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Reverse Engineering as a channel for Technology Transfer: Metal and Engineering Industries in Ethiopia

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Declaration

I hereby declare that the work which is being presented in this thesis entitled **"Reverse engineering as a channel for Technology Transfer: Metals and Engineering Industry in Ethiopia"** is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged.

________________________ ____________________

Ermias Tesfaye Date

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

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Dr.-Ing Daniel Kitaw (Advisor) Date

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Ato Gulilat Gatew (Co-advisor) Date

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Abstract

The process of duplicating an existing part, subassembly, or product without drawings, documentation, or a computer model is known as reverse engineering. Reverse engineering is non-market channel of technology transfer. Through this, technology adaptation, adoption and capability can be built. Currently, the government of Ethiopia is working on import substitution and tries to minimize the spare parts, equipment and machineries requirement of the leather, textile, food processing, construction, sugar and cement processing industries by a substantial percentage. The main emphasis is due given for the success of reverse engineering. Moreover, metal and engineering sector is a leading economy of the sector.

This research focuses on reverse engineering and technology transfer in metal and engineering sectors of Ethiopia. The objectives of the research is to identify the status of reverse engineering in the country, the efforts of local research and development, government policies on reverse engineering and propose a means to strengthen reverse engineering and technology transfer in the country.

Using firm level survey together with the secondary data's obtained from different research and others work, the reverse engineering and technology transfer is assessed. Accordingly, the awareness level of the firms and the undertakings of reverse engineering are significant. The available markets, technical capability and demands for adapted products using reverse engineering are also encouraging for most sectors due to the shortage of foreign currency in the country. Moreover, the research identified the major constraints of the firms not to develop the reverse engineering practice and transfer technology such as low government support which accounts 63.6% of the respondent and lack of research and development at the firm level which accounts to 81.8% of the surveyed company.

The study has developed a model and proposed a solution for the successful implementation of reverse engineering and for developing research and development at the firm level.

Key words: *Technology transfer, reverse engineering, technological capability and import substitution*

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List of Abbreviations

TT – Technology Transfer

ITT – International Technology transfer

FDI – Foreign Direct Investment

MNE – Multi-national Enterprises

IPR – Intellectual Property Right

TNC – Transnational Corporations

MNC – Multi-national Corporations

KTTC – Korean Technology Transfer Center

PRC – People's Republic of China

ITRI – Industrial Technology Research Institute

IOE – Investment office of Ethiopia

ADLI – Agricultural Development Led Industry

BMEIA – Basic Metals and Engineering Industry Agency

MIDI – Metal Industry Development Institute

ECSA – Ethiopian Central Statistics Agency

BME – Basic Metals and Engineering

TVET – Technical and Vocational Education and Training

EABMEI – Ethiopian Association of Basic metals and Engineering Institutes

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Chapter One – Problem and its approach

1.1. Introduction

Technology is the usage and knowledge of tools, techniques, crafts, systems or methods of organization. Technological change is a principal source of sustained growth in living standards and is essential for transformation and modernization of economic structures. It is widely accepted as essential for improving the economy of a nation where industrial growth has occupied a very important role (Guan, Mok, Yam, Chin, & Pun, Technology transfer and innovation performance: Evidence from Chinese firms, 2006).

Evidences across many countries, including both developed and developing ones, have shown that there is an increasing appreciation that in the long term the ability to master technology and to manage and generate technological change is decisive in determining a country's international competitiveness and capacity to grow. As world becomes increasingly interdependent, the firms in developing countries are also increasingly seeking global R&D partnerships and Science and Technology collaboration as a way to build their capacity, strengthen their core competencies and expand into technology fields that are considered critical for maintaining and developing market shares.

The international flow of technological information and its successful integration into domestic production and management processes are central to the ability of developing countries to compete in the global economy and to narrow the technological gaps they face compared to developed countries. In most instances, developing countries find it cheaper and faster to acquire foreign technologies than to develop them with domestic resources.

Technology transfer suggests the movement of technology from one place to another. It refers to any process by which one party gains access to a second party's information and successfully learns and absorbs it into his production function. Clearly, much technology transfer occurs between willing partners in voluntary transactions. It needs to be perceived in terms of achieving three core objectives: the introduction of new techniques by means of investment of new plants; the improvement of existing techniques and the generation of new knowledge. The significant non-marketed channel of technology transfer is Reverse engineering. It is a modeling, modifying, duplicating and improving of an existing parts, equipment and machineries.

Reverse engineering is crucial step and ways to achieve technological capabilities. This method has advantages on various sectors to transfer technology. Among the different sectors, metals and engineering industries are the back bone of countries economy. World giant economies like the US, Japan, China and India are largely dependent on the metal sector both at its upper and lower stream. The available technology in this sector plays a significant role for development and competitiveness.

Ethiopia has been importing technologies since 15 century during Emperor Yishaq who has tried persistently to obtain craftsmen from outside. Later Lebne Dengel (1508-1540) was importing from Egypt all the mail, helmets, swords and spearheads which his elite retainers needed. Since then, most of the technologies transferred in the past with our countries limited resources have failed to be adopted, improved, re-engineered, and disseminated to other similar industries at the desired level which off course should be considered as the ultimate goals of technology transfer. Though, the early arrival of technology to the country, Ethiopia has not developed the technological capability and moves to creation.

At the moment, the government of Ethiopia has prepared five years growth and transformation plan to bring economic growth a year before. The plan is aimed to shift the strategy from foreign investment to locally driven economy. Accordingly, various projects are now ongoing to meet the planned transformation in the country. For the various projects to be successful, metal and engineering industries in the country plays a vital role. The government of Ethiopia is planning to substitute the import of metals and engineering products through local manufacturing. Some of the import substitution plans are producing:

- 90% of spare parts required by leather industries
- 35% of spare parts required by textile industries
- 85% of spare parts required by sugar industries
- 85% of spare parts and machineries required by cement industries
- 75% of spare parts required by agro processing industries

- 95% of the metal products required by construction industries and others.

The substitution of these requirements stated above can be achieved through reverse engineering. Therefore, this research tries to address the status of reverse engineering for technology transfer for metals and engineering industries in Ethiopia and develop methodology for improving it.

1.2. Statement of the Problem

Ethiopia has advantages of low labor cost and abundant natural resource. These resources can be advantageous to be competitive to the global market if technological capability is built. Therefore, reverse engineering is the most important tool for building technological capabilities in the country.

As stated earlier, most leading economic countries have strong metal and engineering industries. However, the contribution of the sector in Ethiopia's economy is so limited and according to the ECSA report, the number of industries in the sector including small scale metal product manufactures is only 7.04 % of the total manufacturing activities 2007/2008. From the 7.04% of basic metal and engineering industries, 5.45% of them are largely engaged in the production of low tech metal products.

It can be seen that the contribution of the basic metal industries to the overall economy is minimal which indicates that there is much to be desired from this industry if it has to position itself to a level where it can be a real contributor to the economy and realize the growth and transformation successfully. The metal products account the highest value of the total import in the country. Presently, Ethiopia has lack of foreign exchange. Accordingly, for the coming 5 years plan, there is an emphasis to substitute this import with local products. Substituting the spare parts, equipment and machineries imported from abroad through reverse engineering is a significant and prior action to be taken.

To realize the ambitious plan of growth and transformation and scale up the country economy, the prior action has to be the metal and engineering industries through building technological build and technology transfer.

Hence, this research tries to answer the following questions.

- What is the status of Reverse Engineering in Ethiopia?
- What is the impact of local research and development for Reverse Engineering activities?
- What are the government policies with regard to technology transfer through Reverse Engineering?
- What are the means to strengthen Reverse Engineering in Ethiopia?

1.3. Objective of the Thesis

1.3.1. General Objective

This research has identified the level of foreign technology adoption locally. In addition, it assesses the problems associated with imitation locally and globally and finally develops a guideline for boosting technological adoption.

1.3.2. Specific Objective

The specific objectives of this research are to:-

- identify the status of technology transfer trough Reverse Engineering which will enhance the technological capability of the local Engineering industries,
- assess the impact of local research and development for Reverse Engineering,
- assess the policies of the government with regard to Reverse Engineering; and
- develop the proposed solutions to enhance technological capabilities through Reverse Engineering

1.4. Research Methodology

Literature survey: detailed literature on the basis of technology transfer, Reverse Engineering and the enabling and disabling factors has discussed. Moreover, Successful technology transfer policy of other countries experience has been assessed together with the limitations.

Data Collection: The information and data needed to compile the paper will be achieved as follows.

Primary Data:

- A questionnaire based assessment has been conducted on metal and engineering industries to understand the potential and level of Reverse Engineering in Ethiopia and its contribution for technology transfer. The survey questionnaire has been distributed to obtain the responses from workers in Metal and Engineering Industries. These industries are Mechanical workshops, basic metal industries, machine fabricators, manufacturers and engineering industries. The target groups of the industries are Large and medium industries with the assumption that the large and medium industries can be the technology supplier for the micro and small scale industries as the employees from large and medium industries graduate as an entrepreneur.

Secondary Data

- Reports from UNIDO, UNICATS, TRIPS, World Trade Organization, Ethiopian Central Statistics Agency, reports from Metal Industries Development Institute, JICA and Ethiopian Science and Technology has all been reviewed and included in the analysis.

1.5. Significance of the Study

The results from this study could be used for frame work on the imitation foreign technology for the development of local technological capability. The study could be used by policy makers to review their policy on technology intensive industries and projects. This study can be used as a reference for further study in the area.

1.6. Scope and Limitation of the Research

This study is conducted within a short period of time and under a given limited financial and other resources normally needed for such study. As a result, the survey is short from encompass most engineering industries all over the country, instead some engineering firms in Addis Ababa and nearby towns only included. For this reason, the conclusion of this study might not necessary extended to all manufacturing industries throughout the country.

1.7. Organization of the study

The study has four major chapters; the first chapter included the problem and its approaches, the second chapter discussed on related literature reviews on technology, technology transfer and reverse engineering including the experience of selected countries. The collected data from primary and secondary sources are analyzed and core problems of metal and engineering industries with regard to reverse engineering are identified in the third chapter. The proposed solutions and developed model for implementation of reverse engineering policy is included in the fourth chapter. The last part included conclusions, recommendations, references used and appendixes.

Chapter Two - Literature Review

2.1. Technology

Technology by definition deals with the application of “scientific knowledge” to practical purposes in a particular field (The Change Book: A Blue for Technology Transfer, 2000).In the broadest sense; it is defined as the knowledge (know-how) that man possesses that, in turn, enables him to perform a particular task. It includes the knowledge of product and process design and the managerial systems that enable the efficient operation of production facilities. It is a combination of knowledge needed to design, create, or implement a production process, methods, skills, and special know-how that is used by humans in understanding and utilizing nature (Liu, Fang, Shi, & Guo, 2010), (Robock & Calkins, 1980). Technology is the specific application of scientific and technical knowledge to the production of goods and services (Technology Transfer to the Middle East, 1984).

In terms of social productivity, the overall technical forces include technical skills, work experience, information knowledge, and equipment of solid tools, namely technical personnel, technical equipment, and technical information in the whole society. The other characteristics of technology include purpose, sociality, and pluralism (Liu, Fang, Shi, & Guo, 2010).

Any new technology arises for a purpose, and the purpose of that technology runs through the entire process of technical activities. Hence, modern technology has strong utility and commercial features. The sociality of technology requires collaboration with the community and social support; it is also subject to a variety of social conditions. These social factors directly affect the success of technology and the development process. The pluralism of technology ensures that it can be expressed not only as tools for tangible equipment, machinery, entity material, and other hardware; but also as processes, methods, rules, and other knowledge software, as well as information and design drawings that are not material entities in themselves but material carriers of other manifestations.

The currently used technology can be usefully classified as follows.

1. Hard and soft,

2. Proprietary and nonproprietary, and
3. Front-end and obsolete

Hard technology is characterized as capital goods, blueprints, technical specifications, and such knowledge and assistance necessary for the efficient utilization of the hardware to produce materials, components, and end products, while soft technology refers to management, marketing, financial organization, and administration techniques. Proprietary technology is owned or controlled by particular individuals or institutions. It may be held as a trade secret or it may be published as a patent. Nonproprietary technology includes knowledge contained in technical literature, hardware, and services that can be imitated or reproduced by observation and through reverse engineering without infringing on the proprietary rights. The classifications front-end and obsolete relate to the newness of technology and its competitive advantage. Front-end technology is the latest available, while old technology, in some cases, is obsolete (Robock & Calkins, 1980).

Technology is widely accepted as essential for improving the economy of a nation, especially in developing countries where industrial growth has occupied a very important role. Evidences across many countries, including both developed and developing ones, have shown there is an increasing appreciation that in the long term the ability to master technology and to manage and generate technological change is decisive in determining a country's international competitiveness and capacity to grow. As world becomes increasingly interdependent, the firms in developing countries are also increasingly seeking global R&D partnerships and Science and Technology collaboration as a way to build their capacity, strengthen their core competencies and expand into technology fields that are considered critical for maintaining and developing market shares (Guan, Mok, & Yam, Technology transfer and innovation performance: Evidence from Chinese firms, 2005).

Technology may, therefore, be in the form of know-how, machinery or tools, technical assistance, processes, organization or products. However, acquiring the capacity to apply, control and adapt the technology is a different issue and constitutes perhaps the key to the transfer process.

2.2. Technology Transfer

Technology transfer is best understood as a process; that is, a process by which "know-how" information called technology is transferred across a boundary or boundaries to another organization (Chinta & R., 1990). Technology transfer is the transfer, proliferation, promotion, and transplantation of technical achievements in different countries, regions, sectors, industries, or enterprises. Through technology transfer, technology combines with production processes to form new combinations and systems of technology. As a result productivity is enhanced, and economic benefit is improved continuously (Liu, Fang, Shi, & Guo, 2010).

Clearly, much technology transfer occurs between willing partners in voluntary transactions. Thus, there are demanders and suppliers of technology and information is traded in technology markets (Maskus, 2004). In the process of technology transfer, the two sides are mutually constrained and interrelated. As a dynamic process, the realization of technology transfer is the result of the joint efforts of both supply and demand.

The technology can be transferred in a pure informational form, which has been called disembodied technology transfer. Or, the technology can be embodied in the form of a product, machine, process, or person and then transferred. The advantage of an embodied form of transfer is that the person, machine, software, etc., "packages" the know-how in a way that makes the technology able to be implemented. Often, combinations of embodied transfers are made where machinery and the personnel to operate it are transferred at the same time (Chinta & R., 1990).

There are three types of transfer that can be associated with the main elements of technology. The first consists of the transfer of materials, final products, components, equipment, and even turnkey and/or product-in-hand plants. The second form of transfer involves the movement of designs, blueprints, and the know-how. It provides the basic information, data and guidelines needed to create a desired capability. The third form of transfer is to provide know-how and software needed to adapt existing technology and innovate.

Technology transfer is one option for a developing country to acquire newer technology. The process of technology transfer to developing countries is increasingly being defined as the process whereby knowledge in some form changes hands from a person or organization who possesses it to another individual or organization (Saad, 2000). Developing countries may consider technology transfer as a base for developing their technology capability implying that the capability required is beyond adapting the technologies to suit the local situation. However, it is postulated that not every transfer process can be expected to upgrade the technology capability of the receiver. Technology transfer that is limited to transfer of capital goods and operating skill can hardly develop technology capability (Putranto, Stewart, & Moore, 2003).

Technology capabilities are not limited to physical equipment, manuals, blueprints, the education qualifications possessed by the employees, and skills of individuals. They encompass the ability to function as an organization. At the industrial branch level, technology capabilities include the ability to select, assimilate, adapt, improve, and create new technology.

