Reverse Engineering: A Way of Technology Transfer in Developing Countries like Iran

Morteza Raei Dehaghi and Masoud Goodarzi

Abstract—**Technology transfer in developing countries vary from those of developed ones, and management of technology transfer during the recent years has been among the cases that has allocated the biggest mental disturbance of senior managers of engineering and manufacturing organizations in developing countries such as Iran. One of the questions that have always been raised is that how Iran can decrease its technological distance with that of developed countries in the shortest time and have a suitable share in the global business. This can be achieved through reverse engineering which includes any activities to determine how a product works or to learn the ideas and technology that were originally used to develop the product.**

Studying about countries like Iran which haven't obtained technology in the course of time, but have tried to encompass it at a point in time, shows that one of the best way to achieve technology transfer is the extensive application of reverse engineering method to determine how a product functions, its fabrication, and then develop it with respect to its own needs. Supervision for good execution of systematic reverse engineering process and the application of engineering tools and techniques in this process could have an appropriate impact on reaching technical knowledge of products in the shortest time possible and with minimum cost.

The aims of this study is to explain briefly the steps needed to manage the different strategies of technologies transfer, role of research and development in achieving them, as well as how to select appropriate reverse engineering strategies as a suitable way towards technology transfer in order that Iran can meet its own demand for new compatible industrial product in a cheaper way as well as market expansion, exporting purposes and, in one way or another, to overcome the imposed economic sanction against her by some countries. The result of this inquiries shows that, in short run, application of reverse engineering method is one of the best solution to decrease technological gap from that of industrial countries and to meet its mentioned purposes.

Index Terms—**Developing countries, management of technology, reverse engineering, technology transfer.**

I. Introduction

Management of technology in developing countries is different from those of first world ones. The requirement for skill in these countries is not growing from within, but somewhat cropping up from new wares imported from first industrial countries. Technological growth in addition does not consequence from inner data and research, but resulting upon the technology transmission from abroad. In these environments, technology management by customary way is barely effective. These are troubles facing some developing countries these days and as a consequence organizations controlling the technology management endure non compliance, then technological development does not trail an accurate trend [1].

Reverse engineering is the process of discovering the technological principles of a human (or non-human) made device, object or system through analysis of its structure, function and operation. It often involves taking something (e.g., a mechanical device, electronic component, biological, chemical or organic matter or software program) apart and analyzing its workings in detail to be used in maintenance, or to try to make a new device or program that does the same thing without using or simply duplicating (without understanding) the original [2].

Reverse engineering is applied for retrieving and specifying constituting elements of a product especially in case of lack of access to the primary designing and is used for maintenance, development and extension of the existing possibilities and re-engineering. It has its origins in the analysis of hardware for commercial or military advantage. The purpose is to deduce design decisions from end products with little or no additional knowledge about the procedures involved in the original production [3].

This method is an accepted strategy for developing countries. Degree of lack of technical information to protect production of a product is determined in this process. Then it is tried to achieve specific documents and maps in order to design the product by performing an integrated team work consisting of experts and researchers of various basic sciences along with suitable management and organization of research and development setting [4]. It is tried to perform pattern-making and semi-industrial phases and product fabrication and production if necessary by considering properties, purposes and conditions of designing of products, national and common standards as well as covering of unknown points [5].

Research and development activities in generic concept have always two products: knowledge and technology. Role of research and development activities in creating technology is to the extent that the intelligential say technology is a product which has been produced in research and development factories [6].

Technology is the master key of development and the most powerful factor of economic revolution in societies. A complex combination of four elements is represented in atlas technology as below:

- Hardware and machineries
- Technical knowledge or information tools

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M. R. Dehaghi and M. Goodarzi are with the Department of Industrial Management, Mobarakeh Branch, Islamic Azad University, Mobarakeh, Isfahan, Iran (e-mail: dr_mraeidehaghi@yahoo.com.ph; ma_Goodarzi@yahoo.com).

- Abilities including human proficiencies and initiatives
- Technology management and organization including mechanisms that are needed to facilitate effective merging of the above elements. Now that importance of technology in national development and role of research and development in achieving technology have been illustrated technology life phases are mentioned.

Life cycle of each technology includes the following phases: designing phase, introduction phase, growth phase, maturation and saturation phase and stagnation phase [7].

