

EXAMINING THE FUTURE DEVELOPMENT TREND OF LONG-DISTANCE STEEP TURN PIPE IMPELLING CONSTRUCTION METHOD (LDSTPICM) THROUGH TECHNOLOGY TRANSFER

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ABSTRACT

In support of the government's promoting Taiwan into a high-tech island, and to excel the national economic development and social prosperity, besides efforts made to actively develop Taiwan's local power facilities in power transmission, distribution and conversion systems, but how best to provide highly stabilized and safe power requirements has also emerged as a critical issue to the power industry. As the construction methods are becoming infinitely more complex and difficult following the conversion of underground electric cable piping works, the earlier shield tunneling method and linear propulsion method introduced to the island can no longer support the demand, and only the "Long-distance steep turn pipe impelling" construction technology can truly satisfy the current versatile power transmission market. The LDSTPICM is of an innovative technology that has not yet been prompted and introduced to the country. The study first attempts to systematically discern the construction method's key technology and implementation tips by interviewing Japanese industry scholars and experts that hold the technology, and then to utilize the Analytic Hierarchy Process (AHP) to examine the key factors in the technology transfer of Taiwan Power Company's Phase VI power transmission plan, and at last to summarize the LDSTPICM's future development trend in Taiwan's relevant industries. The study findings reveal that it not only calls for the technology provider and government outfits to render active support by expeditiously drafted relevant laws, regulations and package measures concerning the construction method, but also detailed guidelines concerning the construction method's technical guidelines and operating procedures. Furthermore, with professional know-how and experience accumulation remain the core factors in achieving technology transfer of the construction method, the construction method's being drastically differ from the current propulsion construction method prevailing locally has its key technology primarily lies in the compatibility of curving machinery, curving propulsion piping and functionality of curved piping. As a result, it is prudent to rely on the means of technology transfer for assimilating professional technical capability and through ongoing experience accumulation can the ultimate objective be achieved in speeding up localizing the technology.

Keywords: Long-distance Steep Turn Pipe Impelling Construction Method, Technology Transfer, Analytic Hierarchy Process (AHP), Delphi Method

1. Introduction

1.1 Research motive

As ample supply of steady power not only remains indispensable for driving the economic growth and a most significant investment among all economic activities, power transmission routes continue to serve as the artery and lifeline for the national

power system, and remain indispensable whether to traditional brick-and-mortar industry or high-tech industry. Following industry upgrade and a high growth of the information technology, only a steady increase of power infrastructure development that is inductive to a steady power supply can the economic growth be sustained and the nation's prosperity be further excelled [26].

Incidents such as the July 27 major power outage occurred in 1999, immediately followed by the Sept. 21 earthquake, only exposed the fragility of

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the local power systems, which not only stood to hinder the national economic development but also inconvenienced the general public. Following a comprehensive review of the current power system's deficiency, Taiwan Power Company is pushing forward to conclude the three major ultra high voltage power circuits for north, central and south, and to promote a Phase VI power transmission project. Amid Taipower's Phase V aerial power transmission routing project constantly being battered by protests staged by landowners whose properties were hindered by the passing power grids, resulting in a severe delays to the project and the implementation ratio, in light of which, there is a growing tendency for Taipower projects to turn underground over the years. For example, in Phase VI power transmission project, the low-cost aerial power transmission routes are being proposed to revamp into the high-cost underground cable routing, which is estimated to cover more than 1,400 underground circuit kilometers at a building cost roughly 10 times that of the aerial routing method, and a project volume 3 times over that of the Phase V project. Moreover, following the surging environmental awareness, coupled with local denizens increasing focus on quality of living and quality urban landscaping, putting power lines underground has emerged as a compelling trend.

To avoid public protests, reduce impact the environment, and minimize traffic chaos arisen from open digging, the straight-line impelling method and submersed digging method have successfully been adopted in Taiwan power transmission systems over the years, yet the restrictions and shortcomings that come with the methods continue to hinder them from fully satisfying a variety of construction needs. Adapting the LDSTPICM, which is now widely utilized in Japan, would help to effectively resolve the many local bottlenecks. For instance, busy traffic, curving pipes, stipulations against installing manholes, requiring longer distance pipe propulsion, bypassing riverbeds and narrow roadways, which tend to curtail the hidden propulsion construction method from being implemented, and to truly provide Taiwan Power a versatile solution in power transmission projects.

In lieu of any local LDSTPICM relevant study, and that the LDSTPICM being an innovative technology that commands an innovative construction method, it is regarded as beneficial in surpassing a host of bottlenecks in the present underground construction work. Given that it could be brought in as early as possible and be used for development and designing Taipower's Phase VI power transmission project, it would poise to conserve enormous social cost, help to improve the stability of local power supply, as well as buoy industry upgrade and economic development.

1.2 Research objective

The objective of the study primarily aims to examining the future development trend of the "Long-distance steep turn pipe impelling method" through technology transfer.

- (1) To extrapolate from expert interviews the key technology, equipment and implementation focus of the "LDSTPICM".
- (2) To examine key success factors in technology transfer of the "LDSTPICM".
- (3) To examine the future development trend of the "LDSTPICM" in the power transmission/ distribution market.

2. Archival Publication Review

The chapter focuses on sorting and examining the study's research subjects of "The measurement factors in technology transfer", and relevant literature on "LDSTPICM" and the "Multicriteria evaluation method", which would help to discern measuring the technology transfer's impact factors, LDSTPICM's key technology and a research method suitable for applying in the study that would serve as a theoretic basis to facilitate validating the study framework subsequently.

2.1 Technology transfer's impact measuring factors

The section focuses on sorting literary viewpoints on factors that impact the technology transfer by referring to what Lin [14] has sorted of a factor framework for measuring the impact of technology transfer, which is used to classify the factors into five, namely the technology provider, technology acceptor, technical capability, environment construct, and technology transfer mode, as shown in Table 1. The study also utilizes these five constructs as the basis of the research framework.

