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Invited research paper

Implementing labor flexibility: A missing link between acquired labor flexibility and plant performance

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ABSTRACT

The existing studies conceptualize a direct relationship between acquired labor flexibility and plant performance, producing inconsistent empirical results, which makes the topic ripe for further inquiry. We believe acquiring labor flexibility is not sufficient; its implementation is an important intervening step when companies have to tackle accompanying technical and behavioral side effects of labor flexibility. In this paper, we develop and test a theoretical model in which we introduce an intervening variable to capture the implementation of labor flexibility. In addition, evolving human resource management practices that promote acquisition of labor flexibility are also examined in our model. Case studies in ten printed circuit board plants validated our model. Subsequently, survey data collected from 74 PCB plants was analyzed using Partial Least Squares method. Supporting the proposed model, the results show that the impact of acquired labor flexibility on plant performance is not direct but experienced through the sophistication of labor flexibility implementation exercised by the plant. Our findings also suggested that plants that emphasized process-focused training, provided greater job-rotation training, and designed positive reward structures, acquired higher labor flexibility.

1. Introduction

Every operating facility offers enormous opportunities to engage the hearts and minds of the people who make it work. Unlike physical resources, which depreciate when used, people tend to become more valuable with time and experience. Management's challenge is to harness employees' latent cognitive energy and transform it into a competitive weapon (Morris et al., 2009). An important characteristic of workforce development in this regard is the development of multiple skills (Hopp and Van Oyen, 2004). The larger a worker's range of skills, the more flexible is the worker, either in terms of the variety of goods and/or services he/she can produce, or in terms of the range of job assignments. As a result, substantial literature recognizes multi-skilled workers as synonymous with labor flexibility or functional flexibility (Bhattacharya et al., 2005; Hopp and Van Oyen, 2004), a definition also adopted in this study.[1]

The relationship between labor flexibility and plant performance is intuitively appealing and has been examined in various academic disciplines. For example, strategy theorists have examined it in the context of resource based theory, human resource theorists have examined it as numerical versus functional flexibility, economists have examined it in the context of labor market analysis, and operations management researchers have examined it from the process design perspective. Despite its conceptual attractiveness, the empirical research is sparse (Aksin and Karaesmen, 2007; Bhattacharya et al., 2005; Karuppan and Ganster, 2004; Upton, 1995) and the results are conflicting (Arvanitis, 2005; Schultz et al., 2003; Pinker and Shumsky, 2000). These inconsistent results suggest that acquiring labor flexibility does not automatically translate to better plant performance, an observation also made by Upton (1995) in a case study of the paper industry. Commenting on the importance of managerial knowhow regarding flexibility implementation, Upton (1995) reports his findings from the paper industry, "Many teams of operators had developed routines and tricks that enabled them to change the plant over efficiently" (p. 79). Similar sentiments have been echoed by Schultz et al. (2003), "Worker flexibility has great potential to improve productivity by avoiding bottlenecks and the resulting idle time, but implementing such a system has negative aspects that are poorly understood. There is a clear need for research to elucidate these effects and for development of models that incorporate them" (p. 82). However, by positing a direct relationship between labor flexibility and performance the existing research assumes that labor flexibility provides pure improvements and overlooks the behavioral and technical side-effects or trade-offs that arise

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[1] There is a parallel stream of literature that has defined labor flexibility as a variation in the quantity of labor input (numerical flexibility), which is not the premise adopted in this research. Readers are advised to see Arvanitis (2005) for a detailed discussion.

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during implementation stage and need to be managed. Addressing this gap, we re-examine the relationship between acquired labor flexibility and plant performance by introducing an intervening variable that captures the sophistication of implementing labor flexibility.

We also provide clarification on the impact of HRM practices that promote labor flexibility, an area where mixed empirical results (Beltran-Martin et al., 2008; Sumukadas and Sawhney, 2004; Hoyt and Matuszek, 2001) have left the debate open for further inquiry.

2. Literature review and hypothesis development

Labor flexibility has been referenced in various studies as the number of jobs or operations performed by a typical worker (Sumukadas and Sawhney, 2004); the number of machines and workstations that can be operated by a typical worker (Hyun and Ahn, 1992; Malhotra and Ritzman, 1990); and the number of interdivisional jobs that a typical worker can perform (Elvers and Treleven, 1985; Fryer, 1974). This form of labor flexibility relates to multiple competencies of shop-floor workers and their managers because it allows employees' work assignments to be adjusted to meet changing production needs (Benson, 1996, p. 45).

2.1. Labor flexibility and plant performance

Plants face temporary overloads and imbalances stemming from a wide variety of internal and external causes. When bottlenecks develop at upstream work centers, for example, downstream operations may stop due to lack of materials, thus adversely impacting plant performance. These resulting uncertainties were traditionally addressed by holding buffer inventories, excess capacity and use of overtime. In the last decade, labor flexibility has been forwarded as a better alternative to address such temporary imbalances, because it provides managers with an ability to move workers to bottleneck work centers (Iravani et al., 2005). Numerous studies have been done on the use of multi-skilled workers, both in serial production lines (Andradottir et al., 2001; Bartholdi and Eisenstein, 1996; Iravani et al., 1997) and in parallel systems (Pinker and Shumsky, 2000; Van Oyen et al., 2001). Conceptual arguments have been presented in the literature associating labor flexibility with plant performance through reducing cost, reducing idle time, improving customer service, promoting variety and economy of scope, and enabling shorter lead-time (Beltran-Martin et al., 2008; Hopp and Van Oyen, 2004; Van Oyen et al., 2001). Optimization and simulation techniques have been used to show the favorable impact of labor flexibility on firm performance in dual-constrained job-shops (Bokharst et al., 2004; Hottenstein and Bowman, 1998).

More recently, researchers have introduced the notion that acquiring labor flexibility is not enough; it has to be properly implemented to enjoy its favorable impact on plant performance (Schultz et al., 2003). The technical and behavioral trade-offs accompanying the use of multi-skilled workforce, such as the loss of walk times, training costs, learning and forgetting time, and efficiency versus quality, need to be properly managed (Schultz et al., 2003). In simple words, the sophistication with which the choice of skills is made and the organization/control of the workers in using those skills is exercised is equally important to enjoy a favorable impact on plant performance.

