13th Cambridge International Manufacturing Symposium

Title:

**Means for transferring knowledge in the relocation of manufacturing units**

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From June 2008, Carlsberg Breweries A/S,

Ny Carlsberg Vej 100, DK-1760 Copenhagen, Denmark

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Keywords: Knowledge transfer, Manufacturing unit, Means, Complicated technology, Emulation

**Abstract**

Based on case studies and action research, this paper investigates and discusses appropriate means for transfer knowledge when relocating manufacturing units. The cases include relocations both within the country and overseas. A framework for identifying suitable means is developed based on the situations which are extracted from the cases. Two parameters are used to classify the situation: the complexity of knowledge, and the environment for transferring the knowledge. Four different groups of means are identified from the case studies; 1) Documents or manuals and peer-to-peer training, 2) Scenarios on real systems, 3) Prototypes and games, and 4) Emulation. These means are evaluated based on the parameters in the framework and proper means are positioned in the framework. This framework can be used to support learning to develop knowledge in the new manufacturing unit.

**Introduction**

As a consequence of today's globalization and fierce competition, manufacturing companies often establish a new manufacturing unit on a new site or move a production unit to another existing manufacturing unit. For rationalization purposes, manufacturing units have been merged together into larger units or manufacturing units have been transferred to low cost countries in other parts of the world (Ferdows, 1997). The relocation has also aimed to support local markets due to changes in markets or custom conditions.

There are several aspects to be considered in the relocation project and many stakeholders are affected. Once the relocation decision has been made, it is important that it is successfully implemented within the time frame and budget. Studies of German manufacturing companies show that the outsourcing process takes 2½ times longer that expected and that 17% of the companies that had outsourced their activities 4½ years later backsourced their activities again (Kinkle & Samola, 2008). It is obvious that relocation of a manufacturing unit includes a number of tasks like the move of equipment, systems and facilities. However, studies point in the direction that the most difficult part to transfer is knowledge and experience. The knowledge transfer is obviously one of the success criteria. Several case studies from Intel, FIAT, Toyota and Komatsu report at the more abstract level about the success of relocations or the establishment of new manufacturing units but without providing a deeper understanding of knowledge transfer on the operational level. (Ferdows, 2006; Patriotta, 2003; Dyer & Nobeoka, 2000; and Morton, 1994).

The challenge of knowledge transfer increases considerably when the knowledge to be transferred is tacit. Naturally, tacit knowledge is more complex and harder to transfer than explicit knowledge. Several studies (Kustere, 1978; Orr, 1996 and Patriotta, 2003) show that basic knowledge about operating the equipment is relatively easy to learn for employees, but supplementary knowledge, such as skills to solve malfunctions, disturbances and interruptions, is much more difficult and time consuming to learn because these skills are mainly tacit.

The knowledge transfer process is similar to most learning processes in a way that it activates people to be able to build up tacit knowledge and competences among employees (Leonard, 2007). In this research, the focus area is the means which stimulate the employees to learn to operate the complicated manufacturing equipment in a more efficient way. The ideas are drawn from studies about simulation and games in production management (Riis et al., 1995) and from research in the field of adult and lifelong learning (Faure et al. 1972; Merriam & Caffarella, 1999), where reflection is used to activate people in a learning situation. Regarding reflection, we use a learning approach as suggested in a study by Wahlgren et.al. (2002).

The intention of this paper is to identify different dimensions of knowledge related to the level of complication of the knowledge and then to identify and discuss different means for supporting the transfer and development of knowledge. Thus, from the academic perspective, this paper aims to make complicated technologies easier to be understood by operators and, more tangible to learn. In this way, the knowledge becomes simpler to be transferred. From the practical perspective, this paper aims to identify and to suggest suitable training means and tools for transferring knowledge when a new manufacturing unit is to be established on a green field or on a brown field in global production. The paper will be organized as following. The first section is a literature review in the area of knowledge management with a focus on transfer of knowledge. The second section is the empirical background which includes two case studies and two cases of action research. The four cases are ranging from relocation of manufacturing units within Denmark and relocation of manufacturing units from Denmark to other parts of the world. Finally, a two-dimensional framework for positioning different types of knowledge is suggested. Furthermore, four groups of means are identified, discussed and concluded to help accelerating knowledge transfer in the context of relocations of manufacturing units.

