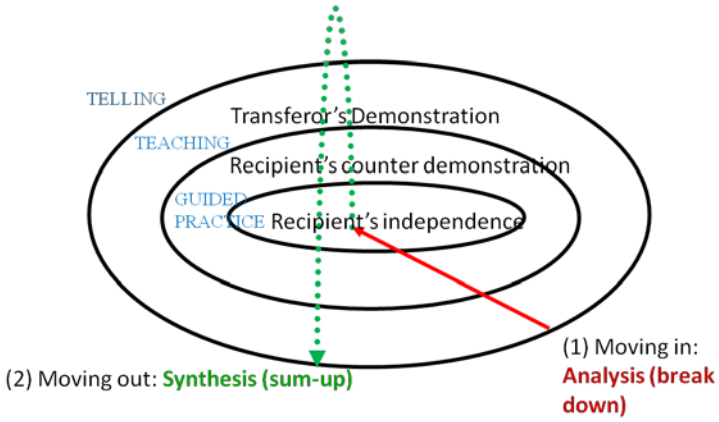

Figure 3. The TTP and analysis and synthesis

The Iterative Methodology of Analysis and Synthesis of Technology Components is based on the hypothesis that technology exists in different forms. Furthermore, some components may be viewed similarly by two or more technology users while other components may be seen differently.

Earlier, it was mentioned that one of the characteristics that a good technology transfer methodology must have is the ability to transfer intangible technology such as know-how. While there are elements of components of technology that are easily articulated such as product drawings, there are those that are transferred only through extended human contact such as knowledge transferred through mentoring. The technology transfer methodology must consider technology components that can be easily articulated from those that cannot. Furthermore, from those that can be articulated, the components that are commonly viewed by different users must be separated from those that vary among users.

To illustrate in detail, Table 1 states the proposal of this research in narrative form while Figure 4 shows the proposal of this research in diagram form.

As a side remark that will be used for later discussions, the reader is invited to compare Table 1 with Figure 4. This research suggests that the reader answer the following questions when comparing Table 1 with Figure 4:

1. Which one states the proposal of this research more completely?
2. Which one is easier to use as a tool for transferring knowledge or technology?
3. Which one is easier to remember?

Table 1. The Proposal of this Research in Narrative Form

"A methodology with the following steps can contribute significantly to more effective and efficient technology transfer activities: Given the technology of the transferor, first, articulate the technology as much as possible, to document the explicit technology. Second, analyze or breakdown the explicit technology into the common elements and the user-specific elements. Retain the common elements and adjust the user-specific elements to the conditions of the technology recipient. Third, given the common and user-specific elements and the transferor's technology, synthesize or sum-up the technology into a narrative or story. The story will contain both explicit and implicit technology. Lastly, verify the narrative or story of the technology with the transferor. If the transferor agrees with the narrative, the narrative becomes the description of the recipient's technology. Otherwise, the recipient's technology can be established through iterations of articulation, analysis and synthesis of the transferor's technology."

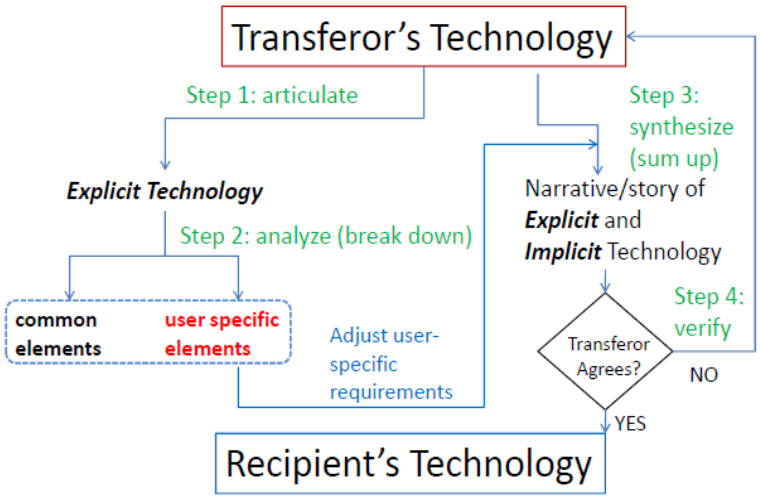

Figure 4. The proposal of this research in diagram form

The answers to the aforementioned questions will be discussed in more depth in the next sections. The formats of Table 1 and Figure 4 are related to synthesis and analysis which are the essential parts of the methodology being proposed in this research.

