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HETEROGENEITY AND TRANSFERRING PRACTICES: IMPLEMENTING FLOW MANUFACTURING IN MULTIPLE PLANTS

CATHERINE A. MARITAN[1]* and THOMAS H. BRUSH[2]
[1] *School of Management, State University of New York at Buffalo, Buffalo, New York, U.S.A.*
[2] *Krannert Graduate School of Management, Purdue University, West Lafayette, Indiana, U.S.A.*

Adopting new practices to develop capabilities and enhance competitiveness is a goal for many firms. This study of a corporate initiative to implement flow manufacturing in multiple plants highlights some elements of the interaction between the content of a complex practice, the sources of the practice knowledge, and the characteristics and competitive priorities of the recipients of the practice. Heterogeneity among the plants, stemming from both differences in resource endowments and differences in choices made by managers, presents challenges to achieving firm-wide distinctiveness.

INTRODUCTION

Adopting new practices to develop new capabilities and enhance competitiveness is a goal for many manufacturing firms. These practices may be based on product technologies, process technologies, or broader business innovations. If a practice or capability does indeed enhance competitiveness and is one that rival firms have difficulty imitating, a firm possessing it may have a source of competitive advantage.

Successfully introducing a practice to a firm means only that at least one part of the firm has adopted it and possesses the associated capabilities. Although we often think of a capability being possessed by a firm, that capability is not necessarily available for use throughout the firm. If a firm is to leverage capabilities residing in one part of the firm by using them in other units serving different product markets (Prahalad and Hamel, 1990), it first needs to transfer them to those other units. Researchers have long been interested in adoption of new practices and how practices diffuse across an industry (e.g., Rogers, 1962). However, it is only recently that scholars have turned their attention to intra-organizational transfer of practices or capabilities (e.g., Cool, Dierickx, and Szulanski, 1997; Szulanski, 1996, 2000; Knott, 2003).

The resource-based view of the firm argues that heterogeneity across firms can create isolating mechanisms that inhibit imitation of superior practices by rival firms and allow a firm to capture rents generated by those practices (e.g., Barney, 1991; Peteraf, 1993; Rumelt, 1984). What about the effect of heterogeneity within a firm on transfers of practices? Previous research on managing multiple organizational units highlights differences across business units (e.g., Ghoshal and Nohria, 1989) and plants (e.g., Ferdows, 1989) in the same firm. These differences are not deviations from a norm to be corrected, but reflect the roles played by the business units or plants. They therefore should be acknowledged and accommodated, and if possible, exploited. We have evidence that inter-firm differences can be positive when they

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*Correspondence to: Catherine A. Maritan, School of Management, State University of New York at Buffalo, Jacobs Management Center, Buffalo, NY 14260-4000, U.S.A.

create isolating mechanisms that impede imitation of superior practices. Do otherwise desirable intra-firm differences create internal isolating mechanisms that impede internal transfer of these same superior practices?

BACKGROUND AND DEFINITIONS

In the context of management, practices are 'approaches used by managers and workers with the goal of achieving certain types of performance' (Flynn, Sakakibara, and Schroeder, 1995: 1326). The term 'best practice' is typically used to refer to a superior or exemplary practice that leads to superior performance (Davies and Kochhar, 2002; O'Dell, Grayson, and Essaides, 1998). Flow manufacturing, sometimes referred to as lean manufacturing, is a best practice that has recently received a lot of attention (Davies and Kochhar, 2002). Flow manufacturing is a process-centered approach, pioneered by Japanese automobile manufacturers, that organizes manufacturing around the value-creating processes used to produce a product instead of around departments or functions (Womack and Jones, 1996; Womack, Jones, and Roos, 1990). It allows a plant to develop its manufacturing capabilities of quality, flexibility, and delivery speed with positive feedback on cost and efficiency. Accordingly, it can change the trade-offs inherent in traditional scale and cost focused approaches to manufacturing.

The implementation of flow manufacturing in a plant involves the redesign of manufacturing processes to synchronize and balance them. Product designs are made more modular and a pull inventory system is introduced. Small quantities of components and products are produced frequently, as demand dictates. In its idealized form, products are produced to customer order rather than in batch to a forecast. The performance benefits to the plant are reduced manufacturing cycle times, minimized work in process inventory, higher first-time quality and more reliable delivery to customers. Implementing flow manufacturing requires changes to all elements of the value chain from supplier management to customer relationships, and to the philosophy underlying the production system.

Drawing on evolutionary economics (Nelson and Winter, 1982), a practice can be characterized as a set of routines. In flow manufacturing, these routines govern production activity such as production planning, parts procurement, inventory reduction, task assignment and quality control, as well as managerial activity such as coordination. The routines are 'web(s) of coordinating relationships connecting specific resources;' transferring a practice from one part of a firm to another requires replicating the routines, that is, using 'similar web(s) of relationships operating on a similar set(s) of resources at a different site' (Winter, 1995: 149–150). For a practice, and the capabilities that a firm acquires from that practice, to provide a competitive advantage and generate rents it must be difficult for competitors to imitate. However, factors that impede imitation also tend to impede replication (Winter, 1987; Teece, Pisano, and Shuen, 1997). Therefore heterogeneity that creates isolating mechanisms making imitation across firms difficult may also make replication of routines and transfer of practices within a firm difficult.

Unlike inter-firm transfer of practices or innovations, intra-firm practice transfer has not received much systematic study. A notable exception is Szulanski's multi-company, multi-practice study of factors making internal best practice transfers difficult (Szulanski, 1996, 2000). Contrary to commonly held beliefs that motivational factors are to blame, he found that intra-firm practice transfer was most hindered by three knowledge barriers: the recipient's lack of absorptive capacity making it less able to exploit the new knowledge, causal ambiguity about exactly how the practice works, and an arduous relationship between the source of the practice and the recipient making communication more difficult (Szulanski, 1996).

