Exploring Intra-firm Technology Transfer in the IC-Industry: Case Study of an International Firm

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Abstract---**Technological advancement in IC- manufacturing continues to increase in demand of about 8-10% per year. Due to continued and rapid growing market for IC industry, extension of semiconductor manufacturing sites wafer fabrication (fab) is necessary. Large-scale firms have to transfer the manufacturing technology from one country to another in order to save cost. One of key issues for the firms is to make sure the most efficient and practical way for technology transfer. The objective of this research is to propose a systematical analysis methodology for international intra-firm technology transfer in the IC-industry. This paper utilizes an international case study on a recent technology transfer in the IC industry. A set of key performance index (KPIs) are defined to measure the grade of success of the project management. This study uses KPIs evaluation of the technology transfer project setup success key factors (SKFs) and process. We combine the literature review, interview expert and project management to construct individual KPIs of technology transfer project. Technology transfer is closely related to knowledge transfer. It's a time limited transaction and is treated as a project. A structured and organized procedure with dedicated teams at the sending and receiving site is necessary. The "copy smart" methodology is applied in this case study. The findings of this study suggest further improvements for technology transfer projects can be made by locating the project leader at the receiving site in order to have better control.**

I. INTRODUCTION

Technological advancement in IC-manufacturing continues to increase in demand of about 8-10% per year. The basis for this is the technological advancements described in Moore's Law [1] and executed following the International Technology Roadmap for Semiconductors (ITRS) Roadmap. As described in Moore's Law: An important trend in the history of computer hardware is, that the number of transistors that can be placed on an integrated circuit is increasing exponentially, doubling approximately every two years. The observation was first made by Intel co-founder Gordon E. Moore in 1965. The trend has continued for more than half a century and is not expected to stop for a decade at least and perhaps much longer. The ITRS Roadmap describes how these technological advances can and should be implemented. The ITRS assesses the principal technology needs to guide the shared research, showing the "targets" that need to be met. These targets are as much as possible quantified and expressed in tables, showing the evolution of key parameters over time. Accompanying text explains and clarifies the numbers contained in the tables were appropriate. It is a guideline for the whole industry, e.g., IC-design, technology development, manufacturing and also the related tool and supply industry.

Due to continued and rapid growing market for IC industry extension of semiconductor manufacturing sites wafer fabrication (fabs) are necessary. International firms built new fabs in one country and have to transfer the manufacturing technology to another country. The question is how to do that in the most efficient and practical way? This paper utilizes an international case study on a recent technology transfer in the IC industry. A set of key performance index (KPIs) were defined to measure the grade of success of the project management. This study uses KPIs evaluation of the technology transfer project setup success key factors (SKFs) and process. We combine the literature review, interview expert and project management to achieve the results of individual KPIs of technology transfer project.

II. LITERATURE REVIEW

A detailed review of the related literature was done. In the following, first, various definitions of technology transfer and knowledge transfer will be reviewed. Then knowledge transfer will be discussed more in detail. After that relevant points to multinational intra-firm technology transfer will be pointed out while looking deeper into the work of several authors and also published cases of other companies focusing on success factors and barriers. Finally there will be a description of common methodologies for technology transfer in the semiconductor industry. Therefore, this research use various definitions of technology transfer and knowledge transfer, multinational intra-firm technology transfer, and common methodologies for technology transfer related literature review as the main direction.

A. Definition of Technology Transfer

The field of technology transfer is very wide and so are various definitions of technology transfer in the literature. Definitions of technology transfer depend mainly on the involved parties and the method of transfer. Followings are the definitions relevant to this study.

(1) Sharing technical information by means of education and training [2].
(2) The transfer of ideas, information, methods, procedures, techniques, tools, or technology from the developers to potential users. Methods of technology transfer include scientific publications in peer-reviewed journals, articles in management-oriented publications, computer

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programs, training sessions, tours, workshops and others [3].

(3) The sharing of knowledge and facilities among industries, universities, governments and other institutions to ensure that scientific and technological developments are accessible to a range of users who can then further develop the technology into new products, processes, materials or services [4].

(4) The transfer of technology or know-how between organizations through licensing or marketing agreements, co-development arrangements, training or the exchange of personnel [5].

