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A Framework for Implementing Appropriate Manufacturing Systems in Developing Economies

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Introduction

The Industrial Revolution began in England, spread to many European countries and the United States, and influenced the world with an impact few other phenomena in the world's history had. Its effects during and after colonization reverberated across the continents, particularly after World War II, with the West (Developed Nations) maintaining a leadership position in the numerous technical inventions and innovations which accompanied it (McGinn, 1991). In the aftermath, many nations were left with little or no technical framework on which to industrialize their economies. These nations are what have been traditionally referred to as Developing, or Third-World Nations. Because some developed countries also have pockets of developing economies, such as the Amish community and Native American reservations of North America, all Third-World nations and these pockets of underdeveloped economies are collectively referred to as developing economies in this article. While some are more developed than others, developing economies are found in every continent of the world, but the majority of them are in the continents of Africa, Asia, and South America.

Historically, developed countries have offered some technical assistance to these economies through various channels to strengthen their industrial base, a process commonly referred to as technology transfer. McGinn (1991) reported that despite the efforts of the West to help these economies, especially since the end of colonialism, the gap in technical know-how between the two economies continues to widen. One of the reasons for this was identified by Middleton and Rassan (1995) who reported that in Africa (just like in most developing economies) "Most postcolonial 'economic development' has failed, owing to its being controlled by 'experts' who have assumed that African societies are the same as those of industrialized nations..." (p. xxxii). While some economies, such as Japan, assimilated much of the technical assistance from the West after World War II and flourished, many economies did not fare that well; in fact, in some cases disastrous consequences resulted because the transferred technology was not compatible with the receiving economy (Salomon & Lebeau, 1993). Sometimes, political and economic instability, plus natural and other man-made disasters, have contributed to the erosion of the "manufacturing base" of many developing economies, resulting in millions of people turning back to "stone age" techniques as means of production.

Technology transfer includes such activities as "machinery and equipment exports, contract awards, personnel training, and technical programs" (Karake, 1990, p. 100), all of which are within the realm of Industrial Technology (IT) and related program professionals. Since many IT professionals are also technology transfer agents in that they visit and/or train people in developing economies, and sometimes help in implementing the technologies, this article is intended to act as an aid to those individuals so that they will be more informed about the nature of the undertaking. It draws from documented experiences and the author's Third-World background to sketch a practical framework for implementing appropriate manufacturing systems in developing economies.

Components of Manufacturing Ststems

The term **system** itself means any collection of component elements that work together to perform a task (Encarta, 1996). In this respect, a typical manufacturing system consists of production methods or procedures, facilities or equipment, tooling, material handling, quality assurance, production control, and people (Seymour, 1995). DeGarmo, Black and Kohser (1997) defined a manufacturing system as a collection of men, machine tools, and material-moving systems, collected together to accomplish specific manufacturing or fabrication sequences resulting in components or end products.

Other than product and material components that are suggested, four groups of related components can be identified from these definitions:

1. Equipment and facilities component: machines, tooling, equipment and facilities.

2. Production methods component: procedures, production methods, quality assurance, and production control.

3. Material handling component: material handling or material moving systems.

4. **Labor component:** people or men.

It is important to recognize some of the differences in the four groups of manufacturing system components with

regard to the two kinds of world economies (Table 1). Such a comparison will help to reveal some of the basic differences in the two economies.

It is equally important to consider the nature of the products produced in the two economies. Unlike developed economies where products are often market driven, the most underlying factors which system implementers should consider first are what Salomon & Lebeau (1993); Malik (1983); and Richardson (1979) referred to as trying to satisfy the basic needs of the people in the economy: education, employment, environment, food, health, housing, and self reliance. For example, while the activities of most of the workers in developed economies are industrial in nature, the traditional economy of some 90 % of African populations has been one form of agriculture (Middleton & Rassam, 1995). This suggests that when determining products to be manufactured in such an economy, factors such as available local resources, employment, food, and parts for maintaining farm implements should be considered to truly serve the interests of the economy. The product should be a major part of these basic needs and should first be considered before any other step is taken.

Factors Influencing Manufacturing System Components in Developing Economies

A closer examination of the individual system components within the context of their application in developing economies reveals why technology transfer sometimes fails to take hold, and why developed and developing economies are so far apart in manufacturing industrial productivity and quality. It also helps to shed some light on what the nature of appropriate manufacturing systems for developing economies should be.

McGinn (1991) reported that technology transfer has some major problems. Three such problems which are pertinent to this study are: (a) Incompatibility of transferred technic (hardware) and recipient country's (economy' s) social-cultural-environmental system, (b) infrastructure support systems either not available or staffable locally or not affordable by locals, and (c) little or no feasibility studies and market surveys which genuine technology transfer demands.

These problems will be briefly reviewed along with factors influencing each of the manufacturing system components.