In the field study reported here we explore intra-firm transfer of a practice in the context of implementing flow manufacturing in multiple plants of a large diversified manufacturing firm. Compared to the practices that Szulanski (1996, 2000) examined, flow manufacturing is more complex.[1] Simon (1962) defines a complex system as one comprising a large number of elements that interact in a nonsimplistic way. Flow manufacturing is a practice designed to affect all parts of an organization. It consists of many different routines operating

[1] Due to confidentiality issues, Szulanski was unable to disclose the specific practices he examined; however, he does provide some illustrative examples, none of which are as complex as flow manufacturing.

at multiple organizational levels to integrate both technological knowledge about 'how to produce goods and services' (Bohn, 1994: 61) and managerial knowledge. As such, flow manufacturing can be best characterized as both a technical practice and an administrative one (Damanpour and Evan, 1984) with the technical and administrative elements highly interrelated. Teece *et al.* (1997) cite flow manufacturing (lean production) as an example of a productive system with high interdependency among shop floor practices and higher-order managerial processes and argue that 'replication may be difficult because it requires systemic changes throughout the organization' (p. 519). Because of the high level of complexity and the broad scope of the knowledge that must be transferred (Winter and Szulanski, 2001), there are features of flow manufacturing and the process of its transfer that provide additional insights into our understanding of impediments to intra-firm practice transfer.

RESEARCH DESIGN

Our objective in this study is to develop a descriptive process model of the transfer of a complex manufacturing practice and identify if and how differences between plants affect the transfer. We investigate the implementation and transfer of flow manufacturing in multiple divisions of a large, U.S. industrial manufacturing firm we label 'Industrial Products' or 'IP.' Confidentiality issues prohibit us from disclosing the identity of the company so we assign code names to the firm and its facilities. We take a case study approach for several reasons: (1) we are interested in how a process progresses rather than its frequency or incidence, (2) we have largely qualitative data, and (3) we have many more variables of interest than data points (Yin, 1994). The study follows an embedded case study design (Yin, 1994). The case is IP's corporate flow manufacturing initiative. Individual plants in which flow manufacturing was implemented constitute units of analysis embedded within the case.

By limiting our investigation to the transfer of a particular practice we hold the content of the practice, that is, the routines and knowledge being transferred, constant. By studying multiple transfers in a single firm we hold the organizational context constant. Holding constant both practice characteristics and organizational context allows us to focus on features of the transfer itself and plant-level differences affecting the transfer of this complex practice.

Research setting

Industrial Products is a *Fortune* 250 diversified manufacturing company with over 40,000 employees working in facilities located across the United States, Europe, Asia and Latin America. In 1996, IP instituted a corporate initiative to implement flow manufacturing throughout the corporation. This high-profile initiative received top management support and was extensively publicized inside and outside the company. The CEO spoke to the financial community about it. The initiative was mentioned in the 1997 annual report and prominently featured in the 1998 report. An in-house corporate manufacturing consulting group comprising 25 staff members and 35 engineers assigned to particular plants was established to oversee this and other programs. A corporate process improvement group was also established. Because they worked together on the flow manufacturing initiative, we refer to members of these two groups collectively as the corporate consultants. Before introducing flow manufacturing to the plants, the corporate consultants established the 'content' of the practice for implementation within IP. These consultants studied flow manufacturing operations in other firms and were formally trained in flow manufacturing principles by outside experts, thus creating a body of knowledge within IP that they could transfer to the plants. Because of this centralization of knowledge, the resulting definition and form of flow manufacturing as implemented at IP was consistent company wide.

The four plants that we studied labeled 'Indiana,' 'Ohio,' 'Illinois,' and 'Kentucky,' are described in Table 1. All four plants are in the same business unit but each is operated as a separate division run by a general manager with profit-and-loss responsibility. All plants in the business unit manufacture branded capital goods used in building construction. Indiana and Kentucky manufacture similar products targeted to different segments of the market. Ohio and Illinois manufacture different products, which in some applications can be used in conjunction with products manufactured by Indiana and Kentucky.

Table 1. Plant profiles at beginning of transfer

	Ohio	Indiana	Illinois	Kentucky
Ownership history	Acquired 2 years earlier	Long-time IP	Acquired 8 years earlier	Acquired 2 years earlier
Labor	Unionized	Non-union	Non-union	Non-union
Market position	One of the market leaders	Clear market leader	Clear market leader	Second place in market share
Financial performance	Poor	Very good	Good	Good
Type of manufacturing operation	Primarily fabrication, some assembly	Primarily assembly, some minor fabrication of inputs	Primarily assembly, some fabrication	Assembly only
Reason for adopting flow	Reduce lead times without increasing inventories	Reduce lead times and improve delivery without reducing variety	Solve capacity problem	Reduce inventory

Consequently, the four plants share some common customers. The customers of all plants are a mix of distributors and industrial end-users across North America. The products are all relatively 'low technology' and are manufactured using conventional fabrication and assembly methods.

The flow manufacturing initiative at IP was a corporate program with the general aim of improving productivity. However, each plant hoped to achieve different benefits that were specific to its competitive priorities and linked to its business strategy. Indiana wanted to use flow to reduce lead times and improve delivery without reducing product variety. It had a very large number of variations in its final product. Competitors carried a smaller set of final products in stock and beat Indiana's delivery times to final customers. Kentucky already had short delivery times, but achieved them through stocking finished goods inventory. Accordingly, it wanted to use flow manufacturing to reduce cycle times. This would permit it to maintain short delivery times while eliminating inventory. Illinois first tried to adopt flow to reduce inventory. This first flow initiative failed and the process was restarted at a later date to address a capacity problem at the plant. Ohio chose to implement flow techniques because it had long lead times and faced pressure from customers to shorten them. Ohio was one of IP's earliest implementation sites, beginning the program in 1997, followed by Indiana and Illinois in 1998 and Kentucky in 1999.