**Literature review**

According to Drucker (1993), Toffler (1990), Quinn (1992), Reich (1991), and Nonaka (1994), a new economy or society, “The knowledge Society” arrives, in which knowledge plays a key role. Drucker argues that in the new economy, knowledge is not just another resource alongside traditional factors of production, e.g. labor, capital, and land; but the only meaningful resource today. The emerging knowledge-based view of the firm (Kogut and Zander, 1992; Nonaka, 1994; Zander and Kogut, 1995; Grant, 1996a, b; 1997; Spender, 1996) suggests that the key role of the firm is in creating, storing and applying knowledge, where the firm is an institution for knowledge integration. Therefore, more and more researchers pay attention to knowledge management. According to the theoretical framework of Argote et al. (2003), there are three dimensions of knowledge management: creation, retention, and transfer, which are echoed by Krogh et al. (2001), who argue that the two core processes of knowledge creation and transfer are central to the execution of strategies for managing knowledge. This paper will only focus on the last one, knowledge transfer, although it has obvious overlaps with general knowledge management. The specific focus of knowledge transfer is the processes by which members within an organization learn from each other. Generally, there are two main research fields for knowledge transfer: (1) attempts to explain the factors that drive or hamper transfer and (2) attempts to explain how to transfer knowledge. This paper will mainly focus on answering some issues in the second field - how to transfer knowledge. The position of this paper in the framework of knowledge research could be shown in figure 1.



*Figure 1: The position of this paper in the framework of knowledge research*

On one hand, from the point of view of research scope, two scopes in the context of knowledge transfer can be distinguished, namely intra-firm transfer and inter-firm transfer. A notable example of the first scope is Szulanski’s multi-company, multi-practice study of factors leading to internal best practice transfers difficult (Szulanski, 1996, 2000). He finds that intra-firm practice transfer is most hindered by three knowledge barriers: the recipient’s lack of absorptive capacity, causal ambiguity about exactly how the practice works, and an arduous relationship between the source of practice and the recipient. For inter-firm transfer, Dyer and Nobeoka (2000) give an excellent example based on how Toyota creates and manages its high performance knowledge sharing network. They show how Toyota solved three fundamental dilemmas with regard to knowledge transfer by devising methods (including supplier association committee meetings, supplier association general meetings, voluntary learning teams, consulting/problem solving teams, and inter-firm employee transfers).

On the other hand, from the content of research point of view, three aspects of research could be generalized, namely knowledge transfer strategy, knowledge transfer process, and means used in knowledge transfer. For knowledge transfer strategy, Krogh et al. (2001) consider knowledge transfer in the knowledge domains to which the “community of practice” participants contribute. They argue that there are two different types of knowledge domain: existing and new. By combining knowledge transfer and knowledge domain, they further propose two strategies for knowledge transfer in different knowledge domains: leveraging strategy and appropriating strategy. The similar research could be found from Williams (2007), as he explores two different strategies in knowledge transfer relationships: replication and adaptation. He develops a model of knowledge transfer in which firms replicate because knowledge is ambiguous and adapt because knowledge depends on context. In the model, firms replicate more when knowledge is discrete and adapt more when they understand the interactions between different areas of knowledge. More specially, as adaptation almost invariably accompanies the cross-border knowledge transfer, Szulanski and Jensen (2006) show there are two conflicting approaches to adaptation. The first, following institutional, motivational, and pragmatic efficiency considerations, presumes that a modified practice can be fine tuned, stabilized, and institutionalized without consulting a working example and that practices thus should be adapted as quickly as possible to create fit with the local environment. The second approach argues, instead, for the need to maintain the diagnostic value of the original practice by adapting cautiously and gradually. In the paper, they investigate the relationship between presumptive adaptation and transfer effectiveness and report that presumptive adaptation of knowledge assets could be detrimental to performance.