Equipment and Facilities Component

Acquisition, type and use of machine tools and facilities by developed economies differ from developing economies' point of view in several important ways: cost of equipment, cost of maintenance, cost of training workers, technical know-how available, complexity/simplicity of equipment, constant power supply in the economy, parts availability, and all the infrastructure needed to support the technologies. The sophistication and quality of these machines make them practically impossible for many developing economies to acquire in terms of their cost, maintenance requirements, and the degree of training required to operate them (Salomon & Lebeau, 1993; Schmitz, 1982). Except in cases where governments or big organizations are involved in acquiring such machines, transferring such technologies today remains a dream still to be fulfilled for many developing economies.

Some possible solutions to this problem might include acquiring simpler, less expensive machines, and making equipment donations when possible. Because of their low cost and simplicity to operate, Singer (1977) suggested that consideration should be given to the acquisition of older types of equipment by developing economies. Singer's recommendation is important in that older equipment tends to be more labor intensive, something many developing economies can afford.

Production Methods Component

Production methods employed in many developing economies can at best be described as crude when compared with those practiced in many developed economies today. In some developing economies, many processes are not controlled, and when they are, their standards or tolerance requirements are not close to what developed economies use. As a result, it is difficult to produce a product that can stand the test of international competition, except

System Component	Characteristics	
	Developed Economy	Developing Economy
Equipment & facilities	Modern	Iron age
Production methods	Scientific	Crude
Material handling	Mostly automated	Mostly manual
Labor	Highly trained	Poorly trained
	Expensive	Cheap

Table 1. Some Basic Differences in Manufacturing System Components in Developed and Developing Economies.

in economies, such as Mexico, where governments or foreign firms are directly involved in the production methods. At the root of this problem are issues, such as: lack of proper experience and/or training of the local labor force; social and cultural road blocks in accepting foreign concepts and methods; lack of necessary skills, knowledge and tools to achieve acceptable quality standards, etc.

This situation has created one of the socio-cultural issues confronting many technology transfer efforts. Salomon and Lebeau (1993) alluded to it when they warned that a technology does not operate as a separate and independent whole, but should move together with society or not at all. Clearly, the economy must be part of any manufacturing system implementation undertaking in virtually every level. Socio-cultural problems must be solved by providing proper training for the local workforce on essential production methods. Moreover, whenever the local labor force is not familiar with any aspect of the production methods, then engineers, technicians, and supervisors must be brought in to make the factory work and to train local workforce (Salomon and Lebeau, 1993).

Material Handling Component

Unlike developed economies where material handling infrastructure is readily available and, in many cases, automated, material handling is critically hampered in many ways in developing economies. Non-availability of good operable vehicles, poor transportation network systems, scarcity of critical raw materials, lack of constant power supply, and poor or absent infrastructure maintenance system can frustrate any attempt to implement a good manufacturing system. Likewise, the cost of installing and maintaining good robotics, automated guided vehicles (AGVs), and conveyor systems or other vehicles can be astronomical for many developing economies.

However, the cheap available labor force can be substituted for the expensive robotics, AGVs, conveyor systems and other material-moving vehicles where possible, and where training can be achieved. The economy's existing means of transportation can also be used to help solve some material-handling problems. Whether it is a horse-drawn carriage or a human-drawn truck, these vehicles can help, to some extent, in moving materials to where they are needed. In some developing economies with poor transportation systems, these manual means of material handling have, in many cases, become more preferable to modern means.

Labor Component

Although labor is something most, if not all, developing economies have in surplus, most of their working age population is untrained and unskilled in modern production processes and know-how. The ones engaged in manufacturing-related tasks are hardly what their counterparts in developed countries are, considering high quality standards involved, sophistication of processes employed, and level of skill and know-how required to perform modern manufacturing tasks. One of the reasons for this is because any culture whose economy is not historically based on mathematical rationality is not readily prepared to adopt the scientific approach (Salomon and Lebeau, 1993). As a result there is little or no modern manufacturing techniques in many developing economies. It is then, not surprising why the world's developing economies have very high unemployment rates and low industrial productivity and quality.

However, labor can be a major advantage which developing economies have on their side. Labor is incredibly cheap in virtually all developing economies. This author has actually witnessed instances where the daily wage was less than $5 per head in some African and Asian economies! This holds true for many developing economies around the world, especially in Mexico, where (as a result of NAFTA) American manufacturers are taking advantage of the cheap labor there to fight domestic and international competition. Because of its monetary advantage, system implementers should always consider how to best use this surplus and cheap labor to help leverage other expensive or scarce component(s). The system should be designed to be as much labor intensive as possible (Salomon & Lebeau, 1993; Malik, 1983). Moreover, labor force can be trained to perform many tasks necessary to achieve virtually any standard.

But embedded in the labor component are many cultural issues. In recognition of the world's cultural diversity, it must be assumed that cultural obstacles are real, but can be solved to a great extent with adequate training whenever encountered.

Recommendations

Some recommendations for consideration by manufacturing system transfer agents who are (or may be) involved in system implementation in developing economies are presented here.