Data collection

We collected data through 30 hours of semi-structured interviews of plant workers, engineers, business unit managers, and corporate staff members who were involved in the implementation of flow manufacturing (refer to Table 2). Most of the individuals interviewed participated in the implementation at more than one plant. Two researchers conducted all interviews. Primary interviews were conducted face to face with some preliminary discussion and follow-up by telephone. Much of the interview data took the form of retrospective accounts; however, part of the process at Indiana, the plant furthest along in its implementation, was tracked in real time over the course of a year. Since retrospective reports may suffer from inaccuracies and biases, steps were taken to improve their reliability. Multiple informants were interviewed (Seidler, 1974) and an effort was made to minimize the elapsed time between an event and interviews concerning that event (Huber and Power, 1985). We

Table 2. IP employees interviewed

Role	Number
Corporate staff	3*
Business unit management	2*
Engineers	4*
Team leaders (plant workers)	2**

* Interviewed about multiple plants.
** In addition to formally interviewing team leaders, we also spoke to other plant workers.

also examined progress reports filed monthly by the corporate consultants. These reports were prepared and submitted in real time as the implementation of flow manufacturing unfolded and therefore are not prone to the same retrospective biases. In addition, we addressed inter-rater reliability by having both researchers record interview notes and code the data separately, and later comparing the notes and coding for agreement. To improve validity, we reviewed our recorded accounts of the implementation processes with key informants for factual correctness and possible omissions. Data were collected primarily between April 1999 and July 2000.

PROCESS MODEL

To make comparisons across plants at different points in their implementations of flow manufacturing, we first identify a schema for positioning the plants. We used the experience of Indiana as a starting point because it was furthest along in the process and IP management considered the implementation to date to be successful. We refined the model using data collected on the other plants and discussed the refined model with key managers to verify that we had accurately captured the scope of IP's implementation of flow manufacturing in a plant. Although some elements of our model do not correspond to steps of IP's initial implementation plan, both corporate and senior plant personnel who reviewed the model agreed that it accurately captures the general process actually followed.

Not surprisingly, we find the implementation process follows a life cycle or stage model (Van de Ven and Poole, 1995). Although the sequence of stages is broadly consistent with Szulanski's (1996, 2000) model of practice transfer, we observed a greater number of distinct stages particular to flow manufacturing that we think are important to recognize. We identify two sequential, multi-stage sub-processes we label pre-implementation and implementation. There were 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 benefits. Table 3 lists the elements of each stage.

Flow manufacturing had been identified as a key component of each plant's business strategy and IP had made a corporate-level commitment to adopt flow manufacturing in each of the plants. The individual plants agreed to work with the corporate consultants on the implementation. Therefore, the decision to initiate the transfer and the competitive rationale for doing so were pre-existing initial conditions and not captured as part of our model. Although the elements of the process are standard, crucial decisions particular to the plant had to be made. In the following section we describe how the transfer process differed among the plants.

RESULTS

Figure 1 illustrates the progress of the plants through the stages of the model. At the conclusion of the data collection period each plant had reached a different stage of implementation. All were proceeding with the implementation as planned except Indiana, which, as described more fully below, chose to stop short of concluding the penultimate stage before beginning the final stage of leveraging the benefits.

Pre-implementation

Assess plant endowment

The corporate consultants performed most of this stage assisted by plant management. Although the processes consisted of similar steps, the resulting assessments differed greatly among the plants, leading to variation in initial starting conditions for the transfers. Indiana was a successful plant that had been owned by IP for a long time. At the time it started to introduce flow manufacturing, the management team in place was eager to embrace change, with no preconceived ideas about how to do things. The other three plants had been acquired within the last decade, and to varying degrees retained evidence of previous ownership. Most of Illinois' and Ohio's managers had been in place for many years prior to IP's acquisition of the plants. Although these managers wanted to adopt flow manufacturing to achieve particular performance benefits, they believed that the operations were performing adequately and that there was no need for major change. As one of the corporate consultants commented:

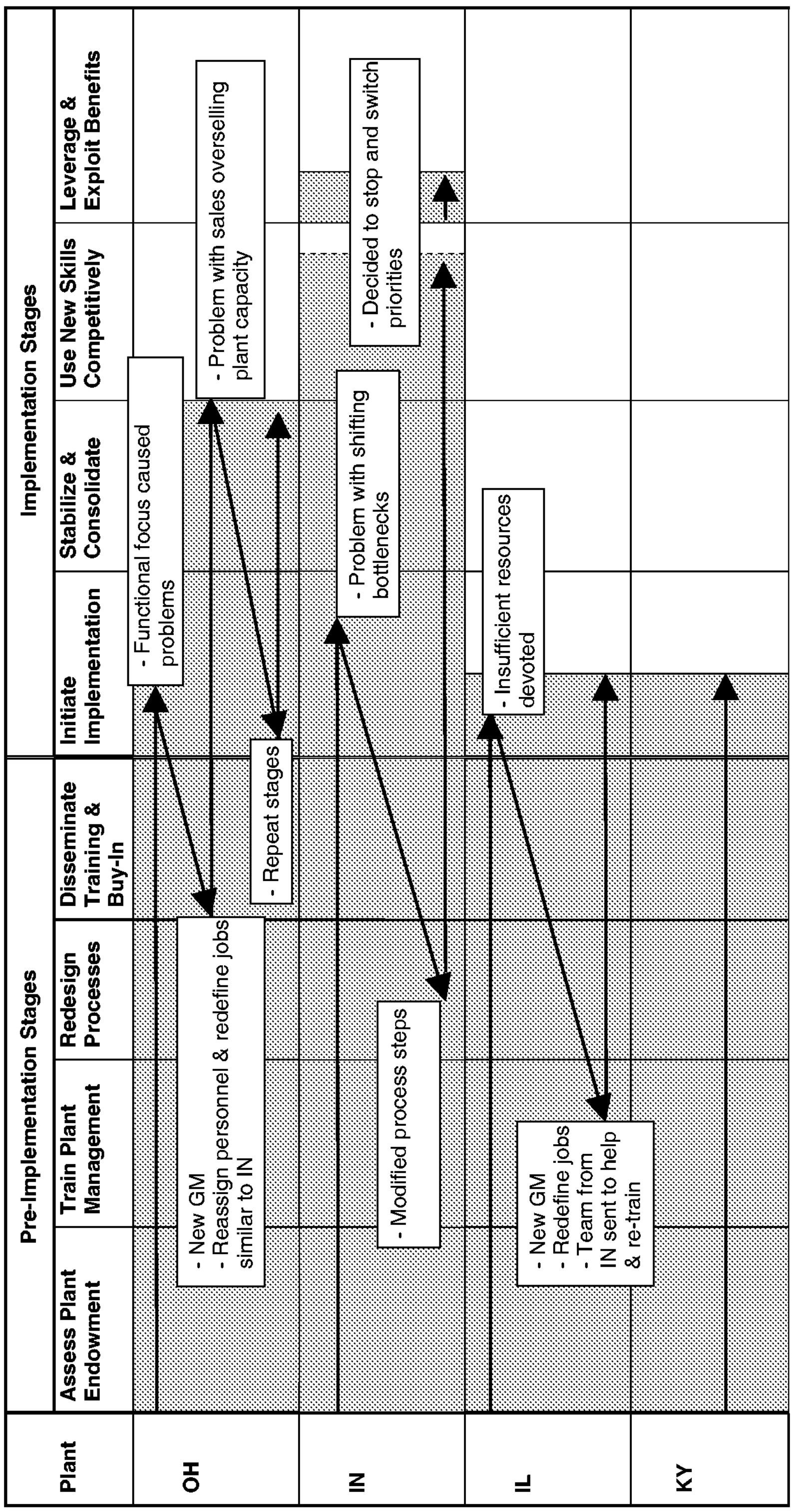
Table 3. Elements of flow manufacturing implementation process

1. Pre-implementation sub-process				
Stage:	Assess plant endowment	Train plant management	Redesign processes	Disseminate training and buy-in
	Determine initial conditions for transfer Inventory resources and capabilities, particularly equipment, production technology, skills, management talent, culture	Decide who will be trained: number of managers to train, what functions represented, what technical areas represented Decide who will do the training: internal sources and if so from where, or mix of internal and external Train managers in philosophy and mechanics of flow Use training to get plant management buy-in	Trained managers decide on scope of implementation: in which parts of plant to apply flow principles, where to apply flow first Identify value-added steps Decide how to redesign each step for flow Plan for connection of these separate initial changes to a demand pull system linking them	Decide which plant line workers to train: team leaders only or workers involved in initial application of flow or all plant workers Decide which plant support staff to train: which functional areas Use training to get plant worker buy-in
2. Implementation Sub-process				
Stage:	Initiate implementation	Stabilize and consolidate	Use new skills competitively	Leverage and exploit benefits
	Convert elements of production process to incorporate flow techniques based on scope determined during pre-implementation Teach plant line workers to monitor production for problems and keep plant engineers informed so they can learn how new system works Experiment to problem solve and find stable operating parameters Alter production process to a 'point-of-no-return' to the old system. Make commitment to flow manufacturing	Consolidate changes made in previous stage Learn to control system as designed: identify control limits, learn to differentiate sources of volatility Identify and understand specific performance improvements Decide if initial implementation will be rolled out to other parts of plant and confirm or amend plans made in redesign stage	Take advantage of benefits of new production system Explicitly incorporate actual customer orders into system	Look beyond current demand and current customers for opportunities to exploit new capabilities Decide which new customers and markets to pursue

> A huge lesson from [Ohio] was that the management team was so associated with the old ways of doing things that they couldn't grasp that things *could* be changed.

Although Kentucky was also an acquired plant, management had a different attitude. As a process improvements engineer sent to work on Kentucky's implementation told us:

> Kentucky was Indiana's biggest competitor before the acquisition. Kentucky had 15% of the market versus 55% for Indiana. Three out of four [managers] were open to change and only one was resistant. The mind-set was that Indiana was the



Shading indicates stages completed as of mid 2000; Arrows indicate progress through stages; Dotted vertical line indicates intentional abandonment of progress
OH = Ohio, IN = Indiana, IL = Illinois, KY = Kentucky

Figure 1. Progress of plants through stages of process model

> enemy and they did not want to become [part of] Indiana.

Train plant management

While all four plants' top management groups went through formal training programs, the trainers differed. Ohio managers were trained by corporate consultants who had attended external training sessions. Indiana, Illinois, and Kentucky managers were trained by external consultants, 'FlowInc,' the outside experts that had trained the internal corporate consultants. As a corporate manufacturing consultant assigned to Ohio told us:

> The first mistake we made was to not send [plant] staff to the FlowInc training program.

Ohio was one of the first targets of IP's corporate flow initiative. As a result of Ohio's experience the corporate group coordinating the initiative decided subsequently to send management from other plants directly to FlowInc. However, the corporate director of process improvement had concerns about the external trainers:

> We send our consultants and people who will be working with the [plant implementation] team to FlowInc since they will be working with the business issues. I [would like to] send as many of the leadership team as possible to FlowInc. We have found it to be a good thought-provoking experience, but typically FlowInc is not good for implementation. They do not take human issues into account.

At this stage there was also variation in who was trained. Senior plant management decided who was sent for training and which functional areas were represented. At Indiana, only engineers and top management were trained. No one from the purchasing, human resources (HR), or production supervision functions attended the external training sessions. A broader group was trained at Ohio, Illinois, and Kentucky.