2.2 LDSTPICM

In recent years, the propulsion construction method widely adopted in laying the piping work in metropolitan areas has, in theory and practical implementation, been developed to a fairly mature level. In the past, the local propulsion construction method has largely been adopted in tap water and underground sewage systems, and has generally taken to the small-diameter propulsion construction method at a propulsion span of largely between 50 and 300 meters, as bound by economic yield [28]. Underground electric cable piping implementation methods can be divided into the cut-and-open construction method, small-diameter propulsion construction

method, large-diameter propulsion construction method, and submersible digging construction method [26]. Table 2. depicts a table of comparison of various underground piping construction methods sorted by the study. The table ominously revealed that the major different between LDSTPICM and the existing local construction methods (the small diameter propulsion construction method and the submersible digging construction method) lied in the medium and large diameters, long-distance construction and bendable piping curvature. It is particularly useful in Taiwan's densely populated area with limited land resources, where laying underground electric cables in urban streets and roadways is often hindered by busy traffic, curved roadways, banning of installing manholes, a longer distance of piping propulsion, bypassing riverbeds and narrow roadways among others. As a result, the presence of LDSTPICM technology support would poise to provide versatile solutions to Taiwan Power's power transmission system constructions.

In light that Taiwan's current technology has not yet able to reach the characteristics of long distance propulsion and small curved diameter, the technology can be obtained through Japan's innovative construction method. Below describes the key technology of the innovative construction method [28].

- (1) Sharp bend propulsion machine: which pertains to the technology and equipment needed in the presence of adding curvature, such as the pipe pushing unit and hydraulic adjustor.
- (2) Curved propulsion piping: the different between cement conduits used between Japan and Taiwan lies in that the length, spec and criteria of cement conduits used in Japan are shorter at 70mm, conduit walls being thinner at 30mm, and the seams where the conduits join have been a unique design that allows an airtight closure making it suitable for smaller diameter turns.
- (3) Functional compatibility between curved pipes: which pertains to the seams between any two given conduits can be closed tightly to withstand fracturing from sharp turns or percolation of dirt and moisture, of which the joints inside the Japanese conduit pipe seams are closed off using double layered rubber gasket with crimping steel ring to achieve three major functions of waterproofing, secured seams, and propulsion conveyance.

2.3 Exploring the multicriteria evaluation method

The multicriteria evaluation method can largely be divided into four types, namely the qualitative evaluation method, medium intermediary evalua-

tion method and quantitative standardization evaluation method and weighted, equalized qualitative and quantitative division evaluation method (MEQQD). Of the four types, the study has separately chosen four commonly seen methods of the analytic hierarchy process (AHP), ELECTRE, TOPSIS, and MEQQD to conduct the comparison [8], in order to select evaluation methods suitable for the research. Table 3 depicts the suitable timing, pros and cons of these four methods.

Recapping the above, ELECTRE tends to be affected by the decision maker's subjective factors in satisfactory, unsatisfactory and threshold ratings, coupled with occasional complexity and difficulty in analysis as a result of excessive evaluation criteria; in the meantime, it cannot effectively rank the solutions. While TOPSIS can only take into account the quantitative criteria and that the separation propensity computation is rather complex. Yet the qualitative and quantitative multicriteria evaluation method, although being able to currently take into account qualitative and quantitative criteria, whose criteria weighing derived may not necessarily meet the actual scenario to render it less used in practical implementation. In addition, the study objective, which aims to clearly derive the impact factors for local LDSTPICM transfer, has adopted AHP that helps to structuralize the problem hierarchy, and clearly derive the relative weighing of all factors, with its theoretic basis being more stringent when compared with other evaluation methods. In the meantime, the study has also improved on AHP shortcomings first by sorting the measurement technology transfer framework as the study's hierarchy framework, which serves to compensate AHP's inability to explore the inter-correlation among the factors. In the questionnaire gathering aspect, the decision makers have been given description on the factors to avoid confusing the decision makers that might result in evaluation variation due to an excessive number of factors, which also serves to reduce the shortcoming of meeting a consistency evaluation under the circumstances of a larger number of factors. As a result, why the study has chosen AHP as the analysis method for assessing LDSTPICM transfer factors do command its applicability and expectant yield.

3. Research Design

To derive key success factors for the long-distance steep turn pipe impelling method more objectively and effectively, the study has adopted the Delphi method and analytic hierarchy process (AHP) for polling a consensus among a majority of the scholars, experts and construction engineers with which to compile and map out key success factors for the LDSTPICM. More details about the research design follow as below.

3.1 Research subjects

The study has conducted a total of four questionnaire surveys, where the first survey entails an open-ended questionnaire poll, which focuses on Japanese industry experts and Taiwanese scholars familiar with the construction method as the subjects, in which it primarily aims to conduct in-depth interviews with the Japanese expert in order to discern the relevant technology behind the construction method, practical implementation issues, and probable difficulties for transferring the technology to Taiwan, before the Taiwanese scholars are to convene discussion and draft the preliminary evaluation categories based on the literature reviewed. The second and third surveys are Delphic questionnaires, which according to Dalkey's [5] assertion that each Delphic group is to consist of at least 10 people engaging in a Q&A session, where the variation of the group consensus derived will be at the least, hence the study's conducting the Delphic questionnaire survey has had a total of 15 questionnaires distributed to the local Taipower and Japanese scholars and experts as the study subjects. Among them, the questionnaire poll on the Japanese side primarily focuses on Japanese scholars and experts stationing in Taiwan, anticipating that the scholars and experts from the Japanese and Taiwanese sides are able to map out a hierarchical framework for the evaluation categories based on their distinct viewpoint and angle, and to design an AHP questionnaire. At last, the AHP questionnaire has focused on relevant Japanese and Taiwanese professional scholars and experts, with three more Japanese industry executives familiar with the construction method as the subjects to conclude the weighing distribution of the evaluation categories; the questionnaire's polling subjects are as shown in Table 4.