The paper has been organized in seven sections. Section 1 is introduction. Section 2 covers methodology and framework used. Section 3 highlights the different between reverse engineering and duplicating. Section 4 deals with application of reverse engineering. Section 5 is about strategies to obtain technology and products. Section 6 discusses difficulties and challenges of technology management in Iran and finally, Section 7 highlights the conclusion of the study.

II. Methodology and Framework

This paper presents an analytical framework which comprises two parts: the first part consists of the technology trajectory in advanced and developing countries as well as their integration; and the second part is the methodology for reverse engineering. These are useful analytical tools in discussing technology transfer policies and strategies in developing countries.

A. Technology Trajectory Comparison and Integration

According to Utterback, industries and firms in advanced countries develop along a technology trajectory made up of three stages – fluid, transition and specific [8].

Firms in a new technology area will show a *fluid* pattern of innovation where products are often crude, expensive and unreliable, but functions to satisfy some market demands. These demands when better understood and alternative product technologies seem to decline, *transition* begins towards a dominant product design and mass product methods, adding competition in price as well as product performance. Production capability will assume greater importance to obtain economic stability. Intense growth in market and price competition in industry will lead to production process to become more automated, integrated, system-like, *specific* and rigid turning out a highly standardized product which is incremental to greater efficiency [9]. Upon reaching this stage, firms are likely to undertake research and development aimed at radical innovations which is important in their competitive position. Some industries, however, are quite successful in extending the life of their products in this specific state with a series of incremental innovations to add new values. However, Utterback model is still useful in analyzing technology management issues in developing countries

But in developing countries on the basis of research in several different industries in Korea, a three stage model was developed - acquisition, assimilation and improvement - to extend Utterback model [10].

- At the early stage of their industrialization, developing countries acquire mature (specific state) foreign technologies from industrially advanced countries. Lacking local capability to establish production operations, local entrepreneurs develop production processes through the *acquisition* of "packaged" foreign technology, which includes assembly processes, product specifications, production know-how, technical personnel, and components and parts. Production at this stage is merely an assembly operation of foreign inputs to produce fairly standard, undifferentiated products. For this purpose, only engineering efforts are required.
- Once the implementation task is accomplished, production and product design technologies are quickly diffused within the country. Increased competition from new entrants spurs indigenous technical efforts in the *assimilation* of foreign technologies in order to produce differentiated products. Technical emphasis is placed on engineering and limited development rather than research.
- The relatively successful assimilation of general production technology and increased emphasis upon export promotion, together with the increased capability of local scientific and engineering personnel, lead to the gradual *improvement* of mature technology. Imported technologies are applied to different product lines through local efforts in research, development and engineering.

Linking the technology trajectories of Utterback, Kim, and Lee, assumes that the three-stage technology trajectory in developing countries takes place not only in mature technology at the specific stage but also in intermediate technologies at the transition stage. Firms in developing countries, which have successfully acquired, assimilated and sometimes improved mature foreign technologies, may aim to repeat the process with higher-level technologies at the transition stage in advanced countries. Through innovations, some successful Korean industries have accumulated enough indigenous technological capability to generate emerging technologies at the fluid stage and challenge firms in advanced countries [8],[11].

In other words, developing countries reverse the direction of technology trajectory in advanced countries and evolve from the *mature* technology stage (for duplicative imitation), to the *intermediate* technology stage (for creative imitation) and to the *emerging* technology stage (for innovation) [10].

B. A Methodology for Reverse Engineering

Reverse engineering includes any activity you do to determine how a product works, or to learn the ideas and technology that were originally used to develop the product [12]. This method in the developing countries like Iran that are not so advanced in terms of product and technology designing knowledge, as compare to that of the developed countries, is a response to increase designing capability and accelerate the evolution process [13].

Establishing a reasonable and systematic method to determine the degree of lack of technical information to protect production of a product and then perform an integrated team work to complete such information is related to a set of operations that are occurred in the process of

reverse engineering. A level of the required technical information that its shortage must be specified and eliminated is called technical data package.