Much research may be found within the area of knowledge transfer process. Szulanski (2000) discusses intra-firm transfer of best practices and argues that one first step toward incorporating difficulty in the analysis of knowledge transfer is to recognize that a transfer is not an act, as typically modeled, but a process. Taking these as the outset, he proposes a process model of knowledge transfer, which includes four stages (initiation, implementation, ramp-up, and integration) and four milestones (formation of the transfer seed, decision to transfer, first day of use, and achievement of satisfactory performance). Although the sequence of stages is broadly consistent with Szulanski (1996, 2000)’s model of practice transfer, Maritan and Brush (2003) observe a greater number of distinct stages particular to flow manufacturing that they think are important to recognize. They identify two sequential, multi-stage sub-processes, which are labeled pre-implementation and implementation. Comprehensively, there are four stages of pre-implementation: (1) assess plant endowment, (2) train plant management, (3) redesign processes, (4) disseminate training and buy-in; and four stages of implementation: (5) initiate implementation, (6) stabilize and consolidate, (7) use new skills competitively, (8) leverage and exploit benefit. Some other scholars also confirm that the knowledge transfer between two or more actors can be defined as the process by which the knowledge of one actor is acquired by another (Cutler, 1989). Meanwhile, Albino et al. (1999) also conceptualize the knowledge transfer process as the combination of two components: “the information system” and “the interpretative system”, related to an operational and a conceptual level of analysis respectively. They also argue that there are five stages in the interpretative system, which are acquisition, communication, application, acceptance, and assimilation.

For means used in knowledge transfer, Argote et al (2003) categorize different means into three aspects: ability (e.g. training, could increase an individual’s ability to transfer knowledge accumulated from one task to a related task), motivation (e.g. social rewards and monetary rewards), and opportunity (e.g. reducing the amount of distance, providing the environment for learning by observation, informal network). More specifically, Corso (2002) sheds light on how management can and should design means to facilitate knowledge transfer in a continuous product innovation perspective. He argues that eight classes of product innovation levers can be used: product family strategy, process definition, organizational integration mechanisms, human resource management policies, project planning and control, performance measurement, design tools and methods, computer-based technologies.

However, according to the above literature review, it seems clear that most research emphasizes the organizational level and predominantly from a cognitive perspective; even several scholars have tried to combine knowledge with manufacturing. For example Grant and Gregory (1997) use life cycle model as the basis for a discussion of knowledge accumulation, and hence for manufacturing process transferability over time and Ferdows (2006) discusses transfer of changing production know-how and suggests a framework, which focuses on the interplay between the level of codification and the rate of change of production know-how. As Ferdows (2006) points out: “… *scholars in the field of operations management are almost absent in the knowledge management literature and our practitioners are often relegated to the back seat in their companies’ knowledge management campaigns*”. Thus, connecting knowledge and manufacturing is needed as it also becomes more and more important for industrial companies currently. This is precisely the aspect which this paper pays attention to. Especially, this paper will mainly refer to means which could be used in the process of relocating of manufacturing units.

**Methodology and case description**

The research is based on empirical studies in three large Danish manufacturing companies. According to confidential agreements, the four cases will be mentioned as case Alpha, Bravo, Charlie and Delta in this paper. Case Alpha and Delta are from the same company, but these two cases are not related to each other and take place at different locations. Case Bravo and case Charlie are from the other two different companies. The four cases have been chosen because each case constitutes different technologies and particularly different means, which were used to transfer and to build up knowledge at the new locations.

A case study was made in the plant Alpha where complicated and sophisticated valves were manually assembled on workbenches and on a semi automatic assembly line. The plant was moved and merged into an already existing plant in the same country which was producing similar products, because the firm wanted to gain advantage of large-scale production.

