The Mediating Effect of Strategic Project Selection in Process Improvement Program Success

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March 16, 2006

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Abstract

Process Improvement Programs (PIPs) such as Total Quality Management, Six Sigma, JIT, and Lean have been the subject of much research over the last two decades. Most research on PIPs examines one specific type of PIP and attempts to evaluate the impact of specific PIP practices on performance. While most scholars agree that PIP research is extremely important, they also agree that it is difficult to make valid assessments about PIPs because the content of PIPs is not clearly defined and changes over time. This research takes a more strategic program management perspective for the study of PIPs. The research empirically examined the fit between two PIP management factors: Strategic Project Selection (SPS) and Disciplined Project Management (DPM), and the impact of fit on performance. Using data collected from 53 supplier plants, regression analysis found that the relationship between DPM and Performance was mediated by SPS. This finding contributes to future theory development and suggests a viable strategy for PIP success: organizations that maintain a focus on DPM will achieve SPS and this will lead to program success.

Keywords: Process improvement programs, empirical research, quality management, project management
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1. Introduction

The focus of this research is on Process Improvement Programs (PIPs), which Zhang, Hill, Schroeder, and Linderman (2006) define as a systematic approach for improving organizational performance that consists of specific practices, tools, techniques, and terminology and is implemented as a set of process improvement projects. PIP research has been directed towards Total Quality Management (Easton and Jarrell, 1998; Hendricks and Singhal, 1996, 1997, 2001a, b; Kaynak, 2003; Samson and Terziovski, 1999), Six Sigma (Linderman, Schroeder, and Choo, 2005; Linderman, Schroeder, Zaheer, and Choo, 2003), JIT (Huson and Nanda, 1995), and Lean (Womack and Jones, 2003; Womack, Jones, and Roos, 1991). Most of the PIP research studies attempt to evaluate the impact of one type of PIP on performance.

While most scholars agree that research on PIPs is extremely important and that the existing research on PIPs has added value to the literature, most scholars also agree that it is extremely difficult to make any strong valid statements about PIPs. One of the most significant challenges for research on PIPs is that widely accepted definitions for most PIPs do not exist in either the research literature or in practice. This challenge is exacerbated by the fact that PIPs tend to change over time, and, in some cases, are even converging (e.g., Lean and Six Sigma). Research on PIPs is further complicated by the fact that few firms implement more than one program at the same time, which makes it difficult (if not impossible) to have a valid comparison of the efficacy of different PIPs in exactly the same business context.

In response to these challenges, this research follows the work by Zhang et al. (2006) and takes a more strategic “program management” perspective for the study of PIPs. They defined
Process Improvement Program Management (PIPM) as the planning, staffing, organizing, monitoring, and controlling of the projects in a process improvement program. PIPM activities include project selection, prioritization, resource allocation, and chartering. Schroeder, Linderman, Liedtke, and Choo (2006) supported the PIPM perspective when they pointed out that Six Sigma and TQM share very similar program practices but differ mostly in program management. This approach is also supported by Pande, Neuman, and Cavanagh (2000) who compared Six Sigma to TQM and ascribed much of the success of Six Sigma programs to program management.

Zhang et al. (2006) proposed two internal PIPM factors, Strategic Project Selection (SPS) and Disciplined Project Management (DPM), and empirically validated a plant-level measurement instrument for these factors. However, that research did not test the relationship between SPS, DPM, and organizational performance. This research tests the relationship between these two factors and organizational performance, and more importantly, also tests how these two factors fit together to improve performance.

Fit theory suggests that the fit between SPS and DPM will lead to performance improvement. However, the specific form of the fit relationship between these two factors has not yet been defined in the literature. Fit can be operationalized as moderation or mediation (Venkatraman, 1989). A clear understanding of the fit relationship between the two factors is needed to further theory development and provide guidance to practicing managers. The goal of this paper, therefore, is to better understand the relationship between the two factors (SPS and DPM) and organizational performance by comparing the two competing forms of fit—moderation and mediation.
This paper is organized as follows. Section 2 briefly reviews the theoretical foundation for the SPS and DPM factors and then contrasts the two competing forms of fit (moderation and mediation). Section 3 describes the empirical research design and the measurement instrument. Sections 4 and 5 describe the research methods, present the empirical results, and discuss the limitations of the research. Section 6 concludes the paper with a discussion of the theoretical and managerial implications.

2. Theoretical development

2.1. Strategic Project Selection (SPS)

Strategic Project Selection (SPS) measures the degree of strategic alignment an organization achieves in selecting and prioritizing process improvement projects. SPS is reflected in the critical program management tasks of project selection and prioritization. Norrie and Walker (2004) argue that the best organizations are careful to select projects that implement their business strategies. The level of strategic alignment in project selection and prioritization demonstrates an organization’s capability to wisely allocate scarce resources to achieve its most important strategic objectives.