In the face of training cost to acquire labor flexibility, a pertinent implementation question for managers to examine is the number of skills a worker should acquire and the type of ideal skill-sets for those who are cross trained, which is the focus of investigation in Aksin and Karaesmen (2007). To help efficient utilization of the acquired labor flexibility, Andradottir et al. (2003) construct dynamic server assignment policies that maximize the capacity of queuing networks with flexible servers. In another study, Pinker and Shumsky (2000) provide answers to the trade-off between the cost efficiency provided by cross-trained workers and the experience-based quality provided by specialists. Using integrated queuing systems the researchers demonstrate that "if the system is small and the rate of learning is slow, flexible servers are preferred. For large systems with high learning rates, the model leans toward specialized servers." (p. 32). Providing a solution to the challenge of learning and forgetting and minimizing the time lost when workers walk back to get more work, Bartholdi and Eisenstein (2005) propose a bucket-brigade technique. Bucket-brigade is a way of coordinating workers on an assembly line that narrows tasks for each worker and allows accelerated learning, which increases production that more than compensates for the time lost when workers walk back to get more work. Providing additional insight, Nembhard (2000) examines the effect of learning and forgetting rates given the task complexity and experience of multi-skilled workers. In this empirical investigation, Nembhard (2000) provides answers to worker allocation, cross-training optimization, and human-resource planning issues. Reinforcing the importance of implementation of labor flexibility, Iravani et al. (2005) demonstrate that systems with fewer capabilities may outperform systems with more when the former are managed effectively. Anecdotal evidence also suggests that the development and effective implementation of labor flexibility in addressing temporary overloads and imbalances provided significant improvements in productivity and reduced costs, bringing major turnarounds in the fortunes of Pilkington Glass Company (Littlefield, 1995) and Celestica Company (Dyck and Halpern, 1999).

Outside the simulated experiments and anecdotes, systematic empirical examination of the association between labor flexibility and firm performance seems to be scarce (Beltran-Martin et al., 2008; Bhattacharya et al., 2005; Karuppan and Ganster, 2004) and provide inconsistent results (Arvanitis, 2005). Some studies have found supporting evidence (Beltran-Martin et al., 2008; Black and Lynch, 2000; Youndt et al., 1996) and others have found evidence negating the association between labor flexibility and plant performance (Godard, 2004; Schultz et al., 2003; Valverde et al., 2000), thus rendering the topic open for further inquiry. These inconsistent results raise serious concerns about the direct relationship posited between acquiring labor flexibility and plant performance in the empirical research. Alluding to this weakness in the existing research, scholars (Hopp and Van Oyen, 2004; Schultz et al., 2003; Huselid, 1995) have called for more empirical research targeted in identifying the various paths, implying the inclusion of mediating variables, through which the acquired labor flexibility may impact firm performance. Concurring with the observation made by Schultz et al. (2003), in this paper we have introduced a mediating variable to capture the sophistication of implementing labor flexibility.

Greater acquisition of labor flexibility increases the options available to a plant manager (Sawhney, 2006), thus reducing the cost of moving workers to address temporary overloads. However, acquiring labor flexibility by itself is not enough; the value added depends on how efficiently managers can implement labor flexibility, which involves the technical and behavioral trade-offs accompanying the use of multi-skilled workforce, such as the loss of walk times, learning and forgetting time, quality versus efficiency issues, etc. that were discussed earlier. Greater sophistication to control and organize the workers in using their acquired skills will lower the technical and behavioral costs attached with moving these multi-skilled workers. When the acquired labor flexibility is efficiently implemented, it allows rapid response to temporary imbalances and prevents work stoppages, and it results in improved utilization of resources and work-center capacity, reduced idle time, decreased work-in-process inventory and cost, all translating into improved plant performance. Alternatively, it may be argued that acquired labor flexibility if not implemented appropriately can impact the plant performance adversely because there are training costs involved in acquiring labor flexibility. In such plants there will be less movement of multi-skilled workers to temporary bottleneck areas.

The above arguments lead us to believe that the acquired labor flexibility will have a direct effect on plant performance (represented in Fig. 2 by a unidirectional causal arrow) and an indirect effect on plant performance through the intervening or mediating variable, namely labor-flexibility implementation. The indirect effects are calculated by multiplying together the path coefficients that make up the indirect causal path. The direct and indirect effect together comprises the total effect of a particular explanatory variable on a specific endogenous or dependent variable.

Hypothesis 1. The acquisition of labor flexibility has a direct positive relationship with plant performance (called the direct-effect).

Hypothesis 2. The acquisition of labor flexibility has an indirect positive relationship with plant performance through an intervening variable, namely, labor flexibility implementation (called the indirect effect).

2.2. Human resource management practices and acquired labor flexibility

Discussions on labor flexibility appear frequently in the HRM and operations management literature. In HRM, labor flexibility is discussed in the context of job enlargement/enrichment, which focuses on an individual's innate need for personal development and growth (Maslow, 1970; Herzberg, 1966). This literature stream emphasizes the need to design jobs that provide employees with a wide range of job functions with frequent assignment changes (Ellis, 1999). More recently, a new paradigm is surfacing in HR discipline called high performance work systems (HPWS) that is replacing the unions and collective bargaining; it is providing extensive development activities likely to favor the abilities needed to promote labor flexibility (Beltran-Martin et al., 2008). In operations management, the kaizen (continuous improvement) literature introduces the notion of each worker performing several different tasks. Workers switching from a traditional work environment to a kaizen environment acquire higher order skills through extensive cross training and participation, and often move from a single repetitive job to a broader range of responsibilities (Womack and Jones, 1996; Shingo, 1988). Likewise, the firms that follow the just-in-time system continuously upgrade employee skills and encourage employees to acquire new skills (Liker and Meier, 2007).

Numerous evolving HR practices, such as training, employee involvement, and incentive systems are offered in both HRM and OM literature to promote labor flexibility (Beltran-Martin et al., 2008; Sumukadas and Sawhney, 2004). In this paper, we attempt to empirically validate the impact of these evolving HRM practices on labor flexibility, and will provide greater insight into the type of training and the method of training that best promote labor flexibility.

2.2.1. Training and acquired labor flexibility

Companies seek good recruiting procedures to influence the skill set of new employees. However, new workers only form a small portion of the total workforce. Therefore, the importance of training in promoting acquired labor flexibility cannot be overstated. Nevertheless, there is cost to train workers to acquire multiple skills. Given budgetary constraints, an important question faced by managers is to examine the number of skills a worker should acquire and the type of ideal skill-sets for those who are cross trained (Aksin and Karaesmen, 2007).