In spite of delicacy and the need to high accuracy in reverse engineering, reduction of time of operations is a very important issue in this regard. In other word reverse engineering is a systematic approach for analyzing the design of existing devices or systems [14]. You can use it either to study the design process, or as an initial step in the redesign process, in order to do any of the following:

- Observe and assess the mechanisms that make the device work
- Dissect and study the inner workings of a mechanical device
- Compare the actual device to your observations and suggest improvements

Before you decide to re-engineer a component, be sure to make every effort to obtain existing technical data. For example, you can proceed with reverse engineering if replacement parts are required and the associated technical data is either lost, destroyed, non-existent, proprietary, or incomplete [15].

Reverse engineering initiates the redesign process, wherein a product is observed, disassembled, analyzed, tested, "experienced," and documented in terms of its functionality, form, physical principles, manufacturability, and ability to be assembled. The intent of the reverse engineering process is to fully understand and represent the current instantiation of a product.

III. Different Between Reverse Engineering and Duplicating

Mistakenly, some people believed that reverse engineering and duplicating are the same, but this is not the real sense, because duplicating process is base on short time benefits in the option of making profit and the manufacture of products will provide less of the properties and functional specifications of the original products standards. Duplicating differs from that of reverse engineering in the sense that products out of duplicating will result in a product of low level technology. In case of complicated products, duplicating will not be conceptual means to adopt, instead reverse engineering will be the option to use for it will give a quality standard the same or even better than that of the original. Manufactured of products in reverse engineering approach will be base on a long term benefits and innovations. With the application of updated standards, manufacture of optimize products and working on their developments and improvements are the best scheme in adopting reverse engineering methods [16].

IV. Application of Reverse Engineering

Reverse engineering is one of the methods by which companies applied to accelerate their product evolution process [17]. This method in the developing countries like Iran, that are not so advanced in terms of product and technology designing knowledge as compared to that of the developed countries, is a response to increase designing capability and accelerate the evolution process, and further can be applied in the following circumstances:

- Interoperability.
- Lost documentation: Reverse engineering often is done because the documentation of a particular device has been lost (or was never written), and the person who built it is no longer available.
- Product analysis. To examine how a product works, what components it consists of, estimate costs, and identify potential patent infringement.
- Digital update/correction. To update the digital version (e.g. CAD model) of an object to match an "as-built" condition.
- Security auditing.
- Acquiring sensitive data by disassembling and analyzing the design of a system component.
- Military or commercial espionage. Learning about an enemy's or competitor's latest research by stealing or capturing a prototype and dismantling it.
- Removal of copy protection, circumvention of access restrictions.
- Creation of unlicensed/unapproved duplicates.
- Materials harvesting, sorting, or scrapping.
- Academic/learning purposes.
- Curiosity.
- Competitive technical intelligence (understand what your competitor is actually doing, versus what they say they are doing).
- Learning: learn from others' mistakes. Do not make the same mistakes that others have already made and subsequently corrected.

A. Benefits and Achievement of Reverse Engineering

Reverse engineering examine how a product works, what components it consists of, estimate costs, and identify potential patent infringement [18]. Some of re-engineering achievements are discuss below:

- Create the capability and technical-technological reinforcement of fabrication through recognition and perfect perception of the product (gaining technical knowledge of the product) and create self-confidence in engineers and experts of industry in confronting with industries and internal technologies
- Possibility of designing a timely product at the level of international standards by discovering of new methods of product development and improvement to satisfy customer's needs like better performance, adding characteristics and eliminate deficiencies of the product. Also satisfaction of needs of the market like changing or improving of the technology or reduction of costs [19].
- Creating of potential ability for attraction to transfer advanced technologies
- Training of the required specialist force in strategic industries
- Establishing of systematic steps to help perceive and document designing and its process

- Possibility of competitive modeling to understand competitors' products and better development of one's own products
- Possibility of performing reverse engineering by means of obtained technical knowledge through reverse engineering.

B. Example of Reverse Engineering

Reverse engineering provides a systematic approach for analyzing the design of existing devices or systems. It can also be use either to study the design process, or as an initial step in the redesign process, in order to observe and assess the mechanisms that makes the device work or dissect and study the inner workings of a mechanical device.

A typical workflow in reverse engineering could involve scanning an object and recreating it. These steps are illustrated below [12].