In Bravo, an automatic manufacturing line including four robots and a number of automated manufacturing processes like welding, rolling, turning, grinding and assembling was transferred from Denmark to a green field site in Mexico. Here a large manufacturing building and a new organization were established within half a year to host the line.

Case Charlie involved centralization of Company C's Danish production and warehousing facilities in order to achieve a more efficient operation for production and distribution. This implied a reduction of activities at regional depots and at external warehouses to a minimum level. To facilitate the increase of production and inventory, a large scale automated material handling system was installed at the central production site. This automated materials handling system was considered as one of the biggest in Europe. In this case, a researcher participated as action researchers particularly in the establishment of the automated logistic systems and in training employees to operate and to solve disturbances and malfunctions.

In case Delta, a parallel production of valves was to be established in China with the objective of producing valves to a growing Asian market. During the last forty years, manufacturing processes and methods had been constantly improved in the Danish lead factory. A researcher participated in the initial training of a group of Chinese engineers by testing developed methods. The methods assisted in identifying, training and handling situations of non-normal operation.

Throughout these studies mainly qualitative methods, such as interviews and observations, have been used. However, a survey of documents to unveil the presence of explicit knowledge was made in case Alpha and Bravo, and in case Charlie questionnaires were used to collect feedback among the participants in a training program. With the purpose of bringing themes, ideas, tasks and training means to the surface, the Delphi method was used for evaluation and feedback in case Delta.

In all four cases, nearly all employees from the dispatching units found new jobs or were not influenced by the establishment of the new production facilities, and therefore 95-100% of the employees were new in the receiving context.

The table 1 shows the main methods that have been used throughout the research.

*Table 1: Information summary of four case stories*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Case | Alpha | Bravo | Charlie | Delta |
| Company | A | B | C | A |
| Methods | Case study  (Interviews, observations, surveys) | Case study  (Interviews, observations, surveys) | Action research  (Interviews, observations, lecturing,  Questionnaires. | Action research  (Interviews,  survey,  lecturing ,  training,  Delphi method) |
| # of employees involved | 120 | 90 – 150 | 800 – 950 | 20 – 25 |
| Nature of production system | JIT production | Batch production | Mass production | Batch production |
| Degree of automation | Medium | High | Very High | Low |
| Complexity of knowledge | Low | Low | High | High |
| Established new production on a: | Brown field | Green field | Green field | Brown field |

**Discussion and findings**

***1. A typology of knowledge transferred***

In this study, the focus is on how to transfer knowledge from one location to another within a manufacturing environment. In that sense, our study builds on our previous work about where and how to transfer knowledge (Cheng et al. 2008), about how to identify knowledge on the shop floor (Madsen et al., forthcoming 2008), and how to use modern tools as simulation (Liangsiri, 2007) and emulation to make complicated equipment tangible in a transfer process. The study points in the direction, that it is not possible to find a single global mean, which suits every situation and every nature of the transfer project. Therefore our intention has been to develop a framework where different means can be identified to support the transfer of knowledge in relation to different circumstances. The development of this framework will be discussed by drawing on other studies and on our studies in the field.

***Environment of the receiving unit***

The environment of knowledge transfer is proposed as the first dimension in the discussion. From the case studies, the nature of the environment of knowledge transfer has been observed. The environment can be distinguished into a brown field and a green field on the basis of two aspects, namely soft aspects (accumulated knowledge) and hard aspects (manufacturing equipment for training). Studies made by Cohen and Liventhal (1990) point out that the *“absorptive capacity”* from each individual and the entire organization can be low in a green field and therefore it can be challenging to assimilate new knowledge in the new organization.

Case Bravo made up a typical “green field” by moving the production line into newly established buildings in Mexico where a whole new organization should take over the line. Even though all employees had experiences from similar manufacturing industry; they had to learn to operate new equipments. Moreover, people at all levels in the new organization had to develop new knowledge together. Some of the challenges in training new employees on the shop floor in the green field company were explained during an interview with a Danish worker who acted as a trainer for the Mexican women assembling components as: *“My job was to train 6 to 8 Mexican women. They had just started a week ago, half of them were divorced and they had just learned each other to know, so they had so much to talk about and they had difficulties to concentrate on the training situation”*.