Equipment- versus process-focused training: We concur with Iravani et al. (2005) that training is an inherently good thing. However, it is important to strategically select the training choices that will yield the most benefit to the company. With a fixed amount of budget and time available for training, an important decision faced by management is that of the breadth versus the depth of skills to be imparted (Gomez et al., 2003). According to Hopp and Van Oyen (2004), two types of training plans are observed: (i) *Equipment-focused training* emphasizes on the acquisition of in-depth skills related to the equipment being operated. Examples include operators learning to perform their own set-ups, in-process inspection, preventive maintenance, and minor repairs. (ii) *Process-focused training* concentrates on building skills focused on operating the different pieces of equipment that are used in the production process, thus adding to the breadth of skills. There are advantages to both methods of training. Workers in plants with process-focused training are almost certain to learn to operate a greater variety of equipment. These workers are better able to conduct upstream and downstream jobs, enhancing cooperation and increasing team-based kaizen initiatives (Hackman, 2002; Ichniowski and Shaw, 1999). Firms that have provided equipment-focused training under the auspices of total productive maintenance have reported significant improvements in quality, maintainability and cost (Hopp and Van Oyen, 2004; Nakajima, 1988). However, to the extent that more equipment-focused training comes at the cost of less process-focused training (as managers work within limited training budgets) one would expect acquired labor flexibility to be adversely affected by an emphasis on equipment-focused training. These arguments lead to the following two hypotheses.

Hypothesis 3a. Process-focused training is positively related to the acquisition of labor flexibility.

Hypothesis 3b. Equipment-focused training is negatively related to the acquisition of labor flexibility.

Job-rotation training: There are various formal and informal mechanisms to provide training, such as classroom training, self-learning through trial and error, shadowing others at workplace, and hands-on experience as an apprentice moving between different work-centers. The last method, also referred to as job-rotation training, is the most mentioned training method for improving employee skill diversity in the organizational learning literature (Eriksson and Ortega, 2006; Bokharst et al., 2004; Osterman, 1994). The job-rotation training method has been reported as a standard practice in many Japanese and Australian organizations (Hoyt and Matuszek, 2001; Cordery, 1989; Bartlett and Ghoshal, 1987), and most firms in the U.S. do the same. Trainees rotate through various jobs as they learn to operate different equipment with coaching and feedback from more experienced employees and supervisors. The job-rotation training at Toyota Tsutsumi plant (Muramatsu and Kazuyoshi, 1987), North American Tool and Die Company (Bobrowski and Park, 1993), General Motors Corporation and National Steel (Denton, 1992) has helped their workers adapt better to redesigned and enriched jobs, promoting the acquisition of labor flexibility. These arguments lead to the following hypothesis.

Hypothesis 3c. Job-rotation training is positively related to the acquisition of labor flexibility.

Job tenure: Due to continually changing technology, a commitment to lifelong training and learning is required to maintain a flexible skill base. Since learning through on-the-job training is cumulative, one would expect to see acquired labor flexibility increase with the number of years employees work in an

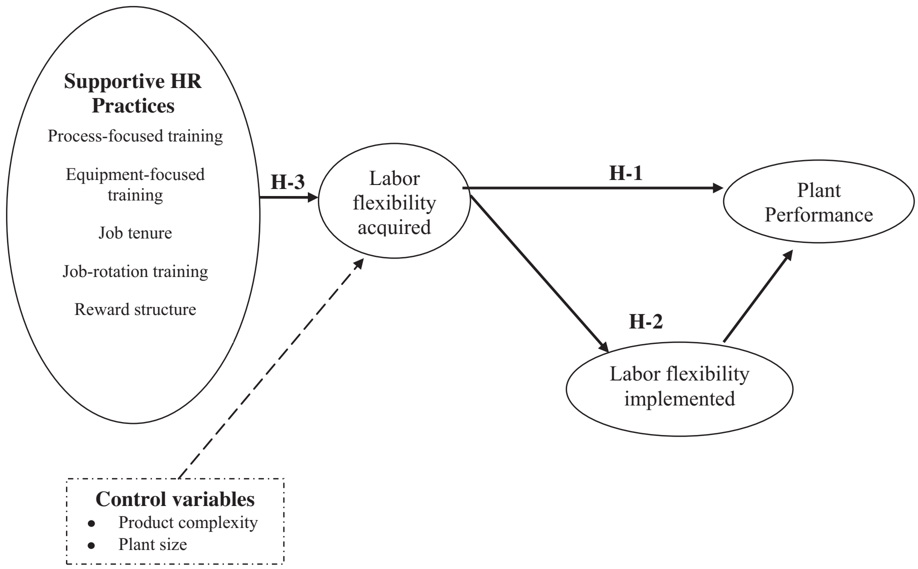

Fig. 1. The research model.

organization. In an empirical study, Giniger et al. (1983) found older employees surpassed the younger ones in speed and skills. When the influence of age was removed, Giniger et al. (1983) found a positive relation between years of experience (job tenure) and the breadth of skills. These arguments lead to the following hypothesis.

Hypothesis 3d. Job tenure is positively related to the acquisition of labor flexibility.

2.2.2. Reward system and labor flexibility

"The effectiveness of skilled employees will be limited, however, if they are not motivated to perform their jobs" (Delaney and Huselid, 1996, p. 950). Expectancy theory dictates that to motivate an employee to engage in desired behavior, reward has to be valued (Beltran-Martin et al., 2008). Based on this tenet of expectancy theory, the compensation literature addresses labor flexibility in the context of skill-based-pay (SBP). Individuals should be rewarded based on the number, type, and depth of skills mastered (Recardo and Pricone, 1996), and to work cooperatively in sharing their knowledge and working as a team (Siemsen et al., 2008), behaviors that are consistent with labor flexibility. Many firms actually follow this practice. For example, Matsushita Electric Company promoted labor flexibility with a six-level pay structure (Frazelle, 1986). Workers reached levels 5 and 6 when they mastered three to five different jobs and could teach them to others. Similarly, Motorola introduced a compensation system that rewarded those who learned a variety of skills at its Arlington Heights plant (Denton, 1992). Studies in Australian (Cordery, 1989) and Japanese (Dore et al., 1989) companies also found a positive impact of compensation and reward system on the acquisition of additional skills. These arguments lead to the following hypothesis.