Step 1: A cloud of points taken from scanned data using a digitizer such as a laser scanner, computed tomography, or faro arms.

Step 2: Convert the point cloud to a polygonal model. The resultant mesh is cleaned up, smoothed, and sculpted to the required shape and accuracy.

Step 3: Draw or create curves on the mesh using automated tools such as feature detection tools or dynamic templates.

Step 4: Create a restructured spring mesh using semiautomatic tools.

Step 5: Fit NURBS surfaces using surface fitting and editing tools.

Step 6: Export the resulting final NURBS surface that satisfies accuracy and smoothness requirements to a CAD package for generating tool paths for machining.

Step 7: Manufacture and analyze the part for physical, thermal, and electrical properties

C. Reverse Engineering of Machines and Military Devices

As computer-aided design (CAD) has become more popular, reverse engineering has become a viable method to create a 3D virtual model of an existing physical part for use in 3D CAD, CAM, CAE or other software. The reverse-engineering process involves measuring an object and then reconstructing it as a 3D model. The physical object can be measured using 3D scanning technologies like CMMs, laser scanners, structured light digitizers or Industrial CT Scanning (computed tomography). The measured data alone, usually represented as a point cloud, lacks topological information and is therefore often processed and modeled into a more usable format such as a triangular-faced mesh, a set of NURBS surfaces or a CAD model.

Reverse engineering is also used by militaries in order to copy other nations' technologies, devices or information that have been obtained by regular troops in the fields or by intelligence operations. It was often used during the Second World War and the Cold War. For example, as quoted by Wikipedia, Iran has done reverse engineering of the BGM-71 Tow Missile. It was stated that in May 1975, negotiations between Iran and Hughes Missile Systems on co-production of the TOW and Maverick missiles stalled over disagreements in the pricing structure, the subsequent 1979 revolution ending all plans for such co-production. Iran was later successful in reverse-engineering the missile and are currently producing their own copy [2].

V. Strategies to Obtain Technology and Products

Reverse engineering is no longer just about bringing old technology back to life. It is also about using that technology as a launch pad into the future [20]. There are different ways to obtain technology as an industrial product that each country uses them in all industrial grounds given to its scientific and industrial structure and degree of self-reliance in sciences and techniques grounds, degree of access to required exchange resources, internal raw material, kind and quality of specialized forces and international and regional political relations. Important kinds of strategies to obtain the new product and the intended technology are cited in the following:

- strategy of innovation and designing to product production through research and production activities
- technology development strategy
- copy making and reverse engineering strategy
- technology selection, transfer and domestication strategy
- effective utilization of possibilities and the existing technology strategy
- strategy of factory purchasing and production process in the form of perfect delivery
- strategy of purchasing the intended product and technology

A. Technology and Foreign Technology Transfer

Technology constitutes three transformation powers.

- Procreation power or transformation power of scarce resources and capital into knowledge
- Transformation power or transformation power of knowledge into an exchangeable product with economic value
- Exchange power or transformation power of the product into money.

Thus three exchangeable elements of technology are knowledge, work (machine) and product.

Technology from one side has the ability of knowledge procreation and from the other side it converts such knowledge into an exchangeable and valuable product in the production and working domain, hence it will finally be converted into financial power in the exchange process [21].

In this era, management is defined as the ability that could create an active relation among three factors of procreation, production and market. Fig.1 shows the regulating process of this complex field called the technology management.

How then can firms build the level of the existing knowledge base? Technology transfer from foreign firms in advanced countries can be a very important source of new knowledge for firms in developing countries. Such transfer has two dimensions for analysis: market-mediation and the role of foreign suppliers. In the first dimension, technology transfer may or may not be mediated through the market. In market-mediated technology transfer, the supplier and the buyer negotiate payment for technology transfer, which may

be either embodied in or disembodied from the physical equipment. Foreign technology may also be transferred to local users without the mediation of market, in this case the technology transfer usually takes place informally without written agreements and payments [22].

B. Selection of Appropriate Strategy

One of the strategic decision-makings in order to achieve a product or technology is to select the most appropriate access method. Such decision making depends strongly on the growth and development phase of that product or technology (in the cradle of formation and emergence and evolution of that technology), for instance if a technology is in the introduction phase in its emergence cradle (the primary country), taking action to achieve that through technology transfer is an unreasonable act. Also if a product is in the stagnation phase in its emergence cradle and a superior technology has replaced it taking action to achieve the first product through the same strategy would be a hazardous act [23].