3.2 Research method

In light that the choice of research method is tied to the characteristics of the issue at hand, and that LDSTPICM being a new technology transfer locally and with a broader base of applications, there is a necessity to take into account the multiplicity and the ability to adopt a problem systemization processing method that would encompass all characteristics of the problem. Hence upon undergoing the fore-said literature review set forth under section 2.3, the study has chosen the analytic hierarchy process (AHP) has the premise for instilling measuring the key factors. In light K.M., Wang and L.F., Hsien's [29] Delphic Hierarchy process (DHP) offers common AHP advantages, but also with three other advantages, which are (1) the addition of the Delphic hierarchy process helps to sort out the expert group's opinions; (2) the reduced decision objectivity following opinion integrating; (3) Under adequate circumstances, un-

important factors can be deleted to avoid unnecessary pairing comparison. With that, the study has undergone key technology and equipment and construction guideline gathering, combining the advantages of the Delphic method and the analytic hierarchy process (AHP) through integrating the opinions, experience and expertise of experts, scholars and relevant construction operators, taking to a questionnaire method for converted the findings into figurative findings that can be analyzed and utilized in locating the weighing for various hierarchies' evaluation indicators, which are ranked in a sequence of priority intending as references to relevant researchers.

3.3 Questionnaire design

The study has focused on exploring the development of local LDSTPICM transfer and its key factors as the premises by polling the opinions of relevant local and Japanese scholars and experts using the Delphic preliminary hierarchy framework to derived at the key factors as the technology provider, technology acceptor, technical capability, environment construct, and technology transfer mode. The AHP hierarchy structure and factors are further sorted as shown in Fig. 1.

4. Research Findings

4.1 Research finding derived from using the Delphi method

First of all, through the analysis and review of relevant archival publications, the Study moves to develop the first questionnaire, with evaluation points being 1 to 100 points; the higher the points the more significant a factor represents, with 70 points being the passing threshold, criteria exceeding 70 points are deemed acceptable, whereas falling under 70 points are deemed unacceptable. The study has adopted Chang's [2] evaluation criteria, where a variable index of ≤ 0.3 indicates that expert opinions have reached a high consistency, and a variable index of ≥ 0.5 indicates expert opinions have fallen within an acceptance range, whereas a variable index of ≥ 0.5 would call for the potential reason be explained. Upon undergoing second questionnaire recall and analysis, the study is able to conclude that expert opinions have reached a high consistency; findings on the analysis figures derived from the second Delphi method are shown in Table 5. What follows is a second Delphi questionnaire survey focusing on related trained local and Japanese scholars and experts as the study subject, in which 15 sets each of the second questionnaire are distributed, with a 100% recall rate.

4.2 Research finding derived from AHP

The study focuses on relevant local and Japanese trained experts and scholars as study subjects, with a total of 18 expert questionnaires distributed, and findings are analyzed using the Expert Choice software, in which consistency ratio (C.R.) is used to measure the overall consistency of the matrix, which according to Satty [21] who pointed out that a consistency is reassured when $C.R. < 0.1$. Thereafter, the effective questionnaires are put through the geometric median method to compute the median rating for each question given, and lastly the median ratings are further analyzed to conclude a relative weighing for all factors.

The assessment factors on tier 2 comprised of five, with their respective weighing as shown in Table-6. In which, the environment factor takes 40% of the weighing, ominously exceeding the rest of the categories, indicating that most significant among the construction method's key success factors lies in the environment factor that the construction method needs to confront with, which would become a key in determine the ultimate success of the technology transfer. As derived from the questionnaire that the comparison matrix has a C.R. value of $0.045 < 0.1$, is an indicator of an optimized consistency as concluded from the study findings.

The third tier evaluation factors are divided into five parts, which are computed and the results analyzed to derive at the following weighing, which are sequentially rated by 1. Technology provider; 2. Technology acceptor; 3. Technical capability; 4. Environment construct; 5. Technical transfer mode, as depicted in the table below.

(1) Technology provider

As can be extrapolated from Table 7, technical proficiency (0.301) and construction experience (0.257) have separately commanded the top two spots of weighing, where the two factors have accounted for nearly 55% of weighing under the technology provider construction, which highlight that the technology provider should emphasize more on technical proficiency and construction experience in order to greatly excel the success probability of a technology transfer, which is also tied in with the technology transfer mode's professional technology learning capability and experience in order to achieve localizing the LDSTPICM technology. Given that a technology provider's role in a technology transfer being to provide whose key technology capabilities, and as the local propulsion construction method that has not only commanded a significant level of foundation capability and equipment, what is needed is merely to bring in the foresaid key technology in order to jump start the relevant local industries for a transformation or industry upgrade.

(2) Technology acceptor

In technology acceptor (as shown in Table-8), increased market competitiveness (0.313) and increased economic yield (0.283) account for nearly sixty percent of the weighing in the technology acceptor construct, which reveal their importance as top two rankings that account for nearly 60%, and highlight the purpose of the technical acceptor's adapting the construction method has been to increase whose own market competitiveness and economic yield which can probably be attributed to how technology acceptors are looking to enhance their own technical capability through technology transfer in order to gain market competitiveness, notwithstanding that putting power cables underground also improve the economic yield, reduce disaster damages arisen from lightning, typhoon and such, toppled electric pole crushing private residences, and how it helps to improve the stability of power supply. Hence, relying on technology transfer to enhance a technology acceptor's market competitiveness and economic yield remain the key factors that would poise to affect the ultimate success of a technology transfer.

(3) Technical capability

Under the technical capability construct (as shown in Table 9), the weighing of construction timing (0.264), operating and maintenance cost (0.255) takes about 52% of the total weighing, which indicates that the scholars and experts have all noticeably focused on construction timing, operating and maintenance cost and practicality. This signifies cutting down the construction time (construction period) and reducing maintenance costing is where the demands of the current construction technology lie, and key contingent factors not only serve to reduce the cost burden to the contractor and the owner, but the practicality of the construction method also serve as a key contingent factor toward the technology transfer.

(4) Environment factor

Under the environment factor construct (as shown in Table 10), the legal stipulation factor (0.322) accounting for a relatively higher weighing is ominous that throughout a transfer process relevant legal stipulations would emerge as important; in the absence of local laws and regulations promulgated to provide more detailed guideline concerning the construction method, resulting in the lack of legal basis with which to conduct the design, implementation or cost assessment to greatly put off the progress of the Phase VI power transmission project, a comprehensive promulgation of relevant laws and regulations would posse to speed up the speed the construction method is introduced, surpass some of the bottleneck that mars the progress of the Phase VI power transmission project. Hence, speeding up drafting rele-

vant technical guideline and legal stipulations is something that the government authorities would need to ponder and improve upon.