(5) Sharing knowledge is fundamentally a matter of the flow of human knowledge from one human being to another. This can be through education, the scientific literature, or direct human contact [6].

(6) The communication or transmission of a technology from one country to another. This may be accomplished in a variety of ways, ranging from deliberate licensing to reverse engineering [7].

(7) The ability to take a concept from outside the organization (typically from a government or university research programs) and create a product from it (Process) [8].

(8) The movement of modern or scientific methods of production or distribution from one enterprise, institution, or country to another, as through foreign investment, international trade, licensing of patent rights, technical assistance, or training. Technology may also be transferred by giving it away (technical journals, conferences, emigration of technical experts, technical assistance programs) or by industrial espionage [9].

(9) The passing of theoretical and practical skills and know-how from the owner of a technology to outside users or beneficiaries of technology. Technology transfer is in comparison to technology cooperation an isolated and time-limited transaction. Technology transfer is not simply about the supply and shipment of hardware across international borders. It is about the complex process of sharing knowledge and adapting technology to meet local conditions [10].

(10) The diffusion of practical knowledge from one enterprise, institution or country to another. Technology may be transferred by giving it away (e.g., through technical journals or conferences); by theft (e.g., industrial espionage); or by commercial transactions (e.g., patents for industrial processes) as well as through cross-national exchanges among components of multinational enterprises. The transfer of technology may be accompanied by transfer of legal rights to use of the technology, such as sale of licensing of associated intellectual property rights [11].

As can be seen in the previous various definitions of technology transfer, the most common key concepts are: *knowledge transfer* and *training.* This will be further evaluated in the following paragraph.

B. Definition of Knowledge Transfer

In this part, current definitions of knowledge transfer, an in depth review of the types of knowledge, followed by discussion of the problems and challenges of knowledge transfer in the related literature will be presented.

1. Definitions in the current literature:

(1) The act of transferring knowledge from one individual to another by means of mentoring, training, documentation, and other collaboration [12].

(2) Effective sharing of ideas, knowledge, or experience between units of a company or from a company to its customers. The knowledge can be either tangible or intangible [13].

(3) The practical problem of getting a packet of knowledge from one part of the organization to another (or all other) parts of the organization [14].

2. Types of knowledge

There are four main types of knowledge defined: "Embrained, encultured, embedded and encoded [15]. It should be mentioned, that these knowledge types can be applied to any organization, not just those that are knowledge-based heavy. All knowledge types which are mentioned are relevant to technology transfer, as can be seen in the mentioned examples.

(1) Embrained knowledge:
   a. It is dependent on conceptual skills and cognitive abilities. We could consider this to be practical, high-level knowledge, where objectives are met through perpetual recognition and revamping.
   b. Example*:* Special skills are often attached to certain key-persons. Only they know how to handle rare critical situations which are not documented.

(2) Encultured knowledge:
   a. It is the process of achieving shared understandings through socialization and acculturation. Language and negotiation become the discourse of this type of knowledge in an enterprise.
   b. *Example:* The corporate culture, the way of doing things might be different from the two sights which are involved in the transfer. Therefore one and the same situation might be handled different dependent on the location.

(3) Embedded knowledge:
   a. It is explicit and resides within systematic routines. It relates to the relationships between roles, technologies, formal procedures and emergent routines within a complex system.
   b. *Example*: Standard and routine tasks are documented business processes. This makes sure, that independent of the individual the work is done in a proper way.

(4) Encoded knowledge
   a. It is information that is conveyed in signs and

symbols (books, manuals, data bases, etc.) and decontextualized into codes of practice. Rather than being a specific type of knowledge, it deals more with the transmission, storage and interrogation of knowledge.

3. Success factors, problems and barriers to knowledge transfer

Knowledge transfer is considered to be more than just a communication problem. If it were merely that, then a memorandum, an e-mail or a meeting would accomplish the knowledge transfer. It is more complex because knowledge resides in organizational members, tools, tasks, and their sub-networks. Therefore moving technology or tasks from one factory to another is more effective when accompanied by moving the related experts because they are capable of adapting the tools and technology to the new factory. People play the most critical role in the success of technology transfer [16].