Technology transfer is likely to provide the receiver with all three types of technology capabilities, namely investment capabilities, operational capabilities, and dynamic learning capabilities. However, the extent of the technology capabilities acquired will depend, among others, on the receiver's learning culture.

From the receiver's point of view, technology transfer can be divided into four stages namely the preparation stage, the production stage, the operation stage, and the evaluation stage (Fig. 2-1). This stage includes: determination of goals, identification of strength and weakness, assessment of managerial resources and infrastructure, specification of the technologies needed, search for and selection of alternatives, offer evaluation, and negotiation (Putranto, Stewart, & Moore, 2003).

The second and the third stages are often referred to as the implementation stage. The production stage includes activities related to design, engineering and construction or fabrication. The operation stage includes activities related to the use or operation of the product resulting from the transfer process.

The fourth is the evaluation stage. The evaluation stage makes a feedback loop in a transfer process.

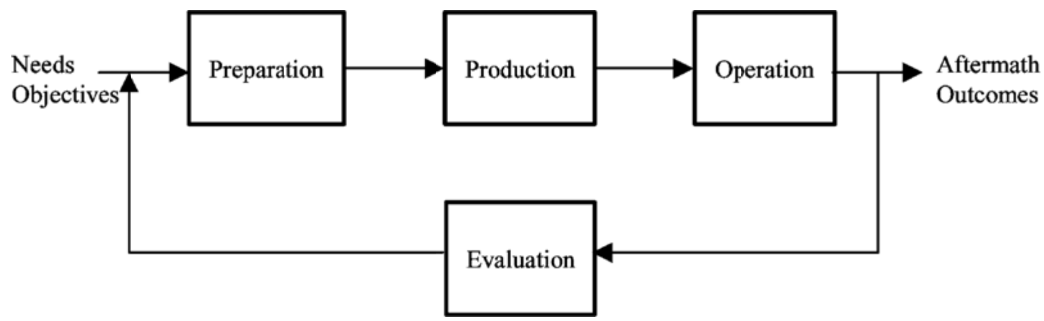

Figure 2-1 stages of technology transfer

In the preparation and production stages, the investment capabilities can be cultivated. Subsequently, in the operation stage, the operational capabilities can be accumulated. Finally, technology transfer can be expected to contribute to develop the dynamic learning capability through the evaluation process in the evaluation stage.

The presence of an evaluation stage is even very useful when, for a particular product or technology, a series of transfers and not a single transfer is necessary. Such post-evaluation will help improve the preparation of the subsequent transfer processes.

2.2.1. History of Technology transfer

Technology transfer (TT) is not a new thing. Researchers have traced back TT process to the prehistory of the human species: where TT largely involved tacit knowledge which is evolutionary prior to explicit knowledge. As there were no written languages until 3000 BC, TT had mainly occurred through language; which were supplemented by equations and diagrams which constitute as the major means of explicit transfer of technological knowledge. The spoken language and gestures have explicitly transferred technological knowledge in friendly encounters. However, much of pre-historic TT between people occurred when people with superior agricultural technology assimilated or eliminated those who could not reproduce as rapidly (Sazali, Haslinda, Jegak, & Raduan, 2009).

The role of Arabs played in transferring technologies from East to West and the transfer of English textile expertise to the American textile industry in the 18^{th} and 19^{th} Centuries. In the 18^{th} Century, despite the English law preventing knowledge migration, France eventually managed to obtain ‘specialized steel making know-how’ by importing English workers and through industrial espionage. The success of the American textile industry in 18th and 19th Century was due to the transfer of knowledge and expertise by the English textile industry. Previous studies have shown that certain industries collapsed, for example the English clock and watch industry, due to the industry resistance to the opportunities of TT.

Indeed, different approaches to shape and govern the TT efforts have been seen. TT as a domain covers all activities around technological development. In the 1970s, studies have adopted “the economic international trade approach” in developing a linear model of TT. In the 1980s, research on TT emphasized on the effectiveness of the specific technology being transferred which in general is within a broader context of economic development. The 1990s approach emphasizes on the significance of learning at the organization level as a key element in facilitating technology transfer.

In late 1980s and early 1990s, TT models have started to absorb the principles of the organization development movement. Strategic management researchers have further contributed to the development of TT frameworks based on KBV and OL perspectives as these perspectives have been found to have quite similar dimensions such as outcomes, processes, barriers and facilitators.

2.2.2. Channels of Technology Transfer

Technology created in the industrialized countries diffuses to the least developed countries when firms enter into international licensing agreements, joint ventures, turnkey projects etc. Technology transfer also occurs via trade in capital goods, imitation/reverse-engineering (Saggi & Kamal, 1997). The preferred or most popular methods of transfer differ from country to country and from firm to firm. In developing countries, this distinction is very significant, especially when it comes to tailoring technology transfer and development policy packages and measures (Miyake, 2005). Very often, the choice of the mode of transfer is influenced by the objectives and capacities of the users and by the desire of the supplier to control or limit the use of the technology (Technology and Skills in ASEAN: An Overview, 1987).

It is useful to make a distinction between international technology transfers that flows through market-mediated mechanisms, meaning that some form of formal transaction underlies the technology movement. In this mechanism, there are literal buyers and sellers of technology and the role of the market is to facilitate such trade and permit negotiations of mutually advantageous terms of transfer. Technology transfer within multi-national firms may not incorporate the same formal terms but ultimately such trades must reflect the true economic value of information to both the parent firm and its subsidiaries. Thus, markets for information play the major role in International Technology Transfer (ITT). To a first approximation, expanding the scope for ITT requires reducing imperfections and impediments in such markets (Maskus, 2004). Some of the market-mediated channels of technology transfer are:

- Trades in goods and services are technological inputs to industries that can improve productivity by being placed into production process.
- Foreign direct investment (FDI) which refers to the direct capital investment in factories and mines of a country or a region of the production output by another country or region for the direct management of the factories and mines. Multinational Enterprises (MNEs) may be expected, in principle, to deploy to their subsidiaries in recipient countries technological information that is newer or more productive than was the case with incumbent firms.
- Technology licensing, which may be done either within firms or between unrelated firms at arm's-length is another marketed-mediated technology transfer. License transaction refers to sale by transnational corporations of patented technology, know-how, the right to use trademarks, product manufacturing, and marketing rights to other overseas subsidiaries or enterprises by signing the license contract and allowing the other party to use it.
- Licensing and FDI are closely related to the establishment of joint ventures (JVs), which are contractual arrangements between two or more firms in which each provides some advantage that should reduce the costs of joint operations. In this context, international firms may provide technically superior production information through licensing, while local partners provide distribution networks, information about labor markets, unique management techniques, brand recognition, or some other local advantages. Under

jointly-owned companies, the industrializing partner gains direct access to training and technology (Maskus, 2004). The foreign firms secure low-cost production. The firm in the newly industrializing country is a junior partner and recipient of technology (Miyake, 2005).

- Cross-border movement of technical and managerial personnel. An important advantage of MNEs is the ability to shift skilled personnel with know how among subsidiaries as needed.

It is important to note that trade, FDI; licensing, joint ventures, and personnel movements are interdependent processes. These decisions are made jointly by firms seeking to maximize returns on their technological assets. The processes described so far may be characterized (save for compulsory licensing) largely as market transactions.

Non-market mechanisms do not involve such transactions. An alternative description would be "formal" and "informal" channels, respectively, reflecting the nature of the information trade. Non-marketed channels of technology transfer are as follows:

- Imitation is the significant one in which the firm learns the technological or design secrets of another firm's formula or products. Imitation may be achieved through product inspection, reverse engineering, de-compilation of software, and even simple trial and error. What distinguishes it from the earlier channels is that imitation bears no compensation to the technology owner in formal markets.
- Technical and managerial personnel, whom knowledge of one firm's technologies has been entrusted leave the firm and join or start a rival firm based on that knowledge. Such competition can be a significant form of information diffusion in industries and locations where cross fertilization of knowledge is important and employees are mobile.
- The study of available information about those technologies. Patent applications, both those registered in a country and (more likely) registered abroad, are available for this purpose. Rival firms in principle can read such applications, learn the underlying technologies, and develop competing processes and products that do not infringe the claims of the original applicants. Thus, patents provide both a direct source of technology transfer, through FDI and licensing, and an indirect form through inspection.

- Through the temporary migration of students, scientists, and managerial and technical personnel to universities, laboratories, and conferences located mainly in the developed economies. Note that in-depth training in science and engineering may be gained this way, suggesting that it is a particularly long-lasting form of ITT. The challenge for developing countries in this context is to encourage its expatriate students and professionals to return home and undertake local scientific, educational, and business development.

The accumulation of skills, experiences and technical know-how at the levels of firms, industrial sectors and countries takes time and is essential for the long run development of national competitiveness. The policies and stances taken by enterprises and institutes are often based on the assumption that acquiring technology in the form of designs and hardware and possibly reverse engineering/imitation are sufficient for absorbing and using technologies and developing innovative capabilities. This may be true for some basic technologies but is unlikely to be the case with more advanced technologies (Bennett & Vaidye, 2001).

2.2.3. Influencing Factor of Technology Transfer

a. Law and Policy Factors

Technology is a kind of knowledge product; it needs to be protected by the legal system, particularly in the field of intellectual property rights. The degree of protection for intellectual property rights varies in different countries in the cross-border business environment. In some countries, a large number of counterfeit products infringe the international technology transfer and reduce the profit of export. Many companies in these countries can rarely get rid of the infringement problem; the protection of intellectual property rights (IPR) of technology transfer in the host country or region is an important factor (Liu, Fang, Shi, & Guo, 2010).

The relationship between levels of IPR protection and the volume and direction of inward technology flows is highly complex, and is likely to involve many factors whose relative importance will vary widely from one country to another. Theoretically, it seems logical to assume that IPR availability would be a prerequisite for the international transfer of new technologies. One would expect companies to be reluctant to lose control over technologies, which may have cost them millions of dollars to develop, to countries where domestic firms could adopt the technologies and produce goods that would compete with those of the technology owners. Accordingly, the only way that companies would feel encouraged to transfer proprietary technologies is where IPR protection is strong enough for them to charge license fees high enough to reflect the costs of innovation, or alternatively by means of FDI or joint ventures where they maintain more control over those technologies. Countries with strong IPR protection and enforcement, transnational corporations (TNCs) are likely to favor technology licensing agreements and joint ventures. In countries with weak IPRs, FDI would be the favored business strategy in overseas markets. Countries seeking to attract high-tech production systems should strengthen their IPR regimes with a view to inducing TNCs to deepen their investments into more advanced technologies (Dutfield, 2004).

However, a great deal of formal international “technology transfer” takes place not between, but within, companies. Given that these companies continue to control access to the technologies, it seems reasonable to question whether such transactions are genuine technology transfers of the kind that would result in widespread adoption in developing countries. A counter-argument can be made that the overall effect of IPRs will inhibit technology transfers.

As an intervention in the free market, patents restrict the number of people who could otherwise freely make, use, sell or import the protected products and processes. This enables owners to maintain high prices, avoiding a situation where the price of their products or processes is driven down towards the marginal cost of reproduction. Foreign patent owners can use their legal rights either to block access to their technologies or to charge license fees that are too high for domestic firms. If so, one might argue that the best ways for developing-country governments to help domestic firms and public institutions to acquire technologies might be to weaken patent rights, such as by allowing compulsory licensing on licensee-friendly terms.

The policy system plays a decisive role in the effectiveness of technology transfer. It is difficult for technology transfer to succeed in a country or region, where there are frequent government interventions and many restrictions on foreign-funded enterprises. Policies of technology-importing countries or regions will have a direct impact on technology transfer in scientific and technical content and quality.

b. Market Factor

Market factors are the fundamental factors of technology transfer. The effect of market competition and market size on technology transfer is particularly obvious. If the opening level of the home country or region is low, only a small number of transnational companies operating a monopoly in an industry will be able to maintain the technical advantage of their monopoly status to gain more profits. So the industry slows down the speed of technical progress and hampers the technical development (Liu, Fang, Shi, & Guo, 2010).

Competition among companies is the essence of technical strength. To gain a foothold in the market, enterprises have to update technology to speed up the pace of technology transfer.

The size of the market determines the scale of production. If the market capacity is large, economy grows steadily, and residents' purchasing power is strong in a country or a region, the growing space of technology-importing countries or regions will be great. Accordingly, these areas' attraction of investment and technology transfer will be stronger.

c. Technology Basis

A nation or region's technology basis is important for technology transfer. The availability of human resources, the knowledge level, the development of productive forces, and the technology level will have a real impact on the transfer. The countries and regions with a great technology base and high skill levels will be capable of exporting technology. The conditions of technology-importing countries or regions restrict their ability to accept new technologies. If other conditions remain constant, the country with high-performance technology and good technical basis is more likely to promote the country's technology transfer. (Liu, Fang, Shi, & Guo, 2010)

d. Infrastructure Status

Infrastructure includes transportation, canals, ports, bridges, telecommunications, electricity, water and urban water supply and drainage, gas, electricity, and other facilities. These are substantial engineering facilities to provide public service for production and the residents. It is the common material base for production, management, work and life, and guarantees that the main facilities in a city operate normally. Moreover, it is not only an important condition for material production, but also an important condition for reproduction of labor. As the exporter or recipient of technology, the infrastructure construction must be taken into consideration in the implementation of technology transfer. (Liu, Fang, Shi, & Guo, 2010)

2.2.4. Reverse Engineering

Reverse engineering/imitation is the process of extracting know-how or knowledge from a human-made artifact (Scotchmer, Samuelson, & Suzanne, 2002). In some situations, there may be a physical part/product without any technical details, such as drawings, bill-of-material, or without engineering data. The process of duplicating an existing part, subassembly, or product, without drawings, documentation, or a computer model is known as reverse engineering/imitation. Bardell et al. (2003) in A. R. Ismail et al. (2009) defined reverse engineering/imitation as systematic evaluation of a product with the purpose of replication which involves either direct copies or adding improvements to existing design. It is now widely used in numerous applications, such as manufacturing, industrial design, and jewelry design and reproduction (Raja & Fernandes).

Reverse engineering may be seen as an unusual application of the art and science of engineering, but it has become a fact of daily life. It could be applied to rectify deficiencies in existing items or to extend their capabilities. In the early 1980s, it was used by the general Motors Corporation to maintain a competitive advantage over Ford Motor Company products (and vice versa). Furthermore, reverse engineering is used by major military powers on the equipment they can acquire from their antagonists. Sometimes, these military powers employ reverse engineering to provide spare parts and maintenance support to smaller powers that are no longer on friendly terms with the manufacturers of their existing weapon systems (Dhillon, 2002).

Currently, reverse engineering is practiced increasingly in industry at large because it offers many benefits, including reducing design and development costs and maintaining high performance manufacturing capabilities. It can also be used as an effective stopgap measure for improving system productivity until the resources required for full modernization are within reach. In general, it may be said that reverse engineering is directed at modernizing single system elements, rather than total systems, for the purpose of maintaining or increasing system productivity.

When planning a reverse engineering project for the purpose of reproducing, say, a hardware item, it is necessary to determine whether the desired end result is to create a clone or a surrogate. In the case of creating a clone, reverse engineering means creating the identical of exact reproduction of the original (i.e., at least as far as circumstances will allow). More specifically, the clone reproduction must have the same form, operating mechanism, function, and fit as the original. By contrast, the surrogate item may carry the same function as the original in addition to being sized to fit in the same place as the original, but may neither appear to be the same, nor use the same operating mechanisms.

Obviously, the reverse engineering effort required in the case of the clone is much more extensive than that for the surrogate. The increased complexity and sophistication of modern equipment have made the task of producing clones even more difficult.

The practice of reverse engineering requires two types of specifications (i.e., functional and dimensional), particularly for complex products. The functional specifications are useful because they describe the work of product or item and its subsets, in addition their interactions. On the other hand, dimensional specifications include item dimensions (e.g. tolerances, lengths, and angles), materials to be used in part or item fabrication, how the parts or items are to be assembled and the materials are to be treated during manufacture, and parameter values and their associated tolerances (Dhillon, 2002).