The positive association between SPS and performance is supported by both the project management and strategic management literature. The Project Management Institute (PMI) considers project selection as one of the most important program success factors (PMI Standards Committee, 2004). Strategy scholars point out that the alignment between strategy and its implementation significantly impacts performance (Chandler, 1969; Porter, 1980; Venkatraman, 1989). SPS reflects the degree of alignment hence is positively associated with performance.

While a positive association between SPS and performance is supported by the literature, an empirical examination of this relationship is lacking in the context of process improvement programs. Therefore, this research will empirically test the following hypothesis:
HI: SPS is positively associated with performance.

2.2. Disciplined Project Management (DPM)

Disciplined Project Management (DPM) measures the degree to which an organization applies a consistent, structured, and accountable approach in managing process improvement projects. DPM includes dedicated and accountable improvement specialists (Flynn, Flynn, Amundson, and Schroeder, 1999; Schroeder et al., 2006) and a standard process improvement methodology with a project charter that defines the project metrics, goals, deliverables, scope, and timeline (Deming, 2000; Pande et al., 2000; PMI Standards Committee, 2004).

The positive association between DPM and performance is supported by the project management literature. The project management literature has long recognized the importance of project management discipline. A project typically consists of multiple interdependent tasks. Without a disciplined approach to project management, projects will not meet their stated objectives, and will not be completed on time and within budget (Eckes, 2003; Gray and Larson, 2000).

The positive association between DPM and performance is also supported by the quality management literature. Well-known standard project management methodologies such as PDCA and DMAIC emphasize a disciplined approach to project management and encourages rational decision making. Rational decisions, in general, will lead to positive outcomes (Churchman, 1962; Goll and Rasheed, 1997; Latane, 1959; Simon, 1979). One important aspect of DPM is a project charter that clearly defines the project objectives. The goal theoretical perspective suggests that clearly defined objectives (goals) can help explain the success of Six Sigma programs (Linderman et al., 2003). In a recent follow-up study, Linderman, Schroeder, and Choo (2005) established a positive association between Six Sigma methods, tools adherence, and
project success. Their research provides strong support for the positive association between DPM and performance.

Overall, strong support can be found for the positive relationship between standard project management methodology, dedicated improvement specialists, and project success. Aggregated project successes will contribute to organization level performance. This research hypothesizes, therefore, that:

H2: DPM is positively associated with performance.

2.3. The fit between SPS and DPM

The structural contingency theory (Donaldson, 2001) provides a framework to understand the relationship between SPS and DPM. A key idea of the theory is fit, that is, various components of a system must fit with each other for the system to achieve performance (Miller, 1992; Venkatraman and Camillus, 1984). SPS and DPM represent two different aspects of process improvement program management. They should fit together for a process improvement program to be successful. Fig. 1 depicts the model theoretically. Then it is necessary to specify the form of fit because the meaning of the theory itself can be fundamentally different if researchers fail to pay adequate attention to the form of fit (Van de Ven, 1979; Van de Ven and Drazin, 1985; Venkatraman, 1989).

A review of the literature suggests that two competing forms of fit are both reasonable: moderation and mediation. These two forms of fit are in the criterion-specific group in the framework developed by Venkatraman (1989). Forms of fit in the criterion-free group are irrelevant to this study because the goal of this research is to investigate the impact of fit on performance. The next two sections discuss these two competing forms. Once the models are developed, empirical data is used to test the two models to find the most plausible one.
2.3.1. *Fit as moderation*

Fit can be operationalized as moderation. Moderation means the relationship between an independent variable and a dependent variable is dependent on the level of a third variable, the moderator (Hair, 1995; Venkatraman, 1989). The fit between the independent variable and the moderator is the key determinant of the dependent variable. A moderator can affect the direction or the strength of the relationship between an independent and a dependent variable.

One plausible fit model is that SPS positively moderates the relationship between DPM and performance. As mentioned above, the positive relationship between DPM and project success is strongly supported by both the academic and practitioner literature, and aggregated project successes can contribute to organizational performance. Strategically selected projects support an organization’s mission and project successes can quickly translate into organizational-level performance.

In contrast, the success of many trivial projects may have little or no impact on organizational-level performance. Robinson’s (1950) “ecological fallacy” suggests that the
simple sum of individual project successes may not equate to significant organization-level performance.

This research hypothesizes, therefore, that the relationship between DPM and organizational performance is positively moderated by SPS. The positive moderating effect of SPS is depicted in Fig. 2 below and reflected in Hypothesis H3.

**H3**: The relationship between DPM and performance is positively moderated by SPS.

![Diagram](image)

**Fig. 2. The moderation model**

### 2.3.2. *Fit as mediation*

Fit can also be operationalized as mediation. Mediation means that the effect of an independent variable on a dependent variable is intervened by a third variable, the mediator. The theoretical basis for the mediation model is the existence of a cause and effect relationship along the chain of the three variables (Baron and Kenny, 1986).

