4]

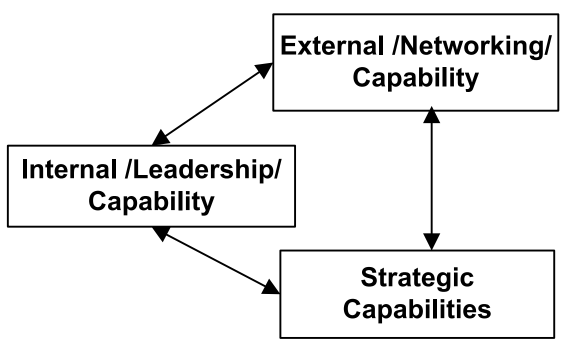



Fig. 5.3 Key for reading table 5.1

**Table: 5-1; Illustrative model/hierarchy Recommended for Developing Technological Capabilities in the Metal Manufacturing and Engineering Industries of Ethiopia**

| | Internal /Leadership/ Capabilities | | | | | | External Capabilities (Customer & Market focus) | Strategic Capabilities |
|---|---|---|---|---|---|---|---|---|
| No | Description | Details | Examples (sub Sector Based) | | | Remarks | | |
| | | | Basic Iron & Steel | Fabricated metals | M/Ch, Equip., & Motor Vehicle. | | | |
| 1 | Managing tangible technology bases | Products | - Billets<br>- Reinforcement bars<br>- V. Castings | - Steel profiles<br>- Parts & Tools | - Machinery<br>- Vehicles &<br>- Equipment | Enable them adequate to meet the competitive needs | Procurement of available inputs from existing suppliers<br><br>Sale of 'given' products to existing and new customers | Search for market opportunities<br><br>Understand and manage the fit between the firm' s capabilities and market needs (Including: Capability to manage data, information, and knowledge) |
| | | Production facilities employed | Shall not be obsolete ( recession - Matured – Growing – emerging) depends on the strategic approach on hand | | | | | |
| | | Routine operation and basic maintenance of 'existing' facilities | - Replication of fixed specifications and designs<br>- Routine QC to maintain existing standards and specifications | | | Develop the basic design and engineering skill | | |
| | | R & D facilities | Various testing Instruments | | | Ensure proper laboratory facilities | | |
| | Develop and manage appropriate intangible resources | Qualification and skills profile adapted to the needs of the firm | Prepare profiles for engineering expertise<br>Work on the aspect of human resource development and management | | | This shall result in preparation of operating procedures; quality manuals, standards & norms | **Access external knowledge**<br>• Science<br>• Technology, techniques<br>• Artifacts, practices<br>• Know-how, tacit knowledge<br>• Information resources | |
| | | Codifying intellectual capital (Tacit knowledge) | Transformation of tacit to codified knowledge | | | | | |
| 2 | Creating needed organization | Technology management Capabilities | - Copying new types of plant and machinery<br>- Simple adaptation of existing designs and specifications<br>- Improved layout, scheduling, and maintenance | | | - For Capital goods related and production activities<br><br>**At Basic level** | - Searching and absorbing new information from suppliers, customers and | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | - Minor adaptation to market needs, and incremental improvement in product quality | | local institutions | |
| | | Change-management capabilities | - Active monitoring and control of: - feasibility studies; technology choice/sourcing; project scheduling. | | | |
| | | Technology management Capabilities | - Incrementally innovative reverse engineering and original design of plant and machinery<br>- Process improvement and 'stretching'<br>- Licensing new technology<br>- Licensing new product technology and/or reverse engineering<br>- Incremental new product design | **At intermediate level** | Access partners with needed Complementary assets; Knowledge; Production; supply-chain role etc…<br><br>Technology Transfer to suppliers and customers to raise efficiency, quality and local sourcing | |
| | | Change-management capabilities | - Search, evaluation and selection of technology/sources; Tenders/negotiation; Overall project management<br>- Detailed engineering; Plant procurement; Environment assessment; Project scheduling and management; Commissioning; Training/recruitment<br>- Introducing organizational changes (JIT, etc.) | | | |
| | | Technology management Capabilities | - R&D for designs and specifications of new plant and machinery<br>- Process innovation and related R&D<br>- Radical innovation in organization<br>- Product innovation and related R&D | **At Advanced level** | Collaboration in technology development | |
| | | Change-management capabilities | - Developing new production systems and components<br>- Basic process design and related R&D | | | |

In summary**:** Especially on selecting production facilities in all sub sectors I recommend it to range from matured to growing technologies. This is mainly because below the matured range the importers may face a serious trouble on spare parts shortage and above the growing range i.e. emerging technologies it will be more expensive and lesser access for knowledge and technology transfer opportunities and also a potential lack on expertise services as the technology is very new.