Table 2 contains a summary of the factors that influence manufacturing system components (including products) with regard to their application in developing economies. Each component in the table is influenced by several factors in positive or negative ways. The factors in parentheses are the ones that appear to favor developing economies in one form or the other, such as: inexpensive, readily available etc., while the rest do not appear to favor them particularly in the area of cost.

Although most of the factors in the figure do not appear to favor developing economies, it should be noted that this is a general characteristic of the situations in developing economies, and therefore, may not properly represent every one of the world's developing economies in their specific situations. It is highly recommended that each economy be studied, and its specific situations be mapped, as shown in Table 2, before any decisions are made. Moreover, the fact that some factors do not favor developing economies does not mean that there is no solution to the situation: it simply means that more or alternative resources may be directed to that component in order to acquire it.

Equipment & Facilities	Production Methods	Material Handling	Labor	Products
Acquisition cost	Know-how	(Manual substitute)	(Availability)	(Food related)
Maintenance cost	Training cost	(Material availability)	(Cost)	(Job related)
Training cost	Quality standards	(Material cost)	(Basic education)	(Education related)
Availability of equipment parts	Available skills	Transport. network	Training/skill	(Health related)
Power supply	Cultural issues	Operable vehicles	Cultural issues	(High demand)
Environmental		Automated systems		(Self reliance oriented)
		Power supply		Environmental
		Environmental		

Table 2. Factors Influencing Manufacturing System Components in Developing Economies

It appears that developing economies do not have much going in their favor in the areas of **equipment & facilities**, **production methods**, and, to some extent, **material handling**. Their strongest areas appear to be in **labor** and **products** components. On the basis of the findings from this study, the following recommendations are made for consideration when planning to implement a manufacturing system in a developing economy. Here, the recommendations are "ordered" sequentially but may be applied as needed.

1. A comprehensive study of the economy should be undertaken to identify critical factors such as basic needs of the people (potential products), available materials, and the level of education and skills of the laborforce which are related to the project. The product(s) must be identified before any plan to system implementation is originated. (Exceptions would be where governments or corporations specifically transfer such a technology for specific purposes, such as for investment, in which case they often bring along their own resources).
2. The product should meet the basic need(s) of the people of the economy, such as: food, employment, education, housing, local needs, etc. The product also should be a part of, or related to, the needs of the economy, and should be manufactured from available local materials, except where they are not available locally, or where they can be imported more cheaply. (Exceptions would be where governments or corporations specifically transfer such a technology for specific purposes).
3. A chart similar to Table 2 could be designed using the data from the market study to help system implementers visualize the economy's areas of strengths and weaknesses. This will help them to make important decisions relating to the project.
4. The local laborforce should be used as much as possible from the very beginning of the project. Although most developing economies have some type of education system usually supported by their national governments, additional training may be necessary to bring the workers up-to-date in the technical areas. The system should be designed to be as much labor intensive as possible to use surplus and cheap labor supply to leverage other expensive components.
5. The system should be designed to be as environmentally and culturally friendly as possible. The local workforce should be informed about safe working habits and keeping the environment safe. Socio-cultural issues relating to the economy should be carefully guarded against and avoided. For example, some workers would like to wear their native attire, which might be in violation of the safety requirements of the system implementers, or prefer not to work on their religious holidays. Local etiquette should be followed as much as possible to avoid any social problem that may adversely affect the progress of the project. Training may be needed when foreign production methods are introduced.
6. Trained personnel and necessary resources should be provided for maintaining the system once implemented, or there is the risk of shutdown and closure once the implementers leave the economy.
7. Because of the available cheap labor, manual and/or other mechanical substitutes should be employed in place of expensive automated systems whenever possible. Although they are not as good and efficient as those in developed economies, the available communications and transportation systems should be employed as much as possible. Even in their handicapped

condition, many developing economies have local mechanics and technicians who can keep their vehicles and equipment operable.
8. Consideration should be given to acquisition of simple, less expensive and older equipment when there is little capital available. Equipment donations also should be considered.
9. It is very important to have a stand by electric generator and/or other power supply substitutes for operating the facilities, since constant power supply is very rarely achieved in many developing economies.

Conclusion

While the world' s developed nations have modernized their manufacturing systems and are thriving, most developing economies have little or no manufacturing base due to few resources. Although the West is trying to help these economies, the pace of progress has been hampered by lack of capital, technical know-how, and sociocultural reasons. This situation has created a major roadblock for technology transfer agents for many years.

This study has endeavored to reveal how components of a manufacturing system can be creatively transformed into appropriate technology for developing economies. The practice of technology transfer demands knowledgeable individuals who can balance what developing economies have against what they lack, and creatively devise a way to overcome the roadblocks inherent in the process.

Industrial Technology professionals are part of the solution to this global problem since many of their programs contain manufacturing systems which students from all over the world study. IT professionals have been and will continue to be part of the technical solutions in a world that is getting smaller every day. This is a new challenge that should be bravely overcome as we march into the twenty-first century.

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