In addition, the scholars and experts also reckoned that relevant industry support and level of government support also accounted for a certain degree of impact. The government's responsibility to develop a set of package measures conducive for excelling the technical capabilities of related local industries would poise to speed up the development, design and implementation of the construction method and for Taipower's Phase VI power transmission project, which in turn would help to reduce the enormous social cost, and hence the stability of local power supply, as well as buoy the industry upgrade and economic development.

(5) Technology transfer mode

In the technology transfer mode constructs (as shown in Table 11), among them, contractor voluntary tendency (0.427) accounts for nearly 40% of weighing, which highlights how the contractor's independent, voluntary capability in the transfer process would poise to increase the construction unit's technology localization to excel the transfer efficiency has made it one of the critical key element. While technology transfer steps (0.226) is also an element that the experts and scholars reckon to influence technology transfer. The above two major factors' having accounted for around 65% of weighing collectively in the technical transfer mode construct also reflects their importance in the technology transfer mode construct.

As can be extrapolated from the findings of the above evaluating ratings are the fact that the top two factors have consistently account for more than 50% of the overall weighing, which highlights that the comparative disparity between the first two factors and the latter rankings has been the advantage of the weighing that the study derived using APH, and intended to provide a vital reference point to relevant decision makers' toward the LDSTPICM transfer.

4.3 An overview on the overall evaluation factors

The study has analyzed the constructs of LDSTPICM's key factors to consist of five constructs, namely the technology provider, technology acceptor, technical capability, environment construct and technology transfer mode. Among them, the environment construct is deemed most important; in addition, key factors derived from LDSTPICM technology transfer have had the first seven factors account for an overall 58% of weighing, which are sequentially identified as laws and regulations, relevant industry support, level of government support, contractor's

voluntary tendency, construction timing, cost of utilization and maintenance, and practicality. In the meantime, the overall hierarchical framework's C.R.H. rating is at 0.028, which is small than 0.1, indicates that the findings also meet Saaty's criteria; the distribution of the structural weighing is shown in Table 12.

In other words, the higher-ranking factors of laws and regulations and level of government support are related to the government outfit, and the factors of relevant industry support and contractor's voluntary tendency are related to the contractors of both sides. In the meantime, the factors of construction timing, cost of utilization and maintenance, and practicality are those that concern the technical capability. The findings highlight how the government plays a significantly vital role in technology transfer. On the other hand, the weighing on the two major factors of laws and regulations and level of government support that account for roughly 22% of the overall weighing may bear certain relationship to the study's choosing Taipower's Phase VI power transmission underground piping as the study subject. In light that the Executive Yuan has motioned that Taiwan Power Company is to undergo privatization Before December 2005, and with the firm's privatization move in a full swing, the company is working to improve its operating efficiency, system and regulatory compliance, step up employee communication and solidify a general consensus; nevertheless, presently, Taiwan Power, running as a state enterprise, is still confined by excessive laws, regulations and government policy [26]. As a result, a general consensus among the experts and scholars reckons that the most critical factors lie in laws and regulations and level of government support, for these factors are inextricably tied to the government, which also reflects how government policy and support level bear a direct impact in determining the ultimate success or failure of the construction method's future development. An optimistic take predicting that a drastic change to the firm's future privatized organization structure, management style, liberating system and regulatory confines than the present state would invariably bring flexibility to its operations, and allow the firm to be able to timely provide a diverse range of services.

5. Conclusion and Recommendation

The study has sorted the foresaid study findings to recap the study conclusion and recommendation as follows.

5.1 Study conclusion

1. Three aspects of the DSTPICM's key technol-

ogy comprise of the bending machine (technical equipment for increasing the turn, such as the pipe pushing unit and hydraulic adjuster), bending propulsion pipes, and compatibility of bent pipe functions (pertaining the seam waterproofing, propulsion conveyance, seaming tightness and tight closure fitting). The foresaid key technology differs from the technology and equipment of the conventional propulsion construction method that has been widely used locally, hence it needs to be brought in from Japan through technology transfer, and that the technology transfer also helps to excel learning the professional technical know-how and accumulate the experience to achieve the objective of localizing the technology.

2. With LDSTPICM's technology transfer key factors and constructs being the technology provider, technology acceptor, technical capability, environment construct, and technology transfer mode, among them environment construct is regarded as most important. In addition, LDSTPICM transfer's top seven critical factors are identified as laws and regulations, industry support, level of government support, contractor's voluntary tendency, construction timing, cost of utilization and maintenance, and practicality. AHP analysis reveals that the top seven factors have account for around 58% of the overall weighing, and that the factors of laws and regulations and level of government support that concern the government also account for around 22%, both reflect the important role that the government plays in the technology transfer process, being that the government's cooperation and support will bear a direct impact to the ultimate success of failure in developing the construction method.
3. In response to Taipower's Phase VI power transmission plan, and with the construction technology for underground electric cable piping projects increasingly becoming complex and difficult, not only do the earlier local construction methods can no longer support the demand, but the local underground piping work has long failed to keep up with the urban development requirement, resulting in frequent digging of the roadways to cause public inconvenience and unaccountable waste of social resources. Given that it be coordinated to underground cable laying construction, it not only helps the avoid the above hindrance, keeping the cable work from being affected by lightning, typhoon flooding, and climatic impacts of saline, dust and fog, but it also helps to reduce public complaint and further improves the stability of

local power transmission and distribution, where the current routes developed in all regions show a dire need for the support of the LDSTPICM construction technology. Furthermore, LDSTPICM is not only suitable for applying in underground electric cable laying, but can be further expanded in the application and breakthrough in underground construction methods for tap water, underground sewage systems and fiberoptic networking routing. With that, relevant local industries not only poise to excel the industry's technical capability but also jump start industry upgrade and economic development, pushing the technology to command an infinite potential in its future marketability.

5.2 Study Recommendation

As the foresaid study findings and conclusion reveal the crucial local factors and future market potential in LDSTPICM transfer, the study further sorts the findings to offer recommendations to the government authorities, industry operators and subsequent studies as separately described below.