Redesign processes

Although the plants had all committed to implement flow manufacturing, each did so for different reasons and anticipated different types of performance improvement. In addition, the degree of improvement possible depends on characteristics of the plant such as manufacturing process, plant layout, and product variety. Flow manufacturing consists of a set of general principles and techniques that must be adapted to different manufacturing circumstances (Womack and Jones, 1996; Liker, 1998). For example, flow techniques are particularly suited to assembly manufacturing processes with large numbers of parts. Ohio has primarily fabrication production with only some assembly while Illinois, Indiana, and Kentucky are more assembly oriented with varying degrees of fabrication. Performance improvements could not be directly compared across plants without considering differences in potential. This lack of comparability made it difficult for IP to track performance and to measure the progress of the corporate flow initiative.

There were also interactions between the process redesign and the training that occurred in the previous stage. Given the basic differences between plants, initiation of flow manufacturing required analysis of plant-specific value-added steps and a mapping of these steps to implement a flow line. Only managers who were trained were able to understand how to incorporate flow techniques into their areas.

Disseminate training and buy-in

Once the production process was redesigned, plant personnel who were going to work with the new system were trained by teams of managers and engineers who had participated in the previous two stages, and who were assigned to manage the implementation. Few differences among the plants were observed. The workers chosen for training represented the areas of the operation that were incorporated into the redesign. For example, the exclusion of Indiana's HR and purchasing managers in the management training stage continued.

Implementation

Initiate implementation

Indiana, Ohio, and Illinois all reached this stage; however, all three plants experienced problems that resulted in regression to a previous stage as illustrated in Figure 1.

Indiana had problems with bottlenecks in the production process. This is a common problem when flow principles are introduced and was expected by Indiana's managers. However, as the vice president of manufacturing who oversaw the initial implementation described, as one bottleneck was solved another was created:

> The process engineers worked for the assembly [production supervisor]. The result was that assembly ran well but ran out of parts. The remedy was to put the process engineers into other areas to work on bottlenecks and other problems [causing the parts shortage]. Specifically, we put people into coatings to work on those problems. As bottlenecks were broken in one area they moved to other areas: from assembly to coating to polishing to fabrication back to coating and back to assembly. [This caused] the production supervisors to violate the [flow principles].

The problem was that initial success created complacency. Production engineers left the assembly area to work on bottlenecks. Assembly workers who had not been fully trained in flow principles had to adapt to new problems on their own. Without the presence of the engineers, and facing parts shortages that were out of their direct control, workers reverted to batch ordering and violated the new order system. Consequently production engineers had to be pulled back for an intensive problem-solving session in assembly.

An engineer working in the plant commented on the underlying causes of the production problems:

> We kept revisiting things that had been resolved. The core team [trained in the previous stage] was not multifunctional enough. The lack of [production supervisors], a buyer and an HR person created problems [in implementation]. We were told that [plant management] can't spare the [production supervisors] but [we] can't implement anything without [the production supervisors'] approval. With no [production supervisor] involved [in the process redesign] there was a problem getting up to speed. With no one from purchasing [involved] there were non-value steps like unwrapping parts [that nobody told the supplier not to wrap]. With no one from HR involved there was a problem with using temps [with full-time staff].

The process design had to be reworked and additional training was required once the production, human resources, and purchasing staff got involved. This resulted in higher costs and delays.

At Ohio and Illinois, the effects of regression on implementation of flow were much more severe than at Indiana. Both plants had similar experiences. The flow initiatives were brought to a complete halt and, unlike Indiana, neither plant was able to overcome the difficulties on its own. As a corporate consultant assigned to the Ohio plant told us:

> The VP of Operations disbanded the (implementation) team. He thinks that people should know how to do their jobs. His attitude is that if we tell them where to go, they should know how to get there.

According to the vice president of manufacturing:

> A staffing issue is putting people full time on flow. Otherwise, other concerns take precedence. We had to convince people that flow managers are needed.

Without a dedicated implementation team the plant stopped following flow principles until a new general manager was appointed by the corporate office. The new general manager reestablished manufacturing support and made organizational changes. By this time, Indiana had made successful progress and the corporate consultants helped Ohio use the Indiana structure as a model.

At Illinois, regression to the train plant management stage occurred. A lack of dedicated resources was also the problem there. As the vice president of manufacturing described:

> Illinois didn't get off the ground. There was a false start when they tried to start flow. They had one engineer who was asked to take on a (production) supervisor role too. The supervisor role, to keep workers happy and make enough product, took priority.

No progress was made until the corporate office hired a new general manager. He resurrected the flow initiative and made changes described by the vice president of manufacturing:

> Illinois and Indiana started [their flow programs] at the same time but Indiana moved ahead while Illinois didn't. At Illinois, there was not the right management team and not the right organization structure. It was a functional structure. The engineers wouldn't go on to the factory floor. Now there is a new management team, a new organization structure that looks like Indiana. They have done [the right] training and have data systems in place. [The general manager] brought in ten Indiana people who knew flow. There was internal training [by the Indiana team] even though many people had gone through the FlowInc training. New performance measures [were developed]. The [implementation] team [led by the Indiana people] put [a new ordering system] in place, put flow

> in part of the plant and broke through some bottlenecks. There has been a major change in six months.

Stabilize and consolidate

Indiana and Ohio reached this stage, which centers on learning to deal with a plant's individual demand characteristics. The processes were similar but important issues were plant specific.

An important refinement at Indiana involved the analysis of data about demand and supply patterns. As the division vice-president of manufacturing explained:

> There is a misunderstanding of how lead time compression can affect demand. Indiana sells to schools. Schools do maintenance during the summer and order [parts] in April and May. This year we had low orders in April and May. Is this difference due to random variation or to a change in the marketplace? [The president of the business unit] didn't do the typical thing and lay people off. It's a good thing since June picked up. He could have cut price and messed up the market. The market appears to now realize that lead times have fallen. Why order early and pay early? The lesson is that when lead time drops you change the market. You need to read the change correctly.