The literature mentions a number of success factors, problems and barriers to knowledge transfer.

(1) Causal ambiguity, barriers to imitation, and sustainable competitive advantage:
Barrier: Causal ambiguity: "basic ambiguity concerning the nature of the causal connections between actions and results" [17].

(2) The codification of knowledge: A conceptual and empirical exploration:
Success factor: To the extend that knowledge can be codified, it is possible to exploit some of the non-standard commodity features of information including the possibility of non-rivalry in use and the low *marginal* cost of reproduction. These features in principle may reduce the cost of technology transfer.
Barrier: Tacitness of knowledge: "implicit and non-codifiable accumulation of skills that results from learning by doing" [18].

(3) Motivation, knowledge transfer, and organizational forms:
Success factor: Intrinsic motivation enables the transfer of tacit knowledge under conditions in which extrinsic motivation (i.e. monetary benefits) fails [19].

C. Perspectives on Intra-firm/International Technology Transfer

The previous section described current definitions, success factors, and barriers to technology transfer. The close relationship with knowledge transfer was explained. In the following the literature on intra-firm and international technology transfer will be evaluated more in detail. General problems associated with knowledge transfer from previous case studies will be presented.

1. Success/failure experience and the cost of semiconductor technology transfer

The following will summarize the main findings out of "Perspectives on the success/failure experience and the cost of semiconductor technology transfer" [20] which are relevant to this study.

(1) Referring to types of knowledge, as defined earlier, technology can be classified in 3 categories:
   a. Product-embodied technology
   b. Process technology
   c. Management techniques and skills

(2) Technology transfer between experts yields more consistent value.

(3) One measure for success of a transfer for semiconductor technology is minimum yield incentive. It provides a valuable benchmark in completeness of the technology transfer.

(4) Buyers without a substantial know-how base must be prepared for long-term continuing support. The direct cost of the transfer is just a drop in the bucket. The buyer should also be aware that the direct costs of transferring technology may turn out to be a fraction of the total cost incurred to effect the new skills, processes, etc.

(5) The difficulty seems to lie in the actual process of transferring know-how from one person to another or one location to another. Difficulty seems to crop up even when the skilled people are transferred with the technology.

2. The typology of intra-firm knowledge transfer: case studies on semiconductor firms

Mao pointed out, that in the knowledge economy era a firm's competitive edge increasingly depends on the possession of knowledge and intellectual capital [21]. Knowledge becomes the key resource for firms, and firms must increase the attention they pay to knowledge management. A very important issue regarding intra-firm knowledge transfer is to identify the model and circumstances in which knowledge can effectively be transferred. However the authors conclude that external benchmarking may not always be the best way to solve problems and maintain competitive advantage. Firms can retain competitive edge by efficiently and effectively applying practices developed in-house.

3. Intra-firm technology transfer by Japanese multinationals in Asia

Urata concludes that an increase in the resources expended for technology transfer does not realize technology transfer if the resources are spent wastefully [22]. To deal with this problem, Urata adapted a different approach. He evaluated the extent of technology transfer achieved by assessing who, either staff from the parent firm or local staff, has responsibility for managing technologies. Technology transfer is deemed to have been achieved if local staff is in charge of managing technologies. This finding will be later used as a key performance indicator (KPI) of the case study.

4. International intra-firm transfer of management technology by Japanese multinational corporations

Urata describes that basically two types of technology transfer involving Multinational Corporations (MNCs) can be identified [23]. One is technology transfer from parent firms of MNCs to their overseas affiliates, and the other is technology transfer from overseas affiliates of MNCs to local firms. The former type of technology transfer is characterized as intra-firm technology transfer, what is relevant to this case study. Intra-firm technology transfer is carried out by various means, including work experience (on the job training), and training programs to local employees.

The following success factors were mentioned:

(1) Availability of high quality of labor is found to promote technology transfer for the countries in Asia.
(2) Development of capable workers through education and training is very important, because without them technology transfer is impossible.
(3) Development of competitive manufacturing sector is important for technology transfer. With competitive local industry, overseas affiliates can increase interaction with local manufacturing firms.

