TECHNOLOGY TRANSFER TO LOCAL PROFESIONALS THROUGH UMA OYA PROJECT A CASE STUDY

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Degree of Master of Science

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Sri Lanka

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Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science

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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person accept where the acknowledgement is made in the text.

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DEDICATED TO

MY BELOVED PARENTS AND TEACHERS

FOR THEIR GUIDENCE,

SUPPORT AND ENCOURAGEMENT

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ABSTRACT

Economic growth of a country is linked with the construction industry. Advancement of construction industry is depend on the degree of transformation of technology in to the field. Therefore it is important to understand deeply the best practices in Technology Transfer (TT) by examining significant areas of enablers and hallmarks. During the past few decades, number of major projects were completed by foreign contractors linking with domestic contractors in various approaches such as joint ventures, partnerships and sub contracts, as well at present large number of foreign firms are involved in major construction projects in the country. Engineering Procurement and Construction (EPC) contract of Uma Oya Multipurpose Development Project (UOMDP) is awarded to FARAB. Though FARAB use new technology, there is a doubt whether appropriate TT benefits will acquire through this contract? Therefore this research was carried out with the objectives of identifying barriers exist in technology transfer to local construction industry through the foreign contract and proposing of strategies to enhance the level of technology transfer to local construction industry from foreign contractors working in Sri Lankan projects. Scope of this research is limited to level of TT to local professionals directly engaged in project activities. Hence carried out interviews with twenty six numbers of senior, middle and junior level professionals working in the project. Collected data was analyzed by Suitability, Acceptability, Feasibility (SAF) model and recommendations were summarized. As a result of deep study through the case, lack of joint venturing (JV) , lack of involvement of junior engineers and insufficient involvement of higher educational institutes are within the finding mentioned in the conclusion. Increase of involvement of local contractors through JVs, giving priority to TT clauses in the formation of EPC contracts, opening of TT offices in the Universities and improvements of skill level of non-professional groups are within the recommendations. Further, responsible institutions such as Ceylon Electricity Board, Mahaweli Authority and Irrigation Department should increase the participation of their professionals covering top to bottom levels of their organizations.

Key words: Technology Transfer, Construction industry, Tunnel Boring Machine

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LIST OF ABBREVIATIONS

Abbreviation	Description
EPC	Engineering, Procurement and Construction
TBM	Tunnel Boring Machine
TT	Transfer of Technology
UOMDP	Uma Oya Multipurpose Development Project
SAF	Suitability Acceptability Feasibility

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CHAPTER 01: INTRODUCTION

1.1 Background

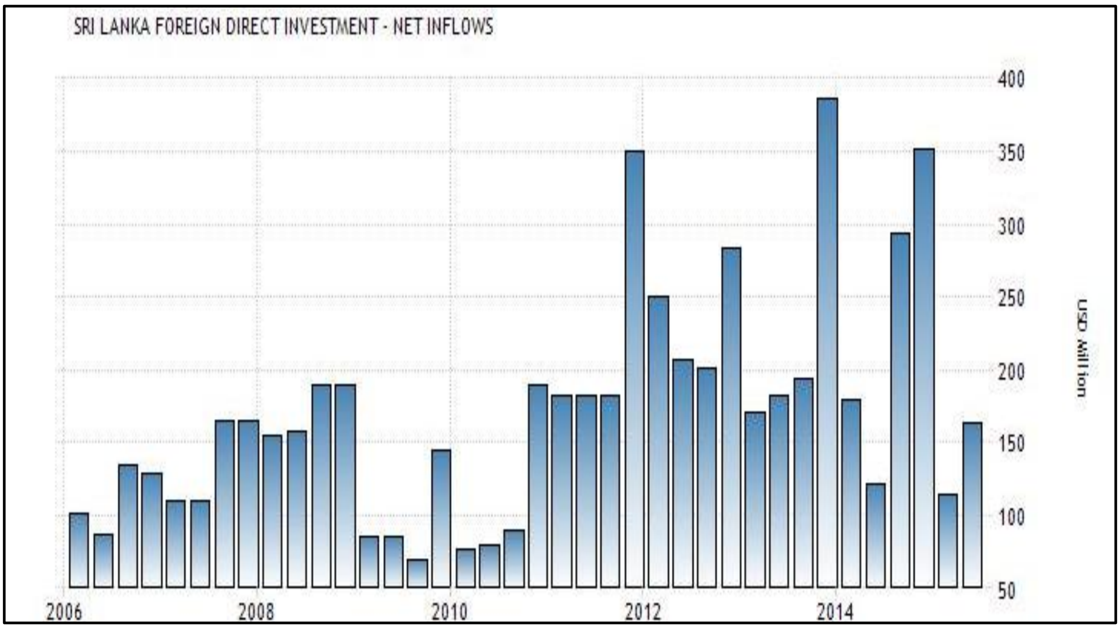
Construction industry plays a dominant role in developing countries such as Sri Lanka. During past few decades large number of major construction projects were launched all over the country, as well at present situation has been boosted. Most of these projects have been led by foreign consultants and constructions firms. Foreign firms use modern technology and knowledge. But transformation of technology and knowledge through these major projects are indeterminate. This urged the necessity of careful studies on this topic.

With the advancement of the society, a country itself cannot accomplish it's citizens requirements with existing resources. To fulfill this gap by enhancing and managing it's own resources, foreign investment and transforming of technology is a vital requirement. Most of the foreign involvements were in the field of infrastructure development in developing countries such as Sri Lanka. Out of this involvement Foreign Direct Investment (FDI) plays a major role specially in construction industry. As per the literature, many different ideas have originated to define FDI. Foreign direct investment is defined as foreign investors moving their assets into another country where they have control over the management of assets and profits (Graham & Spaulding, 2005). With these investments capital transfer, knowledge transfer and Technology Transfer has occurred over the past decades. USA and Japan has well-built evident to emphasize this argument raised by many experts in the field. FDI has become a major form of net international borrowing for Japan and the United States (Ram et al., 2002). In developing countries, FDI helps to tackle socio-economic problems such as unemployment, deficit balance of payment, lack of capacity, scarcity of foreign exchange and poor technological ability etc. (Ram et al, 2002). This argument has been verified by large number of experts throughout the world. The literatures on construction in developing countries suggest that to provide a basis for their socio economic to development, these countries need a large volume of new constructions; however most of the said requirements are beyond the capacity of the local construction industries (Ofori et al, 2002).

As a developing county Sri Lanka needs to expand physical and technological infrastructure, enhance human capital, improve labour market, and administrative capabilities. Therefore identifying and promoting of investment opportunities to foreign firms is an essential requisite to achieve these goals. Careful identification of various sectors which are having opportunity to development with foreign investment is a crucial factor to developing countries, because foreign investment brings both negative and positive impacts. Foreign firms have both positive and negative efforts on the host countries construction industry irrespective of the entry mode (Ofori, 2000). Despite of this the negative impacts, positive impacts are powerful to lead countries to demand more foreign investments. Many analysts express the belief that the promotion of FDI inflow into developing countries is a key solution to resolve social and economic problems faced by host countries (Ram et al., 2002). Further, there are many advantages from foreign investments such as new technology management, marketing, global market, transfer of technical skills, capital formation, infrastructure development and tourism development etc. All these components will lead to borrow more foreign investment to achieve economic growth of the county.

As a developing country after the Independence, Sri Lanka has faced many social and economical problems due to unemployment, lack of investment, balance of payment and deficit of budget etc. Sri Lankan government launched many mitigation strategies, but expected out comes not achieved. As a re medial action government introduced liberation policy reformation in 1977. Objective of the reform was the advancement of economy predominantly with foreign investments. In order to grab these foreign investments Sri Lankan government has taken many actions including incentive packages to investors. With this, foreign direct investments were raised up and Sri Lanka received Rs. 24 million of FDI in 1978. Consequently technology transfer has raised up with major projects such as accelerated Mahaweli development programme. After 1977 up to date many foreign firms invested money as FDI in the country which has contributed to the growth of economy through transformation of technology in the sectors of road, irrigation, agriculture, sea ports, air ports, housings and highways etc. Due to economic reforms, FDI flows rapidly increased continuously until 1983. The impressive upward trend in FDI flow was disrupted by the escalation of ethnic problems into civil war in 1983, but continued up to now in all sectors. Figure 1.1 shows the growth of FDI during 2006 – 2014 period and the sudden increase of FDI flow during post war period.

Future investment opportunities are available in following sectors, such as northern expressway, mixed development complexes, and development of commercial facilities in Colombo, housing, apartments, export processing zones, wear-housing, water sector and agriculture etc. Both technology and knowledge transfer can be anticipated in addition to the economic growth. Opening of export development zones, offering incentive packages, relief of tax & duty and incentives and agreements on investment protection are significant steps taken by the Government.



Source: www.tradingeconnsmics.com (Central Bank of Sri Lanka)

Figure 1.1: Sri Lanka Foreign Direct Investment Net Inflow 2006-2014

There are many ways and means to acquire the technical know-how through foreign investments. Some of these methods which contribute to the degree of technology transfer through FDI are joint ventures, sub contracting, collaborations and licensing etc. Further, transformation of technology can be divided into three basic types of Horizontal, Platform and Vertical. Horizontal technology transfer is the transfer of commercialized or operational (usually mature) technology from one organization in a specific socio-economic context to another organization in a different socio-economic context, through intra-firm, cross-industry, or cross-border channels. And vertical technology transfer refers to the transfer of technology from basic research to applied research to development and their production (Withanaarachchi, 2016).

Main contractor of Uma Oya Project (FARAB) and sub contractors are using modern technology for tunnel boring, power generation and other installations. For tunnel boring they use TBM technology, transferring of appropriate knowledge will be assets to the country.

1.2 Research Problem

Uma Oya Project has mainly two components, power generation and irrigation. Main contractor for power generation component is FARAB. As an international contractor FARAB has experience on water and energy projects in many countries and use modern technology for the construction works. Joint venture of Mahab-Godss of Iran and Poyry of Sweeden is the foreign consultant for the project FARAB is using modern technology such as tunnel boring, raise boring, Roller Compacted Concrete (RCC) dams and electromechanical installations in power house. Although, RCC technology is not entirely new to Sri Lanka, few number of domestic professionals have exposed to the technology such as planning, designing and construction. When foreign contractors are invited host country expects technology transfer to the local construction industry through their Involvement which encourages the flow of new technology to the local industry (Ofori and Leen, 2001). Uma Oya Project is under construction and at present progress of the foreign component is more than sixty percent. The contract is an EPC contract and local professionals including engineers, are working in the project. Since there is no powerful channels to TT such as joint ventures and sub contracting, technology transfer through local professionals has become the key factor. This has led me to do a research on degree of technology transfer to local professionals through foreign contractor of this project.

1.3 Objectives

1. To identify barriers exist in technology transfer to local construction industry through the foreign contract.
2. To propose strategies to enhance the level of technology transfer to local construction industry from foreign contractors working in Sri Lankan projects.

1.4 Significance of research

TBM excavation RCC Dams and other electromechanical installations carry high technology and this is the only occasion so far we received to study and to get technology transferred in to the country.

This is a golden opportunity and, it is our sole duty to get transfer the technology and knowledge and to sustain it for the future of country.

At present construction work of project is in the mid of its life cycle, progress up to now is more than 60%. TBM excavation was started at mid of 2014 and other electrical and electromechanical works are in progress. Therefore this is the time to find the level of transfer of technology, knowledge and technical Know-how through this project. Therefore a research is required to get the level of technology transfer through professionals engaged in the project and to get the outcome. Therefore this is the best time to do a research on this case.

1.5 Methodology

Since this research is a qualitative measure to review, synthesize and criticize the degree of technology transferred to the local professionals through the "Uma Oya

Multipurpose Development Project”, method of data acquisition had to be either direct interaction with individuals of the target professionals or by other means of indirect interactions. Well structured interviews were conducted and acquired data were analyzed by using SAF model. Total 127 numbers of local professionals from Institutions such as Ceylon Electricity Board (CEB), Central Engineering Consultancy Bureau (CECB), Mahaweli Authority of Sri Lanka (MASL) are engaged in the project. Out of this, 28 professionals were interviewed including all disciplines. Respond rate was high as it was planned gathered data were analyzed by using Serviceability, Acceptability, and Feasibility (SAF) model.

1.6 Main Findings

Lack of joint venturing and lack of involvement of middle and junior level engineers are the main findings.

1.7 Structure of the Thesis

This thesis on the case study, “Technology Transfer to Local Professionals through Uma Oya Project” mainly comprises of five chapters. The first chapter includes a brief introduction about the Uma Oya project and the reasons that led me to conduct a case study on the degree of technology transferred through this project. The significance of the research, objectives and methodology are also elaborated in this chapter. The second chapter is comprised of the latest literature on such qualitative researches/studies carried out regarding technology transfer, growth and development. In this rapidly developing global village, Civil Engineering and the technology used in major construction projects subject to subtle changes with the latest innovations and inventions. Therefore the acquisition of latest engineering technology through multi-national organizations that possess the latest technology, while developing indigenous techniques determines the socio-economic growth of developing countries like Sri Lanka.

Going through literature on technology transfer, helps in identifying the methods, advantages, disadvantages, and the problems that could occur during the process of technology transfer. Furthermore this chapter guides on the methods to overcome the common difficulties faced by developing countries in utilizing and importing novel technology and the ways that facilitate an effective TT to local professionals through such major construction projects.