There are many basic considerations associated with the reverse engineering effort. The important ones are shown in the figure 2-2.

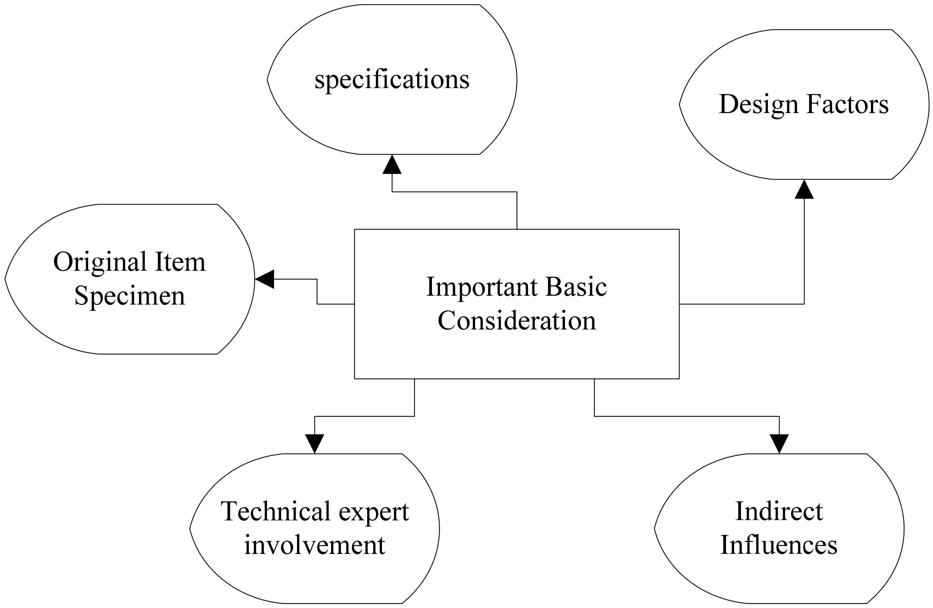

Figure 2-2. *Important basic considerations associated with the reverse engineering effort*

Steven Schnaars in (Kim, Imitation to Innovation: The Dynamics of Korea's Technological Learning, 1997) categorizes several distinct imitations/reverse engineering: counterfeits or product pirates, knockoffs or clones, design copies, creative adaptations, technological leapfrogging and adaptation to other industry.

First, counterfeits and knockoffs are duplicative imitation, but one is illegal and the other legal. Counterfeits are copies that resemble the same premium brand name as the original but of low quality, illegally robbing the innovator of due profits. In contrast, most knockoffs or clones are legal products in their own right, closely copying the pioneering products in the absence or expiration of patents, copyrights, and trademarks but marketed with their own brand names at far lower price (Kim, Imitation to Innovation: The Dynamics of Korea's Technological Learning, 1997).

Duplicative imitation does not require specialized investment in R&D and information channels. Only a low level of learning is necessary since the firms cannot and are not required to generate new knowledge. Unlike replication within the same firm, in duplicating another firm's products or processes, target routine is not substantially available as a template. Therefore, it is not possible to resolve all problems arising in the imitation by closer scrutiny of the prototype's production system. At one extreme, the production in question may be novel combination of highly standardized technological elements. In this case, reverse engineering may result in the identification of those elements and the nature of their combination, leading to an economically successful imitation. At the other extreme, the target routine may involve so much idiosyncratic and firm-substantial help by means of formal technology transfer from the originator.

In the wide range of intermediate cases, the imitator has to obtain as much understanding of the technological elements and the nature of their combination as possible and fill in remaining gaps by independent efforts. Or the imitator must rely substantially on technical assistance in various forms from the forerunner. For this reason, it requires considerable internal capability to identify the nature and source of relevant technology, to negotiate its transfer or reverse-engineer, and to assimilate so as to be able to apply it to the specific market needs and material availabilities facing the firm. Duplicative imitation conveys no sustainable competitive advantage to the imitator technologically, but it supports competitive edge in price if the imitator's wage cost is significantly lower than the imitatee's.

For this reason, when it is legal, duplicative imitation is an astute strategy in the early industrialization of low-wage, catching-up countries, as such technology is generally mature and readily available and duplicative imitation of mature technology is relatively easy to undertake.

Second, design copies, creative adaptations, technological leapfrogging and adaptation to another industry are creative imitations. Design copies mimic the style of the market leader but carry their own brand name and unique engineering specifications. Japanese luxury cars, for instance, emulate German models but possess their own engineering features. Creative adaptations are innovative in the sense that creative improvements are inspired by existing products. Technological leapfrogging depicts a late entrant's advantage in getting access to newer technology in the wake of more accurate understanding of a growing market enabling the imitator to leapfrog the innovator. Adaptation to another industry illustrates the application of innovations in one industry for use in another.

Recent studies seem to suggest that imitation/reverse engineering with local improvements is a precursor of innovative capabilities.

2.3. Country Experiences of Reverse Engineering for Technology Transfer

Learning through imitation may enable firms to improve existing technologies. South Korea, Taiwan, and increasingly China, Malaysia, Indonesia and Thailand, have begun to follow Japan's path by imitating technologies from abroad. Firms from these countries are now beginning to innovate (Glass, Imitation as a Stepping Stone to Innovation). South Korean, China and Taiwan experiences are presented as follows.

2.3.1. Technology Transfer in South Korea

Korea, one of only a few that has managed to make significant strides has transformed itself from a subsistent agrarian economy grew at an average annual tare of almost 8 percent, raising GNP per capita in current prices from $87 in 1962 to $10,550 in 1997.

In the early years of industrialization, firms in developing countries import or imitate mature technologies, whose products and markets have already been well tested in the advanced countries. Technology tends to be readily available in machine-embodied form. Large firms acquire production technologies mainly through turnkey plants or foreign license. Given the scale of large investment required, large local firms at this early stage are highly motivated to look to experienced foreign firms to ensure swift construction and smooth start-up. (Kim, The Dynamics of Technological Learning in Industrialisation, 2001).

In contrast, small firms took an imitative approach, reverse-engineering foreign products and evolving organically over a long period time. Both large and small firms deployed deliberate and aggressive strategies to assimilate foreign technologies. Thus, R&D in the sense of generating new knowledge was not needed; only limited engineering development was necessary. Such imitative reverse engineering was possible only because Korea had a good stock of well-trained human resources. Some developing countries attained rapid growth in elementary education. But what was unique in Korea was the well-balanced expansion in all levels of education early enough to support its economic development (Kim & Yi, The Dynamics of R&D in Industrial Development Lesson from the Korean Experience, 1997).

Small firms, which lacked both financial and technical resources, established their initial production facilities with primitive technologies developed by themselves, and then gradually upgraded product quality through the imitative reverse engineering of foreign products and processes. The lax intellectual property rights regime prevailing at the time meant that little attention was paid to the legal aspects of copying imported technology through reverse engineering (Kim, Technology Transfer and Intellectual Property Rights:The Korean Experience, 2003).

These firms, however, have relied increasingly on their own R&D to master imported technologies and to give rise to product design capabilities in order to reduce their dependence on foreign licensors for subsequent product development, as they accumulated experience in production and product design. In these sectors, expansion of production system can easily be undertaken by adding more capital-goods, once engineers master production processes. In this process, aggressive local firms acquired a large amount of relevant knowledge through informal mechanisms and developed products through reverse engineering processes.

Technical knowledge needed by these local firms during this stage was generally mature and gave little competitive advantage to technology suppliers in advanced countries. Such knowledge is also readily available in the form of printed materials or as embodied in products. For these reasons, smart producers could easily reverse-engineer technology in generating duplicative products.

Small firms in the electronics and automobiles industries deployed small batch production to suit quantity requirements. And smart local firms can easily reverse engineer these foreign products to produce imitative products. For instance, a large number of small electronics firms in Korea have grown through this process in producing final products and components.

These firms soon become important local original equipment manufacturing suppliers for MNCs. In this case, MNC buyers provided product designs and technical assistance free of charge in order to ensure that locally produced goods meet the buyers' technical specifications. Then, these firms accumulated sufficient technological capabilities through 'learning by doing' to become own design manufacturers. In the course of such an evolution, aggressive large local firms acquired technological capability through imitative reverse engineering of existing foreign products traded in the market. Subcontracting arrangements also played a very important role in allowing Korea firms to get acquainted with international standards and technical specifications as well with the international market (Kim, Technology Transfer and Intellectual Property Rights:The Korean Experience, 2003).

Koreans have developed a range of sophisticated procedures for transferring technology, some of which may provide insights to other developing countries. Continuation of Korea’s high economic growth will increasingly depend on the policy related to technology and technological innovations inside Korea. In this regard Korean government places great emphasis on stimulating technology business and on promoting climate conducive to technology market. In 2000, to perform these missions Korean government established Korea Technology Transfer Center (KTTC).

2.3.2. Technology Transfer in China

Since the end of the 1970s, China was witnessed three fundamental transitions of the economy: (1) from a rigid centrally planned economy to an increasingly open and market-based economy; (2) from an internally oriented economy to an externally oriented economy; and (3) from an imitative economy to an innovative economy. Of the first change facilitated the spread of the idea of “knowledge as commodities,” then the second change significantly increased the importance of IP. Both changes contributed significantly to the third transition (Beer, 2009).

China’s considerable imitative capacity played a crucial role in its economic transition. The late leader Deng Xiaopin put tremendous emphasis on *guochanhua*, or reverse engineering, in order to foster China’s technological advancement and, hoped to surpass the developed world. Following Deng’s directive, china launched a large-scale reverse engineering project. Many high-grade consumer goods, such as color televisions, tape recorders, refrigerators, and washing machines were targets of *guochanhua*. This imitative strategy was not only promoted to the establishment of many modern industries in a short period of time and at low costs in china but also narrow the technology gap with the developed world (Beer, 2009).

a. Period of Imitation (1949–1959)

In this period, advanced technology was mainly imported from the Soviet Union and other socialist countries in east Europe. International technology transfer dominated this period; later the imported techniques were promoted in China and modified to suit the practical domestic situation. During the first five year plan, around the beginning of the foundation of PRC (People's Republic of China), China's industries were in a mess and had no advanced techniques. Therefore, China imported massive equipment and the corresponding techniques to pave the road for the industrialization of the new China. Based on the statistics from the national project department, between 1950 and 1959 China signed for over 700 projects, 450 of which were imported and cost 3.7 billion dollars in total, which is roughly about 50 percent. During the first five year plan (1952–1957) 156 techniques were imported, which were also the keys projects in the process of industrialization of China such as coal, electric power, oil, metallurgy, chemical engineering, electric machine, aviation, automobile, light industry, textile, and military industry. With the import of those techniques, the pace of China's industrialization was hastened significantly; every section achieved its own magnificent and expected goals, and the gross industrial output value increased by 18 percent (Liu, Fang, Shi, & Guo, 2010).

b. The Fumbling Period (1959–1978)

In the late 1950s, due to the tension between China and the Soviet Union, the import of techniques from those countries became stagnant; the sequential three yearlong natural disaster brought China's economy to a very critical state. During this period the self-dependence policy basically dominated, and the resistance to imported techniques increased significantly. Especially during the three-line construction period, an avalanche of new techniques and talents moved to the middle-east, promoting the diffusion of technique in the middle-east part of China. During the late 1960s and early 1970s, China gradually established diplomatic relations with European capitalist countries and Japan, and the technology transfer was carried out in non-governmental individual exchanges, and many key techniques and equipment related to oil, chemical engineering, chemical fiber, metallurgy, mining, electronic, nicety apparatus, and textile mechanism were imported from France, Britain, and Japan and the import structure emphasized the importance of the light industry.

c. Stage of Internalization of Development (1978–1992)

In more than a decade from the late 1970s to early 1990s, China imported critical economic construction, chemical, mechanical and electrical, and other aspects of the production from many other countries. This played a great role in promoting China's economic take-off. During this period, China's academic community started research based on international technology transfer, and technology transfer turned from international to domestic technology transfer issues. The access to a number of theoretical achievements helped to guide the practice of technology transfer at various levels. The Chinese government strengthened the development of combination. They believed that technology transfer must combine with independent innovation and international technology transfer must combine with domestic technology transfer. They used the gradient theory of technology transfer theory, and developed science and technology in China in a phased and conditioned manner, and diffused mature technology in domestic regions. All these actions effectively made the natural potential energy brought in by technology transfer into dynamic movement for economic development for the realization of the "three step" strategy. At the same time, Chinese technology transfer policies and regulations improved gradually, and the technology market development standardized gradually. In 1980, State Science and Technology, the annual national work conference on science and technology drafted a report "on China Development of science and technology policy report on the outline." In 1983, the State Science and Technology Commission issued "to strengthen technology transfer and technical services," which marks the beginning of the technology transfer market.

The external influences of the political storm in 1989, as well as China's own economic restructuring caused a low ebb in the introduction of technology again; the developed countries blockaded China's economic technology, so China had to rely on independent innovation and technology transfer to develop domestic high-tech. As a result of this blockade, the computer, telecommunications, and home appliance industry in China got a period of respite for digesting the introduced excess techniques and for innovation.

d. Opening-Round Stage (1992–)

In 1992, China's reform of the economy system met another watershed, the Communist Party of China 14th National Congress put forward the goal of a socialist market and economic system, and China's economic system once again achieved a breakthrough. At the same time, the international situation has been improving, and international economic and technical exchanges redeveloped. Theorists began a multilevel, multi-angle study of domestic and international technology transfer. Technology transfer policy and the building of the legal and economic environment for it continue to push forward. China's technology import has a heightened degree of openness more than ever before; the arrangements for technology transfer are increasingly rich, and the situation is even more diverse. On one hand, advanced science and the techniques introduced from the international community are digested and absorbed in proper areas; on the other hand, domestic scientists and technicians are encouraged to develop advanced technology and help industrialization and transfer and diffuse it to other parts of the country or abroad. This force of domestic technology is in a low state. Through the output of technology to foreign countries, the corresponding profits can be increased.

2.3.3. Technology Transfer in Taiwan

Taiwan shares a number of common features with South Korea. First, like Korea, Taiwan was a Japanese colony (from 1895 to 1945) and was tightly integrated into the Japanese economic system. A substantial industrial base and physical infrastructure was established by the Japanese to utilize local labour and materials; land reform was instituted. Second, Taiwan also has a difficult external political situation to face: the claim by the People's Republic of China (PRC) as an integral part of the mainland. Third, Taiwan has followed a broadly similar path to that of South Korea, although there are some significant differences between these two economies (Eriksson, 2005).

The main challenge facing the Taiwanese economic planners was how to move from a condition of little know-how, inadequate institutions, and an under-supply of trained scientists and engineers to that of a high-tech based economy. The key problem was how to keep upgrading the technological content of the products. To reach this goal an overall strategy of four key components was adopted.

- Building human resources
- Acquiring technology from the more advanced countries.
- Creating science and technology capacities
- Converting research results into commercial products

Building human resources: The building of human resources has several elements. The key element is the education system. Since the early 1960s, strengthening education has been a national priority. This applies to all levels of education, from primary to university. The number of science and engineering degree holders has increased significantly over the years. Recognizing the need to learn from the outside world, the government encouraged students to go abroad for post-graduate studies. Initially, many graduates found jobs abroad, mostly in the U.S., as opportunities in Taiwan were limited. Since the late 1980s, an increasing number of post-graduates have returned to Taiwan. Knowledge conveyed by nationals who had been educated or worked abroad became an important mode of technology transfer as industrialization proceeded and changing factor prices dictated a shift to more capital and technology intensive sectors in which products were protected by patents, employed specialized equipment protected by patents and were characterized by tacit knowledge. One major bottleneck of personnel is in the key engineering and management jobs, reinforced to some extent by satellite production for Japanese firms.