5. Intra-firm technology transfer success factors and barriers

It is argued that the strategies needed to facilitate an effective intra-firm technology transfer process must be holistic, based on an analysis of the entire transfer process and the environment in which it is embedded [24]. Good project managers engaged with technology transfer projects must possess multifunctional and multidisciplinary knowledge which is met with respect by other company colleagues [25].

As shown in a case study of an intra-firm technology transfer where knowledge is distributed geographically, sending technical stuff to the overseas facility will ensure that individuals are socially and not merely functionally integrated into the multinational organization and therefore be beneficial to the project. Time and cost constraints may create a barrier to effective technology transfer, because of higher uncertainties involved where multiple geographically separated business units are concerned. Further it is concluded that where there is evidence of a strong marketing input into the process of intra-firm technology transfer then this increases the incentive to manage the transfer process successfully in order to meet external market expectations [26].

6. Intra-firm technology transfer model

The Intra-firm technology transfer model considers the case, that a company acquires a factory having the desired technology which should be transferred to the headquarters. The model proposes that for a successful technology transfer the following points must be considered [27]:

(1) Approach the transfer process in a systematic and deliberate manner.
(2) Transfer team, called “Maestros of Technology.”
(3) Communications regarding the transfer are channeled through the team leaders.
(4) Proper infrastructure to permit transfer to be set up.
(5) Assemble a competent team to execute the transfer process:
    a. One group at the headquarters, one at the acquired company.
    b. The two groups are on the same team with clear and open communication.
    c. Team involves in developing schedules and budgets and preparing the new site.
(6) Preparations before the transfer: Select and train the employees for the new site at the facility of acquired company.
(7) Keep appropriate amount of inventory of the product, in case there are delays in the transfer.
(8) As parallel production facilities are set up half the equipment stayed at the old site, half relocated to the new site.
(9) As the new site is qualified and the production specifications are achieved. Relocate the remaining equipment to the new site. Full production begins, quality is monitored, the transfer team is disbanded. A subset of the model is shown in Figure 1:

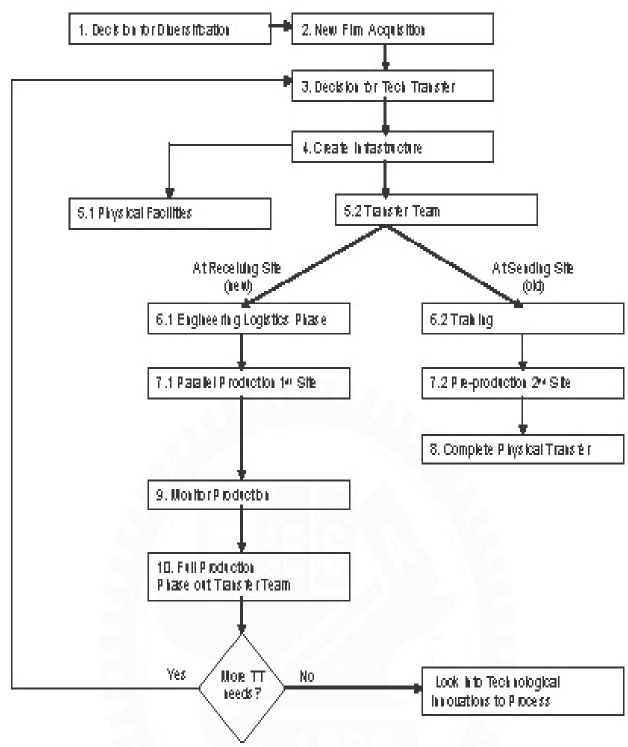

Figure 1 Intra-firm Technology Transfer Model

D. Methodology

This section will describe the “case study methodology”, which is the same research methodology used in this study. The case study is one of several ways of doing social science research. Other ways include experiments, surveys, multiple histories, and analysis of archival information [28]. Rather than using large samples and following a rigid protocol to examine a limited number of variables, case study methods involve an in-depth, longitudinal examination of a single instance or event: a case.

They provide a systematic way of looking at events, collecting data, analyzing information, and reporting the results. As a result the researcher may gain a sharpened understanding of why the instance happened as it did, and what might become important to look at more extensively in future research. Case studies lend themselves to both generating and testing hypotheses [29].