Hypothesis 3e. The reward practices based on greater skills are positively related to the acquisition of labor flexibility.

2.2.3. Control variables

Conceptually, more complex printed circuit board designs may require advanced labor skills, which restricts workers from mastering multiple skills (Schultz et al., 2003; Sawhney and Piper, 2002; Nembhard, 2000) thus adversely impacting the acquisition of labor flexibility. Similarly, plant size may interfere with labor flexibility. Smaller plants can provide rapid decision making ability to acquire additional skills. On the other hand, larger plants can afford greater allocation of resources to train multi-skilled labor, thus having more flexible labor (Sawhney and Piper, 2002). Therefore, product complexity and plant size are employed as control variables in the study, although they have been ignored in the previous empirical studies.

Based on the above hypotheses the research model is presented in Fig. 1 above.

3. Field study

An exploratory field study was conducted in ten printed circuit board (PCB) manufacturing companies with the objective of validating that the questions raised in the theoretical development phase are relevant, that the variables included in the model are meaningful to companies, and to identify the measures for the constructs. Following the advice of Yin (1989) and Eisenhardt (1989) an industry sample was structured to include plants that varied from the most automated to the most labor-intensive; and from the biggest to the smallest. Visits to each company, in which managers were interviewed and company records examined, resulted in the observations below. Since the purpose of the field study is not to test the hypotheses the observations are presented in a consolidated summary. Hypotheses testing are done in Section 4 using survey data.

The PCB industry is chosen for two reasons. First, PCB fabrication operates in a competitive environment in which flexibility in general, and labor flexibility in particular, is critical to success. PCB boards are customized, and production cannot start until customers provide the designs. Moreover, PCB plants do not hold finished goods inventory due to their customers' frequently changing proprietary board designs. Customer demands for product-mix and order-size vary widely and are hard to predict, creating extreme variations in the use of plant capacity along with shifting bottlenecks. Therefore, multi-skilled labor can be expected to play an important role in addressing these shifting bottlenecks and smoothing the production flows. Absence of finished goods inventory also addresses an important behavioral concern, the "motivation of working faster or slower" (Schultz et al., 2003, p. 82). Second, the PCB manufacturing process involves over 40 individual steps spread over an extensive range of technologies;

including mechanical, chemical, electrical, and photographic operations (see Bosshart, 1992). Hence, the results of this study could be expected to have more generalizability than those from a study of an industry that employs a less extensive range of technologies.

3.1. Field study observations

Multi-skilled workers were desired by the PCB plants because such workers could perform a wide range of job functions and accept frequent assignment changes. These plants reported that the cost of moving workers declined as greater number of workers in a plant became multi-skilled. We observed that there was wide variation in both the level of multi-skilled workers in these plants as well as the extent to which they were being moved around to address the temporary overloads. We found that just because a worker could operate another machine and/or handle another job was not the only criteria of moving them around to overloaded work-center, a number of technical and behavioral factors played an important role in this decision making. Loss of efficiency in getting back to their normal work assignment due to learning and re-learning, the extent of physical move, and the labor practices hindering workers to be used for multiple jobs were some of the important technical factors that kept surfacing in our conversations with different plant managers. A number of behavioral issues such as worker motivation, fairness, the free-rider problem, interaction with other workers, also came up in our discussions, which constrained the plant managers when moving the workers to address temporary overloads. Such observations have also been previously reported by Schultz et al. (2003), both in their field study of Daignault Rolland, a sports goods manufacturing company, and in their controlled lab-experiment. These technical and behavioral trade-offs reduced the ability of the plant manager to utilize the acquired labor flexibility in moving them to address temporary overloads and imbalances. We found the extent to which the multi-skilled workers were being moved around in a plant was a good proxy indicator of the implementation effectiveness of available labor flexibility, given all the technical and behavioral trade-offs.

A worker with more number of skills provided greater flexibility to the plant manager to utilize this worker. Respondents felt that a worker handling two operations typically provided 20% more flexibility to the plant manager to utilize him/her as compared to a worker who could handle only one operation; a worker handling three operations typically provided 50% more flexibility to the plant manager to utilize him/her as compared to a worker who could handle only one operation; a worker handling four or more operations typically provided 80% more flexibility to the plant manager to utilize him/her as compared to a worker who could handle only one operation.

In seven plants the emphasis was on training operators to work on more than one workstation, typically comprising the preceding and succeeding workstations, but many workers knew more. Little to no emphasis was placed in these seven plants on training to maintain and service the equipment. Workers were primarily trained through rotation amongst the different stations, working under the watchful guidance of skilled operators and supervisors. By virtue of this process-focused training, greater labor flexibility was achieved by these operators, allowing them to operate more than one workstation. In these plants, we also observed that a part of the worker compensation plan was tied to the number of jobs they were qualified to do. On the other hand, three plants focused their efforts on training employees to acquire skills in maintaining and servicing their equipment. Operators in these companies could do minor repairs, and mostly operated one workstation symbolizing lower labor flexibility.

4. Model testing

4.1. Measuring the variables

In this section, we present the measures based on our field study and the literature review.

Labor flexibility was measured as a proportion of operators able to perform multiple jobs (Sumukadas and Sawhney, 2004; Hopp and Van Oyen, 2004). Based on the field study, we were aware that the number of jobs an operator could perform was an important distinction that needed to be captured as we constructed the labor flexibility index for a plant. Consequently, we asked for a detailed breakup on the operators who could perform multiple jobs, namely, percentage of operators who can perform one job, percentage of operators who can perform two jobs, percentage of operators who can perform three jobs, and percentage of operators who can perform four or more jobs – the total of all these categories was a hundred percent. Based on the expert opinions gathered during the field study, an increasing weighting scheme was adopted that distinguished between workers who could handle one job (weight = 1), two jobs (weight = 1.2), three jobs (weight = 1.5), and four or more jobs (weight = 1.8). Using these weights, we developed a weighted index for labor flexibility for each plant. Similar technique has been used by Bartholdi and Eisenstein (2005) in ranking the workers from slowest to fastest in constructing the flexibility index in their bucket brigade model and by Iravani et al. (2005) in constructing structure flexibility matrix.