Chapter three is basically on the methodology followed in determining the degree of technology transferred to local professionals through Uma Oya Project. Selecting the appropriate method of data collection is a key factor in qualitative researches like this. Method of data collection, comparison of pros and cons of the methodologies used and the method of data analysis are discussed in depth in the third chapter.

Method of data analysis, and the results obtained in the process are described in the fourth chapter. This chapter discusses on many methods that could be used in qualitative data analysis and the facts that should be considered in selecting the most suitable method of data analysis, particularly about the "Suitability, Acceptability and Feasibility (SAF) model" which was identified as the most appropriate method of data analysis for this study.

The final chapter is about the conclusions made from results obtained from the study. The degree of technology transferred through Uma Oya project according to the data analyzed using multivariate models are elaborated thoroughly. Plus the weaknesses, failures and loop holes identified in the process of TT, things to be improved, things to be avoided and future recommendations that would ensure a smooth and effective TT through major construction projects with the assist of multi-national organizations are elaborated in the final chapter.

CHAPTER 2: LITRATURE REVIEW

2.1. Introduction

Transformation of technology through major projects handled by foreign firms has a close relationship to economic growth and future development of a country. This has motivated people to do many academic researches on this subject. Universities has to play very significant role on this as the leading higher educational institutions of a country.

Technology Transformation is an important issue, particularly in developing countries that try to gain new technology by using a technology transfer method. Several methods exist for technology transfer, each focused on certain factors and objectives. Technology transfer is expected to provide better helps and lead companies to further improvement and to new products through technology. However, companies need to absorb technology within their industrial area to reach the objectives. They should elevate their scientific and technical knowledge, enhanced human skills and developed infrastructure (Tahmooresnejad, Sanami and Shafia, 2011). Identifying the proper methodologies for transformation is helpful for companies that plan to access technology to reinforce their knowledge and Research & Development (R&D) basis for further upgrading.

Until the late 1950s, when Robert Solow, an economist at the Massachusetts Institute of Technology (MIT), questioned the thesis it was widely held that the output of an economy–and hence it's productive potential–rested upon just two inputs: labour and capital. Solow won his Nobel Prize for realizing that there must be a missing ingredient in the productivity brew to explain a post-war economic expansion in America, followed by Europe and Japan that was over and above the level suggested merely by the sum of capital and labour inputs. This missing ingredient is now better under-stood to be the application of new technological knowledge.

Kumar et al. (1999) same journal explains that US universities are the benchmark for the structured processes of technology transfer. University technology transfer is all about transforming the fruits of university research into commercial value. But it is worth noting that the other great mission of Universities that of teaching, also has its part to play in this process. Income from these activities has grown markedly in recent years but the barriers to success are still formidable.

In this research paper, I tried to identify the factors required to transform a technology within the country in various groups including governments, firms, institutes and markets, and verify the factors in the analysis based on a survey through professionals within a project. Therefore a detailed literature review has done concentrating on Tecnhnology Transfer, dimensions, enablers and its barriers. With this background taking Uma Oya project as a case, detailed survey was done on the topic. The findings of this research could lead country to select the best method for technology transformation in the long-term, and align it with development paths and future innovations based on the transferred technology.

2.2 Definitions of Technology

Technology is a word in wide spread use, especially in conjunction with other words such as development, growth, and industrialization. Technology means different things to different observers. Its definitions vary from simple dictionary explanations to complex elaboration.

A selection of definitions will be considered to cover the various dimensions of technology. Many scholars define technology as knowledge of particular techniques, for example, the art of industrial production. The Concise Oxford Dictionary, in a similar manner to other dictionaries, defines technology as "the study or use of the industrial and mechanical arts and applied sciences" (Adam and Pearson, 1988).

The mere presence of the traditional economic inputs of land, labour, and capital is no longer enough to ensure economic growth in a nation. What is now important is the rational application of these resources to productive purposes by means of technology. Both the industrialized and developing nations recognize the fact that technology plays a significant role in economic growth and the improvement of living standards of their countries. Schon (1967), Jafarieh (2001) defines technology as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended". Technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired out come Thompson (1967), Jafarieh (2001), Galbraith (1967), Jafarieh (2001) defines technology as the systematic application of scientific or other organized knowledge to practical tasks. Merrill (1968), Jafarieh (2001) all emphasize the importance of knowledge and skills in their definitions. Merrill (1968) argues that technology is a body of skills, knowledge, and procedures for making, using, and doing useful things. Peno and Wallender (1977), Jafarieh (2001) define technology as knowledge embodied in products, process formulas, and techniques needed for managing operations. According to Barquin (1981); Jafarieh (2001) technology is the set of disciplines, methods, techniques, and supporting instruments, which make up the process by which a tangible product is elaborated. Dahlman and Westphal (1981); Jafarieh (2001) define technology as a collection of physical processes, which transforms inputs into outputs. This definition is also similar to that of the "Technology Atlas Teamý', which consider technology as a black box where inputs in the form of natural resources go into the box and outputs in the form of produced resources come out from the other side. Thus, one can say that technology performs as a transformer of inputs into outputs (APCTT, 1981). In its broadest definitions, Evans (1984); Jafarieh (2001) defines technology as the means by which man undertakes to change or influence his environment. Dosi (1984), Jafarieh (2001) sees technology as a set of segments of knowledge, containing directly practical and theoretical know-how, procedures, experiences of successes and points out that technologies consist not only of hardware but also comprise the technical knowledge and skills of participants of an organization.

2.3 Technology Transfer

The literature offers several definitions in respect of technology transfer, which indicate its importance. Technology transfer has been defined initially as the process whereby technology is moved from one physical or geographic location to another for the purpose of application toward an end product (Perlmutter and Sagafi-nejad, 1981). This transfer can take place either domestically from one sector or firm to another or, it can take place across national boundaries, from one country to another, which is generally accepted as international technology transfer. According to Gee (1981); Jafarieh (2001) technology transfer is the process by which technology developed for one purpose is employed either in a different application or by a new user. Kayak (1985); Jafarieh (2001) have defined technology transfer as the transition of know-how to suit local conditions, with effective absorption and diffusion both within a country and from one country to another. According to another definition, technology transfer is "the utilization of an existing technique in an instance where it has not previously been used" (Stewart and Nihei, 1987). The literature on technology transfer and international technology transfer are extensive and varied in perspective from various disciplines which include political science, economics, sociology, public policy, marketing and management of technology (Kumar et al., 1999). Based on the above definitions and concepts gathered from literature, the area of technology transfer is wide and dynamic. The numbers of literatures on the subject is voluminous, extensive and varied in perspectives (Kumar et al., 1999, Zhoa and Reisman, 1992). The above definitions on technology transfer indicate the importance of transformation of technologies for the developing world.

Therefore, when considering the recent developments in developing countries it is evident that TT is a need for the continuity of economic development and human welfare of these nations. More specifically, technology & knowledge transfer are development of crucial forms in manufacturing products and providing services. Resultantly, the rapid developments taking place in developing nations have resulted with higher degree of Technology transfer.

Past literatures have referred technology transfer as the transmission of know-how to suit local conditions, with effective absorption and diffusion both within and across countries (Chung, 2001; Kanyak, 1985). Other early researchers for example Baranson (1970) defines technology transfer as transmission of know-how (knowledge) which enable the recipient enterprise to manufacture a particular product or provide a specific service. As compared to the sale of machinery and equipment, the transfer of technology requires a sustained relationship between two enterprises over a period of time to enable the receiving enterprise to produce the product with the desired level of quality standards and cost efficiency (Reddy and Zhoa, 1990). This is consistent with the earlier argument by Chesnais (1986) who argues that "technology transfer does not only transfer the technical know-how (knowledge) required to produce the product to the recipient but also the capacity to master, develop and later produce autonomously the technology underlying the products". In the context of developing countries, Hoffman and Girvan (1990) argue that "technology transfer needs to be perceived in terms of achieving three core objectives: 1) the introduction of new techniques by means of investment of new plants, (2) the improvement of existing techniques and (3) the generation of new knowledge".

The extensive definitions of technology has resulted owing to the need of a broader definition for the term technology transfer. For example, Schnepp et al., (1990) defined technology transfer as "a process by which expertise or knowledge related to some aspect of technology is passed from one user to another for the purpose of economic gain". In contrast, scholars such as Munir (2002) defined technology transfer as the "process of managing the acquisition and incorporation of technology from a source, external to the firm". Going beyond such a broad definition the Inter governmental Panel on Climate Change (IPCC) report on methodological and technological issues in technology transfer defines that technology transfer in terms of " a set of processes covering the flows of know-how, experience and equipment, for mitigating and adapting to climate change amongst different stakeholders such as governments, private-sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions".

Since the term "technology transfer" provides many dimensions, it has often been used to describe the process by which ideas and concepts are moved from the laboratory to market place (Phillips, 2002; Williams & Gibson, 1990), the transfer of knowledge and concept from developed to less technologically developed countries (Derakhshani, 1983; Putranto et al., 2003) and the transfer of inventive activities to secondary users (Van Gigch, 1978). Autio and Laamanen (1995) suggest a broader definition by proposing that technology transfer involves an intentional, goal-oriented interaction between two or more social entities, during which the pool of technological knowledge remains stable or increases through the transfer of one or more components of technology (Levin, 1996).

The efficient transfer of technology means the transfer not only of technological information, but also the capacity to master that technology. Effective technology transfer is not a matter of identifying one or two best channels but it is the result of a combination of appropriate modes which are highly depend on industry, technology and level of country's development (Elgar,1999). In identifying the difference between technology transfer and knowledge transfer, literature based on many other researchers academics interpretations are significant to study.

A review of literature reveals that past studies have made little effort to explain the difference between knowledge transfer and technology transfer. Many of the studies do not draw a distinct line between knowledge and technology transfer because most of the studies have often applied the term interchangeably in both technology transfer and knowledge transfer literatures. Where majority have considered/ interpreted knowledge transfer and technology transfer to have a similar meaning. Another argument raised about technical knowledge transfer is stated as, the transmission or movement of knowledge as a process. It involves the process how an organization or a country transfers scientific or technological achievements, new uses for technology, designs, and the technical knowledge that can be used in production (Chun, 2007). Based on various definitions from different disciplines of research and background, majority of the researchers have affirmed that technology transfer is closely associated with the transfer of information, know-how, technical knowledge which is embodied in the products, processes and management. A successful technology transfer will eventually lead to a deeper and wider accumulation of knowledge (Shiowattana, 1991). This is obviously because of the critical element of knowledge that underlies technology

Transfer (Hall and Johnson, 1970; Kanyak, 1985; Shiowattana, 1987; Das, 1987; Williams and Gibson, 1990; Hayden, 1992; Gibson and Rogers, 1994). Other definitions of technology transfer, for example Grosse (1996) makes direct reference to knowledge as elements underlying technology transfer of product technology, process technology and management technology. Bozeman (2000), in his study on technology transfer and public policy, states that the approach by Sahal (1981, 1982) has resolved a major analytical problem in distinguishing the technology and knowledge transfer. Both technology and knowledge transfer are inseparable because when a technological product is transferred or diffused, the knowledge upon which its composition is based is also transferred (Bozeman, 2000).

There are many researchers who have endeavored to explain, directly or indirectly, the link between technology transfer and knowledge transfer and some even tried to draw difference between the two concepts. Kogut and Zander (1992, 1993), in their study on knowledge transfer within the multinationals, use both terms interchangeably to establish a close association between technology transfer and knowledge transfer when suggesting that technology transfer within Multinationals can be explained by the attributes of knowledge such as tacitness, codifiability and teachability. Sinani and Meyer (2004), when studying the spillovers of technology transfer from FDI in Estonia, make no distinction between technology transfer and knowledge transfer. Sung and Gibson (2000), in their study on levels and key factors in knowledge and technology transfer, cannot technology and knowledge transfer to have similar meanings. They suggest that knowledge and technology transfer as the movement of knowledge and technology through some channels from one individual or organization to another. Past studies have suggested that technology and knowledge are inseparable. For example Sahal (1981, 1982) argues that technology as ‘configuration’, observing that the transfer object, “the technology must rely on a subjectively determined but specifiable set of processes and products. It is no longer sufficient to simply focus on the product because it is not only the product that is being transferred but the knowledge of its use and application which are embedded in the products”. Bozeman (2000), in his study on technology transfer and public policy, states that "the approach by Sahal (1981, 1982) has resolved a major analytical problem in distinguishing the technology and knowledge transfer". Both technology and knowledge transfer are inseparable because when a technological product is transferred or diffused the knowledge upon which its composition is based, is also transferred (Bozeman, 2000).

A recent study by Li-Hua (2006) on the effectiveness of technology transfer in China indicates that the "technology will not occur without knowledge transfer as knowledge is the key to control technology". Simonin (1999b), in the study of transfer of marketing know-how in strategic alliance, suggests that study on knowledge transfer turn almost invariably to technology transfer when empirical investigation is in order.

Studies have shown that the tendency of the current studies have connected technology directly with knowledge (Dunning, 1994). Although technology transfer and knowledge transfer has been regularly used interchangeably in many literatures, since they are highly interactive, however, they serve different purposes. Gopalakrishnan and Santoro (2004) distinguish technology transfer and knowledge transfer in term of their purposes when they argue that knowledge transfer focuses on a broader and have more inclusive construct which is directed more towards the "why" for change, whereas technology transfer focuses on a narrow and more targeted construct that usually embodies certain tools for changing the environment. Even though there are distinctions between their purposes, majority of researchers agree that knowledge is the critical element that underlies technology transfer. Transfer of technology is the act of sharing know-how by such devices as constancy, joint ventures, gifts, licenses, franchises and patents (Meissner, 1988 & Jafarieh, 2001)

In construction, technology transfer involves individuals at various levels of an organization such as top and middle management and operative levels (Al-Jalal, 1991). The formation of joint ventures between local and foreign contractors has been recommended by the World Bank (1981). The integration of local and foreign construction companies in construction projects can facilitate the transfer of technology (Carrillo, 1993).