There are six primary sources of evidence for case study research. The use of each of these might require different skills from the researcher. Not all sources are essential in every case study, but the importance of multiple sources of data to the reliability of the study is well established. The six primary sources identified by Yin are documentation, archival records, interviews, direct observation, participant observation and physical artifacts [30].

No single source has a complete advantage over the others; rather, they might be complementary and could be used in tandem. Thus a case study should use as many sources as are relevant to the study. Table 1 indicates the strengths and weaknesses of each type:

In this study the methods of “documentation”, “interviews” and “participant observation” by the authors will be applied.

1. Documentation method

Documents could be letters, memoranda, agendas, study reports, or any items that could add to the data base [31]. The validity of the documents should be carefully reviewed so as to avoid incorrect data being included in the data base. One of the most important uses of documents is to corroborate evidence gathered from other sources. The potential for over-reliance on document as evidence in case studies has been criticized. There could be a danger of this occurrence if the investigator is inexperienced and mistakes some types of documents for unmitigated truth. Archival records could be useful in some studies since they include service records, maps, charts, lists of names, survey data, and even personal records such as diaries. The investigator must be meticulous in determining the origin of the records and their accuracy.

2. Interviews method

Interviews are one of the most important sources of case study information [32]. The interview could take one of several forms: open-ended, focused, or structured. In an open-ended interview, the researcher could ask for the informant's opinion on events or facts. This could serve to corroborate previously gathered data. In a focused interview, the respondent is interviewed for only a short time, and the questions asked could have come from the case study protocol. The structured interview is particularly useful in studies of neighborhoods where a formal survey is required. The use of tape recorders during the interviews is left to the discretion of the parties involved.

TABLE 1 STRENGTHS AND WEAKNESSES OF DIFFERENT TYPES OF CASE STUDY METHODOLOGY

Source of Evidence	Strengths	Weaknesses
Documentation	• stable - repeated review • unobtrusive - exist prior to case study • exact - names etc. • broad coverage - extended time span	• retrievability - difficult • biased selectivity • reporting bias - reflects author bias • access - may be blocked
Archival Records	• Same as above • precise and quantitative	• Same as above • privacy might inhibit access
Interviews	• targeted - focuses on case study topic • insightful - provides perceived causal inferences	• bias due to poor questions • response bias • incomplete recollection • reflexivity - interviewee expresses what interviewer wants to hear
Direct Observation	• reality - covers events in real time • contextual - covers event context	• time-consuming • selectivity - might miss facts • reflexivity - observer's presence might cause change • cost - observers need time
Participant Observation	• Same as above • insightful into interpersonal behavior	• Same as above • bias due to investigator's actions
Physical Artifacts	• insightful into cultural features • insightful into technical operations	• selectivity • availability

Data sources [30]

3. Participant observation method

Participant observation is a unique mode of observation in which the researcher may actually participate in the events being studied. This technique could be used in studies of neighborhoods or organizations, and frequently in anthropological studies. The main concern is the potential bias of the researcher as an active participant. While the information may not be available in any other way, the drawbacks should be carefully considered by the researcher.

To practically perform a case study, the literature suggests following six steps [33]:

a. Determine and define the research questions
b. Select the cases and determine data gathering and analysis techniques

c. Prepare to collect the data
d. Collect data in the field
e. Evaluate and analyze the data
f. Prepare the report

III. CASE STUDY

The technology transfer in this case was organized in a project with 3 sub-projects: Business Unit, fab Europe and fab Asia. The overall project leader is located in the business unit in Europe. The sending site is the fab Europe and the receiving site the fab Asia. The flow of communication, people, technology, material and funds was evaluated.

A. Research Framework

This case of technology transfer is handled as a project. The key performance indicators (KPI) of the project are defined as the time necessary for the transfer to be completed, the accumulated cost of the project and the fulfillment of the product and quality specifications. Additional to the common project target a further KPI "Independence" is added, that describes how independent from the sending site the technology could be run at the receiving site. "Independence" is measured in how many percent of the people in the core team at the receiving site are local and not from the sending site. Table 2 below shows the actual achievements vs. the plan. 100% means that the plan is met. Numbers greater than 100% represent over-achievement, numbers lower represent underachievement.