The mediation model posits that SPS mediates the relationship between DPM and performance. The causal link between DPM and SPS is supported by two arguments. First, DPM promotes a highly disciplined, analytical, and fact-based organizational culture that encourages a structured project selection process. The argument is that an organization that is good at DPM will lean toward having a structured analytical process for difficult decisions such as project selection and prioritization. The second argument is that the causal link is also supported by the motivation and reward system for project leaders. DPM promotes the idea of
using dedicated project leaders and holding them responsible for project results. Dedicated project leaders are motivated to select strategic process improvement projects so they can bring significant results to their organization and earn positive performance reviews for themselves. It stands to reason, therefore, that higher DPM will lead to higher SPS, which will in turn lead to better performance. The mediation model is depicted in Fig. 3 and stated in hypothesis H4.

**H4:** The relationship between DPM and performance is mediated by SPS.

![Diagram of mediation model](image)

**Fig. 3. The mediation model**

In studying mediation models, it is necessary to distinguish between a full and a partial mediation model. In a full mediation model, the relationship between the independent variable and the dependent variable is completely mediated by the mediator. In a partial mediation relationship, the independent variable still has some direct effect on the dependent variable despite the mediated effect through the mediator. For the mediating relationship between DPM, SPS and performance, the current literature does not favor either one of the models. Analysis of the empirical data will show which model is most plausible.

### 3. Empirical research design

Plant-level empirical data was collected from the suppliers of a large high-technology electronics manufacturer. This firm will be referred to as High-Technology Inc. (HTI) hereafter, as per the confidentiality agreement between the firm and the university research team. The university research team and HTI invited supplier plants to participate in a web-based survey.
Multiple responses were requested from each plant. The HTI buyer group evaluated all supplier plants to measure performance.

3.1. Survey design

HTI is the largest division of a world-class Fortune 500 electronics manufacturer headquartered in North America with more than 10,000 employees worldwide. It is a world leader in the design and development of high-quality electronics products. HTI considered quality to be critical to its long-term success and emphasized this concept with its suppliers. Almost all HTI suppliers have implemented one or more process improvement programs.

The supplier base for HTI included a wide variety of suppliers from a number of different industries, making both mechanical and electrical parts, engineered and commodity parts, and high-value and low-value parts. Most suppliers were based in North America with a few of them in Europe and Asia. The size of the suppliers, in terms of the number of employees, also varied significantly. The entire population of plants in this supplier base was surveyed. Although the sample was limited to the suppliers for this one large manufacturer, the variety in the supplier base suggests that the research conclusions should be fairly generalizable across industries.

A web-based survey was conducted to collect empirical data for this study. The decision was made based on a thorough comparison of web-based and paper-based survey methods (Boyer, Olson, Calantone, and Jackson, 2002). Klassen and Jacobs (2001) suggested five criteria: cost, coverage error, response rate, item completion rate, and systematic error. The target respondents were professional managers and all had access to the Internet. A web-based survey was considered better than (or at least comparable to) other alternatives on all five criteria.

The survey website was easy to use. All the survey items were listed on one page using the same 7-point Likert scale. This effectively reduced the cognitive burden on the respondents. The items could be answered by simply clicking radio buttons. Several pilot tests were
performed with managers at HTI and other firms not in the sample to ensure that the survey could be completed within 10 minutes.

The survey invitation specifically requested three respondents (one sales manager, one manufacturing manager, and one quality manager) from each supplier plant. The goal was to find respondents who had good knowledge of the research subject (Flynn, Sakakibara, Schroeder, Bates, and Flynn, 1990). Having multiple respondents is desirable for studying complex problems because “a multitude of people at all levels are involved with various operating decisions, then efforts to measure competitive priorities [and other similar constructs] should encompass a broader scope than a single respondent” (Boyer and Pagell, 2000, p. 365, text in bracket added). Using a single respondent can lead to biased results because of the high risk of receiving a skewed perspective from one individual in a plant (Boyer and Verma, 2000).

A high response rate was achieved following the techniques suggested by Frohlich (2002). Response rate measures the quality and relevance of a study and a low response rate immediately raises the concern of nonresponse bias (Flynn et al., 1990; Malhotra and Grover, 1998). The university research team leveraged HTI’s close relationships with its suppliers and had the HTI commodity managers send out the initial survey invitations to suppliers. The survey website was hosted by the university rather than by HTI and the website clearly stated that HTI did not have access to any individual responses. This strong confidentiality protocol was designed to alleviate concerns about confidentiality that might lead respondents to not respond or to provide a biased response. The university research team actively engaged in the follow-up activities, assuring confidentiality, and promising to share the valuable benchmarking analysis to encourage participation.
### 3.2. Empirical data

All supplier plants (130) of HTI were invited to participate in the survey. The final complete data set included 104 valid individual responses from 53 plants, achieving a response rate of 40.8% at the plant level. Table 1 presents some characteristics of the sample.