Process-focused training was reflective of the breadth of skills and ability to work in teams (Hopp and Van Oyen, 2004). It was formed by two items measured from '*1 not important*' to '*7 very important*': (1) importance given in training toward developing skills in handling multiple operations; and (2) importance given in training toward developing ability to work in teams (Gunasekaran, 1998).

Equipment-focused training was reflective of the depth of skills (Hopp and Van Oyen, 2004). It was formed by four items measured from '*1 not important*' to '*7 very important*': (1) importance given in training toward developing skills in reducing set-up time; (2) importance given in training toward developing skills in handling minor repairs; (3) importance given in training toward developing computer skills, and (4) importance given in training toward developing equipment-problem solving skills (Plonka, 1997).

Job-rotation training was formed by two items: (1) extent to which plant floor employees are trained by rotating between work centers ranging from '*1 not at all*' to '*7 a great extent*'(Eriksson and Ortega, 2006); and (2) number of hours of such training per year given to plant-floor employees (Beltran-Martin et al., 2008; Delaney and Huselid, 1996). The second item, which was a continuous variable, was transformed into a seven point interval scale before it was used to form the job-rotation training measure. According to the measurement theory (Suppes and Zinnes, 1962), once a set of measurements have been made on a particular scale, it is possible to transform the measurements to yield a new set of measurements at a different level. It is always possible to transform from a stronger level to a weaker level, as the case here.

Reward structure was based on the work by Sumukadas and Sawhney (2004) and Lawler et al. (1992). This construct was formed by two items measured from '*1 not at all*' to '*7 a great extent*': (1) the extent to which flexibility improvement formed an important component of plant manager's evaluation; and (2) the extent to which the organization's reward and recognition practices were linked to the number of jobs that employees were qualified to perform.

Labor flexibility implementation had no prior empirical measure and hence reliance was placed on the expert opinion gathered during field work to identify its measures. We were given to understand that implementing labor flexibility meant that workers have to move between different jobs at different skill levels, therefore, the labor practices within the plant should be favorable to allow such practices. This construct was formed by three items measured from '*1 not at all*' to '*7 a great extent*': (1) the extent to which the labor practices allowed workers to be used for multiple jobs; (2) the extent to which management used flexibility improvement as a way to increase profits; and (3) how often does the plant resort to transferring multi-skilled labor to bottleneck areas from other areas when faced with temporary bottlenecks and overloads.

Performance measure, Roth (1989) argues, should depend on the research objective. Accordingly, we plan to design the performance measure to reflect the hypothesized consequences of the effective deployment of multi-skilled labor. As discussed earlier, labor flexibility should enable plant management to maintain production flow, thus avoiding queues at bottlenecks and reducing work-in-process (WIP) inventory build-up. Supporting this notion, studies (Hopp and Van Oyen, 2004; Oliver, 1990) have found high correlation between labor flexibility and WIP reduction. These labor flexibility enhancing efforts will concurrently reduce costs by reducing idle labor and equipment. Therefore, the performance measure was formed by two items: (1) work-in process inventory (WIP) and (2) manufacturing cost. Our field study experience and that of prior researchers suggest that there is a respondent reluctance to provide objective data on WIP and cost. Therefore, comparable data on manufacturing performance was obtained by asking respondents to provide a rating of their firm's performance relative to the industry averages. Jayaram et al. (1999) argue that relative measures are good indicators when studying a single industry, the condition in this study. Each item ranged from '*1 far worse than competitors*' to '*7 far better than competitors*'.

Product complexity in PCB industry is measured by hole size, line width, and number of layers that are embodied in the circuitry (Bosshart, 1992). Drilling and plating small holes becomes increasingly difficult as the number of layers increase. Therefore, the measure for product complexity sought data on (1) the typical hole size provided (reverse coded), (2) the typical line width provided (reverse coded), and (3) the typical number of layers provided. Since these were continuous items, they were first transformed into interval items on 7-point scale before they were used to form the scale for 'product complexity'. According to the measurement theory (Suppes and Zinnes, 1962), once a set of measurements have been made on a particular scale, it is possible to transform the measurements to yield a new set of measurements at a different level. It is always possible to transform from a stronger level to a weaker level, as the case here.

According to Wanous et al. (1997), single item measures are appropriate when measuring self-reported facts or when "the construct being measured is sufficiently narrow or is unambiguous to the respondent" (p. 247). Single item measure was used for *job-tenure* that required factual information and was measured by the number of years that a typical shop-floor employee had worked at the plant. On the other hand, *plant size* was measured by the number of employees (Sumukadas and Sawhney, 2004), a measure that is used frequently in the literature.

4.2. Sampling

The population was the 300-plus plants of the North American PCB industry. Equal numbers of plants from three plant-size stratum (less than 50 workers; 51–100 workers; greater than 100 workers) were selected resulting in a stratified sample of 180 plants. Respondents were senior managers responsible for operations, typically vice president of operations, vice president of manufacturing, or director of operations. Thirteen firms were later dropped from the sample because they were either prototype shops or printed wired board facilities not PCB manufacturers. Dillman's (1978) total design principles of mail questionnaires were followed.

Table 1
Sample size and response rate.

Firm size (number of employees)	Response size versus sample size	Response rate
<50	21 of 54	39%
51–100	26 of 56	46%
>100	27 of 57	47%
Total	74 of 167	45%

A total of 74 usable responses were received from the reduced sample of 167 firms, representing a 45% response rate. Three plants had unions; but no noticeable differences were seen as compared to the non-union plants. As shown in Table 1 above, these responses were almost equally spread across the three stratums and thus provided confidence that all the three size categories were adequately represented by our data.

4.3. Methodology

Causal models are frequently examined by covariance structure analysis (e.g. LISREL), which necessitate well developed a priori theory (Fornell, 1983). Given the lack of well-developed theories in our research area, we utilized the structural equation modeling that is afforded by Partial Least-Squares (PLS) method. This modeling approach "makes minimal demands about measurement scales, sample size, and the distribution of residuals" (Fornell and Bookstein, 1982, p. 449) and "avoids many of the restrictive assumptions underlying maximum likelihood techniques" (p. 440). The analysis was conducted using SmartPLS version 2.0 (Ringle et al., 2005) that provides a Graphical User Interface (GUI), which allows a user to easily express his/her model as a path diagram and also to view the estimates of the model parameters in the same diagram.