TABLE 2. ACTUAL ACHIEVEMENT VS. PLANNED

	Plan	Actual	Comment
Time	100%	118%	Target was achieved earlier as planned.
Cost	100%	95%	The budget was exceeded
Spec	100%	90%	Product requirement not fully met
Independence	100%	75%	After project end, still support needed.
Average	100%	95%	

The average achievement is 95%. One could interpret this that the target was successfully met. There is no weighting done. It is very difficult to judge, which factor is more important. In order to do this it would be necessary to translate Time, Cost and Spec into money. Faster time leads to an earlier time to market and dependent on the demand an earlier return on invest and maybe even at a higher price. Higher cost; of course directly influence the financial performance of the company. A reduced spec might lead to lower prices the company could achieve for the product, but this is also dependent on the specific customer needs. It's also hard to judge, how important independence from the sending site is. If foreign stuff is still needed, it of course increases the headcount cost during production. But on the other hand is this only a minor contributor to the total cost of a wafer fab.

All the factors are interconnected. In this case the management put the top priority on time. As the result shows, the transfer could be finished ahead of schedule: Cost, Spec and Independence were from 2nd priority. The project was completed several months ahead of schedule resulting in a score of 118%. On the other hand the budget was exceeded slightly by 5% due to more material and manpower needed to pull-in the project end. Due to the high time pressure also some compromise was taken in the fulfillment of the product specifications: 1 of 5 items did not pass. It was agreed with the management to fix it during the ramp up phase.

1. Analysis of the project setup

As seen in the case study before the following elements are from importance in order to understand the results. Case study framework:

(1) Project organization
(2) Communication flow
(3) Flow of people
(4) Flow of technology
(5) Flow of material
(6) Flow of funds

In the following each element of the framework will be discussed in more detail and evaluated, how it can influence to overall performance of the project's KPIs.

(+) means positive influence
(-) negative influence
(1) Project Organization
(-) Matrix organization
(+) Huge company with many resources

The most important part or core of the project is fab Asia. That's where major part of project takes place resulting in high number of direct reports. The success or failure of the whole project is created there. This means that company wide the management focus is in fab Asia as well.

As described above, the project is set up as a matrix organization, which brings some "built-in" conflicts, like conflicts between local manager and project managers. In this case the local project manager at the receiving site in Asia is reporting to two superiors: the local technology manager and the overall project leader. The local technology manager may have different ideas about how to run this project and urges the local project manager to run the project "our own style". In fact, the responsibilities are clearly defined. But after some technical problems arose, responsibility conflicts between the local project leader in the fab Asia and the overall project leader were created.

Therefore the matrix organization is here considered as having a negative impact to the project compared with a strict line organization. On the other hand the multinational company has a huge pool of resources which are "loosely" assigned to the project (support functions) and could be pulled in for support if requested from the management.

2. Communication flow

(-) Culture

(-) Language
(-) Time
(-) Place

The project setup goes above continents: From Europe to Asia. This brings several difficulties along. Because of the long distance, the control of the overall project leader is limited. The progress of the project can not be monitored so closely and the local project manager in Asia is sometimes bypassing the overall project leader and communicating directly with the project manager at the plant in Europe. As described already this would be correct in case of purely technical discussion, but not for steering the project. The ability of the overall project leader to control the different subprojects is dependent on several factors. The only factor which can be changed by the overall project leader immediately is "Place", meaning the location of his own office. Other factors like the corporate organization are given and can not be changed easily. Table 3 (Europe) and Table 4 (Asia) below are summarizing the level of control of the overall project leader dependent on his location.