In case Charlie, even though the production was moved to the already existing site, the totally new material handling system was installed. As a result, the way of working was changed and all employees had to learn how to operate this new system. Therefore, this case is also classified as a “green field” by establishing a large and new “one off” logistic system. It was difficult to draw on previous experience as the system was new to the Company C and even to the supplier of the system because the installation was unique. The challenge became even more complicated when the automated material handling system did not exist. Generally, the knowledge transfer during initiation and implementation phase would be done in a “learning before doing” approach (Szulanski, 2003). This situation called for sophisticated training means. Company C, alternatively, pushed the knowledge transfer into a next level. They had done the knowledge transfer during the implementation phase in a “learning by doing” approach with the assistance of an emulation system. The training mean "emulation" will be described later on in this paper.

Particularly case Delta constitutes the “brown field” and called for means at a higher level during the initial training. *“Remember that they are not novices”* was the statement that the project leader emphasized when the initial training program was drawn up for the Chinese engineers who could be described as advanced beginner or at a competent level (Dreyfus, 1986). Case Alpha was also a “brown field”. However it was not until the ramp-up phase, that management realized that they could benefit from the experienced employees in existing organization in the receiving unit by mixing experienced workers from the existing organization with new employees. In that way, they started to learn at a higher level.

***Complexity of knowledge***

As the second dimension, we distinguish the knowledge by its complexity to be either high or low, because different knowledge complexity requires different training means in the transfer process. However, it could be described from many perspectives, e.g. tacit knowledge could be related to high complexity while explicit knowledge could be related to low complexity. Actually, in Case Alpha and Delta, complexity of knowledge is classified by normal operations and non-normal operations while in Case Bravo and Charlie, it is distinguished by the time, cost, scope of the project and many other factors. To some extent, this dimension needs to be considered from context to context.

In fact, as shown in the literature review, there are many different typologies of knowledge, e.g. codifiability, teachability, complexity, system dependence, and product observability (Zander and Kogut, 1995), tacit and explicit knowledge (Polanyi, 1962), etc. However, these typologies mainly focus on describing inherent attributes of knowledge, without paying attention to how to connect them with operation management and apply them in practice. To some extent, the typology proposed in this paper could offset this gap. This typology takes a micro level as a starting point, pays attention to the workshop level, tries to discuss knowledge transfer from an operational and a practical perspective, views workers as primary research objectives, and aims at transferring knowledge to workers in the new locations of manufacturing plants or units. It is obvious that the four cases shown in this paper more or less could be classified into the different zones in figure 2. This typology of knowledge could be helpful for choosing means for transferring knowledge in the relocation of manufacturing units, which will be discussed further in the following section.



*Figure 2: A typology of knowledge*

***2. Means for transferring knowledge in the relocation of manufacturing units***

On the basis of the typology of knowledge introduced above, we will underneath discuss the means that were used in the four cases in relation to the framework.

***Conventional means: documents, manuals and peer-to-peer training***

To define means within low complexity of knowledge, we have been inspired by Leonard (2007). She perceives the *“specific directives”* e.g. WI`s (Work Instructions) and SOP`s (Standard Operational Procedures) to create an environment where the receiver is using *“passive perception”*. Means like WI`s and SOP`s seem to be an important tool around which the initial learning can take place when building up “basic knowledge” (Kustere, 1978). These means can help the employees to be able to operate manufacturing equipment in a situation where everything works as intended. The learning that takes place by the use of instructions and procedures seems to be assimilation learning which also can be denoted as “add to learning” but without creating an environment where the learner can reflect and improve his learning radically (Kolb, 1984; Wahlgren, 2002).