1. Recommendation to the government

It is recommendable that the government would need to investigate an overall development and evaluation through a designated project or a project proposal, and to integrate relevant industries in order to facilitate a joint promotion as an industry development. Nevertheless, in the absence of any standardization or regulations done by the government in governing the LDSTPICM processing equipment, it is advisable that pertinent specifications, standardization and relevant transfer logistics be drafted as early as possible in order to facilitate the operators to conduct transfer cost assessment, and that the government is to act as a project manager in the transfer process streamlining various local resources and relevant industries that would poise to distribute relevant technical capabilities to relevant local industries, and to intercept the market early so to jump start the entire industry for technical upgrade and localization.

2. Recommendation to the industry operators

It is doable to heed to the critical transfer factor concluded by the study finding to serve as a reference point in future transfer between the technology provider and technology acceptor. The two parties' cooperating openly and earnestly in search of their respective position, coordinated with government drafted specification and standardization, will be beneficial in helping the two sides instill a transfer evaluation system, which will turn to help the two sides discern the transfer yield and excel the transfer

performance.

3. Recommendation for subsequent studies

As curtailed by time and cost constraints, the study is only able to poll scholar and expert opinions in an attempt to develop a set of key success factors for the LDSTPICM. In light that the construction method has not yet been introduced to Taiwan, an explorative approach has been adopted to recap scholar and expert opinions toward the construction method's future development trend, which are then translated into an indicator manner intended as references to the industry operators. Taking to the notation established by Kartiko [17] that a theoretic hypothesis would need to incorporate a feedback loop in order to map out a comprehensive technology transfer process, this implies that technology transfer per se would need to be incorporated in subsequent stud-

ies to form an integral cycle. With that, subsequent researchers may want to continue with follow-up stud on the construction method's actual implementation so to avail more comprehensive and validated study findings that would supplant Kartiko's theory., coupled with the comprehensive process of AHP has been to rely on the weighing of a set of evaluation factors to choose one or several optimal proposals among a number of alternatives. Nevertheless, as the study has merely examined LDSTPICM's key factors, hence it is recommendable that subsequent researchers may want to develop a multiple alternative solutions for bringing LDSTPICM into Taiwan, and to evaluate and choose an optimal solution using AHP or other multicriteria decision methods that would serve as a reference point to the government and relevant industry's introducing the construction method

Table 1. A sorted classification chart for technical transfer measuring factors

Scholar	Technology provider	Technology acceptor	Technical capability	Environment construct	Technology transfer mode
Teece [23]		<ul style="list-style-type: none"> • Relevant technical experience • R&D capability 	<ul style="list-style-type: none"> • Level of innovation • 2.Future development potential 	<ul style="list-style-type: none"> • Market scale 	
D.K., Chen, J.S. Tu [3]		<ul style="list-style-type: none"> • Technical sophistication • Financial state • Operating capability 			
Singh [22]	<ul style="list-style-type: none"> • Willingness 	<ul style="list-style-type: none"> • Willingness 			<ul style="list-style-type: none"> • Method of technology introduction • Steps of technology transfer
Shidan Derakhshani [7]	<ul style="list-style-type: none"> • Construction experience • Management capability 	<ul style="list-style-type: none"> • Disparity in mutual technical capability • Relevant technical experience • Management capability 		<ul style="list-style-type: none"> • Market scale • State of competition • Public infrastructure • Level of government support • Laws and regulations • Technology receiving country's technical foundation • Similar cultural characteristics • Value perspective 	<ul style="list-style-type: none"> • Contractor's voluntary tendency • Level of stability in mutual relationship
Prasad [16]	<ul style="list-style-type: none"> • Technician proficiency 	<ul style="list-style-type: none"> • Mutual technical disparity 	<ul style="list-style-type: none"> • Applicability 		
Z.N., Huang [9]	<ul style="list-style-type: none"> • Construction experience • Management capability 	<ul style="list-style-type: none"> • Mutual technical disparity • Relevant technical experience • Management capability • Operating capability 		<ul style="list-style-type: none"> • Market scale • State of competition • Public infrastructure • Level of government support • Laws and regulations • Technology receiving country's technical foundation • Similar cultural characteristics • Value perspective 	<ul style="list-style-type: none"> • Mutual mindset on technology transfer
Moiral and Carne [15]	<ul style="list-style-type: none"> • Management support • Provisioning of Training or docu- 	<ul style="list-style-type: none"> • Management support • Willingness • Familiarity toward 	<ul style="list-style-type: none"> • Level of innovation 	<ul style="list-style-type: none"> • Similarity in cultural characteristics 	<ul style="list-style-type: none"> • Means of communication

	<ul style="list-style-type: none"> • Willingness • Technical proficiency 	<ul style="list-style-type: none"> • the technology • Increased market competitiveness • Increased economic yield 			
Y., Chao [1]	<ul style="list-style-type: none"> • Management support 	<ul style="list-style-type: none"> • Management support 	<ul style="list-style-type: none"> • Practicality • Maturity 		<ul style="list-style-type: none"> • Means of communication • Level of stability in mutual relationship
Z.W., Huang [10]	<ul style="list-style-type: none"> • Construction experience • Management capability 	<ul style="list-style-type: none"> • Disparity in mutual technical capability • Relevant technical capability • Management capability • Operating capability 		<ul style="list-style-type: none"> • Market scale • State of competition • Public infrastructure • Level of government support • Laws and regulations • Technology receiving country's technical foundation • Similar cultural characteristics • Value perspective 	<ul style="list-style-type: none"> • Mutual mindset toward the transfer
L.J., Lin [13]	<ul style="list-style-type: none"> • R&D capability • Financial state • Level of understanding toward the technology • Effective technology transfer planning 	<ul style="list-style-type: none"> • Familiarity to the technology • Financial state • Relevant technical experience 	<ul style="list-style-type: none"> • Future development potential • Maturity 	<ul style="list-style-type: none"> • Similar cultural characteristics • Level of government support • Laws and regulations 	
J.Z., Chen [4]	<ul style="list-style-type: none"> • Management support • Supply of training or documents 	<ul style="list-style-type: none"> • Management support 	<ul style="list-style-type: none"> • Maturity 		