A PLS path model is described by two models: (1) measurement model that relates the manifest variables (MV or the items) to their latent variables (LV or the constructs), sometimes called the outer model and (2) a structural model relating the endogenous and exogenous LVs through paths, sometimes called the inner model. A path model can be validated at three levels: (i) the quality of the measurement model, which is similar to testing for construct validity by checking convergent and divergent validity, (ii) the quality of the structural model, which is similar to checking *R*-square and the goodness of fit of the equations of the model using *F*-statistics, and (iii) each structural regression equation, which is similar to checking the *t*-statistics to see whether the association is significant or not.

4.4. Construct validation

Lack of past-validated measures necessitated a significant reliance on the field study for content and construct validity. The survey instrument was developed after interviews at different organizational levels, factory visits, and analysis of company documents, followed by pilot tests at two beta sites. Continuous interaction was maintained with industry experts, who reviewed and commented on the questionnaire, thus enhancing its content validity (O'Leary-Kelly and Vokurka, 1998). A revised questionnaire was reviewed by colleagues for clarity, and finally pre-tested with three managers as a reality check (Malhotra and Grover, 1998). The project's 45% response rate is indicative of strong support that was received from the PCB industry.

A non-response bias check was performed for the companies that did not respond. A comparison of the profiles of responding plants and non-responding plants failed to identify any systematic difference that might explain the non-responses. Further, the last one-fourth of surveys received was not statistically different from the first one-fourth (Lambert and Harrington, 1990). In a few cases phone calls were made to complete missing responses or to verify seemingly illogical ones. Random telephone calls were also made to a few companies to cross validate the data, thus increasing confidence in the results (Malhotra and Grover, 1998). Pseudo test–retest reliability checks were performed using archival data collected from the respondents' public web sites, and from third party Internet information providers.

It is important to ensure that the measures of the constructs are reliable and valid, before proceeding to draw conclusions about the relationships among the constructs. In PLS model, the item reliability is assessed by the loadings of respective items on their respective latent constructs (Hulland, 1999). The higher loading implies that there is higher shared variance between the construct and its measure than error variance. Scale reliability, implying that the measurement is free of random errors, can be assessed in PLS using an Internal Consistency (IC) measure (Werts et al., 1974). Though Cronbach's α is more commonly used, IC is more general and, unlike α, it is not adversely influenced by fewer items in a measurement scale. Cortina (1993, p. 103) demonstrates the extent to which Cronbach's alpha is affected by the number of items, average item inter-correlation, and dimensionality. He shows that alpha can be rather high and acceptable by the standards of 0.7 used by many, inspite of low average item inter-correlation or multidimensionality, provided there is sufficient number of items. Cortina (1993) goes on to show the range of alphas that are possible with increases in the number of items even with pronounced multidimensionality. In addition, theory and measurement are necessarily better integrated because IC is computed within the context of a research model (Sumukadas and Sawhney, 2004). IC values of 0.7 and above (Table 2) indicate that the measurement scales are adequately reliable (Nunnally, 1978).

All measurement items, except one, had their loadings on the construct at 0.6 or above (see Fig. 2), and were significant at $p \leq 0.01$, indicating good convergent validity. The measurement item with loading less then 0.6, namely, number of layers (to measure product complexity) was dropped. The square roots of the Average Variance Extracted (AVE) exceed 0.7 and also are larger than the inter-construct correlations (Table 2), thus indicating good discriminant validity (Fornell and Larcker, 1981). In other words, the measurement items corresponding to a construct did not cross-load excessively on other constructs.

5. Results

Having established the strength of the measurement model above, it is possible to examine the relationships among the model constructs. A PLS model specifies relations between latent constructs that are tested by estimating the paths between the constructs, which are indicators of the model's predictive ability. The path coefficients and significance levels are taken as an indication of support for the hypothesis. The statistical significance (t-values) of estimates is examined in PLS by incorporating bootstrapping technique in which multiple subsamples from within the same sample are taken to build a distribution for each parameter and derive a standard estimate (Efron and Tibshirani, 1993). Therefore, no distributional assumption is made of the data (Sumukadas and Sawhney, 2004). "The number of resamples has to be specified. The default is 100 but a higher number may lead to more reasonable standard error estimates" (Tenenhaus et al., 2005, p. 176). In order to test the robustness of the model, the SmartPLS bootstrapping procedure was run with different number of resamples (namely, 200, 300, and 400) and the results were found to be very stable. Here we report the results from analysis of 300 samples. In addition, the PLS

Table 2
Construct validation.

	Internal consistency	Process-focused training	Equipment-focused training	Job tenure	Job-rotation training	Reward structure	Labor flexibility acquired	Labor flexibility implemented	Plant performance	Product complexity	Plant size
Process-focused training	0.938	**0.940**[b]									
Equipment-focused training	0.870	−0.010[d]	**0.791**								
Job tenure	–[a]	0.098	0.090	–[c]							
Job-rotation training	0.751	0.436	−0.106	0.132	**0.777**						
Reward structure	0.916	0.422	−0.155	0.107	0.472	**0.919**					
Labor flexibility acquired	–[a]	0.567	−0.437	−0.009	0.573	0.630	–[c]				
Labor flexibility implemented	0.768	0.440	−0.151	0.185	0.552	0.712	0.666	**0.726**			
Plant Performance	0.840	0.064	−0.007	0.074	0.110	0.089	0.205	0.308	**0.854**		
Product complexity	0.858	0.116	0.149	−0.020	0.106	0.022	−0.137	−0.078	−0.031	**0.867**	
Plant size	–[a]	−0.106	−0.0003	0.091	0.229	0.058	−0.089	0.067	−0.225	0.178	–[c]

[a] Internal consistency not computed for single item scale.
[b] Numbers in the diagonal, in bold, are square roots of average variance extracted (AVE).
[c] AVE not computed for single item scale.
[d] Off-diagonal numbers are inter-construct correlations.