2.4 Technology Transfer Classifications

International technology transfer has been classified according to different criteria. Useful classification is provided by Mansfield, et. al., 1982, who distinguished between material transfer, design transfer, and capacity transfer. Material transfer consists of the transfer of materials, final products, components, equipment, and even turnkey plants. In brief, this is a transfer of the technological art efact (a product of human art) itself. It is not so much a transfer of knowledge as it is the transfer of the results of knowledge.

The receiving country is merely a passive consumer of the knowledge produced by others which it cannot produce by itself. The main objective is to produce and supply the physical capacity of their desired products (Mansfield, et. al., 1982).

Design transfer basically involves the movement of designs, blueprints, and the know-how to manufacture previously designed products or equipment. The major objective here is to provide the basic information, data, and guidelines needed to create a desired capability. In other words, foreign items are imported in order to copy their designs and the recipient nation begins to produce domestically the art fact formerly imported in the material type of transfer. Nevertheless, it still remains dependent upon technological knowledge produced elsewhere (Mansfield, et. al., 1982). Capacity transfer includes provision of the know-how and software not simply to manufacture existing products but, more importantly, to innovate and adapt existing technologies and products, and ultimately design new products (Gee, 1981).

Another classification distinguishes between two basic types of technology transfer, vertical and horizontal transfer. Vertical transfer refers to the transfer of technical information within the various stages of a-particular innovative process, ie., from basic research to applied research, from applied research to development, and from development to production. In other words it is the transition from the principle to practice, or from pure science to its practical application. Since vertical technology transfer entails technological progression from science to a completed product, there seems to be tend toward organizing R&D by vertical integration. Horizontal transfer occurs when technology is used in one place, organization, or context, and is transferred and used in another place (Brooks, 1967).

If a significant part of technology is tacit and embodied in people and organizational routines, then the efficient transfer of technology means the transfer not only technical information but also the capacity to master that technology (Elgar and Cheltenham, 1999). Making a strong version of this point Westphal et al., 1985 argue that the trading technology transfers the elements but not the capabilities of them. But during the initiation of the first commercial scale wind power project in Sri Lanka, local engineers did not have the necessary technological capabilities to engage in the development process. Therefore, the majority of operational and maintenance know-how, was transferred to the transferee via training and consultation (Withanaarachchi, 2016), which challenges argument made by Westphal et al., (1985) on TT.

Capacity transfer includes provision of the know- how and software not simply to manufacture existing products but, more importantly, to innovate and adopt existing technologies and products, and ultimately design new products. The receiving country is merely a passive consumer of the knowledge produced by others which it cannot produce by itself. The objective is to produce and supply the physical capacity of their desired products (Jafareigh, 2001). The most obvious example of this distinction is technology imports to the Soviet Union, which were restricted to machinery imports and one-off licenses imports (Hill and Hay,1993 , Cheltenham, 1999). One- off import of equipments with little transfer of know- how meant that the Soviets did not subsequently acquire the capability to replicate the plant they had imported (Amman and Cooper,1982 , Cheltenham, 1999). But for developing countries acquisition of technology has become more challengeable with their financial and technical capabilities and restrictive clauses imposed by host countries. In their early critiques of TT, the developing countries focused on reducing what they considered to be the excessive costs of technology transactions and the many restrictive clauses imposed on recipients by the suppliers (Withanaarachchi, 2016). It is further argued that "However, in most cases, current practices of TT do not allow the recipient enterprises to accumulate such technological capabilities.(Katuria, 2002 , Withanaarachchi, 2016). According to Simkoko (1989), the technology transfer process in industrial projects differs somehow from construction projects;

However both sectors undergo more or less similar phases in their realization. The evidence of similarity in life cycles of the industrial and construction projects are seen in the following grouping of construction project phases: conceptualization (i.e conception, feasibility studies and inception); implementation (design, engineering and constructions): and operation or utilization (Bell and Hoffman, 1981). In the construction delivery process, the capacities and capabilities are provided concurrently in the sense that construction techniques are employed in the project execution, while the know-how and managerial skills, and experience act as necessary inputs on the construction techniques. Thus, integration of both local and foreign technological and managerial capabilities in the project delivery process can facilitate the transfer of technological capabilities to the developing countries (Simkoko, 1989). As it explains technology transfer in construction industry can be considered as an investment to both firm and to the country. Since, the end of ethnic conflict of the country technology transfer through foreign contracts such as Hambantota port ,Mattala Air Port, Norochcholai power plant and Southern highway facilitated such as technical, managerial capabilities to the contractors.

2.5 Factors affecting on Technology Transfer

Different factors are important in selecting the appropriate technology transfer method associated with the models presented. Since the methods studied are focused on technology and market, common factors were compared for these two critical factors. The factors could prompt the companies to choose the best approach and should be aligned with the existent situations and priorities to achieve the technology.

Lin, Tan and Chang (2002), in their studies have successfully identified various factors that are critical for determining the technology absorption capacity. Wallender III (1979), has discussed extensively on factors affecting technology transfer in his study in various industries, such as the variety of factors that influence the ability of a firm to receive and utilize technology can be grouped into three categories; firstly, the internal characteristics of the firms; secondly is the external environment , thirdly is the process of consultation. A total of thirty one factors were identified as having some effects on the ability of the firm to receive and exploit technology.

Several factors influence the transforming of TT in the company, government, market and institutes (Kumar and Bhat, 2003; Bennett and Zhao, 2004; Nancy, 2005; Caldera and Debande, 2010). Also divided all identified transformation factors in four groups. On the other hand, lack of government support may cause the failure of technology or create barriers to further development of TT. Government policies providing demands for new products in the market and legislating supportive regulations for the localization of technology are of great importance to companies (Bennett and Zhao, 1997). Furthermore, attracting other support from different institutes could provide the required knowledge and finance when sufficient resources are not available. These institutes affect the function of companies by supporting, planning, consulting and enhancing their knowledge by various programs and are helpful in the success of the localization (Hankel and Kogan, 2010).

Among the different models and factors presented for choosing the technology transfer method, we categorize three models including Chiesa, Ford and Robert & Berry. Each of these models describes impact factors in selecting the specific method for technology transfer and suggests alternatives (Arasti et al., 2008). 1) Chiesa Model: This model analyzes the factors that affect companies' decision in choosing a technology transfer method. Since companies can access technology through various modes, all the company's requirements should be considered through various factors. (Chiesa and Manzini, 1998; Arastet al., 2008). Also, Chiesa et al. (1998) mention that the dimension and priority of requirements in each factor are significant in technological partnering. Company strategies can determine the importance of the factors for selecting the best method (Chiesa and Manzini, 1998; Arasti et al.,2008). 2) Ford Model, this model proposes methods based on different factors related to transferred technology and the company. The position of technology in the lifecycle and the competitive advantage brought about by technology are technology-based factors. The model suggests the internal development for new technology and purchasing approach for the technologies that are past their maturity stage in the life cycle.

The other methods, including joint venture, outsourcing, R&D contracting and licensing are distributed from the early stages of technology to the maturity phase. It also indicates the role of the company’s technology level in achieving the transferred technology and the company’s need for rapid achievement (Khalil, 2000; Arasti et al., 2008). 3) Robert and Berry: This model emphasizes two factors, technology and market. It suggests the methods through the familiarity matrix of different positions of technology and market ranging from base technology/ market and new familiar to new unfamiliar technology/market.

The alternative methods include joint venture, acquisition, licensing, and minority venture capital investment. It also suggests the education and training required when one of the technologies or the market is new and it is expected to develop future market shares (Robert, and Berry, 1985). Comparing the factors drives us to identify the methods that are suggested in the three models studied. The method is completely dependent upon the position of a company in different areas. In this comparison the joint venture is suggested as a common method from all three models.

2.6 Modes of Technology Transfer

Most definitions of technology transfer do not consider the modes of transfer. Fransman (1986) defines the international ‘transfer of technology’ as a process

"Whereby knowledge relating to the transformation of inputs into outputs is acquired by entities within a country (For example, firms, research institute, etc.) from sources Outside the country" In another way technology transfer can be defined as the transfer of systematic knowledge for the manufacture of the product for the application of process or for the rendering of service and does not extend transactions involving the mere sale or lease of goods (Elgar and Cheltenham, 1999). There are numerous dimensions which can be used to classify technology transfer. Criteria like vertical and horizontal; formal (market meditated) and informal (non-market meditated); active or passive role of foreigners; embodied and disembodied: degree of packaging; direct or indirect; institutional form (intra-firm / integration) are few of them (Withanaarachchi, 2016).

Amilth and Sharif (2007) describes that there are four major components of technology required to implement the above transformation namely; Techno ware: Object-embodied physical facilities, Human ware: Human oriented factors, Info ware: Information and knowledge, and Orgaware: Organization-embodied operational schemes. Similar to Sharif�given classification Leonard-Barton (1992) has also suggested four dimensions (or assets) that comprise of the knowledge-set required to promote technological innovation. The four dimensions comprises of knowledge and skills embedded in employees (Human ware), Technical systems: Knowledge embedded in technical systems (Techno ware), Managerial systems: Formal and informal ways of creating knowledge (Orgaware), and Values and Norms: traditions from the founders (Info ware). With this background the next subsections will further discuss them methods under categories: 1) Foreign Direct Investment 2) Joint Ventures 3) Co-operative alliances 4) Licensing 5) Subcontracting 6) Training. Also (Elgar and Cheltenham, 1999) argued that the division of technology transfer among conventional channels such as, foreign direct investment, licensing, joint ventures, franchising, marketing contracts, technical services contracts, turnkey contracts and international sub contracting, and non conventional channels such as reverse engineering and reverse brain – drain. Out of these factors direct foreign investments, joint ventures and licensing is the mostly attended modes of TT. These are called formal channels of technology exchange.

2.6.1 Foreign Direct Investments

Foreign direct investments (FDIs) are those that are made *outside* their home country of the investor, but inside the investing company. In national income accounts, FDI includes all flows, whether direct or through affiliates, from the investor and includes also reinvested earnings net borrowing and equity capital as well. Control over the use of resources transferred remains with the investor, giving in the effective voice in the management of the foreign firm. As Dunning (1993) notes, it consists of a package of assets and intermediate products such as capital, technology, management skills access to market and entrepreneurship. It is believed that Foreign Direct Investment (FDI) is one of the most important channels of technology transfer (Marton, 1988). In the context of technology transfer through FDI, Kogut and Zander (1993) have explicitly indicated foreign direct investment is the transfer of knowledge, which embodies a firm’s advantage, underlies technology, production, marketing or other activities.

There is considerable general literature on the advantages and disadvantages of FDI for developing countries. One of the main advantages of FDI is that it brings in new knowledge, technical know-how, marketing and entrepreneurial skills. Hence this complete package of knowledge and skills can certainly have a major impact on the recipient country. The importance of FDI as one of the major mechanisms for technology transfer can be seen in the preference of this method over the other channels by both receiver and supplier of technology. It is argued that through the 1960s, the establishment of a wholly owned foreign subsidiary or a majority-owned foreign affiliate was the predominant method of MNCs' direct investment and a prime source of technology transfer to LDCs (Reddy and Zhao, 1990). However, many LDCs proposed rather more restrictive policies towards MNCs - in particular their whole ownership, as most of these countries wished to strengthen their indigenous industrial and technological capability, which enabled them to adapt and assimilate foreign technologies more efficiently.

The choice between exports and FDI as channels of technology transfer is more complex. One might expect that export would be the preferred choice as suggested by product cycle theory. However, it can be seen that in many respects, firms in LDCs prefer direct investment for technology transfer (Ailed and Wood, 1981). According to Dunning (1988); Jafarieh (2001), what makes a firm (MNC) enter a foreign investment activity instead of exporting its products is the exploration of the location specific advantage and the ownership specific advantage. In other words, the main reasons for a firm to be involved in foreign investment are to control enterprises in other countries and also to use the firm's competitive advantage abroad. The importance of FDI as a mechanism for technology transfer has been important for many developing countries. This is particularly, the case for the East Asian countries, except for South Korea where FDI has been an important source of technology in specific industries such as chemicals, electronics, and petroleum refining (Westphal et al., 1984).

2.6.2 Joint Ventures

The inter-firm technology transfers (TT) through international joint ventures (IJVs), among others, have significantly contributed to a higher degree of local innovation performance/capabilities, technological capabilities, competitive advantage, organizational learning effectiveness, productivity, technological development of local industry and the economic growth of the host country. Since the focus of inter-firm TT in developing countries has shifted to degree of technology transfer, organizations in developing countries are attempting to assess not only the significant role of technology transfer in strengthening their corporate and human resource performance but also the influence of other critical variables such as MNC’s size, age of JVs (JVAGE), country of origin, and MNC’s type of industries that could significantly moderate the relationship. When compared to various forms of strategic alliance such as distribution and supply agreements, research and development partnerships or technical and management contract, the international joint ventures (IJVs) are considered. as the most efficient formal mechanism for technology transfer (TT) to occur through inter-partner learning between foreign MNCs and local firms (Kogut and Zander, 1993; Inkpen 1998a, 2000). IJVs are also viewed as the most efficient mode to transfer technology and knowledge which is organizationally embedded and difficult to transfer through licensing agreements (Kogut, 1988; Mowery, Oxley and Silverman, 1996). IJVs provide both MNCs and local partners an appropriate avenue to facilitate the transfer of organizational knowledge, particularly for knowledge which is hard to be transferred without the setting up of a JV such as institutional and cultural knowledge (Harrigan, 1984).