## 5.4 Recommended strategic views on achieving the 5 years Growth and Transformation Plan (GTP) of (2010/11 – 2014/15)

In the growth and transformation plan out of the seven main strategic pillars for mentioned, ensuring the industry sector to play a key role in the economic development of the nation and, Expanding and improving the quality of economic infrastructure are the two interrelated pillars that directly influenced by the technological capability level of the nation. Therefore the strategic development targets at macro level are as listed below:-

Table 5.2: GTP for the Industrial Sector

| **The industry sector development targets** | **Start (2010)** | **End (2015)** |
|---|---|---|
| Sugar production (in thousand tons) | 314.5 | 2250 |
| Revenue from garments export (in million USD) | 21.8 | 1000 |
| Revenue from export of leather and products industry (in million USD) | 75.73 | 496.5 |
| Total national cement production capacity (in million ton) | 2.7 | 27 |
| Per capita steel consumption (in kg) | 12 | 34.72 |
| **Infrastructure** | | |
| Railway transport network | | 2395 |
| Energy: Power Generation capacity | 2000 | 8000 |
| Construction and Urban Development**:** Provision of housing and basic services (number of houses) | 213,000 | 700,000 |

[Source: Performance Evaluation of the First Five Years Development Plan (2006-2010) and Growth and Transformation Plan (GTP) Next Five Years (2011-20015); Ministry of Finance and Economic Development July 2010; Addis Ababa]

Further details on the existing status, planed projects and requirements to be ensured in the coming five years are classified below as found from various sources

**Basic metal Sector:** contributions required from the basic metal sector for ensuring the accomplishment of projects under the following sub sectors are: - (Requirements)

- ✓ **Energy:**
  *Current*: 1,600MW (Hydro (86%); Diesel (13%); Geothermal (1%))
  *Plan*: 11,600 to be newly developed (Hydro (10,710MW) Wind (540MW) Geothermal (350MW))
  - ➢ Supply of Penstocks
  - ➢ Accessories and transmission towers for High/middle/and low voltage transmissions: (for plan of extension about 2,440KM transmission lines)
  - ➢ Various parts for wind power generation systems
  - ➢ Water Gate and valve for Dam Gear box etc…
  - ➢ Transformers
- ✓ **Construction**
  - ➢ Reinforcement bar and various metal related construction inputs
  - ➢ Railway bars etc…
- ✓ **Cement and sugar**
  - ➢ Mill rollers crown gears and various related spares
  - ➢ Cement balls
- ✓ **Railway transportation network**
  - ➢ Railway bars and Reinforcement ribs
  - ➢ Bolts and Nuts
  - ➢ Electric poles and transmission cables
  - ➢ Train body, structure, and power system

**Basic metal Sector:** (plan)

- In accomplishing the above and related jobs it is expected and planed to Increase steel consumption per capita from 12kg (current) to 34kg (African average)
    - These means 0.96 million tons (current) to 3.06 million tons (5 years later; assuming 2.5% pop. growth).
    - World average is approx. 200kg

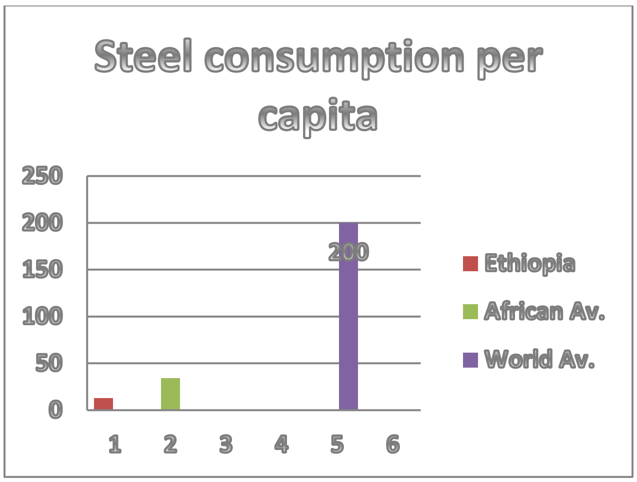



Fig. 5.4: Per Capita steel consumption

As we see the Fig.5.4 above the GTP is attempting to reach the level of African average.