Essentially taking action to transfer technology about those products that have traversed the introduction phase in their emergence cradle and are in the growth phase is more reasonable for developing countries. In this case a developing country's action to achieve the same product or technology through research-production strategy will be an uneconomic and unreasonable act unless purposes like reinforcing technical and scientific bases of the country are proposed that choosing this strategy won't be desirable again. Whatever the evolution degree of a technology prior to the stagnation and abolishment phase is higher; strategy of purchasing a product and technology would be more cost-effective [24].

The intended strategy in this paper is in accordance to technological needs of developing countries like Iran and the compensation of this technological gap by developed countries with the highest speed is reverse engineering strategy.

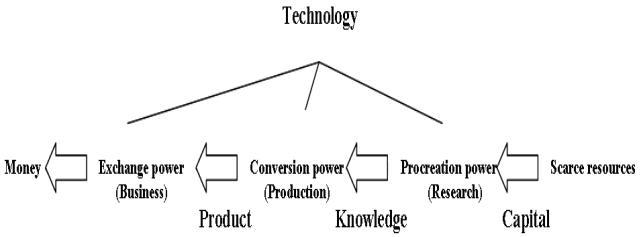

Fig. 1. Process of technology management.

C. Government Structure

One of many questions raised by policy makers of developing countries is whether they should establish a separate Ministry for Science and Technology to consolidate their technology management policies.

There is no doubt some advantages in establishing a separate ministry of science and technology to focus on key science and technology issues, especially when other ministries have little interest in a long-term technology development. Korea for example established its Ministry of Science and Technology in 1967. The Ministry made important contributions for the initial development of science and technology infrastructure and promoted public research and development activities, paving the way for the private sector's subsequent entry [25].

Though, the separate ministry is not necessarily the best way at the later industrialization stage, when other major ministries consider technology development issue more seriously. Japanese and Korean experience indicates that the existence of a separate ministry of science and technology helps little to bring about an effective co-ordination among different government ministries. What is really needed is an overarching organization directly under the President or the Prime Minister, which sets up the goals and co-ordinates science and technology activities of many different ministries.

VI. Difficulties and Challenges of Technology Management in Iran

In industrial countries, to deliver a market requirement typically a new technology and innovation is initiated, which needs investment from study to manufacturing stages, the funding gains earnings in return for advertising the new products and this cycle is endlessly repetitive. In countries like Iran, a market requirement is created after monitoring foreign products rather than on the foundation of local demands, and as a consequence importing foreign technology is unavoidable. In view of the fact that the imported technology in the majority cases is not located on a suitable seat, it compels large extra costs and requires the ability to compete with foreign merchandises. So venture capital investments in such technologies usually are not cost-effective and government has to be paid the necessary capital from oil funds. In such circumstances, researching activities are presently ornamental and some times have no connection to the real needs of the industry [26]. Fig. 2 shows the difference:

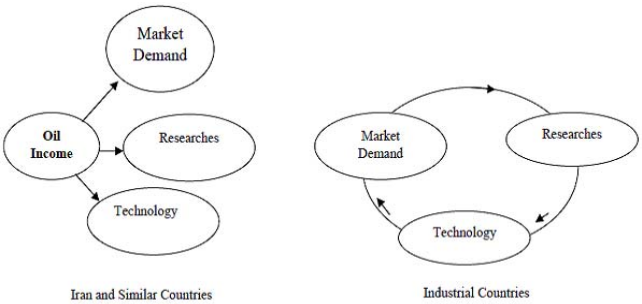

Fig. 2. Market requirement differences between industrial and oil rich country.

VII. Conclusion and Suggestion

Reverse engineering initiates the redesign process, wherein a product is observed, disassembled, analyzed, tested, "experienced", and documented in terms of its functionality, form, physical principles, manufacturability, and assemblability. The intent of this process step is to fully understand and represent the current instantiation of a product. Based on the resulting representation and understanding, a product may be evolved, either at the

subsystem, configuration, component, or parametric level.