To continue the discussion about the Iterative Methodology of Analysis and Synthesis of Technology Components for Technology Transfer and Local Development, it must be mentioned that this research has two underlying hypotheses which are as follows:

1. Technology has different components. These components can be classified into two forms, namely, (i) explicit and (ii) implicit/tacit.
2. Technology has different components. Among different users, the components appear to be either (i) common or (ii) user-specific.

Figures 5 and 6 show the hypotheses of this research in diagram form.

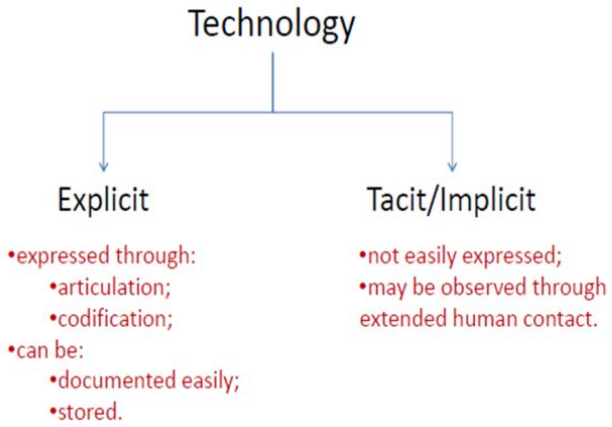

Figure 5. The first underlying hypothesis of this research: the explicit and tacit/implicit components

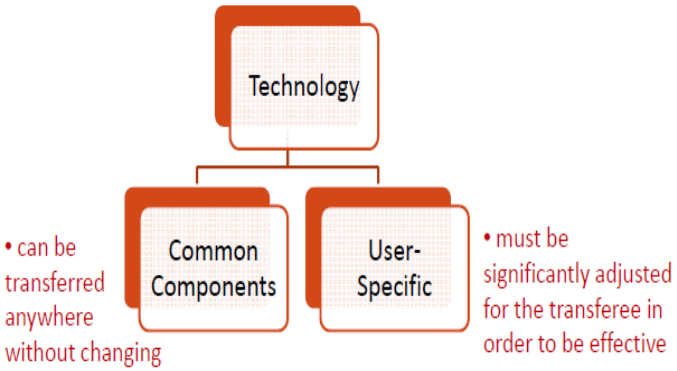

Figure 6. The second underlying hypothesis of this research: the common and user-specific components

The Analysis Process in the Proposed Methodology

Analysis is the process of breaking a complex topic into smaller parts to gain a better understanding of that complex topic. "Analysis" comes from the words "ana" which means, "up, throughout" and "lysis" which means "loosening." The transfer of knowledge first entails the breaking down of the technology into smaller and more understandable units.

The Analysis Process of the Iterative Methodology of Analysis and Synthesis of Technology Components that is being proposed by this research is illustrated by Figure 7. The Analysis Process begins after inputs from the customer and from the technology transferor are obtained. Inputs from the customer may include product sample, product drawing, product specification and other similar documents containing information about the product.