Table 2. Comparison for underground piping construction methods

Type/Construction Method	Cut and dig method	Small diameter impelling method	Large diameter impelling method	Submersed impelling method
Comparison of pipe diameters	<ul style="list-style-type: none"> • No restriction 	<ul style="list-style-type: none"> • Only applicable to spherical configuration • I.D. at 250 – 750mm, which prevents the entry of construction crew to conduct implements within 	<ul style="list-style-type: none"> • Generally in spherical shapes • I.D. within 800 – 3000mm 	<ul style="list-style-type: none"> • Generally in spherical shapes • I.D. at 1,500mm and up
Length of pipe route	<ul style="list-style-type: none"> • No restriction 	<ul style="list-style-type: none"> • The distance of manholes at approximately 50-100m 	<ul style="list-style-type: none"> • At around 200- 700m when combined with midsection jack 	<ul style="list-style-type: none"> • Most often adopted for length of 1km or more, with manholes spaced at between 4km
Linear configuration	<ul style="list-style-type: none"> • No restriction 	<ul style="list-style-type: none"> • The pipe duct may be in a curved configuration, where $R \geq 60m$ 	<ul style="list-style-type: none"> • Bendable to 50m radius when using the standard 1/2" or 1/3" pipe, and up to 15mR to 30mR using special pipes 	<ul style="list-style-type: none"> • Turn radius generally at 60mR
Topsoil	<ul style="list-style-type: none"> • No restriction in construction implementation but generally over 1.2m and under 4m 	<ul style="list-style-type: none"> • Preferably at 1m or more 	<ul style="list-style-type: none"> • 1.5m or more is deemed necessary in general 	<ul style="list-style-type: none"> • Depth of topsoil to be 1.5 times or more over the diameter of the submersed pipes
Corresponding soil texture	<ul style="list-style-type: none"> • No restriction by principle 	<ul style="list-style-type: none"> • Restrictive by diameter of soil particles 	<ul style="list-style-type: none"> • Adequate construction method may be chosen (being that dredgers come in standard type and boulder crusher, etc.) 	<ul style="list-style-type: none"> • No restriction
Roadway condition for pit digging	<ul style="list-style-type: none"> • May hinder the traffic along the digging route • Requires large- scale restoration work 	<ul style="list-style-type: none"> • Needs to take into account the impact of working well to traffic 	<ul style="list-style-type: none"> • Needs to take into account the impact of working well to traffic 	<ul style="list-style-type: none"> • Needs to take into account the impact working well to traffic • Requires to setup large-scale working site

River/rail crossings	• Difficult	• Probable	• Probable	• Probable
Noise, vibration, stratum sinkage, etc.	• With a high probability of creating impact to the stratum	• Creates certain impact with regard to the working well	• Creates certain impact with regard to the working well	• Creates significant impact around the site in light of having to set up large-scale operating site
Impact to substructure templates	• Creates certain impact	• Creates certain impact generally only to the working well	• Creates certain impact generally only to the working well	• Creates certain impact generally only to the working well
Expenditure	• Least expensive	• Being least expensive in cost right next to the cut and dig method	• The distance of upright pit excavation needs to be set to between 50 – 500m to meet economic yield	• Requires large-scale equipment; the longer the average distance between upright pits the lower the cost would become
Duration of construction	• The more the rotation shifts, the shorter the construction period would be	• Requires shortest construction period right next to the cut and dig method	• Requires a shorter construction period than the submersible construction method, usually in 7m/day under normal circumstances	• Requires longer construction period in light of complex work such as grouting and so forth

Table 3. A Summarized Comparison for Multicriteria Evaluation Method

Method recap	AHP [6, 8, 21]	ELECTRE [18, 19, 20]	TOPSIS [11]	MEQQD [24, 25]
Suitable timing	<ul style="list-style-type: none"> • For processing qualitative information • A hierarchical framework exists among the factors. • All evaluation factors and independent from one another. • Applicable for a hierarchy that exceeds four tiers. • To find out the evaluation factors' relative weighing. 	<ul style="list-style-type: none"> • For processing issues that fall between qualitative and quantitative nature. • Applicable to circumstances where there a number of proposals with fewer number of factors. • It can only be used to derive a ranking correlation, but not an intensity correlation. • It is ideal for evaluating non-continuous number of proposals. 	<ul style="list-style-type: none"> • For processing issues bound by quantitative criteria. • It is ideal for processing multicriteria issues. • The evaluation criteria need to satisfy monotonic incrementally increasing or decreasing yield. • All evaluation factors are interchangeable. 	<ul style="list-style-type: none"> • For processing concurrently qualitative and quantitative issues. • Ideal for solving complex evaluation issues.
Pros	<ul style="list-style-type: none"> • Easy to understand and operate • Easy to calculate and practical • Consistency evaluation can be used to evaluate whether the decision makers' consensus contain deviation, with a theoretic basis and objective. • Able to simplify complex qualitative issues into tangible figures derived from evaluating decision groups and through mathematical means 	<ul style="list-style-type: none"> • It is able to concurrently address the qualitative and quantitative criteria. • The preferential correlation does not need to satisfy the conveying hypothesis to provide a greater tenacity. • 3 Numeral information decisions are more prone to be rendered with a sequence of superiority and inferiority. 	<ul style="list-style-type: none"> • It can be used to process various evaluation factors under an interchangeable circumstance. • Its distance expression for deriving the disparity between the various alternative proposals and ideal solutions helps to eliminate the hindrance of not being able to produce a ranking on identical weighing derived from using AHP. 	<ul style="list-style-type: none"> • It takes into account qualitative and quantitative factors. • It is more adaptable to evaluating complex problems.
Cons	<ul style="list-style-type: none"> • Unable to discern the correlation among the factors. • It tends to confuse the decision maker to lead to variations when a large number of evaluation factors tend to lead to a larger number of evaluations. • It tends to be harder to reach a set consistency evaluation criteria when there is a larger number of factors. 	<ul style="list-style-type: none"> • It is more difficult to derive the threshold reading. • The satisfactory and dissatisfactory indicators cannot fully reflect the decision maker's preferences. 	<ul style="list-style-type: none"> • It can only take into account quantitative factors. • The separation propensity calculation may be more complex. • It could only be used to generate the shortest sign of identical disparity on negative ideal value. 	<ul style="list-style-type: none"> • Criteria weighing can be derived using the extreme weighing and random weighing methods. • It may not necessarily support the actual scenario. • The computation process is somewhat fastidious.