Most of the studies on strategic alliance and IJVs have recorded positive relationship between knowledge acquisition or transfer and IJVs'performance for example 1) knowledge acquisition has a positive impact on the IJVs' human resource, general and business performance (Lyles and Salk, 1996), 2) knowledge acquisition as a better predictor for human-resource related performance than the general and business performance (Lyles and Salk, 1996), 3) knowledge acquisition from parent firms has a significant positive effect on IJVs' performance (Lane *et al*., 2001; Tsang *et al*., 2004), 4) explicit knowledge acquisition have a positive impact on IJVs' performance (Dhanaraj *et al*., 2004), and 5) tacit knowledge about overseas information was positively related to new product development capacities (Subramaniam and Venkatraman, 2001). In addition, Yin and Bao (2006) found tacit knowledge acquisition had significantly affected local firms' performance (LFP). Surprisingly, Dhanaraj *et al*. (2004) found tacit knowledge was negatively related to IJVs' performance. The question is no longer whether or not the MNCs are transferring technology to local firms; instead the focus in the literature has shifted to questions on 1) the level (sophistication) of the transferred technology, and 2) the stage where the transfer process has reached (Narayanan and Lai, 2000).

Joint ventures certainly have an advantage in learning technical know-how and obtaining necessary resources from the parent companies, so that they are usually very quick in catching up. Often these joint ventures are equipped with the latest models of machines which are even better than those used by their parent companies in home countries as some Thai and Indonesian managers reported (Chatterji and Manas, 1990). Joint venture agreements have been classified into different types. Killing (1983); Jafarieh, (2001) distinguishes between two ways in which a local firm in the recipient country can use a joint venture to acquire technical and managerial expertise from a potential technology supplier. One is to form a dominant parent joint venture, which is passive with the technology supplier (Meissner, 1988). The other is to enter a shared management venture with the technology supplier. He stated that while there is a possibility of very good technology transfer in a shared management venture for both local and foreign partners, the probability of failure is much higher in a shared joint venture than a dominant parent venture.

UNCTAD, 1988 and many others, have made a distinction between two types of joint ventures: the equity joint venture in which assets, rights, and liabilities are shared through joint ownership of an incorporated enterprise, and non-equity joint venture where the co- operation between partners is established on a contractual basis. Non-equity joint ventures include all types of collaborative contracts and production sharing agreements. There are generally some advantages and disadvantages for joint ventures. Joint ventures represent a significant change in industry structures and in competitive behavior. Joint ventures permit firms to create new strengths. They permit firms to share in the use of technologies they could never afford to explore alone. A joint venture may also create lower operating costs and become more efficient than a wholly owned subsidiary because of complementary skills, economies of scale and scope, and the local partner's knowledge of the local environment. The importance of joint ventures in comparison with other channels of technology transfer has recently increased because product lives are shorter, cost advantages are becoming more pronounced, and greater numbers of firms which operated formerly only in domestic markets are becoming global competitors.

2.6.3 Co-operative Alliances

Co-operative Alliances are widely used by international construction firms with domestic firms enabling the smooth and effective implementation of major projects. This has been rapidly developed in past few decades in Sri Lankan construction industry; co-operative alliances are small in numbers but operated smoothly enabling benefits to both parties. As (Elgar and Cheltenham, 1999) explained their growth has been very fast during the 1980's but involved predominantly companies among economies. Further (Elgar and Cheltenham, 1999) explained that Alliances are studied in two areas. First, the majority of alliances are not direct investments but not arm's length and relationships either. Second, the notation of alliances assumes the existing of distinctive or relatively independent agents.

2.6.4 Licensing

Licensing know-how to established firms seeking to incorporate the technology into the products they sell is the most common practice. Licenses can be exclusive, granting the sole right to a single company in a single country, region or market sector, or non-exclusive.

Exclusive licenses are usually granted when inventions require significant private investment to reach the market place or are so embryonic that exclusivity is necessary to induce long-term investment. Non-exclusive licenses tend to be used where the underlying technology is some form of enabling process or diagnostic method that is likely to be used widely in laboratories and workshops.

It is believed the main advantage for both licensee and licensor is that the license agreement allows transfer of technology to take place without risks associated with financial involvement (Clark, 1993). Moreover, licensing affects the development of new technology and may encourage or discourage new research and development. The advantages of licensed technology depend heavily on how current the technology is, and whether the licensee is permitted to retain the rights to any improvements made (Porter, 1988). Moreover, some of the important factors, which determine the propensity to license are size of local market, the stage of industrial development in recipient country, the availability of skilful and capable labour force in the host country, a level of political risk, and knowledge of the new market (Jafarieh, 2001).

The ability of a licensee to absorb and improve upon licensed technology depends greatly on its capability to understand and control embedded technology as well as embodied technology. In other words, the licensee or the user of licensed technology needs technical expertise nearly equal to that of licensor or supplier of technology in order to absorb the technology more effectively. This knowledge includes contract administration and patent management, which are generally considered to be managerial, rather than technical skills (Jafarieh, 2001).

2.6.5 Subcontracting

Sub contracting is a broad term which expends ranging from domestic sub contracting to international level. It is practiced not only in construction industry but also in many other fields. It is an effective TT mechanism which has been in practice in the global contruction industry. Sub contracting is a channel of technology transfer and it is unevenly spreaded. It is most developed in East Asian countries, comparatively less developed in latin America and is increasingly expanding in Eastern Europe (Elgar and Cheltenham,1999). This sub contracting arrangements are more effectively used in the cases of international original equipment manufacturers globally. In large construction projects international sub contracting is used more productively. For an example TBM manufacture of UOMDP is the “Herrenknecht’ who is the OEM as a sub contractor. In case of East Asian firms that OEM arrangements are an ‘important training school’ for local firms in which production and design techniques are absorbed (Elgar and Cheltenham, 1999). In this case the highest form of subcontracting own design and manufacturing (ODM) is used. Under ODM firms, manufacture a range of products without much assistance from the overseas purchaser.

Although subcontracting is an extremly important channel of technology transfer, a considerable interest has not taken in the international cotracts awarded in the recent past, in Sri Lanka. This is due to a character of technology transfer in sub contracting relationships where technology is not an explicit object of exchange.

Further most type sub contracting during the recent past appear as normal and not considerd as a channel of technology transfer. There is a huge trend of of sub contracting due to insufficient man power availability in the country. Most of the major contractors and foreign firms used sub contracting with small contracting firms where the contracts were limited to supply of labour. Main contractors normally divide the work in to packages and awarded to first layer sub contractors.

The first layer sub contractors further divide their work in to small packages and sublet them in to second layer sub contractors. In the case of Hong Kong a survey has conducted to review the level of sub contracts in different layers and has revealed that, the degree of sub contracting in the local building projects shoes 74 percent, 15.6 percent, 4.2 percent of the respondents were usual second layer, third layer and fourth layer sub contractors respectively (Cheng and Law, 2005).

Further, this provide a platform fostering technology transfer in the construction industry. The role of main contractor gradually transformed to sub contractor layers depending on the complexity and size of the projects. This is defined as,management of the subcontractors as one of the key functions of the main contractor (Frishby,1990).

2.6.6 Technology Transfer through Training and Learning

Learning and training during the process of technology transfer will result in many other socio-technical interactions that will ultimately lead to many modifications and adjustments to inter and intra organizational system processes and procedures. These interactions developed through learning and training will definitely strengthen organizations to deal with discontinuities faced, in a more efficient manner, during the process of TT. The transfer of agricultural, military and construction technology between parties depend on the type of relationships maintained between each other. Close relationships between those parties involved allow them to spend time with each other to learn, which is an obvious part of the transfer process (Gorman 2002).

The process of learning and training depends on many factors like, the nature and the complexity of technology to be transferred, process (mode) of transfer, learning environment, objectives and motives of the parties involved etc. (Gorman 2002 & Wahab et al,). More complex technology will need more skilled recipients in a very good environment with necessary infrastructure for the recipients to absorb the technology effectively. The mode of training could be seminars/ demonstrations / field visits or by any other means, which should be determined under the consent of both parties involved to ensure a proper transfer process through learning. The flexibility and interpretative skills of the trainers/instructors or the donors also will affect the process of learning and training in TT (Huber, 1991; Schilling and Kluge, 2009; Manimala and Thomas 2013). Above all the technology transferred through training should be useable and practical for the recipients and the intentions of training should transparent from both ends. The recipients should be eager to grab, while the donors should have the sole intention of producing high-quality professionals who'll be able to use the technology transferred in a productive manner.

Apart from the above, the following factors were also identified as key factors that will lead to an effective learning and training process.

- Skillfull recipients/ participants that could absorb the complex technology.
- Proper material must be contained in the courses.
- The material must be delivered in an appropiate and satisfactory manner.
- There must be assurance that participants have agreed upon the level of comprehension.
- There must be assurance that participant can use the new skills /knowledge on the job.

2.7 The construction industry in developing countries

The construction industry in developng countries share many of the problems than that of the developed countries (Bakar, 2006). According to Edment and Miles (1984) the structure in developing countries is an extreme version of its developed country. There is a small number of large companies, often foreign-owened, who carry out the majority of the work (Kirmani,1988). The world bank (1984), Edmond and Miles (1984), Rau (1983), Kirmani (1988), UCERG (1972), Chang (1987), Abbots (1985) and many more have listed that due to the ignorance bandon of weaknesses, the construction industry in the the majority of developing countries must be, as Wells (1986) put it, by any definition , 'inefficient', with low levels of protectivity and high costs However, rising greenhouse gas (GHGs) emissions and associated environmental concerns indicates that the developments in these developing countries will not be sustainable if these countries simply follow the historic polluting trends of industrialized countries. Meanwhile, the available literature signifies that in order to achieve a sustainable economic development, developing countries require assistance to enhance human capacity (knowledge, techniques and management skills), with the assistance of appropriate institutions and networks, along with the acquisition and adaptation of specific hardware (Karakosta, Doukas and Psarras, 2010). However, the stated components are based on the transformation of certain resources to one another guaranteeing greater value form which will satisfy human needs and wants.

2.8 Brief History on Technology Transfer in Sri Lanka

Archaeologists have proven that iron smelting was initiated in the past, by using South-Western monsoonal wind power, instead of using the bellow to pump air to smelting furnaces. This technology had been widely used during the period 300-200 B.C. in the Balangoda area, recording Sri Lanka to be the first country to utilize wind energy for productive work (Juleff, 2003).

The models of technology innovation in developing countries are based on several stages, for example, imitation stage, improvement stage and innovation stage

(Ali, Muhammad and Park, 2011). In that sense Sri Lanka still remains in the imitation stage with minor technological adaptation capabilities. But in the Mahaweli projects the transfer of technology, training of Sri Lankan technical personnel and availability of all details of projects helped us to maintain the installations (Mendis,2013)

Sri Lanka has a great history in development of infrastructure during the periods of ancient kings. At that era, technology has mainly developed in Irrigation structures, Buddhists Pagoda's and stone carving etc. There are many evidences that this technology either developed in the country or transformed from other countries such as India, Burma and China etc. According to Sri Lankan history, the first tank was built by King Pandukabhaya who reigned from 437 to 367 BC. After the invasion of European countries in the mid of 15th century, European technology and innovations has started to transfer to the country. Portuguese and Dutch started introducing technology development mainly focused on development of infrastructure. The first important irrigation work undertaken by British was the construction of the Kirama dam across Kirama Oya. Irrigation Ordinance No.21 of 1867 provides a strong evidence to the development of infrastructure with European and domestic indigenous technology. Technology development was continued up the independence in construction of railways, highways, buildings, irrigation and specially in many more infrastructure development activities. Technological era began from the 19th century with British colonization. In order to facilitate their agricultural based market, they developed irrigation, road sector, Colombo seaport and the railway sector etc. (Bandara, 2014). In this period Ceylon Government Railway (CGR), Public Works Department (PWD), Irrigation Department (ID), Survey Department (SD), Government Factory and many other institutions were started and hence technology was transferred to country. After the independence, in order to develop Sri Lankan science and technology, Ceylon Institute of Research (CISIR) was established. But this institution failed to deliver its objectives as reported by many publications.

2.9 Problems in quantifying Technology Transfer

There are main problems in quantification of technology transfer. First, technology itself is not easily identified (Elgar and Cheltenham, 1999). Second, technology flows through different channels where technology is embodied in diverse forms (Elgar and Cheltenham, 1999). Third, it is difficult to separate the technical from the transactional elements and cost in technology transfer. In view of Elgar and Cheltenham, 1999 most of the organizations do not take in to account arise in different forms of co-operative alliances from the beginning of 1980’s which complemented the rise in FDI, into account. Also, they do not take into account the rising of sub contracting as a technology transfer channel since the mid 1970’s.

2.10 Barriers and enablers

Technology Transfer has been advocated as a catalisty of the change or improvement required in many construction industries; however free transfer of technology from one country or region or firm to another has been restricted by various barriers (Shrestha and Kumaraswami, 2000, Weerasingha and Ekanayake, 2012). They identified few Technology Transfer barriers such as (i) Organizational culture (ii) Lack of time (iii) Capacities of individuals (Ex. Training skills) (iv) Altitudes of individuals (v) Lack of clear policy (vi) National / ethnic culture differences (vii) Lack of clear arguments (viii) Lack of clear procedures (ix) Lack of funding provisions and (x) Lanuage.