- Full capacity utilization
- Develop local design/manufacturing capability (90% of leather industry; 35% of textile industry; 85% of sugar industry; 85% of cement industry; 95% of construction steel; 85% of small & medium transport vehicles)

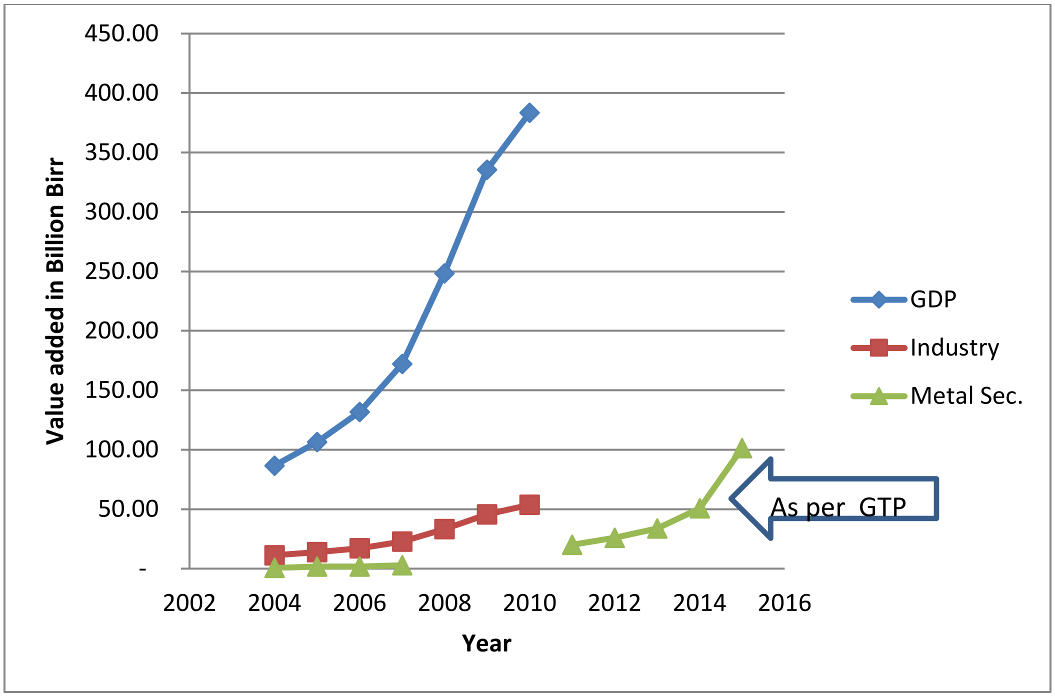



Fig 5.5: Value adding Trend of Ethiopian economy

As seen from the figure above the recent trends since 2004 of GDP growth in value of Ethiopian economy is showing an up righting trend and the data taken from the Growth and Transformation Plan (GTP) of 2010/11 to 2014/15 concerning the metal sector shown at the right, in the figure also implies a positive trend. And probably this shows that government is starting to trust on the importance of the sector