Acquiring technology from more advanced countries: The industrial structure of Taiwan has a large number of small and medium-sized firms and a few large ones. Taiwan's technologies originally came mostly from Japan and the U.S. By establishing backward linkages with materials and technology, mostly with foreign corporations, the industry slowly developed niches of advantage. This strategy was successful in developing a strong position in consumer electronics, small machineries, footwear and textiles, bicycles and other sporting goods.

Through much of its early industrialization, Taiwan employed older machinery and manufactured standardized products that were not subject to proprietary restrictions. Knowledge about how to improve the utilization of this equipment as well as modifications of product specifications was readily available at low cost in trade literature and engineering publications, and from independent consultants. Up to the early 1990s it seemed that reverse engineering was still the most common means of acquiring technology. Invention was a more distant goal.

In the development of knowledge-based economies there are two important issues. One is the extent to which knowledge is shared or diffused and the second is the direction of the diffusion or flow. A study by Fang et.al. (2002) in (Eriksson, 2005) identified the R&D programs and facilities of foreign firms based in Taiwan and their impact on the flow of knowledge.

Creating science and technology capacities**:** In the early 1970s, little research was done in Taiwan. There were few researchers, limited funds and projects scattered loosely. A similar situation existed in the manufacturing industry. Due to Taiwan's industrial structure, based on small enterprises, the development of high-technology industries is somewhat handicapped.

To change these conditions, the Industrial Technology Research Institute (ITRI) was established in 1973. ITRI is now the largest industry-oriented research institution in Taiwan. ITRI receives contracts from the government to develop generic technologies, and transfer the results to the industries in a non-exclusive manner. It also conducts short-term R&D projects in cooperation with private organizations, generally to improve product performance and process efficiency. ITRI's research scope covers electronics and IT, machinery, biomedical and advanced materials, energy and resources, and more recently civil aerospace. At the end of the 1980's the government set up "key research institute" and "center of excellence" at each of the four national universities - *National Taiwan, National Tsing-Hua, National Chiao-Tung*, and *National Cheng-Kung* - in the fields of applied mechanics, material science, information technology and aviation and aerospace technology.

The Hsin-Chu Science-based Industrial Park (HSIP) was established in 1980 under the guidance of national Science Council. Of all industries within the HSIP, the Integrated Circuits Industry is the largest. It is also the most important in terms of number of companies, scale of operations and sales revenues. HSIP is one of the world's main centers of IC manufacture. The second largest industry within HSIP is computers and peripherals.

***Converting research results into commercial products*:** Traditional enterprises are the mainstay of manufacturing. They consist mainly of small and medium-sized companies with assets under NT $40 million and account for 98 per cent of all manufacturing firms. A typical small company has 10-100 employees. The state provides support by funneling cash for industrial automation through *Chiao Tung* Bank, improving management quality through the China Productivity Centre and various industrial development centers give technical support to companies.

In order to speed up the conversion of R&D results into commercialization, The Department of Industrial Technology (DOIT) of the Ministry of Economic Affairs employs the strategy of industry-institute joint research projects. Based on needs of companies with limited R&D facilities, DOIT also promotes a research-based ‘open laboratory’ strategy. These open laboratories give access to companies for the purpose of maximizing existing resources and minimizing investment risks before commercialization can take place.

2.3.4. Lessons learnt for benchmarked countries

- Economic development can be achieved through quality and massive well trained human resources,
- Micro and small especially export oriented industries should have strong policy initiatives and financial support,
- Reverse engineering can be scratch point for countries technological development
- To develop the catch-up and technological adaptation in the countries, the industries need to have their own research and development units,
- Establishing technology center dedicated for undertaking reverse engineering of imported capital goods,
- Developing national innovation programs and projects for the next 10 years,
- Huge markets were created for the technology importing in the country,
- The research and development of university-industry linkage were used for the transition from imitation to innovation,
- Accelerated small and micro enterprise’s development,

- The potentials were used for utilizing, adopting, adapting and innovating energy, transport and communication sectors,
- Developing an effective backward linkages between the medium and small enterprises,
- Establishing industrial technology research centers and science parks and arranging conducive environments for effective university and industry linkages,

2.3.5. Experience of technology transfer in Ethiopia

Ethiopia had its own innovation as one of the oldest countries and societies. The most prominent ones are the creation of its own alphabet through the church and church run school systems for nearly 1700 years. Ethiopia was also owner of boat and ship technology as it crossed the Red Sea to rule southern Arabia. In terms of construction and engineering, the pre-Christian era Axum Obelisks, the Queen Sheba Palaces, the Lalibela rock Hewn Churches, the Dire Sheik Hussein Mosque, the Harar walls and other buildings, and the Gonder Fasil Palaces that are 500 to may be 2000 years old do still exist and some of them are still in service.

There were several closed classes of artisans (blacksmiths, goldsmiths, silversmiths, tanners, weavers, tailors, woodworkers, potters, etc.), which formed strictly endogamous castes. It is relevant to a study of technology in the Ethiopian context to note that the artisan castes, as already observed, were often credited with supernatural powers and much feared. The scar exists even today.

Since the re-establishment of contacts with Europe in the sixteenth century, Ethiopia has shown a desire to acquire European technology. Emperor Lbne Dngl (1508-1540) wanted artisans from Europe. Emperor Sertse Dngl (1563-1595) wrote to the King of Spain requesting that he send artisans who could make cannons and gunpowder. During Emperor Sussnyos's time (1605-1632), a number of new technologies were introduced into Ethiopia by European artisans, including a flour mill which required no human or animal power and which, therefore, was presumably a water mill, a new kind of bridge made with stone and lime, and a palace also constructed with stone and lime. It should be noted, however, that though the use of lime to make strong cemented walls to support vaulted buildings appeared new to Emperor Sussnyos's chroniclers, and presumably to the Emperor and his court, churches similarly constructed had already been reported in Tigray and Wello. The supposedly new introductions of Emperor Sussnyos's time later gave rise to the much grander castles of Gonder. (Woldearegay, 1984)

A large part of the old empire was reunited by Emperor Theodros (1854-1867), who tried to establish a firearms industry in Ethiopia. That gunpowder was locally manufactured has been recorded by visitors to Ethiopia. Emperor Theodros's army made its own gunpowder and bullets. He was very eager to introduce European technology into his country, he initiated a series of diplomatic contacts with Europe, especially with Queen Victoria of England. He exploited the history of the Ethiopian Church to appeal to European Christendom to send Protestant missionaries.

Some of the missionaries did not endear themselves to the king based on their cultural biases or insensitivity. Unable to effectuate his modernizing impulses, with his political fortunes and popularity waning, Tewodros expressed his frustration by holding British missionaries and diplomats captive in Meqdela. This leads to the death of Tewodros.

It was during Menelik II era that modern technologies are started and introduced to Ethiopia from the westerns technological advancement. He was fascinated by modernity and had a keen ambition to introduce Western technological and administrative advances into Ethiopia. Though there was no development plan of the country during this regime, Menelik was able to introduce foreign technologies in Ethiopia. It was Emperor Menelik who brought, through foreign engineer, some of the technologies and instruments that we use today. Tap water (1894), electric power and telephone (1897), gramophone (1897), mills (1901), bicycles (1901), automobile (1908), bullet factory (1911) are a few among others. Through the introduction of all these technologies, he faced many challenges internally starting from his wife, political leaders, religious leaders (the Ethiopian Orthodox Church) and the people at large.

Due to wars and various attitude of religious closed door policies that existed even after the reign of Emperor Menelik, must have limited the country’s external political and economic relations. This made the technological transfer very slow.

The main obstacle for these innovations was the resistance from the community which held that they were “the work of the Devil” – a resistance that stretched all the way from the common people to the priests around the Emperor who refused to drink tap water. The method that the Emperor used to curb such resistance was by testing the technologies first by himself, his family and his executives. For instance, he himself was the first driver, the first to use the grinding mill, the first photographer and the first movie spectator. Then technologies like the airplane and radio were introduced in 1929 and 1936 respectively.

During the five-year Italian occupation (1935-1941), though much technological hardware obviously came into the country with the Italians, Ethiopian technological development was arrested, as the native Ethiopians were not allowed access to education beyond basic literacy in Italian. Nevertheless, owing to the length (over 50 years) of stay of the Italians in Eritrea, many people living there informally acquired knowledge of some European technologies and they played an important role in the spread of European technologies to the rest of Ethiopia in the post-Italian period.

e. The Imperial Period (1950 - 1974)

A number of technologies were introduced by Emperor Haile Selassie in and around Addis Ababa. These include the establishment of schools and universities as well as roads, the airline and TV transmissions. It is to be recalled that technological transfer was better particularly during the last days of the Emperor.

The imperial government has enacted legislation and implemented a new policy to encourage foreign investments. (United, 2002) This policy provided investor benefits in the form of tax exemptions, remittances of foreign exchange, import and export duty relief, tax exemptions on dividends, and the provision of financing through the Ethiopian Investment Corporation and Development Bank of Ethiopia. In addition, the government guaranteed protection to industrial enterprises by instituting high tariffs and by banning the importation of commodities that might adversely affect production of domestic goods. Protected items for foreign investments in that era include sugar, textiles, furniture, and metal products.

With regard to TT, the government used foreign direct investment which is the main channel of International technology transfer and turnkey packages in the government and domestic investment. Though they used the mechanisms of international technology transfer, the domestic absorptive capacity was the main limitation for effective technology transfer in Ethiopia. The Regime was lucking human resource and institutional development in the science and technology fields that builds the national technological capability of the company. There was no technological university-industry technology transfer, no center of excellence, and science, technology, and innovation policy that promotes TT in the country.

The government has also participated through direct investment in enterprises that had high capital costs, such as oil refineries (currently found in Eritrea), glass and bottle, tire, and cement industries.

In this era, the government's policy has attracted considerable foreign investment to the industrial sector. For instance, in 1971/72 the share of foreign capital in manufacturing industries amounted to 4l percent of the total paid-up capital which many foreign enterprises operated as private limited companies, usually as a branch or subsidiary of multinational corporations.

f. The socialist period (1974 – 1991)

After Derg came to power, the country’s diplomatic ties were diverted to the Eastern bloc and as such, lots of technologies and communications were brought to the country from North Korea, East Germany and the USSR. As the policy discouraged private participation and innovation, and as the economy was under government control, the country was almost alien to new innovations.

During the Derg regime, all the policies, plans and programs was towards promoting socialism that prohibits private investment from both foreign and domestic sources. Moreover, the existing foreign and domestic private enterprises were nationalized. As the main channel of foreign TT, the regime totally closed FDI. Though, movement people from Ethiopia to socialist countries for education purposes, there was no as such development program for domestic absorptive capacity during that regime. In fact there were some TT activities in the military industries by establishing some few assembly plants and bullet manufacturing industries. The government also brought and introduced some heavy industries in cement, basic metals, textile, and other sectors in collaboration with the socialist countries. However, these all didn't bring effective TT in Ethiopia due to lack of national capability development program.

The l975 nationalization of major industries has changed the environment drastically and private direct investment according to the National Bank of Ethiopia report at that time has declined from 65 million birr in l974 to l2 million birr in l977. Issued in l983, a new Proclamation No. 235 (the Joint Venture Proclamation) has signaled Ethiopia's renewed interest to attract foreign capital. The proclamation offered incentives such as a five-year period of income tax relief for new projects, import and export duty relief, tariff protection, and repatriation of profits and capital. Despite the government's attempt in this period to reverse the situation, the different proclamations enacted in that era have failed to attract foreign investment as most of the foreign investors were hesitant to invest in a country whose government recently nationalized foreign industries without a level of satisfactory compensation and partly due to the ongoing civil war in that period.

g. *The Market Based Economic Period (1991- to date)*

With the end of the civil war in 1991 and take-over of power by the Ethiopia People's Democratic Front (EPRDF), the government enacted investment proclamation in line with the market oriented economic policy that was being pursued.

To facilitate investment administration, the Investment Office of Ethiopia (IOE) has been established as a 'one-stop shop' to actively promote and co-ordinate all investment activity in the country. The IOE is supervised by the Ethiopia Board of Investment, which is accountable to the Council of Ministers. In an attempt to encourage both domestic and foreign private investment flows, the government provides various incentives, including:

- percent exemption from the payment of import duties and other taxes levied on imports of capital goods, equipment and spare parts up to 15 percent of the value of capital invested;

- exemption from the payment of import duties levied on the import of raw material for production of export-orientated goods;
- income tax exemption for periods ranging from three to eight years; this is a function of where the investment is located and also the priority accorded to the particular good;
- all research and development expenses are tax deductible; and
- Remittance from the proceeds of the sale or transfer of shares or assets upon liquidation of enterprises to domestic investors is exempt from the payment of any tax.

In addition to the above incentives, there is unrestricted repatriation of profits and dividends, as well as the unrestricted remittance of fees, royalties, principals and interests on approved foreign loans. The investment legislation prohibits expropriation of assets, except in accordance with the due process of law and upon the payment of adequate and prompt compensation.

In terms of investment protection, Ethiopia has ratified the Multilateral Investment Guarantee Agency convention, providing protection against political and non-commercial risks. A bilateral investment protection accord has also been signed with some European countries.

The first National Science and Technology Policy of Ethiopia was issued by the Transitional Government of Ethiopia in December 1993 although the efforts to coordinate and guide scientific and technological activities at national level in Ethiopia date back to the early 1970s, the major objectives of the policy include building capability to generate, select, import, develop, disseminate and apply appropriate technologies; and improving the knowledge, culture and the scientific and technological awareness of the peoples of Ethiopia for the realization of the country’s socio-economic development goals.

Implementation of the policies and strategies has resulted in positive outputs that contribute towards building an innovative economy in the country. The following are the major results:

- Rapid expansion of primary, secondary, technical and vocational; and tertiary education (both at undergraduate and graduate levels) through the Government capacity building national program;

- Strengthening of the national agricultural research system through human resource development and infrastructural capacity building of the Ethiopian Agricultural Research Institute and establishment of Regional Agricultural Research Institutes accompanied by deployment of three extension workers per Kebele to assist the farmers in using technologies to improve their productivity and life style;
- Technical, financial and administrative support to young graduates of Technical and Vocational Education and Training Colleges to develop and run their own micro and small business enterprises;
- Creation of conducive business environment and incentives that attracted a good number of foreign and local investors to establish and run business enterprises in agro-industry, manufacturing, construction and services;
- The aggressive and commendable efforts of expanding ICT use across the country (including the Woreda Net and School Net programs).

2.3.6. Factors enabling the Transfer of Technology

- The existence of low labor cost in Ethiopia is a very attractive factor for technology transfer
- Ethiopia has a huge untapped raw material of agricultural products especially Coffee, Cotton and annual Skin;
- In an effort to encourage foreign and private investment, the Ethiopian government has enacted an investment proclamation with many incentives to attract the transfer of technology;
- Ethiopia, with over 70 million population is a large enough potential market to attract foreign investment. Furthermore, the strategic importance of the country for Common Market for Eastern and Southern Africa Countries (COMESA) can be considered as an attractive factor for countries that need to expand their market dominance;

Chapter Three - Data Analysis Presentation

3.1. Socio-Economic Status of Ethiopia

Almost all the socio-economic development indicators show that Ethiopia is one of the least developed countries in the world with a total population of about 82,824,732 growing at an average annual rate of 2.6% (2009). The real per capita income is about USD 344 (2009). Life expectancy at birth of the total population was 56 years while the adult literacy rate stood at 30% (2008). (World Bank)

Ethiopia's economy is predominantly agrarian, which is the major source of livelihood for about 83% of the total population and accounting for 90% of the total export trade. The share of the sector in the GDP is shown in table 3-1, below. It is because of this fact that agriculture is taken as the base for the country's industrialization. Fast and effective development of agriculture will lead to fast export growth, and will contribute to robust raw material supply to the industrial sector.