TABLE 3. ACTUAL LEVEL OF CONTROL OF THE OVERALL PROJECT LEADER DEPENDENT ON HIS LOCATION

Actual	**Overall project leader**	**Business unit**	**Sending site**	**Receiving site**
Location	Europe	Europe	Europe	Asia
Place difference	(-)	Same	Close	Very far
Time difference	(-)	Same	Same	6/7h shift
Organizational relation	(-)	Line	Assigned to project	Assigned to project
Culture and Language	(-)	Same	Same	Different
Level of control of overall project leader	(-)	Very Strong	Strong	Weak

This means, that the most important and crucial relationship between overall project leader and the subproject leader in the fab Asia is weak! In order to increase the level of control of the overall project leader about the project leader in the fab in Asia, it is proposed to relocate the over all project leader to Asia. As shown below, this will result in the following level of controls:

TABLE 4 ACTUAL LEVEL OF CONTROL OF THE OVERALL PROJECT LEADER DEPENDENT ON HIS LOCATION

Proposed	**Overall project leader**	**Business unit**	**Sending site**	**Receiving site**
Location	*Asia*	Europe	Europe	Asia
Place difference	(-)	*Very far*	*Very far*	*Same*
Time difference	(-)	*6/7h shift*	*6/7h shift*	*Same*
Organizational relation	(-)	Line	Assigned to project	Assigned to project
Culture and Language	(-)	Same	Same	Different
Level of control of overall project leader	(-)	Very Strong	Strong	*Strong*

By that move it is assumed, that the overall project leader will not loose control of the Business Unit, because they are still in the same line organization. Besides that the same culture and language will also strengthen their ties. The control over the fab in Europe might be a bit weakened, but is still considered as strong, because of the same culture and language background and the fact that the project leader at the business unit could act "on behalf of" the overall project leader to control the plant in Europe. Despite the different culture, language and line organization, the overall project leader could have strong control over the local project manager in Asia. Just due to the fact to be on-site and "visible", the level of control will be increased strongly.

3. Flow of people
(-) Place
The big geographical difference makes face to face meetings between team members in Europe and Asia difficult. Another reason for low frequency of visits between the fabs might be that the team was so busy in fulfilling the tight time schedule, that there was no time left for those trips. The lowest frequency of visits is surprisingly exactly the crucial one for acquiring knowledge by the fab Asia from fab Europe. This might be one explanation for the fact that product and quality requirements at the end of the transfer were not fully met.

4. Flow of technology
(-) Tools and material
(-) Knowledge difference
The engineers in fab Asia are mostly newly hired. That means they are not familiar with the systems in the company. Besides that there is lack of specific knowledge in the technology which must be transferred. As a consequence some of the earlier mentioned codified knowledge can not immediately be transferred. In addition some tools and materials in the fab Asia differ from the sending site. The transfer methodology is "copy smart" and not "copy exactly". Additional engineering effort is necessary to make necessary adaptations.

5. Flow of material
(-) Place
Time for transportation one way (send and receive) is approximately 3 days. In addition air freight transport is costly, which makes spontaneous exchange of material for engineering purposes difficult. However this is not crucial for the success of the project.

6. Flow of funds
Due to the lower overall costs in Asia this should be beneficial to the project cost. It is difficult for the overall project leader to exactly control the cost, because the sub-project leaders just book their cost to the project account. There is no financial controller directly in the project. The sub-project leaders are not responsible for the budget; they

are only responsible to achieve their technical targets in time and specification. For example the number of consumed engineering wafers exceeded the budget without knowledge of the overall project leader. This is one reason, why the budget was exceeded.

B. Summary of Project Setup

Table 5 below summarizes the findings related to the project setup. The difficulties arising are general for big international projects and not very specific to the case here. However as pointed out before the Communication flow is especially bad because of the project setup.

C. Case Study Analysis

This part analyzes the actual setup vs. suggestions in the Literature. Table 6 summarizes all the barriers and success factors out of the literature research and applies it to the case of study. In the column "This case" the relevance of the respective barrier or success factor (from literature) is evaluated in respect to the actual situation in the case. If a barrier is applicable, the score will be (-1). If a success factor is applicable, the score will be (+1). The results will be used to explain the actual performance measured in the KPIs.