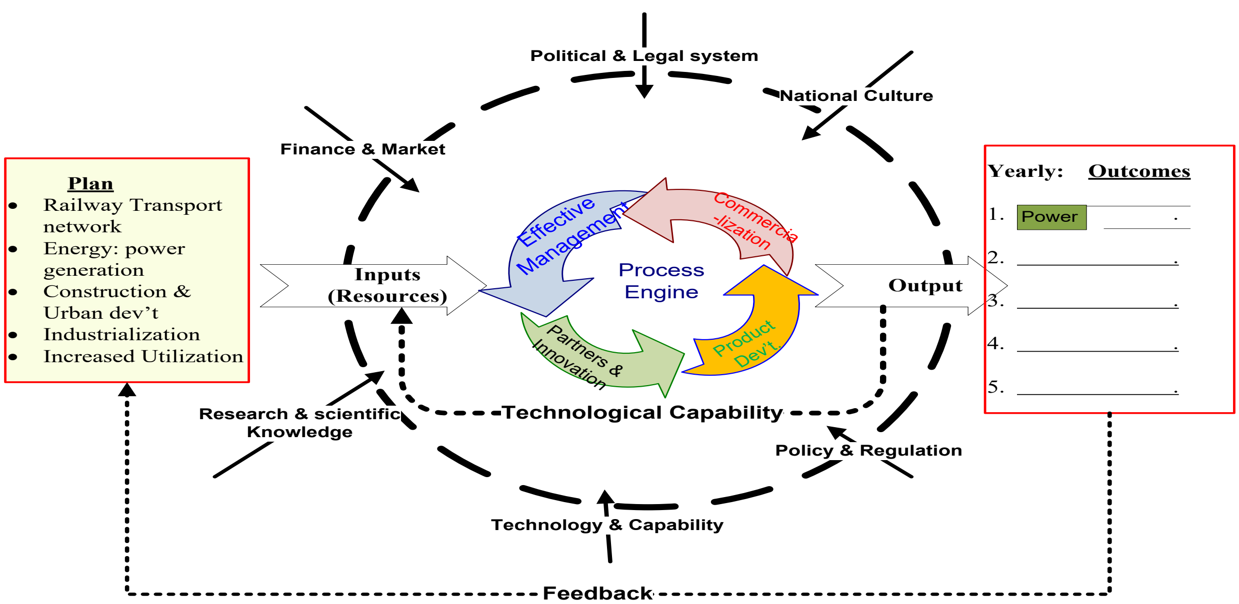



Fig: 5.6 Transformational process Model

The model above shows the Transformational process particularly of the Ethiopian metal manufacturing and engineering industries as per the GTP (2010/11 to 2014/15). The basic idea of the Model is as any other operational process the Transformational process engine receives the various inputs, and executes the operation to deliver output. But the quality of outputs (i.e. achievement of the GTP plan) depends mainly on the quality of the overall direct and side inputs as shown in the model.

**Inputs (**resources**)**: these are the nation's natural, economic, or military assets: the natural, economic, political, or military assets enjoyed by a nation, e.g. mineral wealth, labor, capital, or military personnel etc. Furthermore these could include information, ideology and rationale.

**The Transformation process** (Process engine): the Transformation process having the various inputs with the plans stipulated at the left side of Fig, 5.5; the environmental inputs or constraints like:(Policy & Regulation, National Culture, Political & legal Systems, Technology & Capability, Finance, and Research & Scientific Knowledge etc); and Process Feedbacks, and operates in a way to efficient and effectively managed process to create partners, promote and ensure innovative works, to focus on product development and commercialization in effect to deliver the outputs at the right side of the fig.

**Outputs**: the outputs expected are those inputs fed as a plan to the transformation process engine and as shown in fig.5.5, are classified in yearly achieved outcome bases. Since on the Growth and Transformation Plan (GTP) the tasks are not clearly stated on timely based or as time bounded outcomes, therefore the outcome box is listing those tasks in progress or achieved ones.

**Feedback**: such a transformational process principally is a self learning process and the return of part of the process or output could serve as inputs, and the operation would feeding itself to optimize the outputs.

**Recommended scheme**

In the Manufacturing of Basic Iron and Steel sub sector we have only a conversion process for scraps, slabs and billets etc in to primary metal products. If we have to achieve the growth and transformation plan i.e. increasing our current consumption of 12kg per capita by three folds, we deadly need to have an Iron making process locally that can support the increasing shortage of scraps and it shall also supplement the gap to fill the growing requirement. On the idea of iron making process I recommend the following points to be considered.

- Government shall fund for the exploration work to study and locate the potential areas for iron ore and coal composites which are to be traced throughout the country

- Establish a forum for research and development among universities and public and privet research & development institutes to work on technology transfer, diffusion or development of medium and small scale capacities for producing Iron from Iron ore, through alternative iron making processes as shown in the figure below.