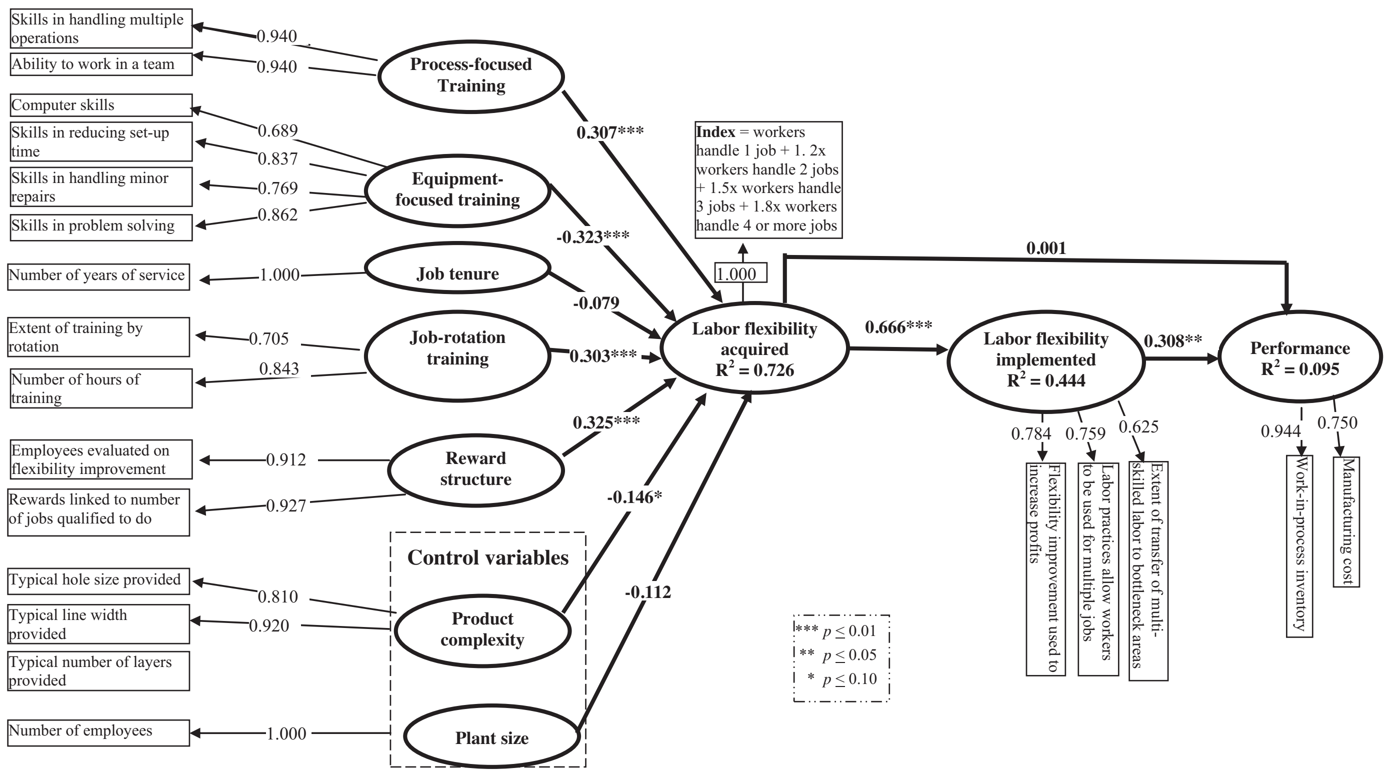

Fig. 2. Analysis of the research model.

methodology attempts to maximize the explained variance in the endogenous constructs (R^2). PLS does not provide a goodness-of-fit index or other measures of model fit because PLS does not make any distributional assumptions. Instead, an indication of model fit is provided by the redundancy between constructs (shared variances, that is, R^2 values). Amato et al. (2004) propose a global criterion of goodness of fit (GoF) as the geometric mean of the average communality and the average R^2. GoF measure is normed between 0 and 1, where a higher value represents better path model estimations.

$$\text{GoF} = \sqrt{\text{average communality} \times \text{average } R \text{ square}}$$

The research model is displayed graphically in Fig. 2 above. In examining the structural model the path coefficients derived are the regression coefficients between endogenous and exogenous constructs. For example, the path coefficient estimating the direct effect of labor flexibility acquired on performance is 0.001. This indicates that, on average, a standard deviation increase in labor flexibility acquired is associated with a 0.001 standard deviation increase in performance, statistically controlling for the effect of other explanatory variables. The path coefficients presented here are accompanied by the corresponding significance levels, indicated by the stars placed in the superscript. Given the exploratory nature of our research, a liberal p-value of 10% was used for testing the proposed hypotheses. The numbers seen in Fig. 2 attest to the predictive strength of the model, the discussion of which is presented next.

5.1. *Labor flexibility and plant performance*

The total effect of labor flexibility acquired on plant performance is 0.206 with p-value ≤ 0.001, suggesting that the effect is highly significant. The total effect is the sum of the direct and the indirect effects. The direct effect of labor flexibility acquired on plant performance is represented in Fig. 2 by a unidirectional causal arrow linking the two constructs. The direct effect is 0.001 with p-value ≤ 0.996, which is not significant, thereby not supporting the first hypothesis.

However, the impact of labor flexibility acquired on performance was channeled indirectly through the intervening variable namely, labor flexibility implementation, thus supporting Hypothesis 2. As theorized, the impact of labor flexibility acquired on labor flexibility implementation was 0.666 with p-value ≤ 0.0001, suggesting a strong and significant positive impact. And the impact of labor flexibility implementation on performance was 0.308 with p-value ≤ 0.043, suggesting a strong and significant positive impact.

The above results are consistent with the notion that simply acquiring labor flexibility is not enough to improve plant performance, but the effectiveness in implementing labor flexibility is an extremely important intervening value added step. In other words, the productivity losses due to technical and behavioral factors accompanying the implementation of labor flexibility need to be appropriately managed to experience improved plant performance from the acquired labor flexibility.

5.2. *Management actions and labor flexibility*

As hypothesized, acquired labor flexibility related positively to process-focused training ($p \leq 0.01$), negatively to equipment-focused training ($p \leq 0.01$), positively to job-rotation training ($p \leq 0.01$), and positively to reward structure ($p \leq 0.01$). The relation between labor flexibility and job-tenure was not significant (see Fig. 2). Although workers with longer job-tenure are likely to have had more opportunities to learn more than one job; beyond a certain age they likely have had less formal education, learn more slowly than their younger colleagues, and therefore, are less easily engaged in multi-skilling initiatives. Under these circumstances, the failure to control for employee age causes job-tenure to act as a surrogate, thereby distorting the hypothesized association. Another confounding variable could be disparities in employees'

Table 3
R-square, communality, and redundancy.