No evidence of significant non-response bias was found in the data. Some previous studies checked for nonresponse bias by comparing early to late responses, assuming that late respondents represented non-respondents (Armstrong and Overton, 1977; Lambert and Harrington, 1990). This research collected demographic information from 20 randomly selected non-responding plants. A two-sample $t$ test on this data showed no evidence of significant nonresponse bias ($p = 0.34$).

<table>
<thead>
<tr>
<th>Sample characteristics</th>
<th>Individual responses</th>
<th>Total individual responses</th>
<th>104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual responses</td>
<td>Individuals from sales</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individuals from manufacturing</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Individuals from quality</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant responses</th>
<th>Total number of plants</th>
<th>53</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plants with 4 responses</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Number of plants with 3 responses</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Number of plants with 2 responses</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Number of plants with 1 response</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Average number of employees</td>
<td>544</td>
<td></td>
</tr>
</tbody>
</table>

Using multiple raters is more difficult in empirical studies but it can provide “a greater degree of methodological rigor, thus leading to a greater degree of confidence in the findings” (Boyer and Verma, 2000, p. 129). However, to obtain the benefits, researchers must carefully assess the inter-rater reliability measures. The Interclass Correlation (ICC) measures for the SPS and DPM factors were both greater than the suggested 0.6.
3.3. Measures

SPS and DPM were measured using the instrument developed by Zhang et al. (2006). The measurement instrument was developed and validated through a rigorous process similar to that of Flynn, Schroeder, and Sakakibara (1994). All the items in the measurement instrument used the same 7-point Likert scale (1=Disagree strongly, 2=Disagree, 3=Disagree somewhat, 4=Neutral, 5=Agree somewhat, 6=Agree, 7=Agree strongly, and N=No response). Ahire et al. (1996) argue that the 7-point scale is better than a 5-point scale because of its capability to capture more variation. Reverse items were used to detect invalid data from respondents who answered questions without reading them. The large-scale empirical test using the Confirmatory Factor Analysis (CFA) method supported the validity of the instrument (Zhang et al., 2006). Table 2 shows the items for the SPS and DPM constructs.

The dependent variable for this study was the Supplier Operating Performance (SOP) factor. Operating performance is typically measured in five dimensions: quality, cycle time, delivery, cost, and flexibility (Benson, Cunningham, and Leachman, 1995; Ferdows and De Meyer, 1990). The scales used by Ahire et al. (1996) were adapted for this study. Their scale was anchored on the worst companies in the industry and was essentially a reversed scale. This research asked the HTI buyers to give their evaluation of supplier performance on all five performance dimensions compared to the “best in the industry” (see Table 2).

Multiple responses from the same plant were first averaged to obtain one observation for that plant. Then the validities of the measurement instrument were examined statistically with SPSS. Principal Components Analysis (PCA) with the Varimax rotation was performed to determine scale unidimensionality. Finally, Cronbach’s alpha for all three scales was examined.

SPS consists of three items. Cronbach’s alpha for the SPS scale was 0.694, clearly exceeding the minimum acceptable standard of 0.6 suggested by Nunnally and Bernstein (1994).
PCA found that all three SPS items loaded onto a single factor. The eigenvalue was 1.893, higher than the minimum acceptable level of 1.0. The SPS factor explained 63.1% of the variation. The factor loadings for all the items ranged from 0.604 to 0.898, all above the acceptable lower bound of 0.4 (Carmines and Zeller, 1979).

DPM consists of four items. The DPM scale had a Cronbach’s alpha of 0.868, much higher than the minimum value of 0.6. All four items loaded onto a single factor and the loadings ranged from 0.794 to 0.913. The eigenvalue associated with the scale was 2.938. The DPM factor explained 73.4% of the variation.

Table 2

<table>
<thead>
<tr>
<th>Measurement instrument</th>
<th>Item</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic Project Selection (SPS)</td>
<td>Process improvement projects are generated based on our strategy.</td>
<td>53</td>
<td>5.67</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>We prioritize new process improvement projects based on our strategy.</td>
<td>53</td>
<td>5.80</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Process improvement project selection is driven by our customers’ needs.</td>
<td>53</td>
<td>5.74</td>
<td>0.93</td>
</tr>
<tr>
<td>Disciplined Project Management (DPM)</td>
<td>Our process improvement projects are led by full-time process improvement experts.</td>
<td>53</td>
<td>4.98</td>
<td>1.65</td>
</tr>
<tr>
<td></td>
<td>Our leadership holds process improvement project team leaders accountable for project results.</td>
<td>52</td>
<td>5.51</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>Our projects use a standard process improvement methodology and language.</td>
<td>53</td>
<td>5.37</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>Our projects have a charter that defines the metrics, goals, deliverables, scope, and timeline.</td>
<td>52</td>
<td>5.55</td>
<td>1.24</td>
</tr>
<tr>
<td>Supplier Operating Performance (SOP)</td>
<td>This supplier has the best internal first pass yield rate in the industry.</td>
<td>42</td>
<td>4.64</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>This supplier's throughput time is the best in the industry.</td>
<td>51</td>
<td>4.35</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>This supplier's delivery performance is the best in the industry.</td>
<td>53</td>
<td>5.04</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>This supplier has the best unit cost in the industry.</td>
<td>53</td>
<td>4.37</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>This supplier has the best ability to quickly adjust production capacity in the industry.</td>
<td>52</td>
<td>4.46</td>
<td>1.26</td>
</tr>
</tbody>
</table>