- Promote and support medium and small scale firms to get on running the technology such as DRI (Direct iron reduction: FASTMELT, ITmk3, ) or SM (Smelting reduction process: FINEX, HISMELT, etc)for producing Iron nuggets as shown in the picture below and supply it for local steel makers

ITmk3 product" Iron nuggets"

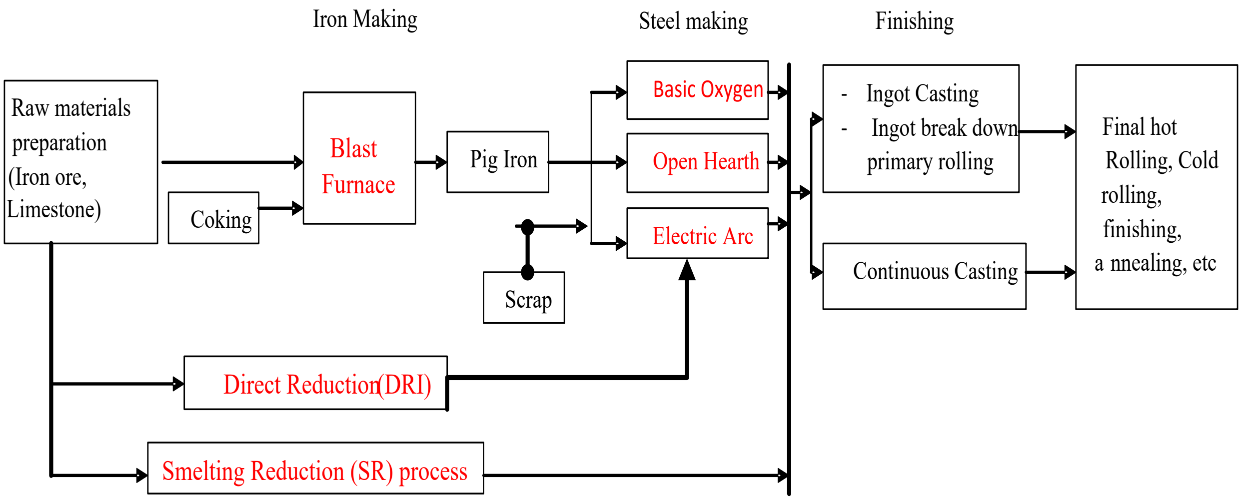



Fig. 5.7 Alternative metal production processes

In the Manufacturing of fabricated Metal Products, Machineries, and Equipment sub sector I recommend the following points to be considered

- Working on the development of design and engineering capability for building the confidence and creating the attitude towards hardworking in the area.
- Support and Promote a reverse engineering works on the major turn key projects
- Work on improving Management and maintenance working capability
- Promote product development works
- Encouraging collaborations between producers and users of steel; and upstream and downstream manufacturers
- Developing the skilled and qualified workforce
- Promoting new applications of steel in selected industries etc…

# 6. CONCLUSION AND RECOMMENDATION

Based on the survey from selected Ethiopian metal manufacturing and engineering industries, this assessment/research work presents the current status of the industries technological capability scenarios. Development strategies for improving or renovating the current situation of the sector are presented and which hopefully will address the major shortcomings.

To enhance the level of technological capability in Ethiopian metal manufacturing and engineering industries and to build a commercially competent sector, needs the managing team to be very dynamic to set a strategic directions that best fit to the industries specific nature and exploit side advantages through strengthening of the complimentary firms while leading towards the technology frontier.

From government side as presented in the benchmarked best practices our case needs to judge the direction of technological change and mobilize technological and capital resources to pursue national strategic goals in line with that change. Furthermore the government also expected to help industries to forecast the new technology trends and facilitate coordination among companies.

Finally an assessment like this would be better if it has been conducted on a way of providing introductive orientation and/or awareness creation about the concept and terminologies of technological capability with the main actors in the sector first and then to conducting the assessment would have given a better results at least with less chance of misleading from the reality.

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**Apendix-1: Questioners**

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

GRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

**Dear Sir/ Madam**
**Completion of research questionnaire**

I am a student in AAU and currently conducting a research entitled, "Assessment on Technological Capability of Ethiopian Metal manufacturing and engineering industries" for Partial Fulfillment of the Award of Masters degree in Industrial Engineering Stream.