Table 4. Statistic chart for study subjects

method \ subjects	Japan		Taiwan	
	Experts	Scholars	Experts	Scholars
Expert in-depth interviewing method	2	0	0	2
Delphi	5	3	5	2
AHP	8	3	5	2

Table 5. Second questionnaire findings derived from using the Delphi method

Construct	Factor	Second questionnaire		First Survey Ranking	Second Survey Ranking
		Median score	Variable index		
Technology provider factor	Construction experience	93.5	0.027	1	1
	Management support	91.5	0.036	2	2
	Technical proficiency	85.0	0.059	3	3
	Willingness	81.5	0.048	5	4
	Management capability	80.5	0.000	4	5
	Providing of training or documents	77.0	0.097	6	6
	Level of understanding towards the technology transfer	76.5	0.102	7	7
Technology acceptor factor	Enhancing market competitiveness	93.0	0.028	1	1
	Improving economic yield	91.0	0.058	2	2
	Willingness	85.0	0.055	3	3
	Effective technology transfer plan	81.0	0.087	4	4
	Related technical experience	78.5	0.115	5	5
	Management capability	77.5	0.086	7	6
	Management support	77.0	0.102	6	7
Technical capability	Practicality	95.0	0.026	1	1
	Future development potential	91.0	0.018	—	2
	Level of innovativeness	88.5	0.085	2	3
	Operating and maintenance cost	87.5	0.076	—	4
	Construction timing	81.5	0.043	4	5
	Maturity	81	0.062	3	6
	Level of standardization	70	0.133	5	7
Environment factor	Legal stipulations	96.0	0.031	1	1
	Related industry support	91.5	0.024	2	2
	Level of government support	88.0	0.041	3	3
	Proximity to cultural characteristics	87.5	0.050	7	4
	Market scale	85.0	0.059	4	5
	Value perspective	85.0	0.046	5	6
	Social system	82.5	0.054	6	7
Transfer method	Operator voluntary inclination	94.0	0.023	1	1
	Communication channel	84.0	0.053	6	2
	Mutual mentality towards the transfer	83.5	0.044	3	3
	Method for introducing the technology	83.0	0.044	2	4
	Stability level of mutual relationship	80.5	0.072	4	5
	Steps in technology transfer	76.5	0.091	5	6

Note: “—” indicates new factor added in the second survey poll.

Table 6. Weighted comparison table on LDSTPICM (second tier)

Factor	Technology provider	Technology acceptor	Technical capability	Environment factor	Technology Transfer method
Weighing	0.089	0.056	0.267	0.419	0.168
Sequence of importance	4	5	2	1	3

Table 7. Assessment ratings of LDSTPICM(technology provider factor) where C.R. = 0.023

Factor	Construction experience	Management support	Technical proficiency	Willingness	Management capability	Providing of training and documents	Level of understanding towards the technology transfer
Weighing	0.257	0.052	0.301	0.043	0.185	0.060	0.102
Sequence of importance	2	6	1	7	3	5	4

Table 8. Assessment ratings of LDSTPICM (technology acceptor factor), where C.R. = 0.023

Factor	Enhancing market competitiveness	Improving economic yield	Willingness	Effective technology transfer plan	Related technical experience	Management capability	Management support
Weighing	0.313	0.283	0.067	0.158	0.092	0.059	0.028
Sequence of importance	1	2	5	3	4	6	7

Table 9. Assessment ratings of LDSTPICM (technical capability), where C.R. = 0.008

Factor	Practicality	Future developing potential	Innovative level	Operating and maintenance cost	Duration of construction	Maturity	Level of standardization
Weighing	0.243	0.108	0.043	0.255	0.264	0.043	0.042
Sequence of importance	3	4	5	2	1	5	7

Table 10. Assessment ratings of LDSTPICM (environment factor), where C.R. = 0.038

Factor	Legal stipulations	Relevant industry support	Level of government support	Proximity to cultural characteristics	Market scale	Value perspective	Social system
Weighing	0.322	0.216	0.204	0.036	0.115	0.075	0.032
Sequence of importance	1	2	3	6	4	5	7

Table 11. LDSTPICM (technical transfer mode) evaluation rating chart (where C.R. = 0.032)

Factor	Operator voluntary inclination	Communication channel	Mutual mentality toward the transfer	Method for technology introduction	Level of stability in mutual relationship	Steps in technology transfer
Weighing	0.427	0.112	0.137	0.038	0.061	0.226
Sequence of importance	1	4	3	6	5	2

Table 12. The research's overall hierarchical structure weighing and ranking chart

The First Objective	The Second Objective	The Third Factor
The Development and Research of Long-distance Steep Turn Pipe Impelling Construction Method.	Technology Provider Factor (0.089)	Construction experience (0.023) 13 Management support (0.005) 28 Technical proficiency (0.027) 12 Willingness (0.004) 31 Management capability (0.016) 17 Provide of training and documents (0.005) 28 Level of understanding towards the technology transfer (0.009) 25
	Technology Acceptor Factor (0.057)	Enhancing market competitiveness (0.018) 16 Improving economic yield (0.016) 17 Willingness (0.004) 31 Effective technology transfer plan (0.009) 25 Related technical experience (0.005) 28 Management capability (0.003) 33 Management support (0.002) 34
	Technical Capability (0.267)	Practicality (0.065) 7 Future development potential (0.029) 11 Level of innovativeness (0.011) 21 Operating and maintenance cost (0.068) 6 Construction timing (0.070) 5 Maturity (0.011) 21 Level of standardization (0.011) 21
	Environment Factor (0.419)	Legal stipulations (0.135) 1 Related industry support (0.091) 2 Level of government support (0.085) 3 Proximity to cultural characteristics (0.015) 19 Market scale (0.048) 8 Value perspective (0.031) 10 Social system (0.013) 20
	Transfer Method (0.168)	Operator voluntary inclination (0.072) 4 Communication channel (0.019) 15 Mutual mentality towards the transfer (0.023) 13 Method for introducing the technology (0.006) 27 Stability level of mutual relationship (0.010) 24 Steps in technology transfer (0.038) 9

Note:

1. The figure in parenthesis indicates the weighing of a particular factor.
2. The numeral figure behind parenthesis indicates the overall importance ranking of a particular factor.