Another interaction between changes in the plant and demand occurred at Ohio, causing a second regression. The director of process improvement described the following situation:

> Traditionally, the production people kept spare capacity because the marketing people would oversell. The GM came out of sales and marketing. He didn't understand capacity and insisted on a fixed lead time instead of listening to the market. He had attended all the flow manufacturing training but it didn't work. There was an inherent belief that if you pushed, the product would somehow come out. People didn't believe that capacity is a hard number. Sales and marketing and the general manager didn't believe capacity constraints existed and grossly overloaded the plant. At one point there were zero on-time deliveries.

The pull order system was stopped. A plant that had successfully achieved the second stage of implementation fell back to the beginning of the initial stage. The director of process improvement continued:

> We learned the hard way. We have gone into more intensive internal training once we get into [initial implementation]. This requires quarterly analysis. We need more training to anticipate [the later stages related to competition] and bring in more training on core competencies and value propositions. We need to train people, the general manager and others, about the financial implications of not moving on.

Use new skills competitively

Only Indiana reached this stage. IP managers felt that the company had an advantage from simply adopting flow before its competitors as explained by the president of the business unit:

> Competitors can copy flow but IP is a first mover and can stay ahead. Small competitors can't copy and they will go away. There will be industry consolidation.

But, IP wanted to take advantage of its capabilities in the marketplace. Doing this presented a challenge, particularly after experiencing problems, as a corporate consultant told us:

> [We] need to create an increased awareness among our client base regarding the impact compressed lead-times has on becoming value proposition advantaged and get them to act on it. [But] the price you pay if you regress is that the customer no longer believes your improved lead time since you slipped.

Indiana also faced a dilemma. It had achieved substantial improvements in assembly; however, flow techniques had not yet been applied to the shipping area. Significant finished goods inventory waited in a holding station occupying a large part of the factory. The lead process improvement engineer raised the question of how far to take the flow initiative:

> Do we put dollars into flow or into other initiatives? How far do you press the logic of flow versus other priorities like cost cutting or manpower reduction? For example, we have temporarily put flow on hold as the current priority is increasing capacity in polishing.

Rather than converting the rest of the plant to flow principles, plant managers decided that a different competitive priority should take precedence.

Leverage and exploit benefits

Once it had achieved some success with flow techniques, Indiana tried to exploit the benefits. Indiana, Ohio, and Illinois all made products that some customers may use together, but the customers had to place a separate order for each component with the IP plant that made it. Indiana attempted to serve as a consolidation point for the orders and shipments but successful implementation of flow manufacturing in each plant is a necessary condition for this new system to work. Business unit managers had to decide whether to complete the flow initiative in all plants before marketing systems of products to customers or to initiate the marketing plan first as a means to drive the implementation. They chose to begin with marketing but suffered some predictable manufacturing shortfalls in the process. Reflecting on progress at Indiana and other IP plants we did not study, the director of process improvement told us:

> The key is to leverage what's been done to generate competitive advantage. This has been a major hurdle. Several plants are trying it but none have made the transition to a business imperative. Production and marketing and sales tend to be separate and tend to be compensated differently. Typically production is rewarded for execution of a plan. Marketing and sales is rewarded for business issues, for example, increasing sales. The [main challenge] is how to balance lead time, market expectations, and charging the customer extra for product [delivered] outside the [time window established by the flow system]. The CEO and COO have the authority [to change the incentive program]. We may see some changes but we don't even know what the incentives should be.

DISCUSSION

Based on our study of four plants operated by a business unit of Industrial Products, we empirically developed a stage model to help understand the implementation of a specific practice, namely flow manufacturing, within a firm. We identified issues that presented challenges for the transfer of the practice and affected progress to the next stage or caused regression to an earlier stage. We also saw how the process varied among the four plants.

We find some evidence consistent with Szulanski's (1996) observations of factors impeding practice transfer. For example, one important difference between plants we observed is the management's willingness and ability to pursue change. This observation could be interpreted as evidence of lack of absorptive capacity (Cohen and Levinthal, 1990). Alternatively, this result might be attributed to inertia in managerial thinking. The managers may be able to absorb the knowledge, but it is easier for them not to do so. Another observation consistent with Szulanski's is the problems that arose as a result of not training representatives of important areas affected by the process redesign. This could be interpreted as an issue of causal ambiguity (Lippman and Rumelt, 1982). Although there existed evidence that applying flow principles and techniques leads to specific performance results, it was not clear how exactly the principles and techniques interact with plant-specific characteristics to produce the results. Therefore, the senior managers sometimes stumbled in selecting the essential personnel to send for training. We found no evidence of Szulanski's third impediment to practice transfer, an arduous relationship between the source and recipient of the knowledge being transferred.

While we find some evidence consistent with earlier work, there is one over-arching issue not previously addressed that dominates our observations: the effects of heterogeneity among the plants. There was heterogeneity in initial starting conditions for the transfer and additional heterogeneity created during the transfer process.

Although the four plants appear to be relatively similar, sharing both the same corporate parent and business unit management, making complementary products and serving many of the same customers, the differences among them are important. There are multiple dimensions of heterogeneity that created variance in the starting conditions for the transfers. This initial variance was associated with subsequent variance in the success of implementation. Some of the differences largely reflected the plants' histories and include managerial beliefs, culture and performance objectives. Many of the problems experienced during the transfer can be traced to these starting conditions, for example, the unwillingness of Ohio's general manager to alter his beliefs about capacity constraints and unwillingness to learn exhibited by the Illinois staff.