The SOP factor consists of five items. However, factor analysis showed that all five items except for the cost item loaded onto one factor. Therefore, cost was dropped from the factor.
The cost item is really the price as seen by the HTI buyers. The suppliers’ prices are affected by many different factors such as the plant’s total volume, market position vis-à-vis its competitors, product technology, process technology, and many other factors that are likely to be outside the buyer’s ability to interpret accurately (Hendricks and Singhal, 2001a). Among the operating performance dimensions, the cost data is confounded by many factors and was eventually excluded from the performance factor. Cronbach’s alpha for SOP with four items was 0.689. Items loadings ranged from 0.437 to 0.921. The eigenvalue was 2.108. The factor explained 52.7% of the variation (see Table 3).

<table>
<thead>
<tr>
<th></th>
<th>SPS</th>
<th>DPM</th>
<th>SOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cronbach’s Alpha</td>
<td>0.694</td>
<td>0.868</td>
<td>0.689</td>
</tr>
<tr>
<td>Factor loadings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 1</td>
<td>0.898</td>
<td>0.794</td>
<td>0.773</td>
</tr>
<tr>
<td>Item 2</td>
<td>0.850</td>
<td>0.869</td>
<td>0.921</td>
</tr>
<tr>
<td>Item 3</td>
<td>0.604</td>
<td>0.913</td>
<td>0.685</td>
</tr>
<tr>
<td>Item 4</td>
<td></td>
<td>0.847</td>
<td>0.437</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>1.893</td>
<td>2.938</td>
<td>2.108</td>
</tr>
<tr>
<td>Variation explained</td>
<td>63.1%</td>
<td>73.4%</td>
<td>52.7%</td>
</tr>
</tbody>
</table>

HTI buyers evaluated SOP for each plant. This avoided problems that can occur with common method bias. Common method biases occur when the variance is attributable to the measurement method rather than to the constructs that the measures represent (Campbell and Fiske, 1959). It is most likely to occur in survey research when all variables are collected from the same informants. With common method bias, the validity of the conclusions is threatened because it is hard to tell whether the relationships represent the reality or just the respondents’ perception (Podsakoff, MacKenzie, Lee, and Podsakoff, 2003). Having different informants for the independent and dependent variables eliminates concern about common method bias and increases the credibility of the results.
Once factor analysis confirmed the validity of all three scales, the factor scores for each construct were calculated using regression in SPSS. Hair (1995) noted that factor scores are “composite measures for each factor representing each subject … Conceptually speaking, the factor score represents the degree to which each individual scores high on the group of items that load high on a factor … these scores are saved for further use in subsequent analyses.” (p. 390). The subsequent regression analyses used factor scores.

Finally, organizational size has been recognized as a critical control variable in empirical studies. Daft (2000) suggested that “because organizations are social systems, size is typically measured by number of employees” (p. 18). Because the distribution of Number of Employees (EMP) was highly skewed (as expected), a natural log transformation was applied following Neter, Kutner, Nachtsheim, and Wasserman (1996).

4. Methods

This study used the ordinary least squares (OLS) regression method. Moderated Regression Analysis (MRA) was used to test the moderation hypothesis. In addition, the Baron and Kenny (1986) procedure was used to test the mediation model. All assumptions of OLS regression were examined before any conclusions were drawn.

4.1. Moderated Regression

Testing the moderation effect by MRA requires the addition of an interaction term in the regression equation. The interaction term is the cross product of factors scores of SPS and DPM in this study. If the interaction term is statistically significant, the moderation hypothesis is supported. Because all regression assumptions were met, it was appropriate to add the interaction term to the models.

Venkatraman (1989) cautioned researchers that the MRA method should only be used when the research hypothesis states that the outcome is jointly determined by the interaction of
the independent variable and moderator. In contrast, if the research hypothesis is that the impact of the independent variable on outcome differs across different levels of the moderator, subgroup analysis is more appropriate. Since the hypothesis states that it is the interaction between SPS and DPM that determines the performance level, MRA is the appropriate method.