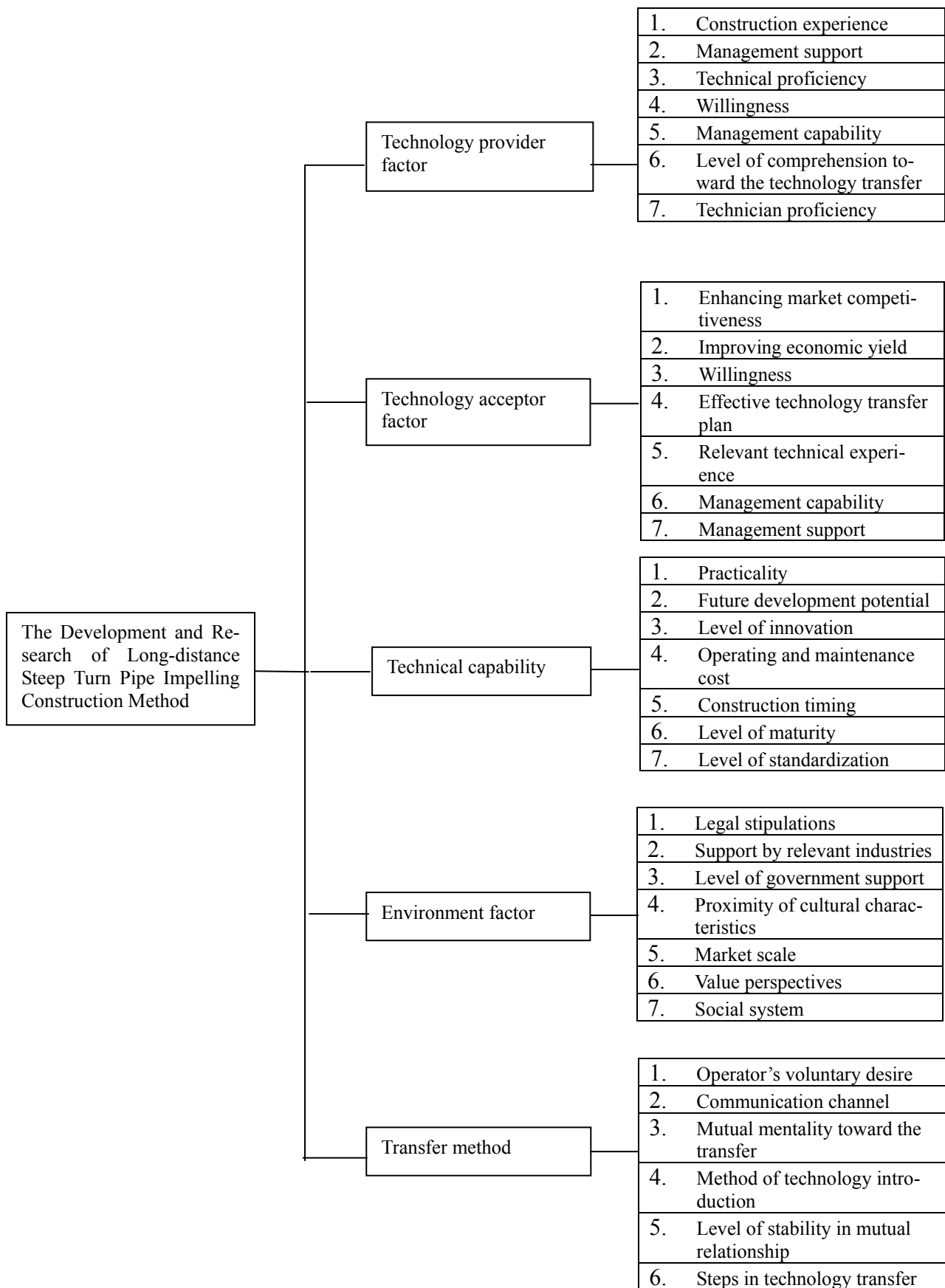


Figure. 1. The AHP hierarchical framework

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以技術移轉探討長距離急彎曲推進工法發展之研究

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摘要

爲了配合政府推動台灣成爲科技島，促進全國之經濟發展與社會繁榮，除了積極建設台灣國內之電力設施（輸配電及變電系統）外，提供高度穩定與安全化之電力需求係電力產業之重要課題。伴隨著地下化電纜管路工程，施工技術亦日趨複雜與高難度化，早期國內所引進之潛盾工法(Shield Tunneling Method)與直線推進工法等已不敷所求，唯有「長距離急彎曲推進工法」之工程技術，才能滿足當前多樣化之輸電市場。「長距離急彎曲推進工法」係屬新型之技術尚未推廣及引進於國內，本研究首先藉由與擁有本技術之日本產業界之學者及專家進行訪談，系統性地瞭解該工法之關鍵技術與施工要領，其次利用層級分析法(Analytic Hierarchy Process; AHP)探討台電六輸計劃案中技術移轉之關鍵因素，最後歸納出「長距離急彎曲推進工法」於我國相關產業之未來發展趨勢。研究結果顯示，技術提供者與政府單位除了必需積極配合，儘速訂定此工法之相關法令規章與配套措施外，亦應對此工法之技術規範與作業指南等做詳細規範。再則，專業技術與經驗累積係此工法技術移轉之核心要素，與國內現有推進工法相差甚鉅，其關鍵技術主要在於彎曲機器、彎曲推管及彎曲管間機能之相容性。因此，經由技術移轉之方式學習專業之技術能力與不斷累積經驗才能快速落實技術本土化之最終目標。

關鍵詞：長距離急彎曲推進工法，技術移轉，層級分析法，德爾菲法
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