Table 3-1: *Structure of the Economy (% contribution to GDP)*

Sector	**2004/05**	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**
Agriculture	47.4	47.1	46.3	44.6	42.4	42.0
Industry	13.6	13.4	13.3	13.1	12.9	13.0
Services	39.7	40.4	41.4	43.4	44.7	46.1
GDP	**100**	**100**	**100**	**100**	**100**	**100**

Source: NBE (2009), MoFED, (PASDEP (2006) and Progress Reports (2007)

The national economic policy has been formulated on the principles of free market economy while the development strategy focuses mainly on Agricultural Development Led Industrialization (ADLI). The objectives of ADLI include promotion of economic efficiency and growth; development of domestic technological capacities and capabilities for the promotion and development of small and intermediate (capital good producing) industries such as those engaged in the production of spare parts and components; promotion of inter and intra-sectorial linkages; creation of a sound domestic base for technological capability accumulation; promotion and greater use of labor intensive technologies and local resources; achievement of industrial competitiveness in areas of clear comparative advantages in industrial exports; and promotion of balanced regional industrial development. To achieve these objectives, the government is engaged in massive capacity building programs and infrastructure development activities mainly in the areas of food security, education, energy, communication, health care, road, water, and housing.

Ethiopia is showing an encouraging pace of socio-economic development in recent times, especially within the last decade as displayed in Table 3-2. For instance, the real GDP of the country grew by two-digits for the sixth time in a row from 2003/04 to 2008/09. This development has been recorded mainly due to improved performance of the agricultural sector as a result of concerted efforts of the federal, regional and local governments to implement the various development policies and strategies.

Table 3-2: *Trends in Economic Performance – Growth Rate (%)*

	2004/05	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**
GDP (1999/2000 Prices)	12.6	11.5	11.5	11.6	11.2	
Agriculture	13.5	10.9	9.4	7.5	6	7.6
Industry	9.4	10.2	10.2	10.4	10.6	10.6
Services	12.8	13.3	14.3	17	17.3	13.0

Source: NBE (2009)

The non-agricultural sectors also contributed a significant share to the overall economic expansion as the growth became more broad-based and structural transformation was evidenced. The growth in industry mainly was derived from manufacturing in the areas of leather, textile, and others. Similarly, the service sector showed a steady increase in its share in overall real GDP during the last four years. In particular (With some period), the financial intermediaries have shown improvements contributing to the boom of the service sector. In fact, this sector continued to operate under a sound domestic environment despite extraordinary shocks in the global financing system that unfolded in 2007 through 2008. The observed growth has in fact been mainly due to putting more agricultural resources into production and the growing public and private investment in industrial and service sectors.

The government adopted Industrial Development Strategy in 2003. The strategy aims to ensure sustainable industrial development and effective linkage with the agricultural sector. The fundamental features of the strategy are among others: promotion of private sector led industrialization; development of export-oriented industries and strengthening the capacity of the existing industries to be competitive at the national, regional and international levels; utilization of labor intensive technologies to the extent possible, with a view to create employment, income generation, and poverty alleviation .The industry sector is generally characterized by production of consumer goods such as food, textiles and beverages. Although the sector accounts for more than 50% of value added to the gross value production of the same year, it has been characterized by a low-level of development. Furthermore, the basic metal and engineering industries sub-sector, which is commonly recognized as the basis for industrialization is characterized by a very low level of development.

3.2. Overview of Ethiopian Basic Metal & Engineering Industries

The history of metal and metal products manufacturing in Ethiopia indicates that iron smelting was a common practice in the country starting from the 14th century onwards according to a study conducted by Alula Pankhurst. People in the area of Adwa have been well reputed for production of good knives, spears, and razors according to this study.

Iron has been produced from Iron ore in areas of Salora, Bora, and Wojjerat, Dime, and other areas where it is found in abundant quantity and reduced to a usable iron form by formerly called "*Buda's*". However, most of the local production has been diminished and replaced by cheap and abundant imported iron. Iron smelting by locals has been survived at Dime till 1973 which is believed to be the total death of the local iron smelting industry though black smith activities on imported iron is still a common practice in many parts of the country.

However, the history of basic metal and engineering industry in Ethiopia doesn't have a long history compared to iron smelting. It is the establishment of the two ammunitions factories in 1927 which starts the era of Basic metal and engineering industry in Ethiopia. At the end of the Imperial Period, the king has succeeded to establish Ethiopian Iron and Steel Foundry, Kaliti Steel Industry, Kotebe Metal Tools Factory and other sheet metal fabrication shops.

Though most of the enterprises nationalized in the Derg Era, the basic metal and engineering sector has been established as National Metal Corporation with the objective to create self-sufficiency in industrial spare parts, tractors, pumps, and other agriculture mechanisms. Akaki Spare Parts and Hand Tools S.Co., Nazareth Tractor Factory and Pump Factory are the leading metal engineering industries established in the Derg era. The emergence of Maru Metal Plc from the private sector is also the other prominent industry in the time.

The current EPRDF lead government has established Basic Metals and Engineering Industry Agency (BMEIA) currently named as Metal Industry Development Institute (MIDI) with the objective to revive the basic metal and engineering sector. However, the government's policy to use the agriculture sector as the dominant economic muscle has made the sector still weak and less competent. However, the number of private investors engaged in the sector in comparison with the previous regimes is still significant though the development of the sector is still at its infant stage.

3.3. Government policy towards technology transfer and reverse engineering

The role of government in paving the roads of the country's technology transfer plays a crucial role and success factor for economic development. Accordingly, the government is currently working and has given technology transfer a priority. The responsible body for promoting and coordinating the technology transfer effort in the country is ministry of science and technology. Currently, ministry of science and technology has prepared a policy on the national technology transfer and waiting for approval. The green paper in the policy has mentioned the phases of national technology transfer. Therefore, the first phase is that technology import, assimilation and diffusion. In this phase, the main objective is to develop and enhance the local technological capability through learning by doing. The next phase is reverse engineering, which is after effective dissimilation of technology followed by technology adoption, adaptation, modification and imitation. The time frame is also indicated in the green paper as an implementation strategy. According to the proposed policy, reverse engineering will be used as a tool for technology transfer by 2015.

The policy indicated in the ratified policy has also mentioned the support for the firms to develop their technological capability; which will enforces to have the firm level technology transfer unit. This unit is responsible for adaptive research and development activities. In doing so, these firms engaged in import substitution will have a preferential treatment such as:

- Tax exemptions
- Duty free for the imported equipment and inputs
- Increase budget allocation for applied research and tertiary education, and other

Even though the document is not approved, the implementation and required preparation is started and ongoing.

3.4. Primary and Secondary data analysis

3.4.1. Secondary data analysis

a) Economic Contribution of Ethiopian Metal Industries

The economies of world giant countries like the US, Japan, China and India are largely dependent on the metal sector both at its upper and lower stream. However, the contribution of the sector in Ethiopia's economy is so limited and according to the ECSA report, the number of industries in the sector including small scale metal product manufactures is only 7.04 % of the total manufacturing activities 2007/2008. From the 7.04% of basic metal and engineering industries, 5.45 % of them are largely engaged in the production of low tech metal products table 3-3.

Furthermore, the employment opportunity created from sector is short of 10,000's according to the same survey conducted in 2007/2008. In the same manner, the metal industry in most African countries could be viewed as undeveloped. However, some countries are still benefiting from the sector as shown in the table 3-3. For example, in neighbor Kenya, the metal sector constitutes about 19 % of the country's GDP and the same is true in most North African countries. Having these facts in mind, building a strong metal sector has to be viewed as a main policy towards building industrial nation.

Table 3-3: *Metal sector contribution to the GDP in the different African countries*

No.	***Country Name***	***% contribution of metal sector to GDP***
1.	*Egypt*	*19.40%*
2.	*Tunisia*	*19.40%*
3.	*Kenya*	*19.00%*
4.	*South Africa*	*17.20%*
5.	*Mozambique*	*10.70%*
6.	*Zambia*	*8.40%*
7.	*Ethiopia*	*0.746%*

Table 3-4: *Distribution of Large and Medium Scale Manufacturing Industries by Major Industrial Group - Public and Private 2000 E.F.Y*

Division of ISIC Rev. 3	***Major Industrial Group***	***Percentage***
15	*Manufacture of Food Products and Beverages*	*25.51*
16	*Manufacture of Tobacco Products*	*0.05*
17	*Manufacture of Textiles*	*2.13*
18	*Manufacture of Wearing Apparel, Except Fur Apparel*	*1.86*
19	*Tanning and Dressing of Leather; Manufacture of Footwear, Luggage and Handbags*	*4.04*
20	*Manufacture of Wood and Products of Wood and Cork, Except Furniture*	*2.18*
21-22	*Manufacture of Paper, Paper Products and Printing*	*5.76*
24	*Manufacture of Chemicals and Chemical Products*	*3.4*
25	*Manufacture of Rubber and Plastic Products*	*3.95*
26	*Manufacture of Other Non-Metallic -Mineral Products*	*27.6*
27	*Manufacture of Basic Iron and Steel*	*0.82*
28	*Manufacture of Fabricated Metal Products -Except Machinery and Equipment*	*5.45*
29	*Manufacture of Machinery and Equipment N.E.C.*	*0.23*
34	*Manufacture of Motor Vehicles, Trailers and Semi-Trailers*	*0.54*
36	*Manufacture of Furniture; Manufacturing N.E.C.*	*16.48*
		100

b) The Role of BME Sub-Sector in the Development of the Country

The basic metal industry is crucial to the development of any modern economy and is considered to be the backbone of human civilization. It is for this reason that the level of per capita consumption of steel is treated as an important index of the level of socio-economic development in any country. It is a product of a large and technologically complex industry having strong forward and backward linkages in terms of material flows and income generation. All major industrial economies are characterized by the existence of a strong steel industry and the growth of many of these economies has been largely shaped by the strength of their steel industries in their initial stages of development. Historically, steel industry was in the vanguard in the liberalization of the industrial sector and has made rapid strides since then. Worldwide, output has increased, the industry has moved up in the value chain system.

Basic metal industries, as the name implies are normally upstream technologies that cater to the requirements of downstream technologies through providing the required raw material in sufficient quantity and acceptable quality. In this connection, virtually all engineering industries, engaged in the manufacture of components, parts, capital goods, etc., depend on the output of the basic metal industries for their raw material requirement. The construction sector also depends on the basic metal industries when it comes to concrete reinforcement and pre-engineered buildings. The agricultural sector also is a consumer of the output of these industries in some of its requirements such as structures for green house, pipes for irrigation, etc.

Currently, the major consumer of the outputs of the basic metal industries is the construction sector. With the current growth of the construction sector, however, it has not been possible to meet the demand with the existing basic metal industries because of which the country is forced to import the balance. The volume of import is immense and characterizes the dependence of our economy on this important material.

The engineering industries mainly require mild steel for welding fabrication, and alloyed steels for engineering components and parts. However, because of the low level of development, the materials requirement are limited which doesn’t go along with the production capacities of the basic metal industries in general and hot rolling facilities in particular. As a result, the material demand for the engineering industries is fully met through import and for some time to come the engineering industries can’t be a market base for the basic metal industries. In this regard, the focus of the market for the basic metal industries shall be the construction sector at least for the foreseeable future.

There are few plants, which can be considered as engineering factory. The manufacture of machinery and equipment is almost non-existent with the exception of the former pump factory, truck, bus and tractor assembly plant and trailer manufacturing plant and the abandoned light aircraft assembly plant of Ethiopian Airlines.

Engineering industries in Ethiopia is still in its infancy over the years even if expansion of this industry is making a very substantial increment and is not likely to make a very potential contribution to the National Economy. However, it is evident that engineering industries can play an important role in serving other industries by providing experienced technical manpower at large and also a significant role by incubating small-scale industries.

c) Performance of Basic Metal Industry

Local Production

The range of products to be contained in the basic metal industries constitute hot rolled ribbed and plain reinforcement bars, wire rod, angles, cold rolled tubes of various profiles, cold rolled sheets, galvanized sheets and tubes.

As per the Statistical Abstract of 2005, the performance of the basic metal industries by way of production volume and value addition can be summarized as given in table below.

Table 3-5: *BMI Performance*

2002		*2003*		*2004*	
Gross value of Production ('000 ETB)	*Value added (ETB)*	*Gross value of Production ('000 ETB)*	*Value added (ETB)*	*Gross value of Production ('000 ETB)*	*Value added (ETB)*
454,473	*68,212*	*382,701*	*61,111*	*761,825*	*122,851*
8,0917,737	*3,810,499*	*8,996,093*	*2,567,797*	*10,871,759*	*3,709,502*
0.56	*1.79*	*4.25*	*2.38*	*7*	*3.31*

With regard to gross value of production the basic metal industries constitute 0.56% to 7% of the manufacturing sector in the period 2002-2004. If we consider the performance of the basic metal industries in the year 2004, its contribution to the GDP is to the magnitude of 7%. Overall, it can be inferred that the contribution of the basic metal industries to the overall economy is minimal which indicates that there is much to be desired from this industry if it has to position itself to a level where it can be a real contributor to the economy. However, the overall trend of the industry is very much encouraging if it continues to grow, especially in a better enabling environment. As can be seen in Table 3-5 the performance of the industry in the period 2002 and 2004, one can witness that there is an increase of 67% in the gross value of production.

Because of the limited capacity, the market base for basic metal industries has always remained to be the domestic demand which has been partly met through these local industries and predominantly through import.

Imported Basic Metal Products

Imported basic metal products cover billet, slabs, coils, bars, wires, ribbed bar & water pipe, nails and structural sections manufactured by processes of casting and rolling. While ribbed bars, water pipes, wires, nails are for direct use, sheet metal & stripe imported in coil form are cut to length or converted into tubes and hollow section by local industries. Sheet metals and structural hollow sections are used to manufacture tanks, doors and windows and other products. Bar Rod and plates are machined and fabricated to produce machine components.

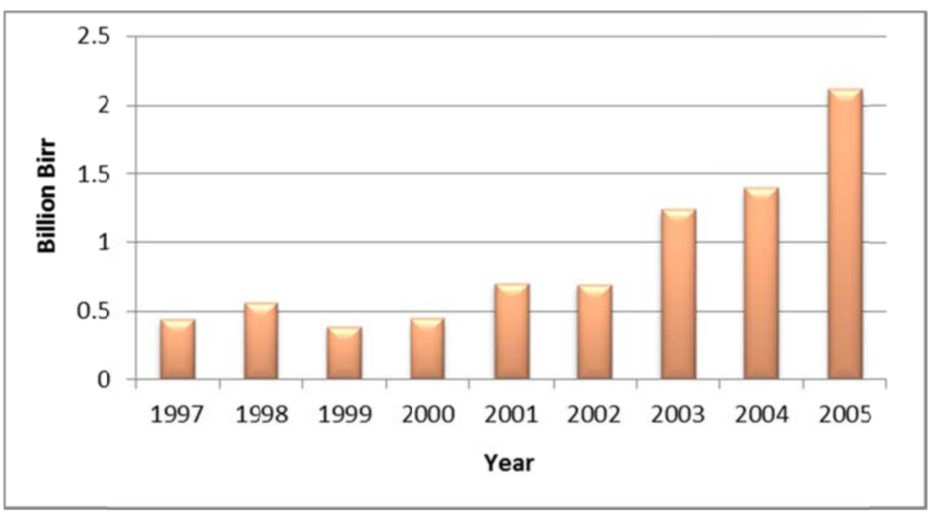

Figure 3-1: *CIF value of Imported Primary Iron and Steel products*

Figure 3-1 indicates primary metal products import except tubes. From 1997-2002, there was minor growth whereas from 2003-2005, considerable growth of primary metal products is seen. It has grown by nearly 300% compared to the figure of 2002 mainly attributed to accelerated growth in the construction sector. The total value of imported primary metal products of this category amounted Birr 2.16 Billion in 2005.