4.2. Mediation model test method

Testing mediation models is more complicated than that of moderation models. Baron and Kenny (1986) and Judd and Kenny (1981) suggested a general procedure for testing mediation using multiple regression, illustrated in Fig. 4. The procedure has four steps with the fourth step being optional. The steps are:

**Step 1:** Conduct a regression analysis to show that the independent variable (IV) is correlated with the dependent variable (DV) (path $c$). A statistically significant correlation is the prerequisite for a mediation model to hold.

**Step 2:** Show that the IV is correlated with the mediation variable (MV) (path $a$). Path $a$ must be significant for the mediation model to hold.

**Step 3:** Show that the MV affects the DV by regressing the DV on both the IV and MV together. Regressing the DV on the MV only is insufficient because the MV and the DV may be correlated if the IV causes them both. Thus, the IV must be controlled when establishing the effect of the MV on the DV.

**Step 4:** To establish that the MV fully mediates the IV-DV relationship, the effect of the IV on the DV controlling for the MV (path $c'$) should be zero, otherwise a partial mediation model is supported.

Mediation is supported when all the paths (except $c'$) are statistically significant, provided that the causal links among variables are established by the theory. Step 4 is optional because it is only required for the test of full mediation effect. If the IV no longer has any effect on the DV
when the MV has been controlled, the full mediation has occurred. If the coefficient of path $c'$ is different from zero, the effects can be partitioned into direct and indirect effects. Statistical significance of path $c'$ is irrelevant in Step 4 because trivially small coefficients can be statistically significant with large sample sizes and very large coefficients can be insignificant with small sample sizes (Baron and Kenny, 1986).

Fig. 4: The mediation model test

To establish a mediation relationship, it is important to rule out other possible models that are consistent with the data. One possibility is the reverse causal effects, that is, the MV is, in fact, caused by the DV. Because regression analysis does not assume causality, it is not possible to rule out this alternative model simply by evaluating the regression results. However, a reversed causal effect is not a concern in this study because the reversed causal link (SOP $\rightarrow$ SPS) is not supported by the literature or by logical reasoning.

One important methodological issue is whether the IV should be controlled in Step 3. James and Brett (1984) argued that Step 3 should be modified by not controlling for the IV. Their rationale is that if there is full mediation, there would be no need to control for the IV. However, full mediation does not always occur. In this study it is more sensible to control for the IV in Step 3 so that the empirical results can reveal whether the full or partial mediation model is most plausible.
Although the above steps can be used to informally judge whether mediation is occurring or not, a formal assessment will involve statistical tests (MacKinnon, Warsi, and Dwyer, 1995). The mediation effect is also called an indirect effect and is defined as the reduction of the effect of the IV on the DV, mathematically, \( c - c' \). Studies have shown that the reduction is theoretically the same as the product of the effect of the IV on the MV times the effect of the MV on the DV, mathematically, \( c - c' \approx ab \), when there are no missing observations (Baron and Kenny, 1986). A test of the null hypothesis of \( ab = 0 \) can reveal whether a mediation effect is present. Although it is possible to test both \( a = 0 \) and \( b = 0 \) simultaneously with the appropriate family alpha level, a single test is preferred (MacKinnon, Lockwood, Hoffman, West, and Sheets, 2002).

The most commonly used test is the Sobel (1982) test, which is a \( z \) test, with two major variants. This test is based on the fact that the standard error of \( ab \) is approximately the square root of \( b^2S_a^2 + a^2S_b^2 \). The two major variants are Aroian and Goodman (Sobel, 1982). The difference is whether the term \( S_a^2S_b^2 \) is included in the denominator or not. The Aroian version is recommended by some scholars because it does not make the unnecessary assumption that the product \( S_a^2S_b^2 \) is vanishingly small. The Goodman version of the test subtracts the third term for an unbiased estimate of the variance of the mediated effect, but this can sometimes have the unfortunate effect of yielding a negative variance estimate. The Sobel test and the Aroian test seemed to perform the best in a Monte Carlo study, and converge closely with a sample size greater than 50 (MacKinnon et al., 1995). This study performed all three tests and found the same results for all three. The equations for these three tests are given below.

\[
\begin{align*}
\text{Sobel version} & \quad z = \frac{ab}{\sqrt{b^2S_a^2 + a^2S_b^2}} \\
\text{Aroian version} & \quad z = \frac{ab}{\sqrt{b^2S_a^2 + a^2S_b^2 + S_a^2S_b^2}} \\
\text{Goodman version} & \quad z = \frac{ab}{\sqrt{b^2S_a^2 + a^2S_b^2 - S_a^2S_b^2}}
\end{align*}
\]
4.3. Multicollinearity

Multicollinearity is an important analytical issue in regression. When two or more independent variables are highly correlated with each other, the overall fit of the model to the data will not change significantly but estimation of individual coefficients can be significantly comprised (Hair, 1995). Usually with multicollinearity, the estimation of the standard error of individual coefficients is not stable and is biased toward enlargement. This can lead to incorrectly concluding that an important variable is statistically insignificant.