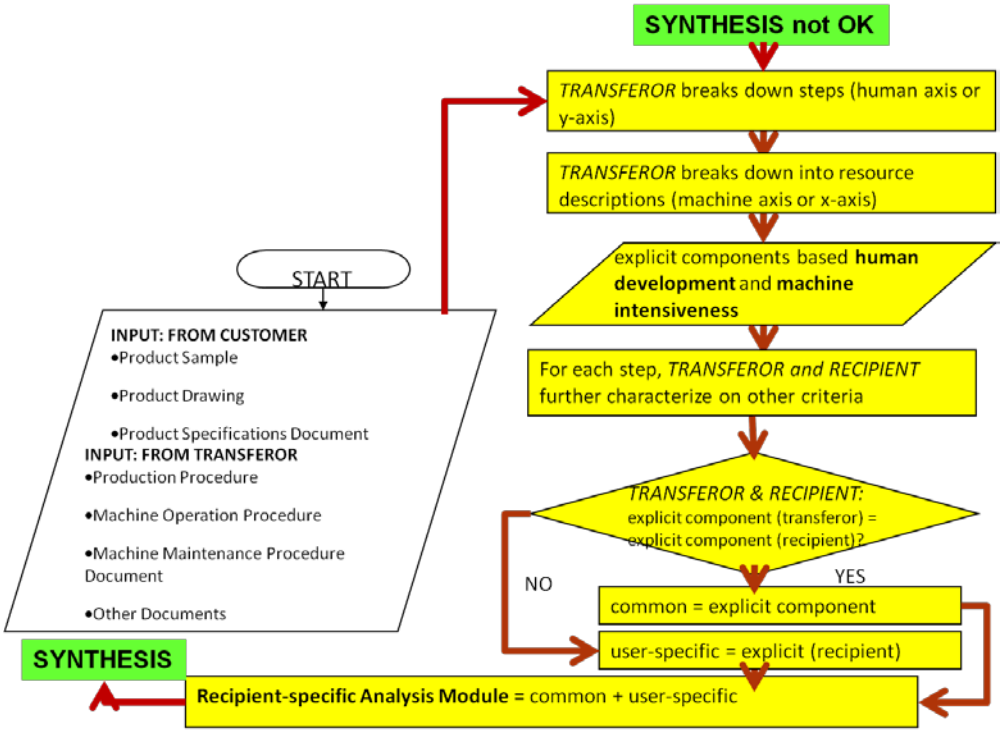

Figure 7. The analysis process

The inputs must be broken down by the transferor into two aspects, namely, human and machine. These components that can be articulated and classified as either human or machine are the explicit components of the technology.

Once the explicit components are unveiled, the transferor and the recipient must decide together if the component will be "common" between them. Otherwise, the transferor and the recipient can agree that the technology component can be executed or utilized in a user-specific way.

Common components should be transferred without any adjustments. On the other hand, this research suggests that the user-specific components be adjusted to take the form that best fits and recipient and this must be approved by the transferor.

The output of the Analysis Process would be the Recipient-specific Analysis Module. This module will be composed of the common and the user-specific components. User-specific means recipient-specific. This Recipient-specific Analysis Module will be an input to the Synthesis Process. Furthermore, the Recipient-specific Analysis Module will continue to be revised until the output of the Synthesis Process is finally approved by the technology transferor.

Tables 2, 3 and 4 show the Recipient-specific Analysis Modules of Japanese, Taiwanese and Korean Machine Tool Manufacturers for their Process Planning Technologies. These examples were obtained from an actual investigation performed by the author in 1995. The actual investigation conducted on 12 Japanese, 4 Taiwanese and 5 Korean machine tool companies. The findings of these earlier research papers by the author were proven to be valid qualitatively [8] and quantitatively in 1997 and 1998 [9], respectively.

Table 2. Recipient-specific Analysis Module for the Process Planning of Japanese Machine Tool Manufacturers

ANALYSIS MODULE FOR JAPAN				
Man	Machine Operation	Machine Maintenance	Decision-making Priority	Other Considerations
Select raw material	None	None	Lowest material + machining cost Easiest fixing method	None
Determine machining process	None	None	Highest efficiency Lowest cost	None
Similar Design	None	None		Retrieve from database
New Design	None	None		None
Arrange machining sequence	None	None	Effect of heat treatment	None
Select machine tool	None	None	None	None
Determine standard time	CAM	CAM	None	None

Table 3. Recipient-specific Analysis Module for the Process Planning of Taiwanese Machine Tool Manufacturers

ANALYSIS MODULE FOR TAIWAN		
Man	Decision-making Priorities	Other Considerations
Select raw material	Highest quality	None
Determine machining process	Highest quality	None
Similar Design		Retrieve from database
New design		None
Arrange machining sequence	Parts with high accuracy requirements	None
Select machine tool	Highest quality	None
Determine standard time	None	Compute total lead time

Table 4. Recipient-specific Analysis Module for the Process Planning of Korean Machine Tool Manufacturers

ANALYSIS MODULE FOR KOREA		
Man	Decision-making Priorities	Other Considerations
Select raw material	Shortest time; Highest machinability; Highest efficiency	None
Determine machining process	Best workflow; Balanced workload	None
2.1 Similar Design		Retrieve from database
2.2New design		None
Arrange machining sequence	Shortest time for changing tools	None
Select machine tool	Best load distribution	None
Determine standard time	None	Compute: (Net machining time + Preparation time) + Allowances

The Synthesis Process in the Proposed Methodology

Synthesis is the summing up of the technology into a story or narrative. This is a proposal of this research. The aim is for the technology transfer to utilize synthesis as a tool to provide additional information that may be not be sufficiently provided by analysis.