According to Barrow & Sala (1995), ‘TT is not a simple automatic process with availability of technical knowledge and abroad market facilities’. It requires a better set up process which may exploit these opportunities and which may compliment them with domestic technology accumulation. Therefore it is essential to have proper procedure and context in understanding why some countries made good use of external opportunities and why other have not.

According to Dainty et al. (2005) following are the three principal barriers to the creation of TT related to the large construction companies.

- Unsupportive culture
- Poor communication
- Time constraints

According to Dainty et al. (2005) eleven essential hurdles applicable to knowledge sharing were identified based on above three principles. Significantly identified highest scored three hurdles are as follows.

- Insufficient sub contractor's involvement in the pre-construction planning stage
- Heavy day-to-day pressure of working within the project environment likely to prevent open knowledge sharing
- May hoarding knowledge help to their specialty, job security or promotion etc.

  Further comprehensive research program is necessary to find out enablers and barriers and to facilitate the development of appropriate policies and strategies for improving the TT through construction projects involving foreign firms or personals.

CHAPTER 3: METHODOLOGY OF STUDY

3.1 Introduction

Since this research is a qualitative measure to review, synthesize and criticize the degree of technology transferred to the local professionals through the "Uma Oya Multipurpose Development Project", method of data acquisition had to be either direct interaction with individuals of the target professionals or by other means of indirect interactions.

Direct interactions include discussions, interviews and long verbal conversations in-person which would enable gathering reliable information from a limited sample space, whereas written questionnaires, checklists and multiple choice questions fall into the category of indirect interactions. Basically indirect means of interactions are productive for a larger sample where huge amount of data is to be handled while costly direct interactions are preferred in qualitative researches like this.

In order to quantify the degree of technology transferred, the technical knowledge of the professionals should be evaluated. The technical expertise of a personnel depends on the knowledge, hands on experience, attitudes and many other individual characteristics which could be identified through very well structured interviews with the target professionals. As shown in Figure 3.2, there are several stakeholder institutions responsible for various disciplines of the project. In order to come to a conclusion regarding the technology transferred through Uma Oya Multipurpose Development Project as a whole, the technology absorbed by different institutions has to be evaluated. Further the employees had to be classified according to their level of exposure to the foreign counterparts, because the job responsibilities and the engagement with foreign contractors may vary with different job titles. Senior Engineer might be responsible for policy making and decision making with foreign contractors, while the junior and middle level engineers will be monitoring field work which supports senior administration.

So, the interviews had to be job specific and relevant to their area of expertise. The questions were common for all levels of engineers and the interviewing procedure for different levels varied according to their job roles. Nine senior level Engineers from each institution were interviewed according to the schedule given in Annex 1. Engineers engaged in civil engineering construction work i.e. engineers from MASL, ID and CECB were interviewed in a similar process while the other senior engineers from CEB and PMU were interviewed regarding their area of expertise (Mechanical, Electrical and Administration). Unique questions for interview guide (Annex. 04) to different professionals were prepared in order evaluate the knowledge gained from the foreign contractors regarding the new technology they've been using in the project and the issues faced by the local officials. The guidance for questions (Annex. 04) and the list of interviewees are listed in Annex 1.

Middle level engineers again were grouped according to their area of expertise and were asked a set of unique questions to evaluate the degree of technology they've been exposed to. The list of the interviewees are listed in Annex 2. Unlike the senior level engineers, these groups of middle level engineers directly engage in the field with the foreign contractors. Since the middle and junior level engineers are the ones who should grab the latest technology in order to make use of it in future projects, the degree of technology transferred to them should be evaluated thoroughly.

The questions developed for them had to take a different form, questions 04 and 05 specially concentrate on this group. The list of the junior engineers representing each stakeholder institution of the project and the procedure of the interviews carried out is listed in Annex 3. Out of the 28 junior engineers employed in the project, selected engineers were interviewed according to their level of exposure to the foreign counterpart. In addition to that, the interviews were structured in a way to evaluate the degree of technology transferred to the junior engineers through middle and senior engineers as some middle and junior engineers might not be significantly engaged directly with the foreign counterparts.

Received high response rate from all categories of professionals in all senior, middle and junior levels. Response level was 96% and all the junior and middle level engineers were responded and only one senior level engineer was not responded from the target group. Directives of senior level engineers in the interview were helped to interview the junior level professionals. Within the process of interview it is revealed that some of junior level engineers are willing to get experience in all activities of the project. But due to the implementation method and organization cultures it has not been realized as expected.

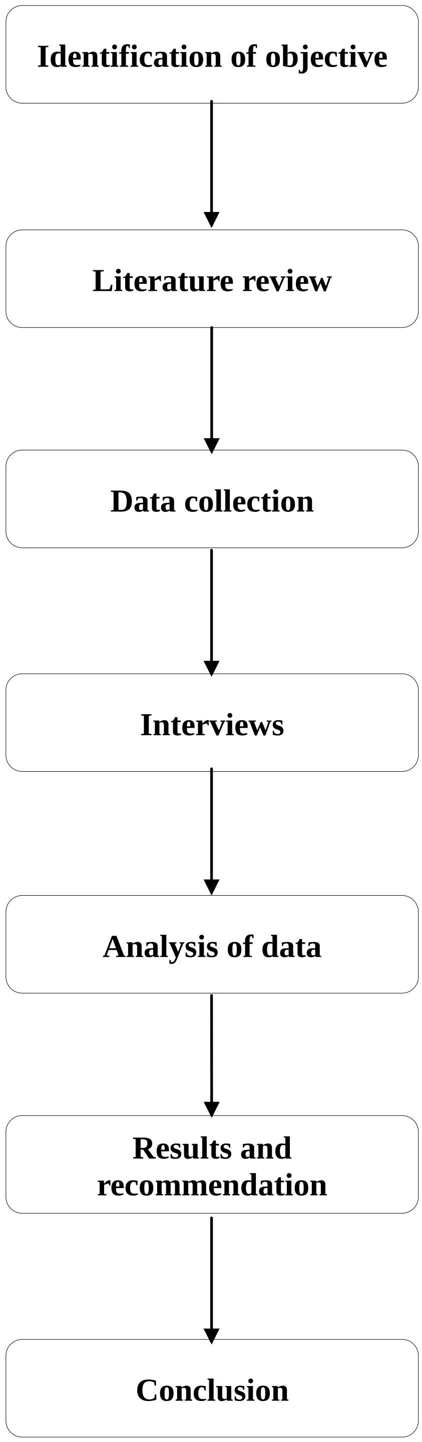


Figure 3.1 Flow chart of methodology of study

Further, during the interview it is revealed that few engineers are willing to leave the country seeking foreign jobs and citizenship. This is due to personal interests of their own such as income and job satisfaction related issues.

3.2 Method of data Collection; Reasons for selection of the methodology

Interviewing or asking questions has been identified as one of the most (probably the only) result oriented method of collecting data regarding someone's knowledge, past experiences, attitudes etc. for a qualitative research. Questionnaires are commonly used to collect data from a large sample space with a specific generalized set of questions. This method is quite effective when there is a large amount of data to administer. But the quality of the answers obtained might not be reliable due to lot of reasons as the whole process depends on the respondent. In most cases respondent might not answer the questions truthfully as they are concerned about privacy and anonymity. The respondents may have different perspectives on a single question and the way they interpret the questions may vary. Therefore the final answers obtained from such questionnaires may not meet the demand characteristics.

But when it comes to face to face interviews/discussions, the interviewer gets the chance to ascertain reliable details through direct verbal instructions that would guide the respondent to meet the demand characteristics. The possibility of "don't knows", misunderstandings could be prevented as the researcher can clarify and expand questions even providing with examples, which would give the interviewee a clear idea about what is expected by the researcher. Since the interviewer is in charge of the situation the questions will not be general as in questionnaires, researcher will have the opportunity to design and structure the interview according to the interviewee. Plus there won't be any messy paper work for the respondent which would allow them to concentrate on the questions.

Furthermore, the key advantages of interviewing/ discussions for data collection could be listed as follows.

- Accurate screening
- Capture verbal and non-verbal clues.
- Consistency / Focus
- Reliability
- Capture emotions and behaviors
- High response rate
- Opportunity to comment and respond immediately

Obviously conducting interviews and discussions in-person is not very economical. This could only be done to a limited sample space. Travel and transport, personnel costs and many other costs have to be incurred when arranging such deep conversations. Not only the costs to be incurred, but scheduling and making appointments is also a fact to be considered when arranging interviews. Professionals like Engineers barely have time to make such arrangements for time consuming conversations within their tight schedules. Further more, the privacy or the anonymity will be a major drawback of such conversations as some respondents may be reluctant to share personal information. Above all, the quality of information gathered will depend on the ability of the interviewer. Communication skills of the interviewer should be excellent in order to gather unbiased, reliable and accurate data.

In the past number of multipurpose development projects have been completed such Mahaweli development project, Samanalawewa hydroelectric project, Upper Kotmale project, Kukuleganga project etc. Most of this project were implemented under Foreign Direct Investment (FDI) method and foreign multinational companies (MNCs) were the foreign contractors. But level of technology transfer trough this FDI is questionable. In such a way Uma Oya Multipurpose Development (UOMDP) is a FDI implemented through MNCs. Since there no major local sub contractors are engaged main channel of TT through local professionals working in the project.

Most of the local engineers working are very senior personals hence they are having high theoretical knowledge and work experience. Therefore it is not possible to completely absorb the correct position of level of technology transfer by using the methods such as questionnaire survey. Therefore method of interview is the best fit mechanism for this specific case of interest. By this method every layer of level of technology acquisition and level of getting technical know-how can be achieved. Taking all the above facts into consideration, conducting interviews / deep verbal conversations was identified as the most suitable method of data acquisition for a qualitative research like this where the knowledge, experiences and the attitudes regarding the degree of TT is analyzed. Since the target respondents are professionals (Experienced Engineers), discussions related technical aspects also will not be very much difficult. Complexities in communication will be minimal which would smoothen process of data acquisition.

3.3 Interview schedule & guide

Interviews with professionals of different levels were conducted to evaluate the degree of technology transferred as the interviews generate successive platform in absorbing the reality. Both local and foreign officials including senior & junior engineers, geologists, managers and technical officers who are employed at foreign contractors and consultants were interviewed thoroughly to study the level of technology passed to the local officials within their stay in the Uma Oya Multipurpose Development Project.

Though the questionnaire guide is used at the interview, questions asked were based on the individuals working experience, work environment and specific expertise etc. It is revealed that classified long answers were given by the professionals when they have acquired more experiences and they have given short answers if they are not having more experience. In the case of given answers it is understood that some answers can be more classified, if interviewed second time.

If it is possible to interview second time more accurate and detailed answers can be expected from same professionals. Therefore few professionals were interviewed second time and this cannot be applied to all due to time constraints. Informally collected date such as meeting, discussions and lunch table were highly contributed to get the interview procedure successful & to collect accurate and precise data covering wide area as expected.

My work experiences are more than four years in this project. Relationships with persons and exposure to all project activities made study straightforward. This factor highly contributed to lead the study towards the winning completion.