Other sources of variance in initial conditions represent fundamental physical differences in plant operating characteristics that affect the potential benefits of adopting the practice. This variance in operating characteristics also created heterogeneity in the knowledge that was transferred. We originally selected transfers of the same practice within a single firm to control for the content of the knowledge being transferred. However, because plant-level characteristics interacted with the content of the practice we find that we could not hold the content constant. Flow manufacturing is a complex technical and administrative practice that, to be most useful, must be tailored to the characteristics of the plant in which it is applied. The distinction between conformity of adoption vs. the need to customize the adoption of practice in order to take advantage of it fully is very important (Westphal, Gulati, and Shortell, 1997). To exploit flow manufacturing principles, the routines and knowledge must be customized to recognize certain plant characteristics that reflect how the plants compete. But, along with this customization, the plant must avoid the tendency to question elements that are essential to the practice and that should not be compromised.

Heterogeneity stems not only from differences in initial plant endowments, it also arises from the choices made during the transfer process, and in some cases from interactions between both starting conditions and choices. Some choices we observed are whether to use internal or external trainers, which departments to send to training, whether new or experienced managers should manage implementation, and how much process engineering support to provide. These choices generated additional variation in transfer success across the plants. The result of the different choices made by the plants during the transfer process can be framed in terms of variation in copying rules, a concept developed in work on population level learning (Miner and Haunschild, 1995). In that stream of research, variation in the rules different organizations use to copy routines increases population level variation, or heterogeneity across organizations. If we apply this logic to a group of plants within a firm, we can see how variation in the decisions made by plants, or the rules they use to copy the routines constituting the practice, increases firm-level variation or heterogeneity across the plants.

However, there is an important difference between variance in copying rules leading to sustained variation in a population and variance in the copying rules used for intra-firm practice transfer. Subunits of an organization such as multiple plants function with more hierarchy and internal cohesion than organizations in a population (Miner and Haunschild, 1995); therefore, the variation may not be sustained if mechanisms exist to alter the copying rules through explicit coordination and development of a standard replication routine. The emergence of Indiana as a template for practice transfer illustrates a possible coordination mechanism.

Figure 2 maps the transfer of knowledge to the plants. The pattern for each plant is different, indicating the evolving process of knowledge transfer in IP's flow initiative and the development of a transfer routine with Indiana as a template. Ohio received knowledge directly from the corporate consultants and only indirectly from FlowInc via the corporate consultants. Indiana and Illinois were the next sites to take part in the initiative, beginning 1 year after Ohio. As result of the consultants' dissatisfaction with Ohio's experience, Indiana and Illinois received knowledge directly from both the corporate and outside consultants. Although the two plants started the process at the same time, Indiana progressed with fewer problems and consequently at a faster pace than Illinois and even overtook Ohio. When Ohio experienced problems in implementation, the corporate consultants used lessons learned from Indiana to successfully make changes. Later, when Illinois experienced problems in implementation, instead of the consultants transferring learning from Indiana, personnel from Indiana were temporarily transferred to Illinois. These temporary transfers from Indiana brought knowledge with them and helped Illinois to overcome its difficulties. By the time Kentucky began its flow program Indiana already provided a successful working example, and transfer of knowledge from Indiana, through the temporary assignment of Indiana personnel, was formally made part of Kentucky's process.

The picture that emerges is one of knowledge being transferred from a successful plant that serves as a model, first indirectly to a plant experiencing difficulties, then directly to a plant experiencing difficulties and finally as a matter of course to facilitate subsequent implementations. However, using Indiana as a model of knowledge transfer is too simplistic a description of its role. Such transfers go beyond simply increasing absorptive capacity at the target plants in order to get over initial hurdles of transferring best practice. Instead the set of routines transferred can be considered