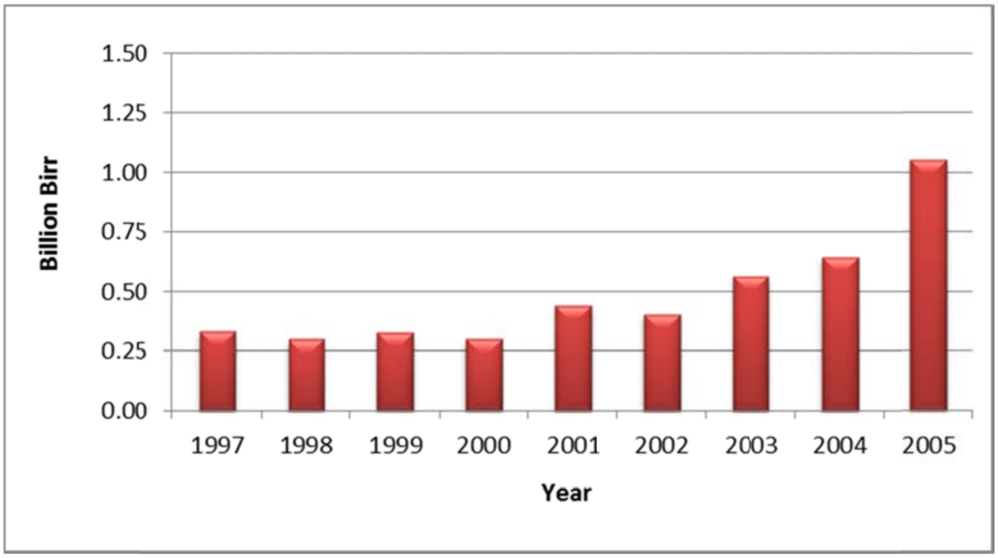

Figure 3-2: *CIF Value of Iron and Steel Articles*

(Tubes, pipefitting, tanks, structure, nail, bolts and nuts, cooking pan)

Similar trend can be also observed from Figure 3-2 of imported iron and steel articles which mainly consists of tubes, pipe fittings, tanks, structure, nail, bolts and nuts and cooking pan.

Generally, the volume of import coils for a balanced increase of local production in guiding and supporting industrialists in the field.

d) Performance of Engineering Industries

Local Production

While the major outputs of basic metal industries are corrugated sheets, bars, tubes and hollow sections, the major product of local engineering industries are machines, equipment steel structures, metallic door and window frames, spare parts, tankers, vessels and truck trailers.

Production Volume and Industry Contribution

The engineering industry is presently at a very low level of development in Ethiopia. This is illustrated by the low valued added and the low share of manufacturing industries which is 0.77% of the manufacturing industries.

The share of engineering industries from the overall manufacturing sector in Gross Production value amounts 12.43 % in 1996 E.C. The growth of this sector from 1994- 1996 was on average 29.28 % as computed from CSA data.

Imported Engineering Products

Imported engineering products include fabricated metal products such as prefabricated & transmit tower and green house structures, metallic window, doors and vessels, machinery, spare parts, vehicles, and electrical and electronic equipment. Since the local supply of machinery is almost insignificant to satisfy the demand of new and existing industries in the country, imports of machinery and equipment is necessary. The imported engineering products are categorized in to machinery, trucks, electrical and electronic equipment, motor vehicles and miscellaneous fabricated products as given in Fig. 3-4 respectively as per trade classification.

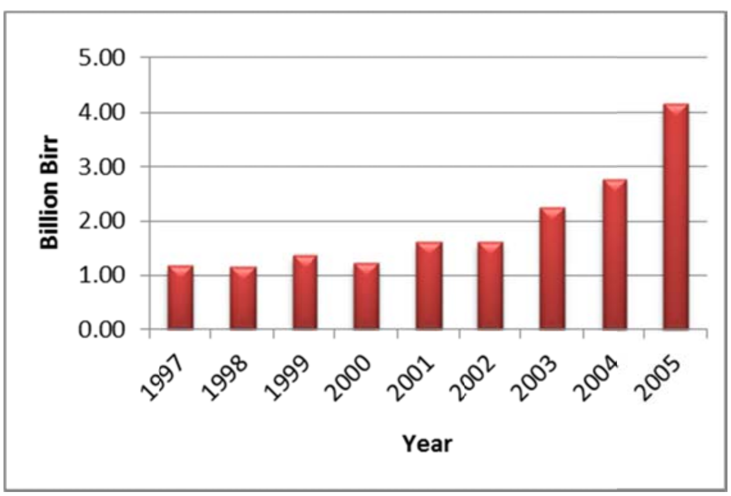

Figure 3-3: *CIF Value of Imported Machinery from 1997 to 2005*

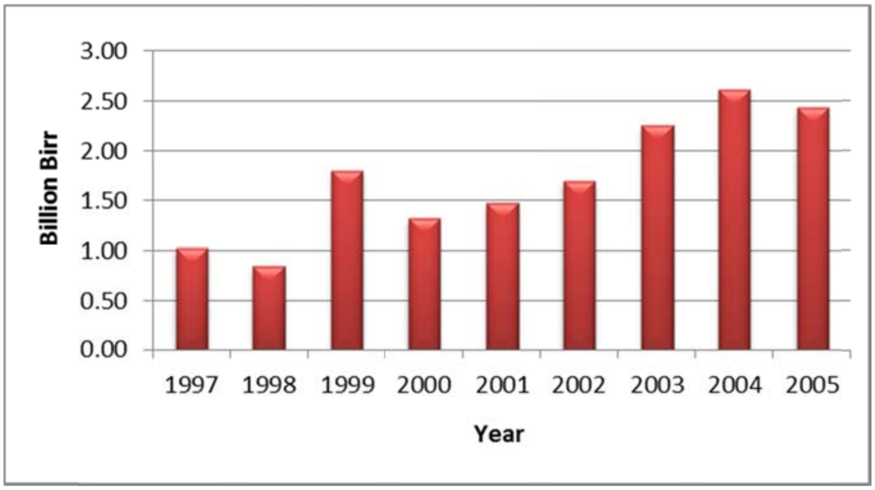

Figure 3-4: *CIF Value of Imported Motor Vehicles from 1997-2005*

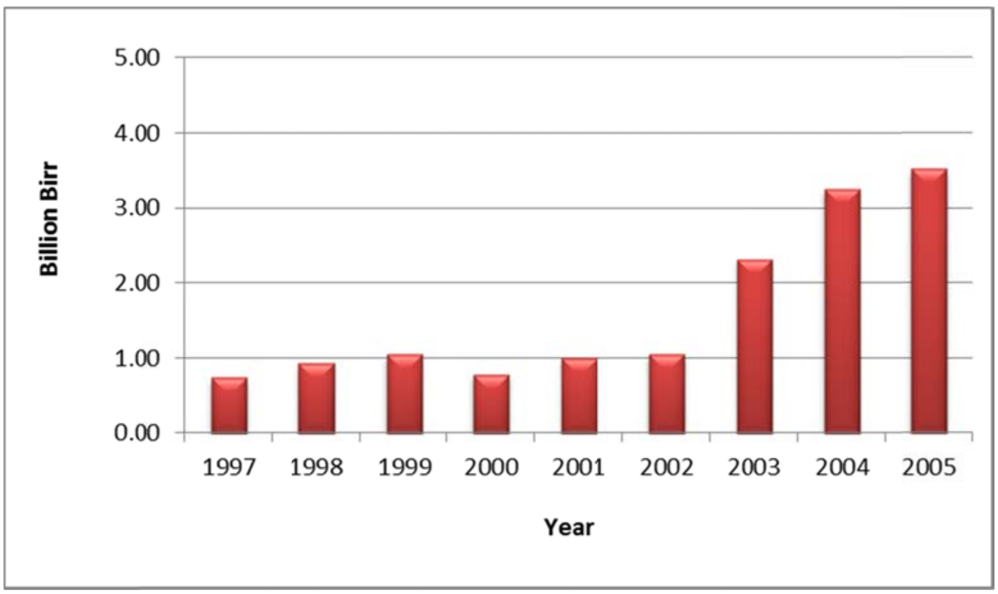

Figure 3-5: *CIF value of Imported Electrical & Electronic Equipment from 1997-2005*

During the period 1997-2001, import of these products was nearly constant with some fluctuations. For the period 2002-2005, however, the import of engineering products was growing at a higher rate and its total value reached Birr 10.86 billion in 2005. This was mainly due to intensified manufacturing activity and infrastructure building. As more manufacturing industries are to be established and infrastructure has to be built the trend will continue even at higher growth rate. This positive indicator that shows industrialization growth can have negative effect in the balance of foreign trade of the country unless checked.

The overall picture of the local production mix and enterprises engaged on one hand, and the import volume in terms of foreign change share requires special policy attention and appropriate development program to enhance local capacity to substitute imported products.

In general, the above data's shown clearly indicates the urgency for intervention of metal and engineering import substitutions. Though the import data for metal and engineering products is up to the year 2005, it clearly shows a booming demand in the country. Accordingly, the current rank for the import is metal and engineering products in the first place followed by the oil. From these it can be concluded that reverse engineering plays a crucial factor for this sector by substituting the import and building technological capability.

It is therefore necessary to assess the metal and engineering sectors to identify the status of reverse engineering, technological capability and technology transfer undertakings at the firm level through the primary data collection.

3.4.2. Primary Data Analysis

The primary data collection was conducted with the help of questionnaire. The questionnaire is designed based on the factors that affect the practice of reverse engineering. Accordingly 41 companies were randomly selected from metals and engineering industries around Addis Ababa for survey and questionnaire was distributed for each firms. In addition to the major markets for the industries, Addis Ababa is the capital city of the country and most of the companies are located is the city. Among the distributed only 31 questionnaires were collected and data analysis is formulated based on these inputs. The main focuses of the questionnaire are:

- ✓ The status and situation of reverse engineering in the country
- ✓ Technological capabilities of the firms that are engaged in metal and engineering industries for reverse engineering/imitation
- ✓ The effort of research and development of the firm which enhance the development of reverse engineering/imitation activities and innovation capacity
- ✓ The government support and determination for reverse engineering and firm level research & development.

- ✓ The support and determination of management of the firm for research and development, reverse engineering and technology transfer.
- ✓ The market conditions for reverse engineered parts, equipment and machineries in the country.

Accordingly, SPSS software is used as a tool for analyzing the questionnaire. The data presentations are based on the basic contents of the question and summery of the result is presented as follows.

a) Awareness and practice of Reverse engineering

For the reverse engineering to be executed at the firm level, awareness is the first step and plays crucial role. Awareness of the industries in this context means, what reverse engineering meant, the methods to conduct reverse engineering and the resources required for conducting reverse engineering at the firm level. The company awareness level of the surveyed companies can be seen in the table 3-6.

Table 3-6: *Reverse engineering awareness and practices at the firm*

Item	*Yes*	*No*	*Total*
Awareness on Reverse Engineering	*89.7%*	*10.3%*	*100%*
RE practice at the firm	*75.9%*	*24.1%*	*100%*

According to the survey the awareness level of the firms to reverse engineering is significant. Among the respondent, only 10.3% needs awareness on Reverse engineering. The rest 89.7% of the firm has the awareness on Reverse Engineering.

One of the objectives of the research is to identify the status of reverse engineering in metal and engineering industries. Though the firms have awareness on reverse engineering, only 75.9% of metals and engineering firms from the result are engaged in reverse engineering. On the other hand, 24.1% of the firm has never been engaged in reverse engineering.

There are different reasons for the firms not to conduct reverse engineering as shown in the figure 3-7. From the various reasons of limitations the highest percentage accounts for the lower demands of the product according to the survey which is 56%. This result is only for the respondents that have never conducts reverse engineering. Another factor that limits the firm from conducting reverse engineering is higher cost for reverse engineering which accounts for 22%. The technical level, IPR regulations for the innovator and other reasons account for the rest of the factors that impedes them to conduct reverse engineering.

Since metal and engineering firms are high capital intensive which requires machineries and technologies, technical capabilities and other equipment vis-à-vis the revenue obtained through reverse engineering is discouraging.

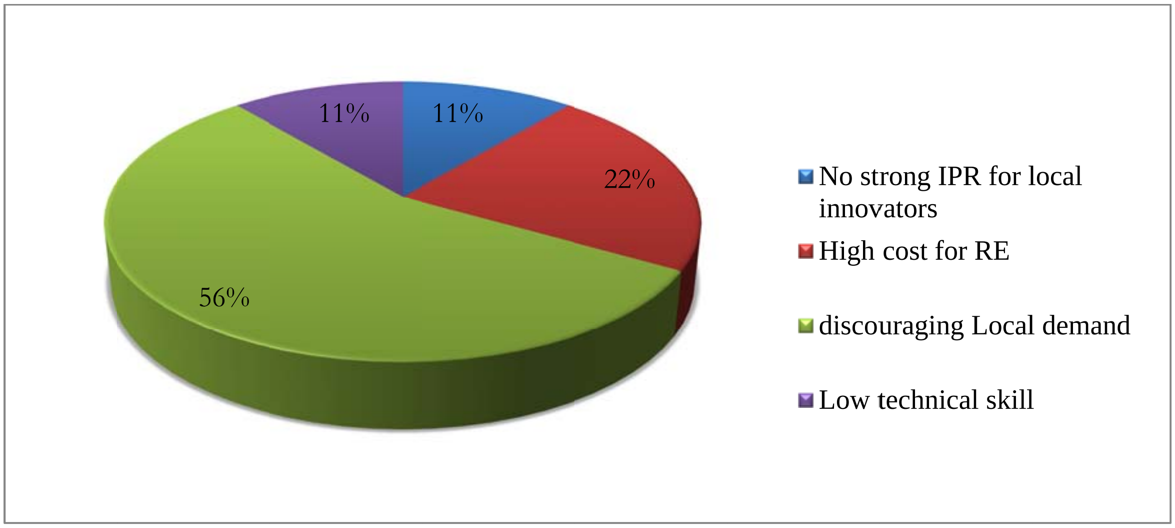

Figure 3-6: *Reasons not To conduct Reverrse Engineering*

In addition, the rationale of the firms engaged in reverse engineering is assessed and the summery of the result is indicated in the table 3-7.

Among those engaged in reverse engineering, the result shown that 50% firms are engaged in reverse engineering because of the original manufacturer no longer exists or the original manufacturer of the product no longer produces the product. This can also indicates that there is still the demand for obsolete part, equipment and machines that are not available in the markets.

Moreover, the higher cost of the original products or the imported products and shortage of foreign currencies in the country which is 63.6% is the motivating factors for the firms to be engaged in reverse engineering. As indicated from the secondary data, the highest and substantial value of import accounts for metals and engineering products. And now days the country is facing a shortage of foreign currency because of unbalance import and export in the country. The result indicates that the arisen problem in the country for the highest demand and shortage of foreign currency creates an opportunity for these firms to be involved in reverse engineering and maximize their market share. Likewise, the devaluation of money and cheap labor force in the country created a difference in the market value of the imported one from the local products.

Table 3-7: *Rationale for Reverse engineering*

Item	***Yes***	***No***
The Original manufacturer no longer exists or the original manufacturer of the product no longer produces the product	*50.0%*	*50.0%*
Shortage of Foreign currency	*63.6%*	*36.4%*
The cost of original product is higher	*63.6%*	*36.4%*
Loose Patent right in the country	*4.5%*	*95.5%*
Exploring new avenues to improve product performance	*36.4%*	*63.6%*

On the other hand, the issue of loose patent right has insignificant factor for the firms to undertake reverse engineering. It accounts only 4.5% of the firms are provoked on loose patent rights unlike the Korean firms as shown in the country experience.