	R-square	Communality	Redundancy
Labor flexibility acquired	0.726	1.000	0.178
Labor flexibility implemented	0.444	0.527	0.233
Plant performance	0.095	0.727	0.0002
Average	0.422	0.751	

work experience prior to being employed at the plant. A new plant would employ, by definition, workers with extremely low job tenure. If these employees had worked at another plant, however, they might already possess the skills needed for flexible job assignment. The various factors (including employee age, education and work experience) that modify the impact of job-tenure on labor flexibility, need to be examined in future research.

We found that product complexity had a negative impact on acquired labor flexibility, thus supporting our conceptualization that more complex boards require advanced labor skills thus restricting workers from mastering multiple skills. On the other hand, plant size did not have a significant relationship with acquired labor flexibility. These results support our hunch that embedded in plant size are two opposing forces working simultaneously, which tend to neutralize each other. On one hand, large plants have more resources to train their workers and hence have greater ability to acquire higher labor flexibility. On the other hand, larger plants are also involved in manufacturing more complex boards that require advanced labor skills thus restricting workers from mastering multiple skills.

5.3. Model evaluation statistics

For evaluating the model, the fit of model to the data is summarized by the model-evaluations statistics presented in Table 3 above.

As shown in Table 3, the research model explained 72.6% of the variance observed in labor flexibility acquired. Using Chin's (1998) recommendations where R^2 values of 0.67, 0.33, and 0.19 for endogenous latent variables are described as large, moderate and weak respectively, a R^2 of 72.6% would be considered a large effect size. Additionally, 44.4% of variance observed in labor flexibility implemented would be a moderate effect size. And 0.095% of variance observed in plant performance would be considered a weak effect size. Overall, the average R^2 of 42.2% and GoF value of 56.3% suggest a good indication of model fit (Amato et al., 2004).

6. Conclusions and future research

Although a positive relationship between acquired labor flexibility and plant performance is intuitively appealing, the empirical research has lagged behind. Moreover, prior empirical evidences have not fully clarified the processes through which evolving HR practices impact plant performance (Beltran-Martin et al., 2008). Our research delineates this process and advances the understanding of this relationship by introducing a mediating variable, namely, labor flexibility implementation that captures the sophistication of moving flexible labor to manage temporary bottlenecks and overloads. In doing so, this mediating construct captures the actual efficiency of managing the technical and behavioral trade-offs, such as the loss of walk times, training costs, learning and forgetting time, and efficiency versus quality, that have been at the heart of the debate (Schultz et al., 2003; Aksin and Karaesmen, 2007). It supports the notion that the server assignment policy (Andradottir et al., 2003) needs to be astutely managed to maximize the capacity of the queuing network leading to improved plant performance. Our findings lend further empirical credibility to the findings of Schultz et al. (2003), suggesting that in the act of implementing labor flexibility the plant managers must minimize the emerging behavioral trade-offs to help increase plant performance. In other words, simply acquiring labor flexibility is not enough to improve plant performance; managers need to be also astute in implementing labor flexibility.

We develop a measure for acquired labor flexibility based on our field study observations. Our research also offers a fresh look at some of the HRM actions that enhance the acquisition of labor flexibility. Perhaps the strongest and most consistent pattern of findings in our study is the beneficial impact on labor flexibility of a change in management actions from directive to supportive. Plants that provided greater levels of process-focused training instead of equipment-focused training, greater job-rotation training, and more reward practices based on greater skills acquired higher labor flexibility.

Our results lend credibility to the resource based view arguments that highlight the relevance of creative and flexible labor resources to a plant's performance. In addition, this study connects current approaches to job design such as the job characteristics model, job enrichment, quality of work life, just-in-time, and kaizan, to labor flexibility and plant performance.

6.1. Managerial implications

For many years there has been a wide belief among academics and practitioners that employees are the most important resource to achieving superior plant performance. Our results endorse this assertion by supporting the notion that the plants that acquired higher labor flexibility and executed it well in the form of implementing labor flexibility by transferring multi-skilled workers to bottleneck areas enjoyed higher plant performance.

This paper contributes by helping OM and HR researchers and practitioners gain insight into potential value of HRM practices to OM related performance indicators by providing a theoretical framework of value creating relationships. In this study, higher acquired and implemented labor flexibility has been identified as a significant contributor to plant performance measured by reduced WIP inventory and cost. While these performance indicators are typically the responsibility of operations managers, the management actions that promote both the acquisition and implementation of labor flexibility are frequently in the domain of HR managers. Our results suggest that firms who establish a culture of high integration and joint working between operations and human resources departments will realize significant improvements in plant performance. Similarly, both the operations manager and the human resource manager need to work cooperatively in work reorganization to allow for sophisticated labor flexibility implementation.

In addition, given the sustained and long-term efforts required to change the capabilities of workers, management needs to adopt a long-term strategic approach in the development of labor skills and attitudes. There needs to be a change in the trend that was reported in 1990s (Reich, 1991), and still continues to persist (Mangan and Christopher, 2005), that U.S firms invest inequitably far more in new plants and equipment than they do in education and training of their workers, which provides for labor flexibility.

The value of our study to practitioners lies in the findings from our empirical research in the printed circuit board industry. The single-industry investigation has the benefits of more control and richer explanations, while encompassing the technologies used in a much broader industrial segment. There is reason to believe that these findings extend well beyond the printed circuit board fabrication industry. As already noted earlier, PCB fabrication shares a broad range of processes with many other manufacturing industries, so it is reasonable to expect comparable impact of management actions on plant performance via improved labor flexibility in other industries.

6.2. Future research

The development of a strong theoretical foundation for managing labor flexibility is only in its infancy. Additional theoretical and empirical research is needed for many of the relationships explored in this paper. First, future research can refine the new constructs identified in this study, namely, labor flexibility, management actions, and plant performance. The various factors (including employee age, education and work experience) that modify the impact of job-tenure on labor flexibility also need to be examined in future research. More research is also needed on the determinants of and motivation for investment in both acquiring and implementing labor flexibility. In other words, greater understanding is required to decrease the technical and behavioral trade-offs that interfere with implementing labor flexibility. Second, other plant performance measures such as profitability, net profit margin, market share, and return on equity can be introduced to enrich the construct. A natural order of progression for such research would involve repeating this study with a larger sample of firms in another industrial setting. Before repeating the study, it would be advisable to first revamp the survey to expand the single item scales. Another useful extension would be to replace the present study's exclusive reliance upon operations managers with respondents also from HRM.

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