I should appreciate if you would complete the attached questionnaire or direct it to the person in charge with this responsibility. Due to limited resources a fairly small sample was selected to receive this questionnaire, thus your response is very crucial to the success of the survey.

> Technological capability: is defined as the knowledge and skills required for firms to choose, install, operate, maintain, adapt, improve and develop technologies (Romijn and Albaladejo, 2004)

## I. Introductory part

Company Name…………………………………………………………..Date………….....

Number of permanent employees / Annual turnover……………………………………….

Product type/market……………………………………….……………….……………………...

Name of interviewee……………………………………….…………………………..………

Change in no of product mix

1. Which could best describe your company? (select only one)

   - ☐ Basic Iron and steel (Rolling mills and profiling)
   - ☐ Steel structure and fabrication
   - ☐ Spare parts and tool manufacturing
   - ☐ Manufacturer of Vehicle body and trailers
   - ☐ Manufacturers of machinery and equipment
   - ☐ Other ____________________________________________

2. Do you execute /practice one or some of the following activities in your daily business operations, please indicate in the check box.

| | | |
|---|---|---|
| 1 | Reverse Engineering | |
| 2 | Preparation of Design | |
| 3 | Performing Research and Development (R&D) | |

3. Have you experience some innovations in any one of the following areas during the last five years? Please indicate in the check box.

| | | |
|---|---|---|
| 1 | Product, (own Brands) | |
| 2 | Process, and | |
| 3 | Organizational innovations | |

4. Please indicate your permanent employees as classified below:

| | Description | (Amount) |
|---|---|---|
| 1 | Management personnel's | |
| 2 | Number of technicians | |
| 3 | Number of Engineers | |
| 4 | Others | |
| | Total | |

5. How about your Company's expenditure on:-

| | Description | (Amount) |
|---|---|---|
| 1 | Training expenditures | |
| 2 | R&D investment (annual budget/expenditure) | |

II. Please answer the following questions according to the scale presented – enter 1, 2, 3, or 4, for each question.

| No | Key Questions | Strongly Disagree | Disagree Some-what | Agree Some-what | Strongly Agree | *N/A* |
|---|---|---|---|---|---|---|
| | **Assessment Score** | ***1*** | ***2*** | ***3*** | ***4*** | |
| 1 | Technology plays an important part in my company's business strategy | | | | | |
| 2 | My company is well aware of the technologies most important to its business | | | | | |
| 3 | My firm is well equipped to assess technological opportunities | | | | | |
| 4 | My company can assess technology threats without difficulty | | | | | |
| 5 | My company has special technological strengths which it is able to exploit | | | | | |
| 6 | My company knows which technologies to outsource and which to develop internally | | | | | |
| 7 | Our management is skilled at formulating a technology strategy to meet business goals | | | | | |
| 8 | Our firm knows its main technology priorities | | | | | |
| 9 | Our firm has a well developed technology 'vision' | | | | | |
| 10 | Our firm knows how to select the technology needed for its business | | | | | |
| 11 | Our company knows which are the best sources of technology | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | Our company is effective at acquiring technology from external sources | | | | | |
| 13 | Our company has good links with important external suppliers of technology | | | | | |
| 14 | Our technology activities (e.g. engineering and R&D) are organized effectively within our company | | | | | |
| 15 | We have clear processes for carrying out technology projects | | | | | |
| 16 | Our company has a good system for assessing technology projects. | | | | | |
| 17 | Our firm carries out post-project reviews | | | | | |
| 18 | We are able to learn from one technology project to another | | | | | |
| 19 | Government policies encourage us to invest in technology | | | | | |
| 20 | We use external organizations (e.g. consultancy firms) to assist us with technology assessment institutes in important technology projects | | | | | |
| 21 | We use outside bodies to help us develop technology | | | | | |
| 22 | External organizations help us assess our technology performance | | | | | |
| 23 | We work with universities in key technology projects | | | | | |
| 24 | We work with government research | | | | | |