This research proposes that the Synthesis Process be performed after the first iteration of the Analysis Process. Consequently, after the first iteration, the synthesis process must be performed after every revision of the Recipient-specific Analysis Module.

The proposal of this research is that the recipient be responsible for performing the Synthesis Process. This research believes that making the recipient perform the Synthesis Process will result in the recipient's better understanding and retention of the technology. Furthermore, and more importantly, with synthesis by the recipient, local development of the technology is stimulated. The story of the technology is absorbed in the culture of the recipient. As time passes, the recipient-specific components become more adjusted to the user or more user-harmonized.

The output of the Synthesis Process is the Recipient-created Synthesis Module. The Recipient-created Synthesis Module must be reviewed and approved by the transferor before technology transfer is considered complete.

To further show the importance of the Synthesis Process, the reader can go back to the comparison of Table 1 and Figure 4. Perhaps the reader can recall his answer for the question on which one is easier to remember. Which one did the reader really remember?

It is highly likely that it is the format of Table 1 that will be found easier to retain. The human mind remembers stories. In 1996, Turner said "Narrative imagining – story is the fundamental instrument of thought. Rational capacities depend on stories. They are our chief means of looking into the future, of predicting, of planning, and of entertaining. Most of our experience, our knowledge and our thinking are organized as stories" [10]. Thus to impart lasting knowledge, we must use stories.

Figure 7 shows the Synthesis Process. In comparison with the Analysis Process, the Synthesis Process requires less number of steps. With the Recipient-specific Analysis Module, the Transferor's demonstration of the technology and the Synthesis Module Template as inputs, the recipient must create the narrative of the technology. The resulting narrative should be reviewed by the transferor. Then, if approved, it becomes the Recipient-created Synthesis Module. Otherwise, the Analysis Process is again performed and the iterative process repeats until the Recipient-created Synthesis Module is approved by the transferor.

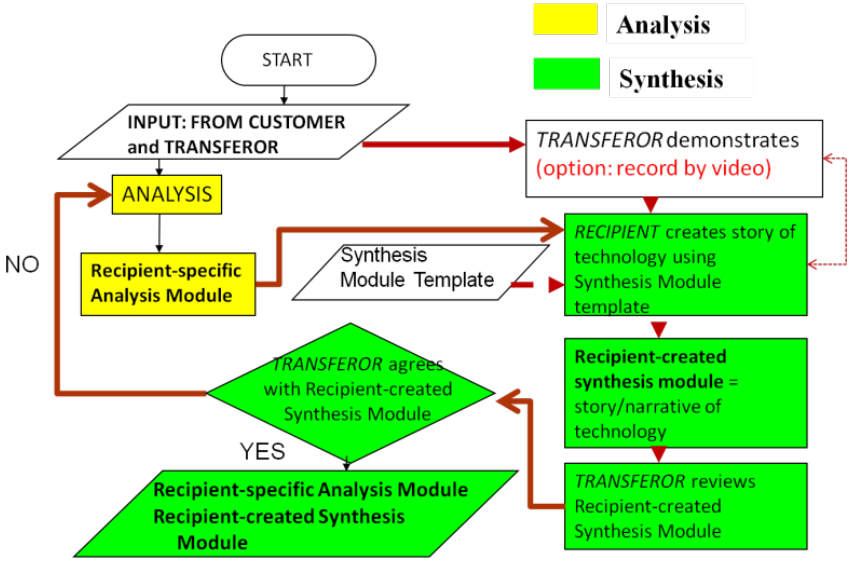

Figure 7. The synthesis process

For first-time users of the Iterative Analysis-Synthesis Methodology, the Synthesis Module Template will not be available. Thus, it is important that there be continuous discussions between the transferor and the recipient about the variables and parameters that must be contained in the Synthesis Module. The first few times that the Synthesis Module

is created will be done by trial-and-error. Eventually, the transferor and the recipient will explicitly agree on the essential variables and parameters to be contained in the Synthesis Module. When this happens, the recipient can begin to create the Synthesis Module Template. This template is expected to result in the faster creation of the subsequent Recipient-specific Synthesis Modules.