In analyzing both the moderation and mediation models, multicollinearity is expected. In moderation models, the interaction term is likely to be strongly correlated with the independent variables. However, it is worth noting that although statistical estimations might be problematic due to multicollinearity, establishing the existence of moderation effects is not a problem (Venkatraman, 1989). In fact, simple transformation of variables such as centering can reduce the level of correlation between the interaction term and the original variables, hence decreasing the negative impact of multicollinearity.

In mediation models, multicollinearity exists by definition. For a mediation model to hold, the IV is correlated with the MV, hence the estimation of the coefficients of path $b$ and $c'$ is compromised. The Variance Inflation Factor (VIF) and a large sample can be used to manage the issue. VIF measures the impact of collinearity among the independent variables in a regression model on the precision of estimation. It expresses the degree to which collinearity among the independent variables degrades the precision of an estimate. In general, a high VIF suggests an unstable regression analysis and the resultant estimation is invalid. However, different disciplines have suggested different cutoff values. Hair et al. (1995) suggested a cutoff value of 10, whereas many social science disciplines suggest 4. All VIF values reported in the
regression analyses in this study were lower than 2. Multicollinearity, therefore, was judged not to be a problem in this study.

5. Results and Discussion

5.1. Results

The means, standard deviations, and correlations of the variables under consideration are displayed in Table 4. The effect of the control variable is examined first, followed by the hypotheses in order.

Table 4
Descriptive statistics and correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOP</td>
<td>53</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPS</td>
<td>53</td>
<td>0</td>
<td>1</td>
<td>0.492***</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPM</td>
<td>53</td>
<td>0</td>
<td>1</td>
<td>0.407**</td>
<td>0.620***</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Ln(EMP)</td>
<td>49</td>
<td>5.223</td>
<td>1.357</td>
<td>0.254</td>
<td>0.067</td>
<td>0.282</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 5 provides the results of the regression analysis. Model 1 gives the regression of the control variable on the performance variable, which is insignificant ($F = 3.236, p = 0.078$). This suggests that HTI buyers’ evaluation of supplier plant performance was independent of plant size. Model 2 examines the individual contribution of SPS on performance. The model is highly significant ($F = 10.198, p = 0.000$) with a positive coefficient for SPS, suggesting that SPS is positively associated with performance. The $R^2$ is a very decent 30.7%. Therefore, hypothesis H1 is supported. Similarly, Model 3 examines the individual contribution of DPM on performance. The model is also highly significant ($F = 5.553, p = 0.007$) with a positive coefficient for DPM. Therefore, hypothesis H2 is supported. DPM is positively associated with performance.

Model 5 examines the moderation hypothesis. The cross product of SPS and DPM is added to the model. The model is highly significant ($F = 5.532, p = 0.001$); however, the
coefficient for the interaction term is not significant \( (p = 0.234) \). The analysis does not find support for the moderation effect of SPS. Hypothesis H3 is not supported.

A test of the mediation hypothesis requires several simultaneous regression analyses as suggested by Baron and Kenny (1986). First, Model 3 proves that DPM is positively associated with performance. This establishes the basis that there could be an effect to be mediated. Model 6 then shows that SPS and DPM are positively correlated \( (F = 31.845, p = 0.000) \). Finally, Model 4 shows that the coefficient of DPM is smaller than that of Model 3 when the mediator SPS is added. This pattern informally suggests the existence of mediation effect from SPS. The three formal Sobel tests reached the same conclusion, statistically confirming the mediating role of SPS. Hypothesis H4, therefore, is supported.

5.2. Discussion

These empirical results confirm that both SPS and DPM are important factors in the effectiveness of process improvement programs. Individually, each is significantly correlated with SOP. This result confirms both the content and predictive validity of the constructs. Empirical results further reveal that the inter-relationship between the two factors is best described by a partial mediation model rather than a moderation model. The moderation hypothesis is not supported, suggesting that the effect of DPM on SOP is not moderated by SPS. Instead, the mediation hypothesis is supported. Overall, a higher level of DPM will lead to both a higher level of SPS and a higher level of SOP, and a higher level SPS further contributes to SOP.

The coefficient of DPM in Model 4 is smaller than in Model 3. This size reduction is key to the establishment of the mediation effect. The coefficient, although smaller, is not close to zero. This suggests that a partial mediation model is more appropriate than a full mediation
model. While SPS mediates the relationship between DPM and SOP, DPM still has some direct effect on SOP.

5.3. Limitations

Two limitations of this study need to be acknowledged. First, empirical data for this study was from supplier plants for one large high-tech firm. The study, therefore, may not be generalizeable beyond the types of suppliers in that sample. Replication of this study is needed to address this concern. Second, the sample size ($N = 53$ plants) was not large. A larger sample size would provide for more statistical power and also enable the use of more powerful statistical methods such as Structural Equation Models.