The experience on reverse engineering together with the variety of project can reveal the status and level of reverse engineering. For the reverse engineering practices to develop and embark on import substitutions, the variety of projects at the firm level is crucial. The variety of project conducted together with the experience indicates the developed technical capability and technological acquisitions.

Therefore, the survey assesses the experience of reverse engineering at the firm level and the varieties of projects conducted through that experience. The varieties of project indicate how far the firm is embarking on reverse engineering and import substitution. This question is dedicated only for firms that had already practiced reverse engineering.

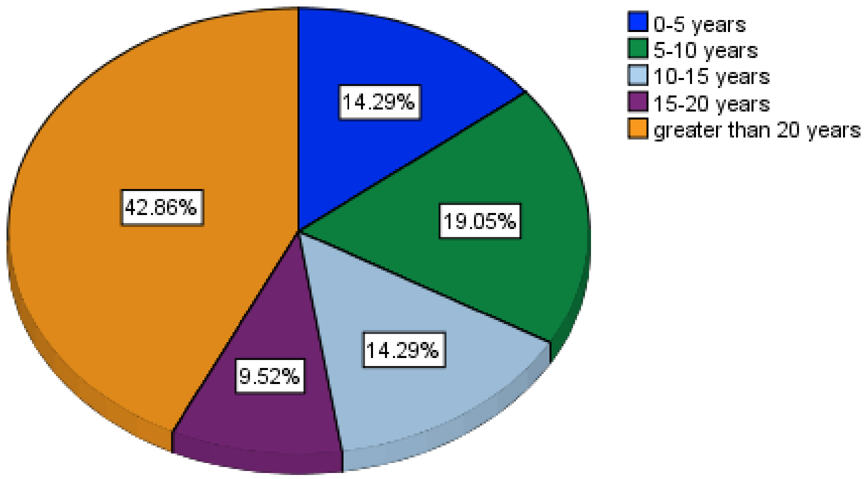

Figure 3-7: *Reverse engineeirng experience in the firm*

Hence as shown in the figure 3-7, the result indicates that most of the firm's 42.86% have an experience of more than 20 years. In addition, Firm with the experience between 15-20 years account to 9.52% of the respondent. On the other hand 14.29% of the firms can be categorized as an infant stage in reverse engineering which has between the beginnings to 5 years. The survey also indicates that most of the firm's 52.38% have the experience of more than 15 years.

In addition, the variety of projects with regard to reverse engineering indicates 65% of the firms have conducted more than 20 different projects. Nevertheless, 10% of the respondents have undertaken less than 10 different varieties of project. Again adding the companies that had conducted more than 15 projects, 70% of the respondents have an experience of more than 15 on reverse engineering projects.

The two statistical data's obtained from the survey indicates that most of the firms have an experience of more than 15 years and had carry out more than 15 projects on reverse engineering.

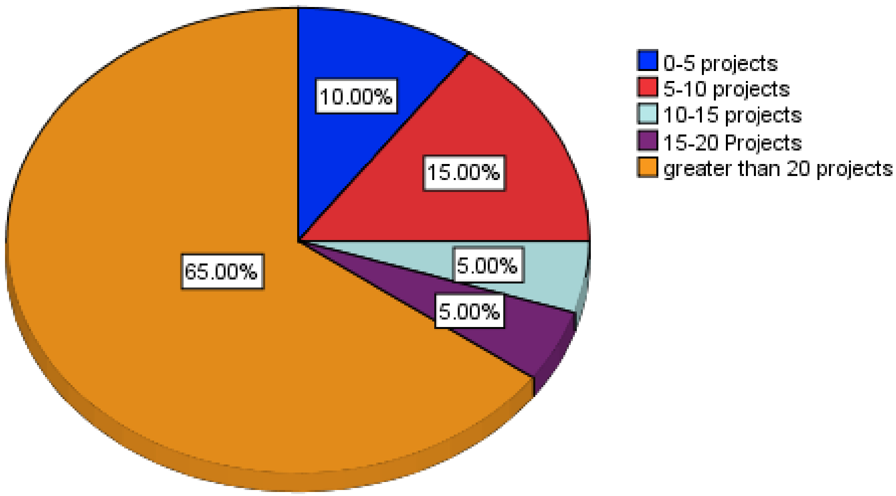

Figure 3-8: *Variety of Reverse Engineering at the firm*

b) Educational level of technical employees in the firm

In this case, technology capability can be obtained basically through education followed by experience. In order to assess the technological capabilities of the firm, the highest level of education in every firm are collected and presented in the figure 3-9.

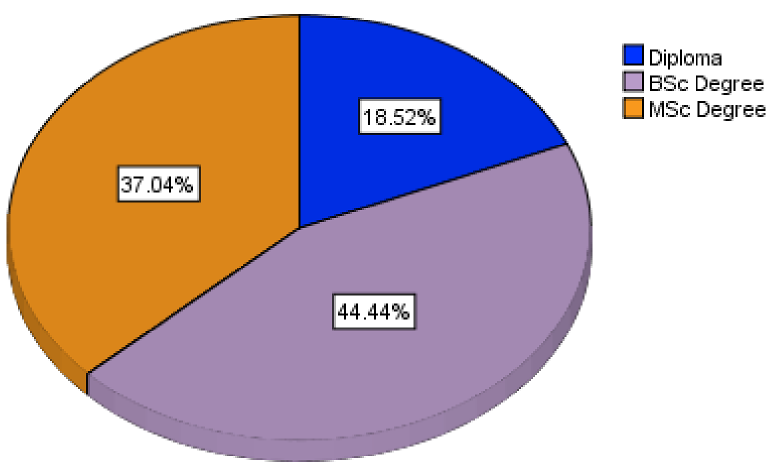

Figure3-9: *percentage level of highest educational level of technical employee*

The result shows that most of the companies 44.44% have BSc degree for the highest education level among the technical employee, whereas only 18.52% from the respondent companies have diploma. The rest 37.04% of the firms have a technical educational level of MSc degree. The education levels in the firms with more than BSc degrees and above accounts to 81.48%, which is remarkable for conducting technology adoption and reverse engineering. Companies with highest qualification (MSc) have a better opportunity for building technological capabilities faster than those who may have diploma and BSc degree.

In addition to the highest educational level, the questionnaire tries to assess the percentage level of the technical employees in the firm. This would be helpful for evaluating the engagement of the firm in technical activities.

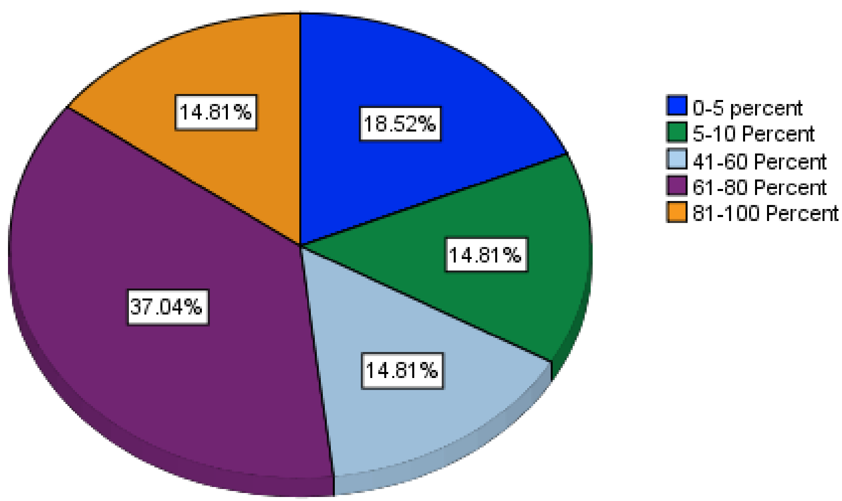

Figure 3-10: *percentage level of technical employees in the firms*

The result indicates that 14.81% of the firms have the technical employees more than 80%. The main activities in such a firm can be inferred as highly technical. Here also the aggregate percentage value of the technical employees with more than 60% in the firm accounts to 51.85% of the respondent which is above half of the firms in the survey.

c) *Technological capability, Transfer, Research and development and other variables of Reverse engineering at the firm*

One method of transferring technology transfer is through documentation. The acceleration of reverse engineering is also determined by the documentation of the standards, models and drawings of parts, machines and equipment. In addition to acceleration of technology transfer through documentation of specifications obtained through reverse engineering, the other methods of achieving technology is through hiring foreign nationals as a trainer or consultant to the employees. Through this technologies can be transfer beyond the building up of technological capabilities of the firms.

Moreover, the training programs arranged through the firms to build technological capability and the research and developments in the firm level fosters technology transfer and the practice of reverse engineering in the firm and further boost competitiveness of the firm.

The above aspects are assessed and the results are presented in the table 3-8.

Table 3-8: *technology capability, transfer and R&D in the firm*

	yes	***No***
RE documentations	*72.7%*	*27.3%*
Hire trainer or consultant from foreign	*50.0%*	*50.0%*
training in the firm	*63.6%*	*36.4%*
R&D in the firm	*18.2%*	*81.8%*

From the total firms that conduct reverse engineering in the survey, 72.7% have recorded and documents the specifications of reverse engineering projects. Furthermore, technology transfer from foreign nationals has been attained by 50% of the firms through consultancy and training. The training practice in the firms the survey shows 63.6% of the firms has arranged training to their employees to develop their technological capabilities. Moreover, the firm level research and development from the survey clearly indicates that most of the companies 81.8% have no research and development. And from the result of the questionnaire,

The open ended question in the questionnaire, the firms that conduct trainings to their employees 63.6%, most of the training is more of technical development such as productivity improvement, welding, different modeling software and other. The various training arranged at the firm level can and will be helpful tool in developing the reverse engineering practice and produced quality and improved products.

On the other hand, the Korean experience has shown clear steps in technology acquisition and dissemination in the literature. The technology transfer stage using reverse engineering first was to conduct reverse engineering at the local firm level. Afterward, the firms have relied increasingly on their own R&D to master imported technologies and to give rise to product design capabilities in order to reduce their dependence on foreign licensors for subsequent product development, as they accumulated experience in production and product design.

It shows that in most of the firms the top managements do not have a clear awareness on the significance research and development of reverse engineering to their firms. Most of the respondent that does not conduct research and development at the firm level believes that they have enough customers and they do not need research and development in their firms. This can also indicates the lack of awareness in the firm level. The other main problem is lack of finance budgets for research and development in particular. If the company has engaged in research and development, the government will deduct the tax for the budget allocated to research and development. However, most of the respondent has no awareness. It is therefore, the critical and major steps to conduct research and development at the firm level so that to transform the firms as well as the country Ethiopia from technological dependency to the foreign technology to the creation of technology.

Nevertheless, agreement level of the respondents to the impact of research and development to reverse engineering is indicated in table 3-9. As a result, it indicates that 50% of the respondent have strongly agree with the advantages of research and development to the reverse engineering at their firms. Moreover, 83.4% of the respondent has an agreement level of 4 and above. From this we can infer that most of the respondents believe that the research and development is mandatory for developing the reverse engineering practice at the firm level. The mean value also indicates 5.5455 which indicate the aggregate respondent is more than 5 with standard deviation of 1.79224.

Table 3-9: *affecting variables of Reverse engineering at the firm*

	1.0	***2.0***	***3.0***	***4.0***	***5.0***	***6.0***	***7.0***	***Total***	***Mean***	***STD***
	SDA						***SA***			
The Research & Development in our company supports the activity of RE	*4.5*	*0.0*	*9.1*	*18.2*	*9.1*	*9.1*	*50.0*	*100*	*5.5455*	*1.79224*
Reverse Engineering is successfully commercialized	*9.1*	*0.0*	*0.0*	*18.2*	*22.7*	*4.5*	*45.5*	*100*	*5.4091*	*1.86851*
Firm Technical level to Reverse engineering	*0.0*	*0.0*	*0.0*	*4.5*	*13.6*	*27.3*	*54.5*	*100*	*6.3182*	*.89370*
Materials, machines and other equipment in market that are required for RE	*9.1*	*4.5*	*13.6*	*13.6*	*22.7*	*18.2*	*18.2*	*100*	*4.6364*	*1.86562*
Management support for RE	*13.6*	*0.0*	*4.5*	*27.3*	*4.5*	*36.4*	*13.6*	*100*	*4.7273*	*1.90693*
Incentives of government for RE	*31.8*	*9.1*	*22.7*	*13.6*	*18.2*	*0.0*	*4.5*	*100*	*2.9545*	*1.75871*
The current demands of other industries for RE	*9.1*	*4.5*	*4.5*	*9.1*	*9.1*	*18.2*	*45.5*	*100*	*5.4091*	*2.03912*

On the other hand, for the reverse engineering to be successful in the country and to substitute the imported foreign items locally, the available market plays a major role. Based on the survey, 45.5% of the respondent have strong agreement on successful commercialized the imitated items in the market. Additionally, adding the agreement level of 4 and above, the result show that 90.9% respondent has agreement level of 4 and above. The mean value for the market is 5.4094 with a standard deviation of 1.8685. This also means that the aggregate respondent from the survey has successfully commercialized their products obtained through reverse engineering with higher standard deviations.

Another critical success factor for reverse engineering is the technical capability of the firms for the undertaking project. This also determines the successful commercialization of the project as well the involvement and diversification of reverse engineering tasks. According to the survey, all the firms engaged in reverse engineering have a satisfaction level of 4 and above with regard to the technical capabilities they possess. Also the mean value for the rating indicates the higher value which is 6.3182 with the lowest standard deviation of 0.8937.

Though the technical capabilities, markets and demands in the local markets are high, if there are no adequate materials, machines and equipment in the markets that are required by the projects as an input, reverse engineering cannot be successful. On the basis of materials, machines and equipment the satisfaction level of the respondent shows 72.7% satisfaction level of 4 and above. Also the standard deviation and the mean is 1.86562 and 4.6364 respectively and 22.7% of the respondent has the satisfaction level of 5. Though the satisfaction rate is higher the standard deviation is also higher which shows a wide dispersion of the satisfaction rate among the firms.

Another critical success factor for reverse engineering is the support and determinations of top management to develop this activity at their firm level. Looking at the survey result from the table 3-9, it shows that the 81.8% of the respondent has agreement level 4 and above with mean and standard deviation of 4.7273 and 1.90693 respectively. the standard deviation indicates the highest diffusion of the respondent with the level of agreement.

Between the other factors, the negative result is indicated to the available incentive of the government for reverse engineering. As it is mentioned before, the government is currently working towards import substitution and developing local capabilities. Yet, the survey depicts this has not benefited the metals and engineering industries. The result shows that 63.6% of the respondents have the satisfaction level of less than 4. In other word, more than half of the surveyed companies has not benefited from government incentives. The mean value 2.9545 also shows that the agreement level on government incentive is lower.

Lastly, the current demand of other industries to the products obtain from reverse engineering is surveyed. Since the products obtained from metals and engineering industries using reverse engineering would benefit the other industries in supplying the required machineries, equipment and spare parts, the demand of other industries can be the motivating factors to conduct and branch out reverse engineering tasks. Consequently, the agreement level of the firms shows that 81.8% have a satisfaction level of 4 and above and the rest 18.2 have the agreement level of less than 4. The mean value of for the current demand of other industries for reverse engineered product is 5.4091 and 2.03912 standard deviations.

3.4.3. Major findings

From the primary and secondary data's obtained and according to the analysis, the following major findings can be indicated.