Table 5 shows a sample Synthesis Module that is created for the Process Planning Technology of Taiwanese Machine Tool Manufacturers.

Table 5. Sample Synthesis Module for the Process Planning of Taiwanese Machine Tool Manufacturers

Example of Process Planning for Taiwan Procedure Step 1 Action: Select Raw Material Topics/activities covered: Refer to Table of Standard Raw Materials. Given part number, select corresponding raw material. For more than one possible raw material, use decision-making priority. Add allowance. Decision-making priorities considered in this action: quality Modification of the planned activity: ex. Raw material X will not be included in selection Reason for modification of the planned activity: Supplier quality rating for Raw material X is not available; supplier is new. Results of this activity: Selected 200 unit of Raw material Y; highest quality rating at 0.99.

The Iterative Combination of Analysis and Synthesis

Combining analysis and synthesis enables the technology transfer to benefit from the advantages of the methods of analysis and synthesis. This research believes that to make the technology more understandable, the technology must be broken down into its component parts. However, in order to put more meaning to the component parts, the story of the component parts must be told again. The objective will be to make the true insights of the transferor more properly conveyed.

The output of analysis has the advantage of being concise, easy to understand especially for analytical users or skilled engineers. It can also serve as quick reference and can accommodate minor modifications such as changes in language, format, etc. However, it has the disadvantage of being not very clear about critical information such as decision-making priorities or checkpoints. Furthermore, it may be difficult to understand especially for the novice user of the technology.

On the other hand, the output of synthesis has the advantage of being easy to retain in the human mind. Furthermore, it has the ability of capturing more information than what can be done by the simple listings that can be provided by analysis.

Thus, analysis will be able to tell and teach the technology to the recipient. Synthesis will enable the recipient to form the story of the technology. Later, the recipient may be able to develop the technology to his own preference. Therefore, the combination of analysis and synthesis will result in the effective transfer of the technology. Furthermore, the "iterative" characteristic of the methodology will be able to provide a feedback system to both the transferor and the recipient that can lead to a clearer agreement between the transferor and the recipient on how the technology should be executed.

Case Study: Japan-Philippines Technology Transfer on Software Technology

To validate the proposed methodology, this research conducted a case study. The first case study that was performed by this research which is discussed in this paper involves technology transfer between a Japanese mother company and a Philippine subsidiary [11]. For this case study, technology transfer involves the development of software technology for consumer electronics.

The history of the Philippine subsidiary dates back to 1991. The Philippine subsidiary was started by a Japanese venture company. At that time, the Japanese venture company had less than 100 employees while the start-up Philippine subsidiary was composed of 10 employees. From 1991 to 1998, the Philippine subsidiary was involved in the software development of a wide variety of electronic consumer products. In 1998, the Japanese venture company sold the Philippine subsidiary to a Japanese corporation. The Japanese corporation then had more than 1000 employees and was one of the biggest players in its industry. Until now, the Japanese corporation continues to be the leader in its industry.

From 1998 up to the present, the Philippine subsidiary has been developing software technologies for the exclusive use of the present mother company which is the Japanese corporation. At present, the number of employees in the Philippine subsidiary is a little more than 500. In terms of technological capability, the Philippine subsidiary may be rated as one of the highest in the Philippines. Most of the 500+ employees are graduates of the top universities in the Philippines.

Figure 8 presents the flowchart of activities jointly undertaken by the Philippine subsidiary and the Japanese mother company for each development project. In general, each development project obtains starting information from the following inputs: job order, specifications document and the estimated project schedule. From these inputs, the Philippine subsidiary (recipient) breaks down all the input information into smaller work elements. Then, together, the Philippine subsidiary (recipient) and the Japanese mother company (transferor) identify which work elements are to be done in the "Philippine-specific" way and which ones are to be standard between the recipient and the transferor. The output of these activities will then be the list of deliverables and milestones, and other detailed documents. These outputs will be checked by the transferor. If the transferor approves the Project Detailed Documents and Lists, these become the final version. Otherwise, the recipient revises these documents and lists until they are approved by the transferor. This whole process is equivalent to the analysis process of the proposed technology transfer methodology of this research.