Reverse engineering is one of the ways to achieve technical knowledge. Existence of samples of the product is the necessity to execute this method that is considered as the basis of research project. We resort to projection of technical information through product's disintegration in this method in order to achieve technical knowledge that is idiomatically called defaktage. The relevant experts consider characteristics, purpose and conditions of designing of the product in this process and try to make and produce the product according to their common and national standards and cover unknown and passive points of the problem with intelligence and expert studies and researches without being involved in technical details and designing of the product from the beginning. Perhaps we can call reverse engineering as deliberate copying of a product, the method that many countries in eastern Asia and Europe implemented practically after the Second World War and now are among the developed and industrial countries.

For instance, countries such as Korea, Taiwan and Singapore have transformed themselves from technologically backward and poor countries to relatively modern and affluent economies. Each now has a significant collection of industrial firms producing technologically complex products and competing effectively against firms based in advanced countries.

Anyway precious experiences that wear obtained in the recent decade by support of the governmental on different issues and products in the country all confirm productivity and helpfulness of this strategy in response to the needs of the country. The interesting point is that internal experts find the necessary self-confidence and technical effrontery in confronting with foreign experts in technology transfer phase. It is obvious that conditions of total attraction of technology transfer phases, recognizing technical and scientific blind spots of internal industries and trying to eliminate them, correct directing of technology transfer, consulting with authorities for decision making and conclusion of production and participation contracts with foreign companies and so on will be provided.

Reverse engineering is used in various hardware and software fields including overcoming the deficiencies or extending capabilities of the existing devices, preparing repair parts and establishment of maintenance and repairing centers for advanced devices as a tool for learning, a tool for making new and adaptable products that are cheaper than the current products in the market as well as a tool for competition and enhanced efficiency of utilized software. Specifically it is important in the computer.

Aside from that reverse-engineering is used for many other purposes such as a learning tool; as a way to make new, compatible products that are cheaper than what's currently on the market; for making software interoperate more effectively or to bridge data between different operating systems or databases; and to uncover the undocumented features of commercial products

Lastly in Iran since the government has the vital position in the economy, it takes on the responsibilities of developing national technological hierarchies and therefore market systems cannot work effectively. Consequently, the Iranian government ought to try to diminish its allocation in economy and on the other hand, sustain development of domestic technologies. The Government's most imperative obligation here is researching technology, development of systems and chain-work and be acquainted with the missing links. If not, mechanisms required for implementation of the chain would not be created and therefore technological projects and research would remain incomplete.

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Morteza Raei Dehaghi was born in Dehagh, a province of Najafabad, Isfahan, Iran on May 1, 1955. He finished Bachelor of Science in Electrical Engineering at Mapua Institute of Technology, Manila, Philippines, 1980, Master of Business Administration, major in Industrial Management and Doctor of Business Administration, at Manuel L. Quezon University, Manila, Philippines, 1991 and 1993 respectively.

He worked in Modhej Thermal Power Plant as an Operational Engineer; Ministry of Foreign Affairs as a Consular and Students Affairs Officer; Councilor in Dehagh province as a President and Islamic Azad University – Mobarakeh Branch as an Assistant Professor at Mobarakeh, Isfahan. He wrote the book, Specialized English for the Students of Industrial Management; Isfahan, Iran: Jahad Daneshgahi, 2001, and wrote the articles, Nuclear Energy and Its Environmental Worries; International Conference on Power Plants; Vrnjacka Banja, Serbia, Oct. 26-29, 2010 and Cost Comparison between Nuclear and Fossil Fuel Power Plants ICEESD 2011; Bangkok, Thailand, 2011.

Dr. Raei Dehaghi is a member of Iran Management Association (IMA); Isfahan Association of Professional Engineers and Management Scientific Association of Mobarakeh Azad University.

Masoud Goodarzi was born in a town in Shiraz province, Iran on 1968. He finished Master of Industrial Management in Najafabad Azad University on 1999. He worked in Finance Department of Mobarakeh Azad University as a Vice-President from 2000-2003. Presently he is a faculty member as well as a Vice-President of Student Affairs section. He wrote an article entitled, the Relations of Income and Human Productivity which was published in Garmsar Azad University Journal in 2011. Mr. Goodarzi is a member of Management Scientific Association of Mobarakeh Azad University.