6. Conclusions

This research began with a definition of process improvement programs (PIPs) and the program management mechanism for PIPs. The research posited that two process improvement program management (PIPM) factors, Strategic Project Selection (SPS) and Disciplined Project Management (DPM), had significant impact on performance. The research further posited that SPS and DPM need to fit with each other to achieve performance, but raised the question of the nature of that fit. The paper then developed four hypotheses dealing with relationships between SPS, DPM, and Supplier Operating Performance (SOP), with emphasis on the form of fit between the two factors.

A large-scale empirical study was conducted in collaboration with the largest division of a large high-tech electronics firm that allowed the research team to survey its key suppliers. This cross-program study did not ask respondents to identify which process improvement programs they had implemented. This approach avoided the difficult definitional issues around specific process improvement programs such as Six Sigma and changed the focus of the research to the program management issues that are shared by all process improvement programs.
### Table 5
Regression results

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV = SOP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-1.017</td>
<td>-1.800</td>
<td>-0.85</td>
<td>-1.051</td>
<td>-0.757</td>
<td>-1.503</td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>-1,800</td>
<td>0.164</td>
<td>1.073</td>
<td>1.515</td>
<td>1.073</td>
<td>1.403</td>
</tr>
<tr>
<td>Ln(EMP)</td>
<td>0.188</td>
<td>0.164</td>
<td>0.110</td>
<td>0.135</td>
<td>0.505</td>
<td>0.620</td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>1.799</td>
<td>1.793</td>
<td>1.047</td>
<td>1.047</td>
<td>3.025**</td>
<td>5.643***</td>
</tr>
<tr>
<td>SPS</td>
<td>0.505</td>
<td>0.505</td>
<td>0.446</td>
<td>0.811</td>
<td>0.134</td>
<td>0.145</td>
</tr>
<tr>
<td><strong>t</strong></td>
<td>4.015***</td>
<td>2.725**</td>
<td>2.781*</td>
<td>1.206</td>
<td>0.811</td>
<td></td>
</tr>
<tr>
<td>DPM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPS × DPM</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>6.4%</td>
<td>30.7%</td>
<td>19.4%</td>
<td>31.3%</td>
<td>33.5%</td>
<td>38.4%</td>
</tr>
<tr>
<td>F</td>
<td>3.236</td>
<td>10.198</td>
<td>5.553</td>
<td>6.822</td>
<td>5.532</td>
<td>31.845</td>
</tr>
<tr>
<td>p</td>
<td>0.078</td>
<td>0.000</td>
<td>0.007</td>
<td>0.001</td>
<td>0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>N</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>53</td>
</tr>
</tbody>
</table>

* *p < 0.05
** p < 0.01
*** p < 0.001

Sobel test: 2.495, p = 0.013
Aroian test: 2.464, p = 0.014
Goodman test: 2.527, p = 0.012
The majority of the 53 plants in the sample provided multiple respondents. The analysis of empirical data strongly supported the posited relationship between both factors (SPS and DPM) and Supplier Operating Performance (SOP). More importantly, the empirical results found that SPS partially mediates DPM and SOP.

This study makes several contributions to the literature. First, the study empirically confirms the validity of the PIPM research perspective: how process improvement programs are managed has a significant impact on the program effectiveness. Second, this is the first paper to empirically test the relationships between two new PIPM factors (SPS and DPM) and performance. The empirical results show that the two factors can explain a large portion of the variation in performance. The validity of the PIPM research perspective is thus empirically confirmed and the research perspective can now be used to explain some of the differences in program success for process improvement programs. The study shows that SPS and DPM are generalizable “best practices” for process improvement program management, independent of which process improvement program is implemented. Third, the study contrasts two common forms of fit and finds that SPS partially mediates the effect of DPM on performance. This is the first research study to identify the mediating role of SPS in process improvement programs. This new insight will contribute to future theory development.

This research also provides some guidance for practicing managers. Many managers are perplexed by the problem of selecting the right process improvement program for their organization -- Lean, Six Sigma, Lean Sigma, etc. This study challenges managers to reframe the question in terms of PIPM factors SPS and DPM. While process improvement program selection is important, this research suggests that program management may be even more important. This study also challenges practicing managers to re-think the role of both SPS and
DPM. Leading Six Sigma consultants and successful business leaders have emphasized DPM in the practitioner literature (e.g., Bossidy, Charan, and Burck, 2002). However, this body of literature has never explored the relationships between SPS, DPM, and performance. An important message for the managers from this study is that DPM will, in fact, promote a highly disciplined organizational culture and positively influence SPS. This approach suggests that managers should focus on creating a disciplined project management environment. The disciplined culture will then drive improvement into their organization’s process improvement project selection effort, and eventually lead to performance.

References