Simultaneous with the breakdown of the inputs into detailed documents and lists, the recipient creates a brief narrative of the project. Aside from the inputs such as job order, specifications document and rough schedule, the recipient uses the Coding Guidelines to create a brief narrative of the project. In effect, the Coding Guidelines serve as the Recipient-created Synthesis Template. When the brief narrative of the project has been created, the transferor reviews this narrative. If the transferor approves of the brief

narrative, it becomes the final version of the project narrative. Otherwise, it is revised until the approval of the transferor is obtained. This whole process involving the creation of the project narrative is equivalent to the synthesis process of the proposed methodology of this research.

The method shown by Figure 8 has been used by the technology transfer participants of the case study since early Year 2000. Previous to that time, the method of transferring technology from the Japanese mother company involved the shorter process shown in Figure 8.

According to the interviewee who comes from the Philippine subsidiary and who is in charge of overseeing the transferred software development projects, the present method has the following advantages over the old method:

(1) Lower incidence (and cost) of rework. With the present method, there is more control of the quality of output of the technology transfer. Quality control is provided during each iteration, composed of activities shown by Figure 8. The old method, in which the way of processing the requirements by the Philippines is not clear, resulted to more rework than the present method. Oftentimes, with the old method, rework had to be done from the beginning of software development even when the output has already been produced by the Philippine subsidiary. The cost of output plus the cost of rework could reach significant amounts.

(2) Higher repeatability of technology-related processes. With the present method, technology transfer can be performed by different teams. Even with less knowledgeable engineers, technology transfer can become successful because templates and reviews of outputs are sufficiently provided. The old method was highly dependent on the inherent skills of the engineers to whom technology was transferred by the transferor.

(3) Higher predictability of time estimates. Usually the project time based on the old method would be underestimated. As can be seen in Figures 8 and 9, the iterative process of Figure 9 is shorter than the iterative process of Figure 8. Correspondingly, project time estimates when the old method was used were shorter than the project time estimates at present. However, the present time estimates tend to be closer to actual project times. Typically, project time estimates computed based on the old method were smaller but projects based on the old method would tend to be delayed due to rework requirements.

Comparing the case study and the proposal of this research, the case study shows a combination of analysis and synthesis. Figure 8 highlights the analysis in yellow and the synthesis in green. This seems to be in agreement with the proposal of this research. However, a major difference between the case study and the proposed methodology is that the analysis is performed by the recipient. Such case is not the same as the proposal which suggests that the analysis be performed by the transferor. When the Philippine subsidiary was interviewed for the reason behind this, the company mentioned that both they and the Japanese mother company believe that if the analysis is done by the recipient, there will be more understanding and retention of the technology. Both companies think that their close to twelve years of experience of working with each other has properly taught the recipient the correct procedure for analyzing or breaking down the technology into its details. When asked about the advantages and disadvantages of using the Iterative Analysis and Synthesis Methodology, the interviewee mentioned the following:

Advantages:

1. There is more understanding of the technology by the Philippine subsidiary. In the long term, this results in the upgrading of skills of Philippine subsidiary;
2. There is less analysis work for the Japanese mother company. Because of this, the Japanese mother company is able to perform other high value-adding activities.

Disadvantages:

1. Specifically in the narrative, the language used by the Philippine subsidiary is hard to understand. Sentences are very long.

Overall, both the Japanese mother company and the Philippine subsidiary are satisfied with the analysis and synthesis procedure. Since the time that they started undertaking their projects using this methodology, they have significantly decreased the need for face-to-face meetings. Furthermore, they have observed that there is less loss of information because of double documentation, i.e., one by analysis and the other by synthesis. As drawback, however, there is now a necessity to review.