According to our interviews and observations in case Alpha, instructions and manuals served as quick guides with less text and more pictures and were found to be relevant means for training of new workers. In case Alpha, the focus was on peer-to-peer training to transfer experience and knowledge from the experienced workers on the shop floor to the new workers. Workers on the shop floor appreciated this peer-to-peer training for the reason that *“I can ask stupid questions”* as expressed by a new worker during an interview.

This training method seemed to create a learning environment where the experienced worker could act as trainer, and in some occasions the new employee was able to reflect on tasks and the way he was practicing the tasks. The method seemed to work both in case Alpha and in case Bravo as long as equipment and tasks were rather simple. However the more complicated the tasks became, e.g. searching for the causes of a malfunction on a semi automatic assembly, the more sophisticated training means were necessitated.

***Scenarios on real systems***

In the Delta case, the participants were Chinese engineers, who had experience from a similar manufacturing process in China. Therefore, much more complex tasks were planned to be trained, in order to build up knowledge at a higher level. In this case, malfunctions about how to resolve specific problems in operation were dealt with during the training in Denmark. Particular “what-if” scenarios were used as training means. These "what-if" scenarios were based on the real non-normal operation in the manufacturing environment, and the training was carried out on the physically available equipment. The method was used to create an environment for reflection and discussion among the participants. In addition the Delphi method was used for evaluation and reflection and was also found suitable for identifying where to focus in the next steps of the training program.

Kustere (1978) denotes the use of “supplementary knowledge” as complex knowledge that an operator uses during interruptions, malfunctions and disturbances. Leonard (2007) underlines in her studies about knowledge transfer that the “active learning” by using means like “learning by doing” or “guided practice” is able to transfer the complicated knowledge. Having this idea in mind, it is possible to create an environment for accommodative learning (Kolb, 1984) where the learner is given the freedom to reflect by building on his previous experiences during the learning process. In studies from FIAT, Patriotta (2003) explained how employees used the activities of assembling and disassembling a whole car as an important task to develop knowledge about the whole process. That knowledge was particularly useful when malfunctions showed up in an extremely complicated manufacturing system.

The idea of using what-if scenarios turned out to be a very useful method for transferring complicated knowledge such as know-how about non-normal operation in the manufacturing environment. During the evaluation, one of the Chinese engineers expressed that: *“Without these demonstrations, we would never have realized so many small details that we have to be aware of when we are going to start up this production”* and further: *“we have really got good connections to the Danish organization”.*

***Prototypes and games***

In case Bravo, the idea was to make a knowledge transfer through an extensive use of conventional knowledge transfer means, i.e. documents, manuals, instructions and peer-to-peer training, for each individual process on the line. However, the description of malfunctions and non-normal operation was experienced to be very difficult to make. Even with a long tradition of writing down in log books on the line, it was difficult for operators and set-up fitters to describe on paper exactly what was done to solve a particular malfunction that showed up on the line. Thus, the situation was hard as a Mexican manager in the receiving unit stated: “*“we were told that it was easy to run the line and it looked easy – but we later found out that it was much more difficult*”. Research in the receiving unit pointed in the direction that, on the individual level, operators, technicians and managers were well educated and had experience from similar industry. But transferring and developing knowledge on the collective level was experienced to be a large task which lasted much longer time than expected.

The responsible project management experienced that a quick knowledge transfer by the use of documentation and peer-to-peer training by a Danish “traveling team”, which consisted of 23 operators and technicians, was not enough to build up knowledge in the new unit on a green field. Therefore, there seems to be a need of a more effective means for knowledge transfer. By drawing on Riis et al. (1995) and our studies from the use of emulation in case Charlie, we shall in this case argue for the use of prototypes and games as relative simple means to transfer and to establish knowledge on a green field.

In a green field environment, the operator cannot gain experience by training with the real equipment since it does not yet exist. Therefore, a certain environment, which can represent the real system, should be constructed. Prototypes and games seem to reflect two aspects from the environment for knowledge transfer. Prototypes represent the hard aspect where workers and technicians can train and build up knowledge on specific, simple, stand alone equipment before production on a production line. On the other hand, games represent the soft aspect of a production environment. Games are open-source and can be established rather simple by the use of boxes, whiteboards and other available objects. These objects create a learning environment where normal and non-normal situations can experienced and tested with the purpose to build up knowledge on the individual and particularly on the collective level before production in full scale.