Table: A-1 Creation Capability Elements and Possible Indicators for their Assessment

| Capability Elements | Indicators | Criteria for Evaluation | | |
|---|---|---|---|---|
| | | Low | Medium | high |
| CRC1. Capability to adapt and modify existing process, applications, and service | CRC12. R&D budget as a percent of annual turnover | If less than 1% | If between 1 and 5% | If more than 5% |
| | CRC14. Percent of research contracted to outside agencies in the total R&D budget | If less than 20% | If between 20 and 50% | If more than 50% |
| | CRC15. Percent of R&D projects reaching completion out of total number of projects undertaken | If less than 60% | If between 60 and 80% | If more than 80% |
| CRC2. Capability to create new organizational structures. | CRC21. Degree of dependence for undertaking major changes in the organization structure of the company during the last five years | If outside consultants are required only to review company's action plan | If company is dependent on outside consultants for analysis of business environment but not for action plan formulation | If completely dependent on outside consultants |
| CRC3. Capabilities to plan, monitor and control research and development projects | CRC31. Percent of projects completed without cost and time overrun | If less than 70% | If between 70% to 80% | If 80% or more |
| | CRC32. Strength of linkage of R&D division with outside agencies | External agencies are rarely or never involved in R&D project selection, or joint research projects involving an amount less than 5% of R&D budget. | Few external entities are involved in R&D project selection informally, and joint research projects involving external (to the service provider) entities fall between 5 to less than 10% of R&D budget | Major external entities are involved through a well structured consultative body, and level of joint research projects involving external (to the service provider) entities exceed 10% of R&D budget. |
| | CRC34. Ratio of short term to long term R&D projects in terms of budgetary allocation | If l or less than 1 | If more than 1 and less than or equal to 1.25 | If more than 1.25 |
| CRC4. Capability of managing joint venture partnerships | CRC41. Increase in equity investment with partners during the last five years as the total contracts | | | |
| | CRC42. The outcome of the joint venture partnership | If the joint venture partnership brings in lot of conflict | If the joint venture partner sticks to the original agreement and is not very flexible in making the necessary changes as and | If the joint venture partner is very flexible and operates well with necessary changes |

| | | | | |
|---|---|---|---|---|
| | | | when it is required | |
| CRC5. Capability of production process engineering | Internal defect rates | No measurement | <2% | >2% |
| | ISO 9001/2000 status | no accreditation | ISO 9001/2000 in-progress | ISO 9001/2000 obtained |
| | Maintenance awareness | repair when breakdown | preventive system | TPM (total productive maintenance) etc… |
| | Substitution of local raw materials | None | Little | A lot |

Table: A-2. Design and Engineering Capability Elements and Possible Indicators for their Assessment

| Capability Elements | Indicators | Criteria for Evaluation | | |
|---|---|---|---|---|
| | | Low | Medium | high |
| Capability of product development and productivity engineering | Copying (reverse engineering) | None | Ad-hoc | Systematic |
| | Introducing new products in-house | None | Some | Considerable |
| | Improvement on existing products | None | Some | Considerable |
| | Industrial Engineering and Productivity improvement activities | none | Some | systematic |

Addis Ababa University

School of Graduate Studies

Faculty of Technology

Mechanical Engineering Department

**TECHNOLOGICAL CAPABILITY ASSESMENT IN**

**METAL MANUFACTURING AND ENGINEERING INDUSTRIES**

**(ETHIOPIA)**

**BY: MANDEFRO TADESSE**

## APPROVED BY BOARD OF EXAMINERS:

| | | |
|---|---|---|
| ______________________ | ______________ | ________ |
| CHAIRMAN, DEPARTMENT GRATUATE COMMITTEE (DGC) | SIGNATURE | DATE |
| DR. TAFESE G/SENBET | ______________ | ________ |
| ADVISOR | SIGNAURE | DATE |
| ______________________ | ______________ | ________ |
| INTERNAL EXAMINER | SIGNATURE | DATE |
| ______________________ | ______________ | ________ |
| EXTERNAL EXAMINER | SIGNATURE | DATE |

# Declaration

I hereby declare that the work which is being presented in this thesis entitled "Small Scale Metalworking Industries Cluster" is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been accordingly acknowledged.

_______________________________ _________________________

Mandefro Tadesse Date

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

_______________________________ _________________________

Dr. Tafese G/Senbet (Advisor) Date