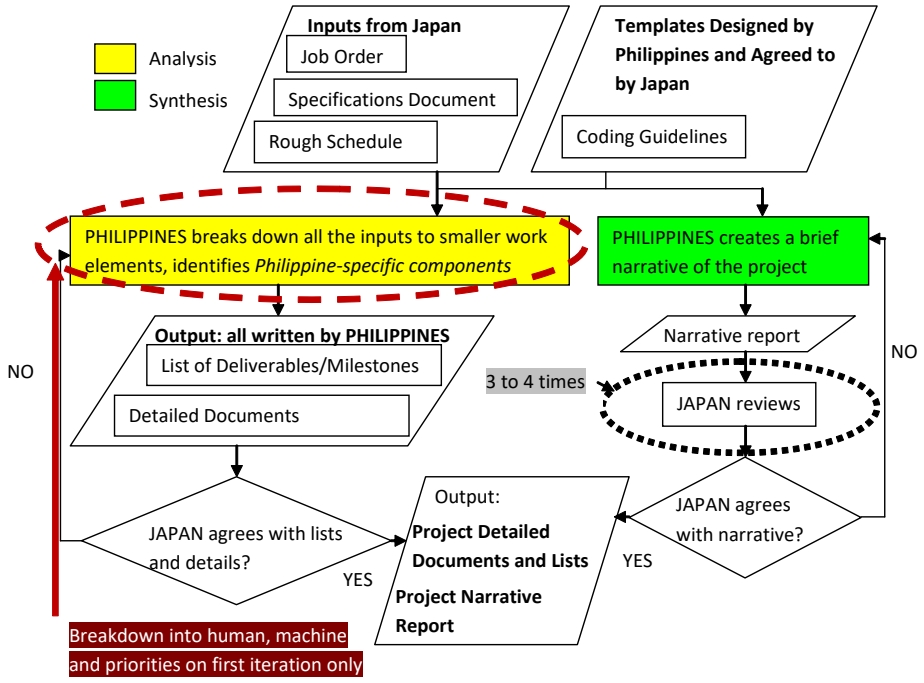

Figure 8. Flowchart of activities undertaken by the Philippine subsidiary and the Japanese mother company for each development project (present method)

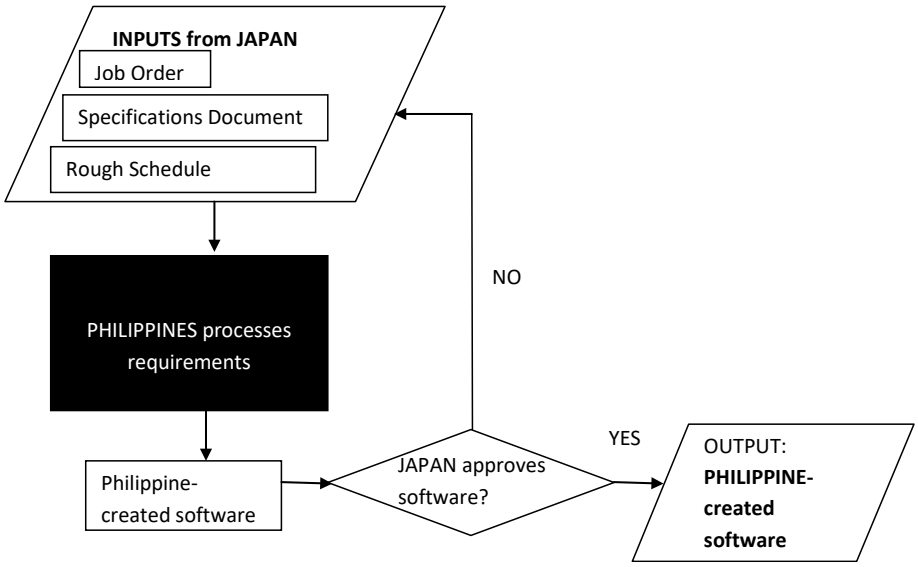

Figure 9. Flowchart of activities undertaken by the Philippine subsidiary and the Japanese mother company for each development project (old method)

To summarize, Table 6 shows the comparison of the technology transfer methodology being used by the case study and the proposed methodology of this research.