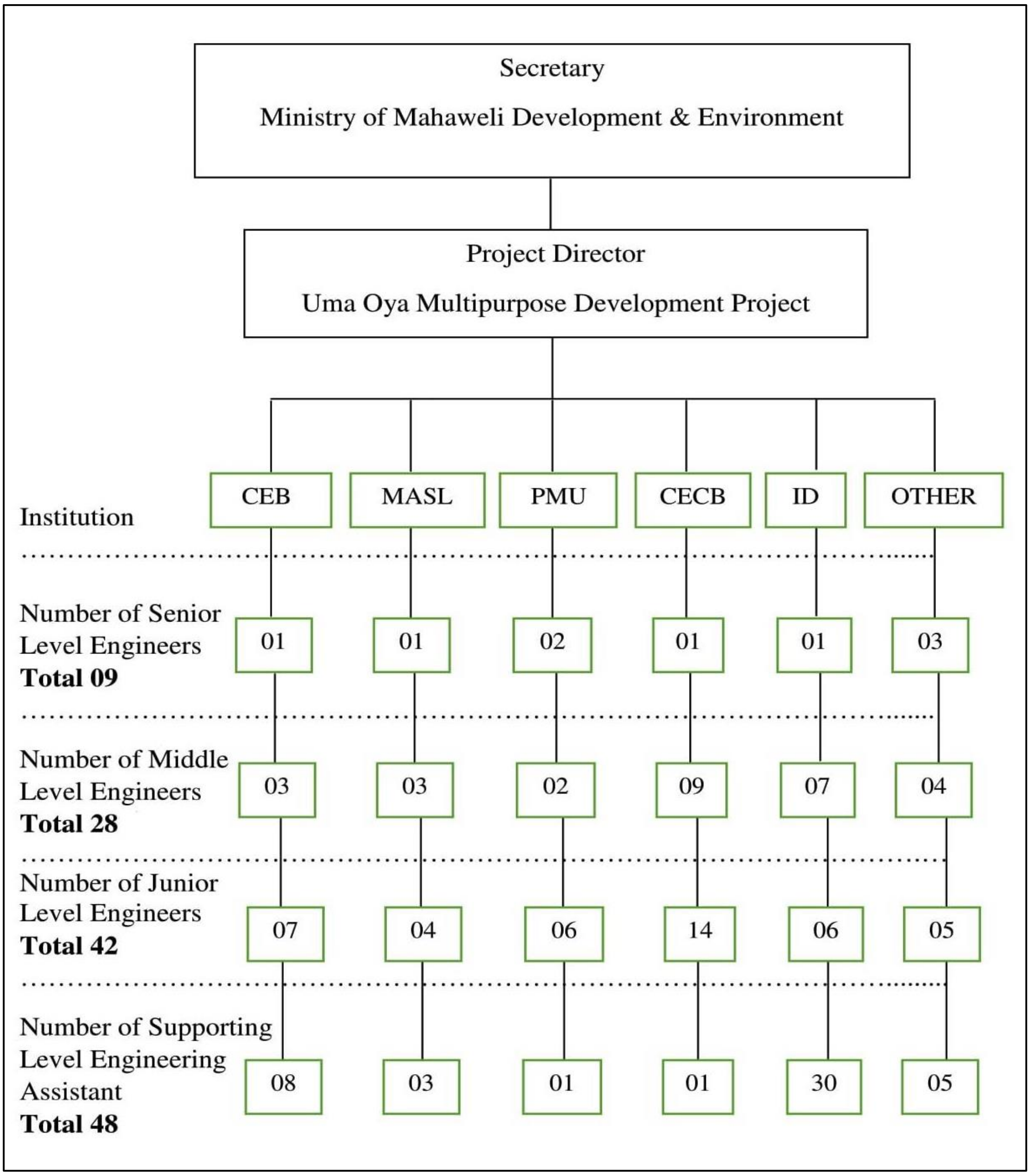


Figure 3.2 Summary of staff involvement UOMDP by Stakeholder Institution

3.4 Data Analysis

Interpretation and analysis of data ascertained using the structured interviews is the next step in obtaining a qualitative measure of the technology transferred in the project. Data analysis is the process of reducing and summarizing large amounts of data into a sensible and readable format. At the end, the method chosen for should basically familiarize the researcher about the data obtained giving himself an idea on similarities, patterns, relationships and other characteristics. There are many methods of data analysis in qualitative researches. Although there is no prescribed way of doing this, the method chosen should be compatible with the data to be analyzed, address the research question and should drive the research to its expected objectives based on the theoretical foundation (Kawulich)

One of the widely used methods for corporate strategy development and decision making is the Suitability, Acceptability, Feasibility (SAF) model developed by Johnson, Scholes and Whittington. The data obtained from the interviews and the questionnaires were put in to this model to determine the ‘success criteria.” In order to judge the success of a certain strategy, following “success criteria” Suitability, Acceptability & Feasibility of the option should be evaluated. (Johnson, et al., 2008) Suitability is concerned with whether the particular strategy addresses the organization in operation –strategic position (Johnson, et al., 2008).Suitability can be thought of as the rationale of a strategy and whether it ‘makes sense’ in relation to the strategic position of an organization (Johnson, et al., 2008). Current strategic position of a certain organization could be determined by a SWOT analysis.

In this research, it is to find out whether Uma Oya Multipurpose Development Project addresses the current operational needs of the project area (Badulla, Moneragala & Hambantota Districts) and the whole island. The data obtained from the surveys are to be used to check the suitability of the project and whether the technology to be obtained from the foreign organizations suits the operational needs of the community at the moment.

Acceptability is basically to determine whether a certain strategy will drive the organization and the stakeholders to the expected outcomes (return or risk) (Johnson, et al., 2008). Benefits and the losses should be analyzed to determine the acceptability of a certain process. It could be cost benefits or any other social, environmental or cultural benefit gained from a certain strategy compared with the losses imposed by the same strategy.

The comments and the opinions expressed in the interviews and the questionnaires could be used to determine the degree of technology transferred to the local professionals through Uma Oya Multipurpose Development Project which automatically will assist to determine the acceptability of the complete project to the general public. Long term impacts on the public in obtaining technology through such a project also is an aspect to be considered in analyzing data using this model. Furthermore the long term and short terms risks should be analyzed using a thorough risk analysis process which is very important in implementing such projects. SAF model could be used effectively to analyze all these factors in determining the acceptability of the project using the available data.

The ultimate success criterion to be determined is the feasibility. Feasibility can be defined as the ability to make a particular strategy into practice. The constraints, capabilities and other practicalities should be analyzed thoroughly to determine the feasibility of a certain strategy. When it comes to the Uma Oya Multipurpose Development Project, feasibility studies on diverse disciplines should be conducted to determine the feasibility of the project. Technical, Financial, Environmental and Socio-Cultural feasibility should be evaluated prior to implementing this kind of large scale projects into practice.

Impressions conveyed in the interviews and surveys will be used to determine the feasibility of the project, where the degree of technology transferred with that of the expected and the pros and cons will be evaluated in the process of data analysis using the SAF model.

Once the major success factors are evaluated using the data available, the SAF model will assist to conclude whether the strategy proposed, in this case the project implemented will be a success or a failure. Opinions of the senior and junior professionals gathered during interviews will be input to this model to determine the success criteria regarding the Uma Oya Multipurpose Development Project. Once those factors are determined, the degree of technology transferred could be determined.

CHAPTER 4: ANALYSIS OF DATA AND DISCUSSION OF RESULTS

4.1 Introduction

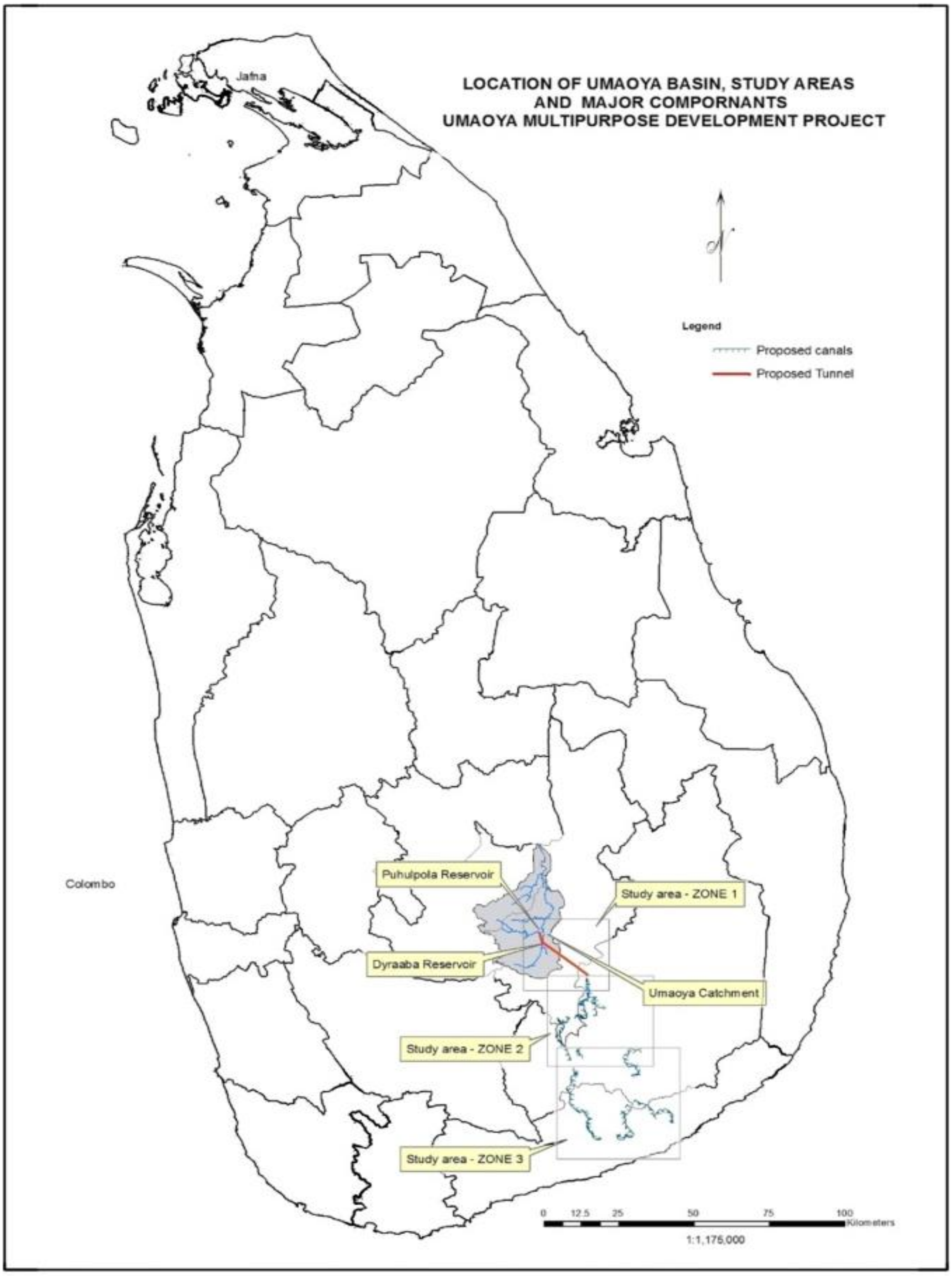
Main contractor of the project is FARAB, and most of sub contractors are foreign companies including Iran, German, and Indian etc. Project monitoring Unit headed by Project Director, Mahaweli Authority, CECB, CEB and Irrigation Department are local organizations engaged in project monitoring, supervision, quality control and quality assurance activities. They are working under PMU. For the project implementation work 127 number of professionals are engaged in construction and monitoring activities. CECB and CEB engineers including other professionals are the local consultants. Number of local professionals joined through local sub contractors are limited. Through this channels it is possible to transfer technology up to a certain limit to the local professionals.

4.1.1 Introduction to the selected case

Umaoya project has launched in year 2010 by Ministry of Irrigation and Water Management to cater power demand in the country and irrigation demand in Kirindi oya basin. Sri lanka is a developing country and its construction industry was unable to take over this mega project. The literature on construction in developing countries suggests that to provide a basis for their socio economic developments, these countries need a large volume of new constructions, How ever most of the said requirements are beyond the capacity of the local construction industries (Ofori et al., 2002). Power generation (generates 120 MW) component is awarded as a EPC contract at a cost of 529 million USD due to insufficient financial and technological capacity of local contruction firms. Previous studies on the impact of involvement of foreign contractors, revealed that these foreign firms have both positive and negative effects(Ofori, 2000). Therefore In this research Uma Oya project is selected and study was carried out to find whether new technology is transferred to local professionals who involved in project activities. Uma Oya is a major tributary of

Mahaweli River, the longest river in Sri Lanka. It originates in the central highland approximately at an elevation of 2500 m MSL and flows eastwards initially and changes its course northwards beyond Welimada plateau and joins Mahaweli River discharging into Rantambe Reservoir at an elevation of 152 m. The Uma Oya drains a catchment of 720 km^2. Figure: 1 illustrates location map of Uma Oya. There is a water scarcity prevailing in the South-East Dry Zone (SEDZ) and ever increasing demand for power and energy in Sri Lanka. To meet these requirements, this proposed project will transfer 145 MCM of water annually (without affecting the downstream requirements) from upper reaches of Uma Oya basin to KirindiOya basin in the South- East Dry Zone, such that the demand for water in the region is met in an optimal manner. During this process, 231 GWh electrical energy also will be generated annually.

Figure: 4.2 illustrates, power generation component includes Puhulpola reservoir Diarraba reservoir, 3.7 km long link tunnel, 15.3 km long head raise tunnel, underground power station and 3.5 km long tail raise tunnel.



Source: Supplementary EIA Final report for the proposed Uma Oya Multipurpose Development Project Volume 2 Maps & Figures.