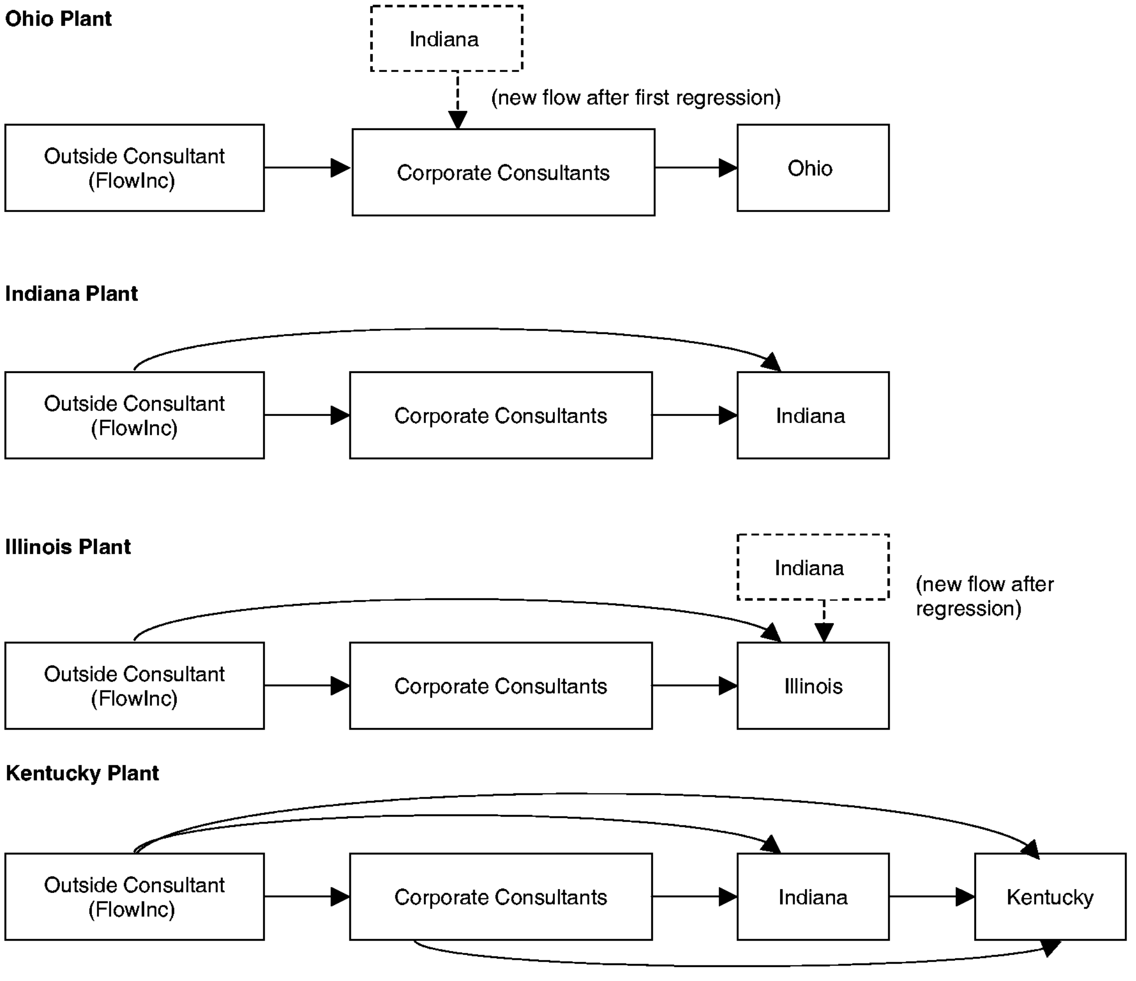


Figure 2. Knowledge flows

a template for the practice being transferred. This emergent role for Indiana is similar to Winter and Szulanski's (2001) description of a template used in replication of a business model.

Although Illinois and Ohio clearly benefited from acquiring knowledge from Indiana, and Kentucky has not yet experienced problems, it is still too early in the progress of these plants' implementations and we have too few observations to strongly conclude that knowledge transfer from Indiana as a model plant systematically improves practice transfer. However, the possibility of this being the case raises interesting questions. How does the use of a model plant to facilitate transfer relate to the degree and type of heterogeneity among the plants? How similar do the model and the recipient plant have to be? Winter and Szulanski (2001) describe a template used to replicate a complex business model and recognize the possible need to subsequently adapt the 'copy' to accommodate different environments. However, they argue that that replication is more effective when the template is first copied precisely. In the case of flow manufacturing, precise copying will lead to inferior results because the practice needs to be tailored to the context to be useful. Our observation of Indiana's emergence as a template for transferring general principles that require explicit management of differences between the template and the recipient extends the concept of replication using a template.

If we consider the idea of practice transfer as a corporate initiative to achieve firm-wide distinctiveness, another issue comes to light. What constitutes a successful transfer of a practice? Is it the same for all plants? Differing competitive priorities of the plants may result in differences in the adoption of the practice. Competitive priorities may be in conflict with the practice being transferred, requiring trade-offs to be made as we observed at Indiana. It is important to distinguish this type of trade-off, which is an explicit decision, from an impediment to be overcome. In this case, the result, namely not fully implementing flow techniques, was not failure. This finding is consistent with Hayes and Pisano's (1994) argument that practice implementation and its derived capabilities should support the strategy of a business and not be pursued independently. Corporate-wide distinctiveness may be sought through a corporate initiative emphasizing plant-level capabilities, but competitive advantage is defined within the individual businesses and their priorities need to be considered.

The incompleteness of the transfer of flow manufacturing to Indiana did not appear to inhibit performance improvement in the parts of the operation that did adopt the practice. This result contrasts with conceptual arguments in the literature that claim partial replication of a complex practice may not be profitable (Milgrom and Roberts, 1990; Teece *et al.*, 1997). The apparent conflict may be explained by Winter and Szulanski's (2001) proposition that there is a subset of elements that truly matter to success because those elements contain all the information necessary to successfully operate and replicate the practice. They label this information set the 'Arrow core.' Partial transfer may be profitable provided the Arrow core is replicated. Although we cannot claim that Indiana's successful use of flow manufacturing is a manifestation of the Arrow core of this practice at IP, its emergence as a template is consistent with that view.

An important issue that we did not examine: if a firm is going to generate rents from adopting and transferring a practice, there must be intra-firm replication without inter-firm imitation (Knott, 2003). Using a simulation, Rivkin (2001) demonstrates that for systems of moderate complexity there can be replication within a firm without imitation by competitors. Flow manufacturing with its multiple interacting elements meets Rivkin's definition of a complex system; however, it is not clear where in the range of low to high complexity it falls.

Our study of flow manufacturing at Industrial Products has provided several insights. It appears that successful transfer of this practice requires that a variety of conditions be acknowledged and accommodated. These include not only the operating characteristics of the plant but also characteristics of the plant arising from its history and the history of its managers. It is important to have the right organizational structure, train the right people and transfer experienced personnel to assist with the transfer. These steps can be facilitated through the use of a model plant or a template. We document the emergence of a template and illustrate that a template may be used to transfer general principles requiring tailoring and not just for exact replication. More generally, we observed that intra-firm isolating mechanisms do exist and they can inhibit internal practice transfer similar to the way in which inter-firm isolating mechanisms can inhibit imitation of practices. Further, the study illustrates that multiple sources of heterogeneity in starting conditions may affect practice transfer, and that heterogeneity may be increased through specific choices embedded in the transfer process. The use of a template may serve to reduce some of the undesirable variation, thereby preventing the creation of some isolating mechanisms.

These insights are important in understanding the costs and benefits of developing capabilities. They also imply something about sources of heterogeneity between firms. Even with access to the same knowledge and to some extent the same people, starting conditions combined with decisions made during the process have a profound influence on what knowledge is transferred and used, and on the types of approaches that might be used to develop and transfer capabilities internally.

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