Table 6. Comparison of the Technology Transfer Methodology being used by the Case Study and the Proposed Iterative Methodology of Analysis and Synthesis of Technology Components

Proposal	Case Study	Proposal and the Case Study Same?
Analysis by Transferor	Analysis by PHLIPPINES (Recipient)	Similar: analysis present
Breakdown by Human Level	Breakdown by half or into two steps (1991-early 2000) Almost no breakdown (early 2000-present)	Same
Breakdown by Machine-intensiveness	Information on computer care/maintenance	Same
Breakdown by priorities (common and user-specific)	Breakdown by priorities of JAPAN and PHILIPPINES	Same
Synthesis by Recipient	Synthesis by PHILIPPINES (Recipient)	Same
Use of Synthesis Template	Use of Narrative Template	Same
Systematic Iterative Analysis-Synthesis Methodology	No system in second+++ pass or iteration	Not the same

In almost all aspects listed in Table 6, the Iterative Analysis and Synthesis Methodology is in agreement with the methodology of the case study. Hence, it may be said that the proposed methodology of this research may be valid. To a large extent, the proposal is credible. Furthermore, with the cited advantages of the proposed iterative combination of analysis and synthesis, the proposal is also, to a large extent, confirmable. One area where the proposal differs from the methodology of the case study is that analysis is being done by the Philippine subsidiary. This research agrees with the argument if the analysis is done by the recipient, benefits such as higher retention of the technology by the recipient can be realized. However, this can only be possible when the relationship between the transferor and the recipient has been a long one like in the case study discussed. For first time users of the proposed Iterative Analysis and Synthesis Methodology, the "analysis by the transferor" method is still suggested by this research. Eventually, as the recipient gains full understanding of the technology, then the performance of the Analysis Process may be transferred to the recipient.

A possible significance of this research which cannot be found in the case study is the systematic methodology of technology transfer in the event that the result of the first iteration or first trial is not successful. For the case study, the first iteration of technology analysis and synthesis is clear. However, if the first iteration results are not understood by the recipient, the methodology of technology transfer reverts to trial and error. This research aims to bring more systematic methodology by providing a procedure for the second iteration onwards in the event that the first iteration does not become successful.

In general, given that the case study has been utilizing a slightly modified version of the proposed Iterative Methodology of Analysis and Synthesis of Technology Components for technology transfer since the early part of the 21st century, the proposed methodology can be judged as dependable.

Discussion: Possible Limitations of the Proposed Methodology

While the proposed Iterative Analysis and Synthesis Methodology is believed by this research to be feasible for a wide range of technology transfer activities, possible limitations of the methodology include the following:

1. Difficulty arising from the non-receptiveness of the transferor or the recipient to systems. It will be difficult to implement the Iterative Analysis and Synthesis Methodology if the transferor and the recipient are not receptive to the idea of systematizing the technology transfer process.
2. Risk to mutual protection. It is risky to implement the Iterative Analysis and Synthesis Methodology if the technology transfer activity has not defined the output of the technology transfer activity that would mutually protect the interests of the transferor and the recipient.
3. Failure arising from short-term foresight. The Iterative Analysis and Synthesis Methodology will not be successful if the foresight of the transferor and the recipient about the technology transfer relationship is short.
4. Fewer benefits from implementing in the latter technology development stages. The Iterative Methodology of Analysis and Synthesis of Technology Components may have fewer benefits when the technology being transferred is in the operations stage than when in the development and production stages.

Conclusions

This research has proposed the Iterative Methodology of Analysis and Synthesis of Technology Components for Technology Transfer and eventual local development of the

technology. The combination of analysis and synthesis is aimed at addressing the need to break down (analyze) the technology to present it in a more understandable form and the necessity to put a story (synthesize) to the technology to ensure the understanding of the technology by the recipient. Moreover, the "iterative" characteristic is to make sure that there is feedback and agreement between the transferor and the recipient.

The case study discussed that involves the long-standing technology transfer between a Japanese company and its Philippine subsidiary aimed at developing software technologies confirms the validity of the proposed Iterative Methodology of Analysis and Synthesis for technology transfer.

The proposal of this methodology has met the objective of this research which is to propose a methodology that is believed to play a role towards more successful technology transfer activities in the future. The proposed methodology is believed to be effective because it adjusts the technology to the user which is the recipient organization. Furthermore, the proposed methodology is believed to be efficient because it systematically presents the step-wise procedure for transferring knowledge. These characteristics are perceived by this research to be significant improvements to the technology transfer activities that hitherto have been conducted by trial and error.

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