Figure 4.1 Uma Oya Multipurpose Development Project-The Project Area

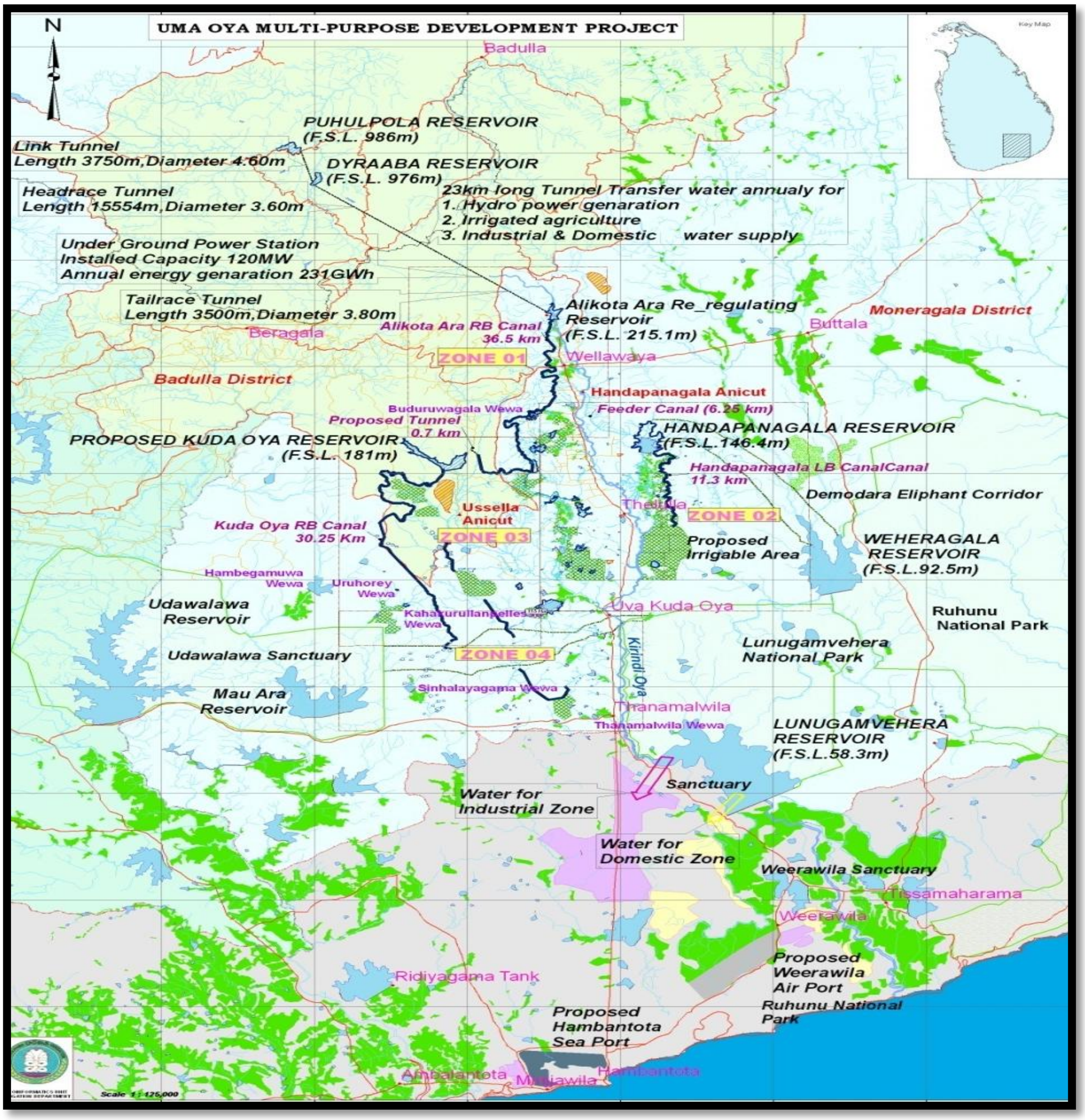
Objectives of the proposed Down Stream Development Work is to regulate 145 MCM water annually received by AlikotaAra reservoir to distribute to Kuda Oya through Right Bank Main Canal (RBMC) to irrigate existing & proposed new lands directly. Also it is planned to irrigate the existing farmlands and an extent of new lands through the enhanced quantity of water received at the Ussalla Anicut through the feeder canal system.
The balance portion of water from Alikota Ara will be transferred through Left Bank Main Canal (LBMC) to Handapanagala reservoir & to Kirindi Oya satisfying the water requirements in existing & proposed irrigable areas.

Following are the main components of downstream development proposals of Uma Oya multipurpose project:

1. AlikotaAra Re-regulating reservoir with RBMC
2. KudaOya reservoir with RBMC
3. UssellaAnicut and related canal system
4. Handapanagala reservoir & its LB canal

Construction of a series of irrigation canals is also included in the proposed project as illustrated in Fig 4.2. Three reservoirs will regulate the stream flow in the KirindiOya and the flow diverted from Uma Oya basin is mainly to satisfy the demand of existing and proposed irrigation areas in the Moneragala and Hambantota districts.

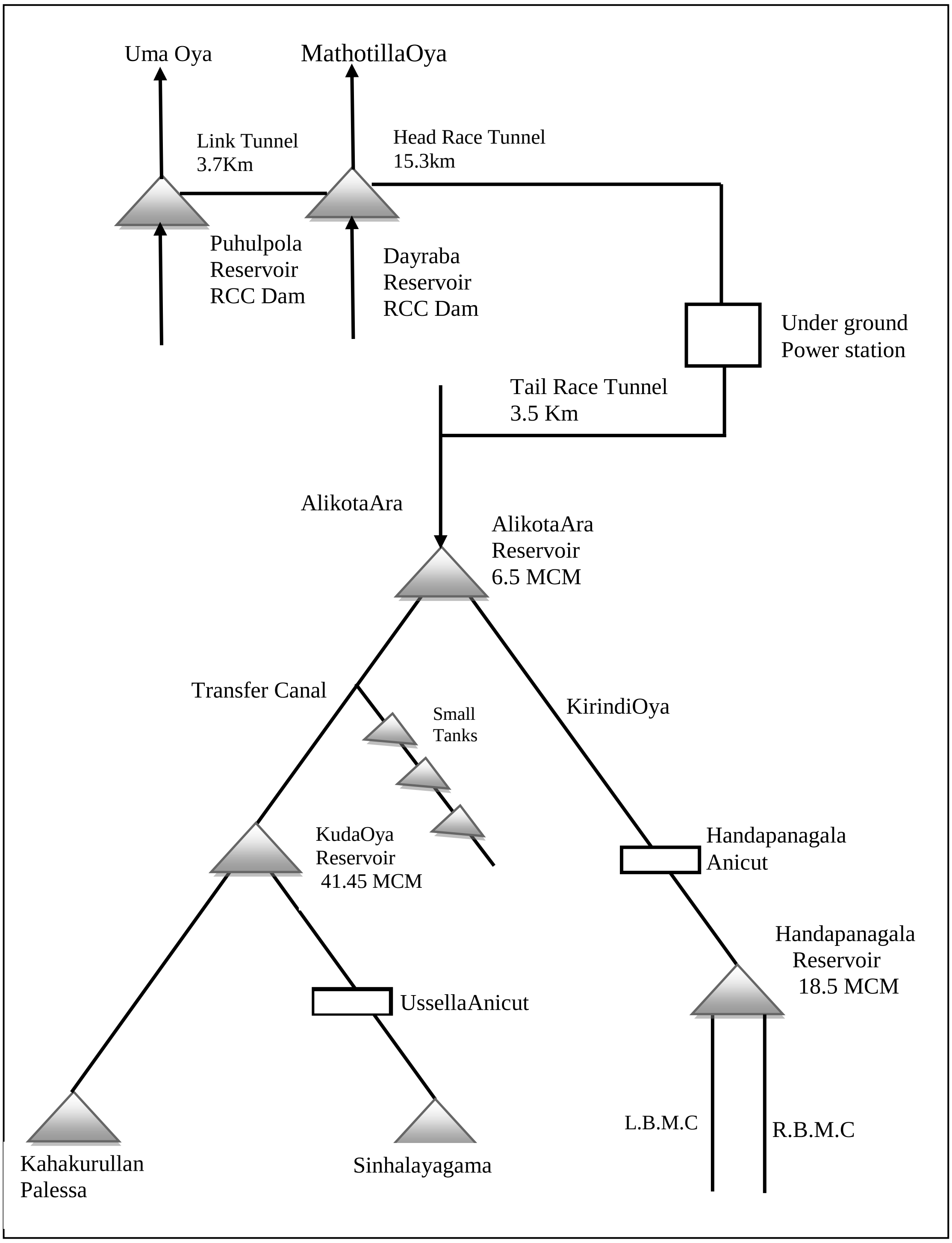
Ministry of Irrigation and Water Management was the client representing Government of Sri Lanka and the foreign main contractor was FARAB representing the donor country, Republic of Iran. A Project Director was appointed by Govt. of Sri Lanka and Project Management Unit (PMU) was established to monitor the project. Organization structure of PMU is explained by Contract was awarded as an EPC contract to Farab of Iran. Farab has selected Mahab Ghodss-Poyry Joint Venture (JV) as the international consultant and few other foreign and local contractors as sub-contractors. Poyry, Mahab-Ghodss and Farab are international consultants and contractors having experience internationally in major projects, individually and as joint ventures and other collaborations. Technology Transfer is depend on the capability of foreign contractors and consultants.



Source: Supplementary EIA Final report for the proposed Uma Oya Multipurpose Development Project Volume 2 Maps & Figures.

Figure 4.2 Uma Oya Multipurpose Development Project Map

Poyry is an international consultants began 1958 firstly in Sweden and the other Nordic countries followed by Europe, the Americas and eventually to the rest of the World. As the company grew internationally, so did its culture-enriched through diversity and shared knowledge. Poyry apart already in the early years was its high standards of integrity and quality. Clients could always count on Poyry engineers and consultants when a problem needed solving- and that remains unchanged today. In 2000's Poyry developed a wave of new competencies in energy, water and environment, transportation and construction services. It expanded its local office network into nearly 50 countries.



Source: Supplementary EIA Final report for the proposed Uma Oya Multipurpose Development Project Volume 2 Maps & Figures.

Figure 4.3 Schematic Diagram of UmaOya Multipurpose Development Project

Mahab - Ghodss Consulting Engineering Company (MG) was established in1983 to realize the long term objectives of Iran and especially major development projects in the water industry. At present Mahab has 2800 people working and out of this 2000 having PhD, MSC, BS and HND degrees in 85 fields and 155 disciplines.

FARAB began operating as a main contractor of water projects in 1992 and has done few big water projects during year 2002 & 2003, has expanded its operating in other related fields of water and energy. FARAB with cooperation of other local & foreign companies has been entered as a turn - key contractor for major project.

4.1.2 Analysis of Components of Technology that is being transferred through Uma Oya Project

In the technology transfer process, the term "technology" is used in the context of four components, namely: technoware, humanware, infoware and orgaware. The detailed evaluation of the above four components with Uma Oya project in Sri Lanka as follows.

Components of Technology	Uma Oya project
Technoware	Almost all the key components of the Uma Oya Project were imported through the supplier. The key components comprise of: TBM machine, generator, controller, RCC dams etc.
Humanware	The foreign engineers who manufactured the components of TBM machine, hydropower turbine etc. The trained foreign technical staff who undertook the installation. Local technical staff who assisted in the installation process. Other staff such as local engineers and the management, local O&M staff.
Orgaware	Mahaweli Authority, Ceylon Electricity Board, Irrigation Department, Central Engineering Consultancy Bureau are engaged in project activities.
Infoware	Hydrological and hydraulic data , Geological data of the tunnel construction area ,Existing structures and human activity data, Natural resources data ,Archaeology data etc.

Table 4.1 Evaluation of Uma Oya Project based on components of technology

4.1.2.1 Vertical Vs Horizontal Technology transfer

Vertical and horizontal technology transfer indicates the direction in which the Uma Oya Project technology is transferred. Specifically, horizontal technology transfer is the transfer of a commercialized or operational (usually mature) technology from one organization in a specific socio-economic context to another organization in a different socio-economic context, through inter-firm, cross-industry, or cross border channels. And vertical technology transfer refers to the transfer of technology from basic research to applied to development and then to production. The following section provides an analysis of Uma Oya project technology transfer approaches.

Technology transfer involved in Uma Oya Project can be primarily categorized into six stages. Commencing from research and development (R&D), commercialization of technology, component manufacturing, TBM machine and full turbine manufacturing, installation and the operation and maintenance of the machinery. In this first commercial scale Uma Oya Project the first four steps (from R&D to first TBM machine and first turbine manufacturing) was implemented by the foreign supplier. Resultantly TBM machine and hydro power turbine which were already developed by the transferor were installed in Sri Lanka with assistance of the local engineers. Though there have been certain adjustments in the TBM machine and hydro power turbines to conform to local conditions the local value addition has remained at a relatively nominal level.

In Uma Oya project, the technology already established has been transferred from an overseas destination to Sri Lanka. Thus the technology transfer process that was used in the Uma Oya can be identified as the "Horizontal transfer of technology".

4.1.3 Water ingress issues and concerns for TBM excavation

During TBM operations of this project severe water ingress occurred (450 l/s) during the month of December 2014, causing ground settlement and ground water draining of the area. At this moment TBM head was 200 m below the ground level and length of advancement was 4800 m towards up-gradient. With this incident more than 1000 families was affected by water shortage due to draining of their domestic wells, Further more than 700 numbers of houses were affected by consequent ground settlement. Possible situations of this nature has explained by (Smith,1992) stating for most tunnels driven up-gradient from portals water inflows can be more of a nuisance than a problem in terms of creating poor working conditions, dampness affecting unshielded electrical equipment, laying invert segments in muddy conditions, de-silting causing train derailments and the need for settling lagoons.

For tunnels driven down gradient and from shafts the need for pumping and risk of flooding exists. Water tightness specifications and final lining design philosophy in terms of drained versus un-drained options are also a key issues. Inappropriate selection of design criteria can result in delays caused by unnecessary grouting of minor water inflows during excavation.

Despite of water ingress issues and other issues can be occurred due to down-grade excavation, second TBM was launched in mid July 2016 starting from Puhulpola site and advanced only 800 m at the end of 2016.After the first water ingress cement injecting was commenced by German sub contractor and started reducing the out flow at the end of 2014. As per (Smith, 1992).

The key factors controlling water inflows in the local rock masses have been are observed to be:-

- The size of the water source
- The head of water above the tunnel
- The horizontal separation between the water source and the tunnel
- The recharge to the water source
- The degree of joint openness (not easily measurable from site investigations).

The allowable inflow must be determined by the designer and owner and will take into account factors such as:

Temporary Conditions

- Requirements for temporary stability
- Tunnel drive up gradient versus down gradient
- Requirements for operation of tunnel excavation equipment
- Requirements imposed by parties responsible for water resource protection
- Consideration of the effect of water table drawdown on adjacent structures.
- Predicted inflows and reductions achievable by grouting

Permanent Conditions

- Requirements imposed by parties responsible for water resource protection
- Resign of the permanent tunnel i.e. fully watertight versus drained tunnel
- Consideration of the effect of water table drawdown on adjacent structures
- Owners willingness to maintain drainage system (and pumping systems)

Although this type of remedial measures are adopted unfortunately after two years of first water ingress second water ingress was appeared at the end of December 2016, causing further damages to the properties and livelihood of the people living in the area. This ingress also was in same magnitude (about 500 l/s) and damaged further houses and occurred ground water lowering issues. Addressing the social issues raised due to water ingress is a challenge to both Govt. of Sri Lanka and to Farab.