TABLE 5 SUMMARY OF FINDINGS RELATED TO PROJECT SET UP

	Positive	**Negative**	**Impact**
Project organization	Huge MNC	Matrix org	Responsibility conflicts
Communication flow		Culture & Time & Place	Bad communication and project control
Flow of people		Place	Rare face to face meetings
Flow of technology		Tools & knowledge	Technical difficulties
Flow of material		Place	No impact to the project
Flow of funds	Place		Low cost in Fab Asia

TABLE 6 THE SUMMARY OF ALL THE BARRIERS AND SUCCESS FACTORS

No.	**Barrier**	**Success factor**	**This case**	**Score**
1	Causal ambiguity		Actual technical problem. Relation between cause and effect is not clear.	(-1)
2		Codification of knowledge	Tool recipes and process descriptions are available.	+1
3		Intrinsic motivation	Team in Asia is highly motivated to learn.	+1
4		Trained teams of people	The complete transfer team got trained at the sending site.	+1
5	Strong independent individuals		Overall project leader and the project leader in Asia with overlapping responsibilities and different management styles.	(-1)
6	Transfer of a complete team to a foreign country is difficult		It is not possible to transfer the complete team from then sending site to the receiving site. A new team at the receiving site was setup and trained at the sending site.	(-1)
7		Obtaining know how by acquiring experts.	Know how is already available at the sending site. No budget for hiring external experts.	0
8	Difficulty of transferring knowhow even with skilled people		Technical problems arose in spite of well-trained people.	(-1)
9		Availability of high quality of labor	Not available in this region.	(-1)
10		Development of capable workers through education and training	Big effort is spent to educate and train local labor.	+1
11		competitive local industry	Wafer fab technology is not very common in this area.	(-1)
12		Project managers must possess multifunctional and multidisciplinary knowledge	Project managers at sending and receiving site are experienced and fulfill these criteria.	+1
13		Sending technical stuff to the overseas facility.	Engineers from the receiving site were trained at the sending site.	+1
14	Time and cost constraints		Not sufficient time and funds for engineers to fully optimize the product at the receiving site.	(-1)
15		Strong marketing input	High demand for the product pushes the project.	+1
16		Approach the transfer process in a systematic and deliberate manner	Professional project planning and setup was done	+1
17		Infrastructure: including facilities; equipment; and personnel	Professional project planning and setup was done	+1
18		Transfer team called Maestros of Technology	Team with responsible leaders was setup.	+1
19		Include teams at the sending and receiving site	Dedicated teams in fab Europe and fab Asia were setup.	+1
20		Communications are channeled through the team leaders	Clear channels are established.	+1
21		The smaller the team the better	The teams in sending and receiving site are relatively small.	+1
22		People work best in trust and healthy competition.	The people at the sending site are afraid of loosing their job. Support only on request.	(-1)
23		Building teamwork and motivation are critical	Team at the receiving site is highly motivated.	+1
24		Success depends on the quality of people performing the task	Team at the receiving site is not experienced in this technology.	(-1)
	TOTAL (-9 + 14)			**+5**
	Relative (0 – 100%)			**60%**

Out of 24 items of barriers and success factors for technology transfer, a positive score of +5 (60%) could be achieved. There is no weighting done here, meaning that all items are treated with the same importance. This might not be correct; however, we can conclude that more items are supportive to the transfer than hindering it. In the actual project setup the management considered many points, which could be found in the literature as well. This agrees with the overall positive result of the project as can be seen on KPI in the previous chapter. However, there is still room for further improvement.

IV. CONCLUSION

Due to the technological progress in IC-manufacturing, the market continues to increase in demand of about 8-10% per year. Technology transfer of the highly sophisticated manufacturing process comes into play if, for example like in this case, the established technology should be used in another manufacturing site. Technology transfer is closely related to knowledge transfer. It's a time limited transaction and treated as a project.

A structured and organized procedure with dedicated teams at the sending and receiving site is necessary. Technical execution wise the "copy smart" methodology is applied in this case study. The case study methodology is a widely accepted research method and the data were gathered by participant observation by the author. The technology transfer in this case was organized in a project with 3 sub-projects: Business Unit, fab Europe and fab Asia.

The overall project leader is located in the business unit in Europe. The sending site is the fab Europe and the receiving site the fab Asia. The flow of communication, people, technology, material and funds was analyzed in detail. Comparing the actual project setup with the recommendations for technology transfer out the literature, the project follows 60% of it. The average achievement in KPI of the transfer project is 95%. One could interpret this that the target was successfully met, however there is still potential for improvement. For future transfers to come, the proposal is to relocate the overall project leader from the Business Unit Europe to the fab Asia. This could help to get better control of the project and therefore be more focused in achieving all targets.

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