***Emulation***

Due to the size and complexity of the systems of case Charlie, it was difficult to use the means mentioned above to transfer and to establish knowledge concerning operation of the system. In addition, the time between when the physical material handling system was installed and when the system had to be in full operation was very restricted. The training of the operators had to start without the physical system. Consequently, Company C decided to use emulation as the mean for knowledge transfer.

Emulation is the ability of a computer program or electronic device to imitate another program or device. In case Charlie, emulation was originally built for the purpose of testing, finding defects and verifying the capability of the high-level control software, as well as transferring knowledge from suppliers to employees in Company C. The emulation model is a virtual model of the system that represents the non-existed system, e.g. the equipment and the reaction of the equipment. As a result of communications between several software and emulation model, the movement of the entity in the model occurs. The user or tester can verify whether the communication is correct by tracing the entity in the model. The operator can observe the reaction of the system to their action.

Approximately 140 test cases were created which include, for example, normal flow situations, error handling situations and difficult situations. These situations were identified from experiences of many years’ production in Company C. To a certain extent, they could be viewed as the accumulated knowledge. However, as the new system does not exist, these situations need to be tested and verified in the new context. During the implementation of the physical system, the operators were trained "on the job" with the model.

The model received positive responses from the users. Based on the questionnaires, the users believed that the emulation model represented the real world and helped them in understanding how the system functions without the real system and without causing any damage to the real world. From the management perspective, emulation had helped to shorten the ramp-up phase of the real system and the error reduction both from the operators and from the system itself. In case Charlie, there is no doubt that emulation was a beneficial training tool. However, it came with an expense. Emulation requires adequate and committed resources. Much effort has to be put into it. Therefore, it is only recommend for a large and complex project with a limited time frame but adequate resources. The cost and effort in developing the emulation model would not be justified if the project is simple, if there is an available real system for training or if there is no time constraint.

Taking the typology of knowledge proposed in this paper and the above discussions as the starting point, different means could be identified and classified into different zones for different knowledge, as shown in figure 3.



*Figure 3: Means for different knowledge*

**Conclusion and implications**

Based on two case studies, two action research studies and a literature review, we have developed a framework to identify different means to support the transfer and establishment of knowledge in a manufacturing environment based on the complexity of the knowledge and the environment of the receiving unit.

To some extent, well arranged documents, manuals and peer-to-peer training seem to form the basis around which an initial learning can take place. The instructions that are drawn up as quick guide, which focus more on pictures and less on text, are useful on the shop floor in a manufacturing environment. However the establishment of a new plant on a green field is much more difficult and this situation calls for other means like prototypes and games for developing knowledge about new equipment and to build up knowledge on the collective level among employees.

Another type of means, i.e. what-if scenarios, is also essential when the complicated knowledge is required to be built. It enables the employee to learn how to handle non-normal operation such as malfunctions, disturbances and interruption in a manufacturing environment.

Our study points in the direction that it is extremely expensive and time consuming to build up knowledge among employees about new, complicated and intangible “one off” systems where a number of different technologies are merged together. Our research also indicates that emulation, which has its roots in testing computer software, can be used to establish knowledge before a new complicated system is put into service and in that way the ramp up phase is shorten down.

Ferdows (2006) argued that scholars from the field of operations management are almost absent in the knowledge management literature and that practitioners are often relegated to the back seat in their companies when it comes to knowledge management. From this research, there are some uncertainties among management about how to transfer knowledge in an environment where production is moving back and forth around the globe. However, the paper has offered a way of structuring means for knowledge transfer. It is believed that much more studies and tests are needed about how to transfer knowledge in a global manufacturing environment where manufacturing facilities are constantly moving.

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