4.2 Identified issues in transferring of technology

After the deep seated interviews with professionals, following main short comes were identified.

- Lack of joint venturing
- Insufficient involvement of local junior engineers
- Lesser number of site visits of academics etc.
- Insufficient opportunities for training facilities provided by foreign contractor to engineering undergraduates etc.
- Constrains to visitors from General Public
- Less authority to local professionals for TT relating concerns provided by EPC contract
- Lack of sub contracting to local contractors.
- Time constraints to local professionals to acquire and commercialize the technical knowledge

4.3 Proposed Solutions

Following proposals are made with thorough study of literature survey and interviews.

- Joint venturing with foreign companies
- Enhanced involvement of junior and middle level engineers
- Opening of Technology Transfer offices in Universities

4.4 Analysis of the Proposed Solutions using SAF Model

In analyzing the proposed solutions, SAF model has been used, which is commonly used to analyze solutions and opportunities. Johnson, Scholes, Wittington's model of Suitability, Acceptability and Feasibility (SAF Model).

4.4.1 Enhanced involvement of junior and middle level engineers

Suitability

In Sri Lanka there are many young and middle level engineers and they are willing to work in this kind of projects and grab the new technology. Then technology can be transferred through them.

Acceptability

This will highly accepted by local construction industry due to following reasons.

- Create job opportunities
- Increase the income
- Opportunity to gain knowledge and experience
- Economic gains through technology transfer

Feasibility

This will create new job opportunities and engineers will entertain with high salary and knowledge acquired. Companies engaged in the industry will improve their technical know-how and financial gains. Because of these factors this solution is financially feasible. This will create opportunities to transfer technology to local construction industry and will diminish the leaving rate of qualified professionals and engineers out of the country. Therefore this is technologically and socially feasible.

4.4.2 Joint Venturing with foreign companies

Foreign companies are performing vital role in local construction industry during now and during recent past. New technology is transferring to the country through the channel of joint venturing. Joint venturing specially with foreign companies is a strategic approach to gain the technology and knowledge.

Foreign countries such as China and India do not allow foreign contractors to engage in construction works without joint venturing with domestic contractors. They have set this type of regulations by their internal laws. In China if joint venturing are done the leading firm should be the domestic partner and not the foreign partner. Analysis of above solution by using SAF model is as follows

Suitability

- Provide companies with the opportunity to gain new capacity and expertise
- Allow companies to enter released businesses or new global markets or gain new technological knowledge
- Access to greater resources, including specialized staff and technology
- Sharing of risks with the venture partner
- Joint ventures can be flexible for example, a joint venture can exist for a limited life span and cover the balance by one partner.
- The advantages gain through JV’s are mentioned above. Therefore JV’s are suitable for local construction industry.

Acceptability

Share of profit and power of self-independence are high, working in a joint venture rather than subcontractors. Joint venturing give power to local companies to use local resources and man power etc. Therefore this alternative solution will be accepted by the local construction companies.

Feasibility

Local construction companies have to work with foreign companies having high financial base. Therefore local companies should have equal financial states to form a joint venture with equal states. Local companies should acquire high technological knowledge for major constructions projects. To fulfill this joint venturing with companies which is having advance technological knowledge is a beneficial technique practicing in many countries during past few decades. Concurring to the factors discussed above joint venture would be feasible in developing country such as Sri Lanka.

4.4.3 Opening of Technology Transfer offices at Universities

Suitability

Foreign direct investment play a vital role in developing countries such as Sri Lanka. Entry modes of foreign firms through this investment are Joint Ventures, Licensing, Sub contracting, Collaborations, Co-operations etc. Implementation, controlling, monitoring, quality concerns are the responsibilities of the government. As per the past experiences level of technology transfer and knowledge transfer through foreign investments are not in a satisfactory level. Introducing technology transfer offices in higher education institutions such as Universities will be the most appropriate action which is practicing in United States and Japan .Therefore opening of TT offices in Universities are highly feasible.

Acceptability

Opening of TT offices will provide a good platform to acquire knowledge and technology at this level and will create job opportunities to many disciplines in the country. It may reduce the tendency of hunting job opportunities in foreign countries. This will be a demarcating factor in retaining professionals within the country. Subsequently this will be a solution to decrease Brain-Drain. Further, this will enhance the commercialization of new innovations and technologies. Therefore opening of TT office in Universities is highly acceptable.

Feasibility

This will expose new engineers and other disciplines to the industry and to new technology and knowledge. Improving of income and job opportunities will lead to the advancement of economic and hence with the economic growth livelihood of people will elevate to a higher level. Therefore this proposal is financially and socially feasible.

Alternative Solution	Suitability	Acceptability	Feasibility
Enhanced involvement of junior and middle level engineers	H	H	H
Joint venturing of foreign firms	H	H	M
Opening of TT offices in Universities	H	H	H

Table 4.2 Summary of SAF Analysis

CHAPTER 05: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study has closely examined the level of technology transfer to the local professionals involved in the consulting and construction activities in the Uma oya project. This professionals are the receivers and users of technology in construction industry as well as consulting agencies. In that view, it is necessary to investigate the factors influencing the transformation of technology, technological and managerial capacities. Systems approach management and organizational theory were chosen in identifying the variables, providing a frame of reference and for constructing the research model.

The study has revealed that technology transfer contribute in some way or another to the enhancement of technological and managerial capabilities and capacities of professionals geared to the UOMDP activities. Cooperation between local and international professionals has greatly contributed to the degree of technology transfer.

Findings of the research indicate that some factors have stronger influences on transformation of technology to individual professionals such as increased involvement of junior engineers rather than engaging very senior engineers. Paying more attention to such vital factors, the rate of success in transferring the technology can be expected to be higher.

Further the study has revealed that another crucial factor of TT of this nature is insufficient involvement of other categories such as engineering assistants, technicians, supervisors, skilled and unskilled personnel etc. Lack of instructions, specifications, catalogues etc. in mother tongue and insufficient translation are barriers to TT in such categories as well.

Lack of coaching and mentoring system that enable foreign/senior experienced employees to provide face-to-face training to junior professionals/staff and formal feedback such as regular meetings, reports between main contractor, foreign and local sub contractors and local staff to transfer and validate knowledge are within the finding. Findings of research also revealed that there are insufficient arrangement of regular cross-projects site program to enable the transfer of lessons learned within the project and to others. Knowledge exchange seminars between main contractor, PMU staff, sub contractors and other stake holders as means of learning and best practice, establish informal networks and collaboration, and 'know how' to locate the repository of knowledge and the other important areas of TT. Insufficient legislation facilitating technology transfer enabling to establish required clauses at the signing of agreements.

In the case of foreign contractors, they haven't much interest or commitment on technology transfer to local industry (Ex. In the case of un expected water ingress issue sealing works was sub contracted to German company by main contractor FARAB).

Government organizations such as Central Environmental Authority, Geological and Mines Bureau and professionals such as environment specialists, sociologists, archeological specialists and ecological specialists etc. should pay more attention to get technology transferred through this type of project.

5.2. Recommendations

This research aimed to assess the level of technology transfer through the EPC contract of UOMDP to the local professionals engaged in the project. The research identified enablers, barriers and gaps relating the TT through contract and hence revealed the level of TT with following recommendations.

- To open Technology Transfer offices at University level to acquire, protect, and commercialize technology through foreign construction companies and to provide funding for researchers on TT.

- Joint venturing (JV), collaborations and sub contracting and. joint venturing for consultancy services between local and foreign firms should be enhanced.
- It is important that people working in construction industry such as TBM of UOMDP will be adequately trained. Increase the intake of institutional level and provide necessary training facilities to cater severe shortage of related human resources.
- In order to reduce foreign labor involvement increase the capacity and involvement of man power suppliers such as local labor contractors. Hence TT will take place in many different levels.
- TT has some limitations in EPC contracts therefore priority on TT shall be given at project planning, investigation, design and at initiating stages of contracts.
- Increase the involvement of local procurement specialists in international procurement which carries modern and high technology. (Visiting and procurement)
- Responsible institutions such as CEB, MASL, IESL, ICTAD and ID should increase the participation of their professionals covering top to bottom levels of their organizations.
- Find the ways and means to promote the involvement of local contractors in overseas construction projects as main or sub contractors.
- Introduce an appraisal system among professionals to enhance TT specially in government and semi government organizations. Which promotes the transformation of new technology

This research has been done only for UOMDP and interviewed only limited number of professionals with the limitation of time. Technology transfer in conjunction with the present situation and only for the project’s life cycle so far completed is considered at this Study.

5.3. Recommendations for Further Studies

Outcomes, findings and solutions proposed are limited to this project only. These will vary for any other time period, project, or type of contract agreement etc. Basically this research based on case study with the limitation of time. To provide better solution more projects of this nature shall be inspected and shall be analyzed more data and hence, future researches can be identified with better solutions. Following topics are proposed to further studies.

- Policy options to enhance technology transfer through FDI projects.
- Ways and means to increase technology transfer through local contractors handling overseas construction projects.

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Annex-01

List of senior level professionals interviewed

NO	DESIGNTION (EXECUTIVE LEVEL)	INSTITUTION
1	Project Director	PMU
2	Deputy Project Director (P & C)	PMU
3	Deputy Project Director (Engineering.)	PMU
5	Deputy Project Director (E & M)	PMU
6	Chief Resident Engineer	CECB
7	Section Engineer - Tunnel, Power House & Shaft	CECB
8	Senior Site Engineer - Dams	CECB
9	Senior Site Engineer - Tunnel, Power House & Shaft	CECB
10	Senior Engineer - Planning & Monitoring	CECB

Annex-02

List of middle level professionals interviewed

NO	DESIGNTION (EXECUTIVE LEVEL)	INSTITUTION
1	Deputy Project Director (MASL)	MASL
2	Project Manager (Mechanical)	CEB
3	Project Manager (Transmission Line)	CEB
4	Senior Civil Engineer	CEB
5	Senior Civil Engineer	CEB
6	Senior Civil Engineer	CEB
7	Material Engineer	CECB
8	Project Engineer - Contracts and Procurement	CECB
9	Senior Geologist	CECB

Annex-03

List of junior professionals interviewed

NO	POSITION	INSTITUTION
1	Resident Engineer	CEB
2	Resident Engineer	CEB
3	Resident Engineer	CEB
4	Resident Engineer	Irrigation Dept.
5	Resident Engineer	Irrigation Dept.
6	Mechanical Engineer	MASL
7	Site Engineer (Civil) - Dams - 02	CECB
8	Site Engineer (Civil) - Dams - 03	CECB
9	Site Engineer (Civil) - Power house & Shaft	CECB
10	Mining Engineer	CECB
11	Mechanical Engineer Power house & Shaft - 01	CECB
12	Junior Geologist - 01	CECB
13	Junior Geologist - 02	CECB

Annexex-04

Questionnaire to guide interviews

Q. 1 Area of inquiry - ***Background of professionals and working experiences***

i. Organization ………………………………..
ii. Designation …………………..
iii. Educational Background …Ph.D./M.Sc./ B.Sc. etc.………………………
iv. Position Project Director/ DPD/ CRE/ RE/ Snr. Engineer Etc. …………
v. No of years having experience in this project………………………..

Q. 2 Area of inquiry - ***Views of individual Professionals on Level of Technology Transfer***

Explain the extent to which each of the following were contributed to the technology/ knowledge transfer

1. As you think what is the level of technology / knowledge transfer through this project?
2. What is the interest of foreign firms and professional towards the training of local professionals?
3. Explain the level of interest in acquiring and practicing of the new technology in junior level Engineers?
4. What are the problems en counted in technology transfer through this EPC contract ? What are your proposals in future contract agreements?
5. What are the proposals to increase the level of O & M activities after commissioning?
6. What is the attitude of foreign engineers in training of technology transfer to local staff?
7. In future, if we need to implement this type of project, do we have the capacity?
8. What Govt. should do to get TT in future project initiation?

Q. 3 Area of inquiry - ***Type of contract and proposals to be included in future contracts towards technology and knowledge transfer***

How the following factors can use for effective technology transfer?

i. Joint venturing with local companies
ii. Level of sub contracting
iii. Local engineers in foreign sub contracting firms
iv. QC, QA and Testing
v. Propose clauses to include in future contracts? (at least 10 % of engineers by contractor etc.)

Q. 4 Area of inquiry - ***Construction of RCC dams at Diarraba and Puhulpola***

Explain the extent to which each of the following were contributed to the technology/ knowledge transfer

i. Planning and designing of RCC Dams
ii. At implementation and construction techniques
iii. RCC plant operations
iv. Placing and compaction techniques
v. QC & QA procedures
vi. Maintenance of RCC dams
vii. Documentation & communication techniques

Q. 5 Area of inquiry – ***Tunnel Boring Machine (TBM) machine and its installation and operation experiences***

Explain the extent to which each of the following were contributed to the technology / knowledge transfer

i. Procurement of TBM (specification etc.)
ii. Installation and O &M
iii. Special issues Risks and other problems encountered
iv. TBM – forecasting and testing before advancement and avoid risks
v. Raise boring techniques and its experiences
vi. Electromechanical parts procurement, installation, testing and operation experiences