Reverse engineering in the country and to metals and engineering industries are not a new concept. It has been practiced for more than three decades. However, the development of the methodology is not as such remarkable. In reference to the experience of the firms in reverse engineering, the companies must have been currently at the innovation and technology creation stages. According to the questionnaire result and site observation most of the projects in the firms are limited to routine works. The technological capabilities of the firm are not also astonishing to transform the sector to innovation level. Shortage of foreign currency in the country and lower cost of the reverse engineered product is a leading factor for the sectors to conduct reverse engineering.

Though most of the firms have conducted different project through reverse engineering, it is mostly limited to modification of common parts. And the modifications have not been changed from time to time as to the sight observation and through interviews. In addition, the main motive for the modification is due to the obsolescence of the products at the market level as clearly indicated at the analysis.

It can be inferred from the result, the most inhibiting factors for the sectors not to develop together with the state of the art of technology and to step up from imitative technology to innovation and technology creation is the lack of research at the firm level. Due to this factors the firms are engaged in routine works which does not account to the development of the sector if it is still dealing only about the obsolete technology that are already left years ago.

Furthermore, the government is not currently giving attention to this sector to develop the technological capability through reverse engineering. As we have seen the different countries experience in the literature, the government has ratified strategies for technology transfer through reverse engineering project as a means to technology acquisition at the national level.

Chapter Four – Proposed Solution

4.1. Policy Issues

The government policy in the green document indicates that the second phase of national technology transfer strategy is reverse engineering. The national reverse engineering policy as a method of technology adoption, adaptation and building technology capability has to begin from the consensus of the actors as line ministries like ministry of industry, ministry of trade, Ethiopian association of basic metal and engineering industries, other professional societies and association such as National Association of Ethiopian Industries, Ethiopian society of Mechanical Engineers, Ethiopian Society of Industrial Engineers, Ethiopian Society of Electrical Engineers, Ethiopian Economics Society and universities particularly Institute of Technologies of the country. Based on this accord, the ministry of science and technology develop a policy particularly on enhancing and developing reverse engineering undertakings.

The policy issue should include preferential treatment for the industries engaged in import substitution such as reverse engineering. This preferential treatment includes:

- Tax holidays
- Duty free
- To link patent documents with the investors
- Market protections of local products

On the other hand, for the industries to benefit from this preferential treatment each sectors need to establish research and development and hire qualified personnel.

4.2. Technical Consortium

The most important steps for effective use of reverse engineering and maximize the import substitution activities is the establishment of technical consortium. This technical consortium will consists of technical persons from different sectors particularly priority sectors of the industries, association and societies form different professions mentioned above, Institute of Technologies and research institutes to undertake the demand assessment of both technical and human resource. The demand assessment should be focus on particular issues of spare parts, equipment and machineries required by the priority sector industries for reverse engineering. The achievements of technical consortium output will be helpful for universities, TVETs, metal sectors and line ministries to support reverse engineering at the national level.

4.3. Technology transfer center

Technology transfer center is useful for developing the performances of reverse engineering in the country. It is therefore necessary to establish the center. In the center, different product development and tests can be done. The center can be used for training TVET's and for researchers from the universities especially from institute of technologies. Accordingly, this center can be Metal Industry Development Institute's which has the already established facilities.

In the center, the trainings for technical capabilities will be given to both the sectors employee and for TVET students. Moreover, product testing of reverse engineering can be done for the assurance of the required standards and quality.

4.4. Patent diffusion

Different countries have different patent protection rules and policies. This protection is mostly valid for specified years. After a certain period of time the patents will be revealed for free. This will be helpful to developing the technological capabilities.

Hence, to further strengthen the reverse engineering acts in the country, the technology transfer center will search valuable international patents helpful for the country that has already released from protection to adopt the technologies locally and assimilate to the industries. This information contains all the necessary drawing and technical documents for product development. This will diversify technology acquisition in the country.

4.5. Implementation of reverse engineering

It is therefore necessary to develop a model for an effective implementation model for the reverse engineering strategy. Accordingly the model shown in the figure 4-1 is owned by the ministry of science and technology since the body is currently engaged in national technology transfer.

This policy implementation can be coordinated by reverse engineering team under the technology transfer directorate. The team form technical consortium from different sectors, ministry of industry and trade office, institute of technologies, research institutes and association and societies to assess the required technologies and human resource assessment with main focus of reverse engineering.

Accordingly, the ministry will allocate budgets to coordinate and maximize the efforts of technical consortium. This budget will enhance the research and development activities in the universities through the collaborated efforts with the consortium. Through this, the consortium will have consultancy service and cooperation from the universities particularly from institute of technologies.

Not only the technical consortium that supports the universities in research and development through funding and budget allocation but also the metal industry development institute is also work jointly towards research and development focused on product development and reverse engineering. Beyond research and development, the university gives service to the sector through training and consultancies. For the success of this linkage the institute will provide the facilities.

Furthermore, the consortium will have an effective linkage with the ministry of education down to the regional education bureau, universities and to the TVET's for the information dissimilation useful for curriculum development and concentrated efforts of the industries demand in human resource training. This linkage helps the educational system helpful for the sectors by providing technically capable technicians and uses the creams of it.

The technical consortium will also have an effective cooperation with the metal industry development institute to support the undertakings and concentrate the efforts on the reverse engineering. This institute will also have a linkage with the Ethiopian Association of Basic Metal and Engineering Institutes (EABMEI) which is a helpful to in information exchange, problem solving and linkages with the sectors.

The individual sectors will work together with the universities to solve the problems through applied research and development. The responsible office for the partnership of university and the industry will be the university-industry linkage. Not only the individual sectors, but also the associations will cooperate with the universities in research and development to coordinate multi-company sectorial problems. The research and development in the university will be back up by the ministry of education and curriculum review will also be done by this body.

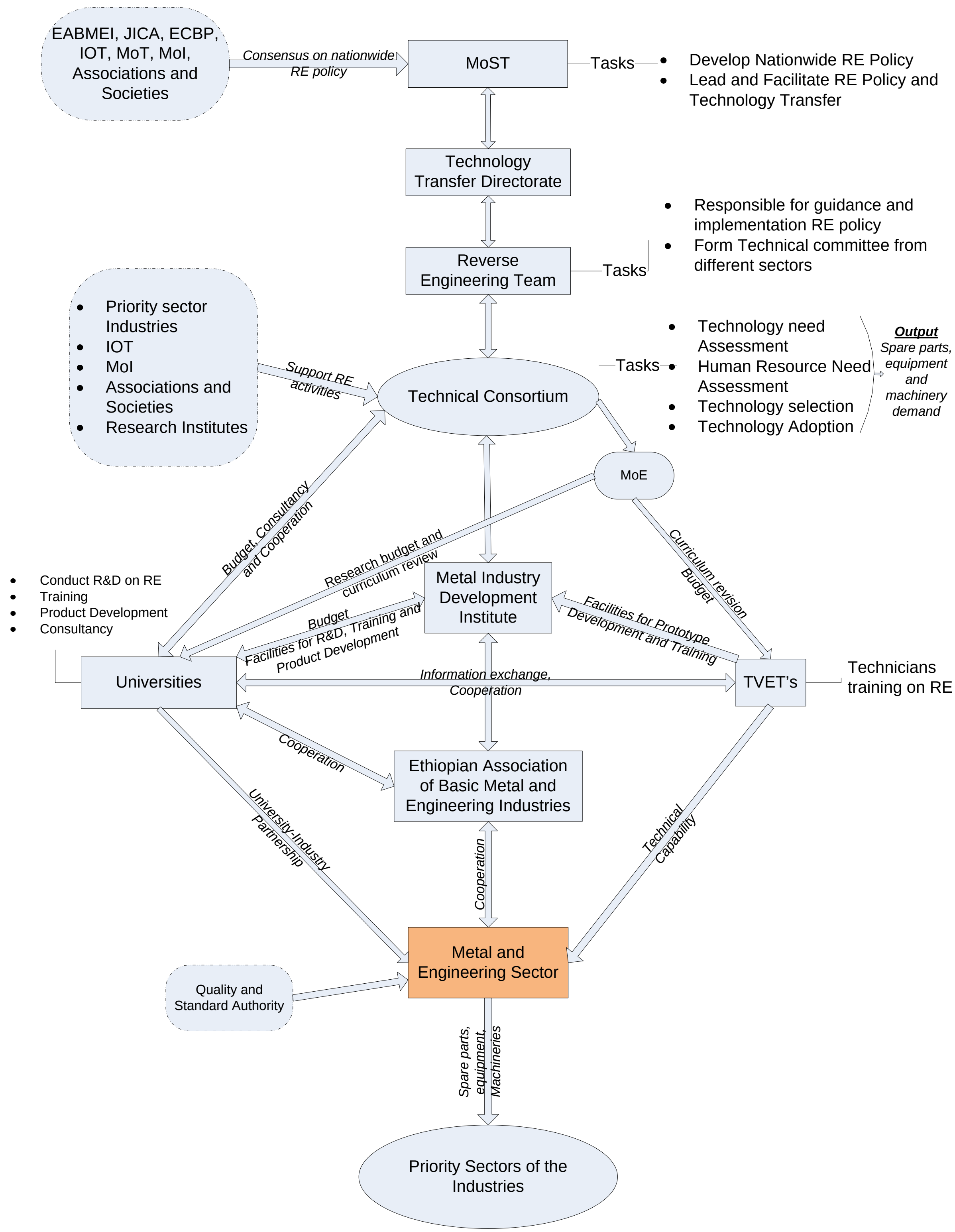

***Figure 4-1**: reverse engineering implementation model*

Chapter Five - Conclusions and Recommendations

5.1. Conclusion

In conclusion, the basic metal industry is crucial to the development of any modern economy and is considered to be the backbone of human civilization. It is for this reason that the level of per capita consumption of steel is treated as an important index of the level of socio-economic development in any country. It is a product of a large and technologically complex industry having strong forward and backward linkages in terms of material flows and income generation. All major industrial economies are characterized by the existence of a strong steel industry and the growth of many of these economies has been largely shaped by the strength of their steel industries in their initial stages of development.

Therefore, for the country to be out of circle of poverty and transform the economy to the level of middle income country, the government has to support and develop this sector through technology assimilation and adoption.

Basic metal and engineering industries in Ethiopia is currently engaged in low level of and obsolete technological sophistication. The research and development practice at the firm level to support this undertaking at most is insufficient and negligible. If the sector is not reinforced with research and development, it is impossible to develop technological capability and at large difficult to realize the ambitious five year growth and transformation plan. Though it is clearly stated to firm level research and development for deduction of tax, almost most of the firms have no clear idea and awareness about it. In addition, the support and determination of government to this section for the contribution of import substitution is very low and at all absent.

To sum up, the most limiting factors for the development of reverse engineering and technology transfer to metal and engineering industries are low level of research and development at the firm level and low support and determination of the government for reverse engineering practices in the firm.

5.2. Recommendations

In order to boost the level of participation, increase the outputs of reverse engineering and transfer appropriate technologies to the country the prior action should be nationwide technology transfer action plans and government policy and the official should martial the existing growth and transformation.

The nationwide action plan for technology transfer can be proposed as follows.

1. Technology demand assessment currently established by the ministry of science and technology should be strengthen, finalized and implemented as soon as possible,
2. Martialling the potential demand with the available technology, technology selection and importing should be done
3. To build the technological capability of the firm, the human resource development should have to be done together with the technology selection and assessment
4. The research and development at the firm level, research institutes and universities has to focus and support the reverse engineering activities in the country

To enhance the participation in reverse engineering, government support for the firms should be there in various aspects such as advertisement and arranging favorable markets for the product and tax holiday for the firms engaged in import substitution manufacturing firms. Moreover, high tax for imported similar products can be incurred to support the firms and increase the competitiveness.

The government should establish the technology transfer center to develop reverse engineering and research and development in the country.

The government should select the potential technology and conduct research and development and afterward, the finding will be disseminated to the respective firms through training, joint research and development, material or documentation.

Moreover the firms should also conduct research and development at their premises to build their technological innovation capacity and capability beyond competitiveness in the section.

Last but not least, the required and basic materials used as an input for technological development should be assessed and cluster should be formed with the basic metal industries with engineering. Through this the companies can support to each other along the supply chain. In addition, different reverse engineering tools such as measurement tools should be properly selected and disseminated to the firm for the products to confirm the requirement of the customer.

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Appendix – Questionnaire

Please answer the following Questions

1. When did the initial investment take place? __________ (years)
2. What is the estimated percentage level of technical employee in the firm? _______%
3. The highest level of education among the technical employee ________________
4. Do you have awareness on Reverse Engineering/imitation in your company?

Yes _____ No ______

5. Do you manufacture and/or modify any equipment, products or parts (Reverse Engineering/Imitation) that are imported from abroad? Yes _____ No ______

If "yes", Please answer part I, **if "No"**, please answer part II

Part I

I. When did you start imitation/Reverse Engineering? ________________

II. Why do you use Reverse Engineering? ***(you can circle more than one)***

a. The original manufacturer no longer exists or the original manufacturer of the product no longer produces the product. Eg. The original product has become obsolete, but the customer needs the product
b. The shortage of foreign currency in the country
c. The cost of the original product is higher that the imitated one.
d. The loose patent right in the country
e. Exploring new avenues to improve product performance
f. Others, please specify

____

III. How many different reverse engineering/imitation project have your company conducted so far? __________________

Part II

IV. Why don't you use Reverse Engineering? ***(you can circle more than one)***

a. There is no strong Intellectual Property Right (IPR) for local innovators
b. The cost of Reverse engineering is very high to compete with the product
c. The local demand for imitated products are discouraging
d. The available technical skill in the country is not encouraging
e. Others, Please specify

____

6. Do you have the documentation of product design, parts and equipment which has been imitated/reverse engineered so far? Yes _____ No ______
7. Have you ever hired temporarily or permanently a foreign national as a trainer or consultant, just looking for technical assistance? Yes _____ No ______
8. Do you arrange training programs to your employees both internally and/or externally to upgrade their technical skill? Yes _____ No ______

   If "yes", please list out the type of trainings conducted in the past with the objective to upgrade the technological capability of your staffs.

   a. ______________________________________
   b. ______________________________________
   c. ______________________________________
9. Do you have a research and development activity in your company or industry? Yes ___ No ___

If "yes", Please answer the following question

I. How much budget is allocated for research and development annually in your company? ____________________

II. In what areas is the research and development of your company focused mostly?

____

If "No", what are the constraints for conducting research and development in your company?

____
____
____

Rate your agreement as 1= strongly Agree -----------------------------7 = strongly Disagree

	1	2	3	4	5	6	7
10. The research and development in our company supports the activity of reverse engineering project.							
11. Our company has successfully commercialized the products, spare parts or equipments that are obtained trough reverse engineering							
12. Our company has the technical level to modify or reproduce parts, products or equipment for the imported							
13. Our company can easily get materials, machines and other equipment in the market that are required for modifying and imitating the imported items							
14. Our company's management support and determination to solve spare part and capital good problem through reverse engineering							

15. Availability of technical and economic incentives from the government in particular to industries that have the potential to make critical and major contribution to import substitution through reverse engineering is enough							
16. The current demands of for other industries for spare parts, products and equipment obtained by reverse engineering is very high							

Concluding Remark

17. If the level of participation in reverse engineering is low, what do you think your company should implement to boast the level of participation?
    ____
    ____
    ____
18. What are the constraints not to conduct/ participate on reverse engineering?
    ____
    ____
    ____
19. If your company has used Reverse Engineering before, what benefit did you get?
    ____
    ____
    ____
20. What do you plan to do in the future on reverse engineering and technology transfer?
    ____
    ____
    ____
21. What are the incentives of the government for the company to engage in research and development?
    ____
    ____
    ____

Profile of the Respondent

1. Position in the Company: ______________________________
2. Experience in Years: _________________
3. Gender: Male _____Female _________
4. Highest level of Education: ________________________________

MANY THANKS FOR YOUR KIND COOPERATION!