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Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices

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ABSTRACT

Manufacturing firms operating in rapidly changing and highly competitive markets have embraced the continuous process improvement mindset. They have worked to improve quality, flexibility, and customer response time using the principles of *Lean thinking*. To reach its potential, lean must be adopted as a holistic business strategy, rather than an activity isolated in operations. The lean enterprise calls for the integration of lean practices across operations and other business functions. As a critical component for achieving financial control, management accounting practices (MAP) need to be adjusted to meet the demands and objectives of lean organizations. Our aim is to help both researchers and practitioners better understand how lean MAP can support operations personnel with their internal decision making, and operations executives and business leaders in their objective of increasing lean operations performance as part of a holistic lean enterprise strategy. We use survey data from 244 U.S. manufacturing firms to construct a structural equation model. We document that the extent of lean manufacturing implementation is associated with the use of lean MAP, and further that the lean MAP are related in a systematic way: simplified and strategically aligned MAP positively influences the use of value stream costing, which in turn positively influences the use of visual performance measures. We also find that the extent of lean manufacturing practices is directly related to operations performance. More importantly, lean manufacturing practices also indirectly affect operations performance *through* lean MAP. These findings are consistent with the notion that lean thinking is a holistic business strategy. In order to derive the greatest impact on performance, our results indicate that operations management cannot operate in a vacuum. Instead, operations and accounting personnel must partner with each other to ensure that lean MAP are strategically integrated into the lean culture. In sum, lean MAP provide essential financial control that integrates with and supports operations to achieve desired benefits.

1. Introduction

Manufacturing firms operating in the rapidly changing and highly competitive market of the past two decades have embraced the principles of *Lean thinking*. In doing so, they reorganize into cells and value streams to improve the quality, flexibility, and customer response time of their manufacturing processes. Decisions previously made by managers are instead made by those teams close to the work processes. The organization is transformed from a traditional structure characterized as top-down with project-driven improvement led by middle managers into one where continuous improvement is conducted throughout the company by locally empowered teams. This change in manufacturing strategy is associated with increased operational efficiency and effectiveness, which positively impacts firm performance (e.g., Fullerton and Wempe, 2009; Hofer et al., 2012; Kaynak, 2003; Yang et al., 2011).

The Shingo Prize, which awards world-class companies for their adherence to lean principles, evaluates companies that have achieved a "cultural transformation through the integration of principles of operational excellence across the enterprise and its value stream to create a complete, systemic view, leading to consistent results" (Shingo Prize, 2010, 5).[2] It supports lean as an

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[2] The Shingo Prize is an annual award that recognizes operational excellence. It is based on the lean management approach and model taught by Dr. Shigeo Shingo, and is awarded to companies per their effectiveness in transforming their organizations through the application of specific lean principles, systems, and tools. Those principles, systems, and tools are carefully outlined in a set of guidelines,

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integrated, complex management system that spans the entire company (Ahlstrom and Karlsson, 1996), where all people at all levels have to be involved and committed to continuous improvement (Furlan et al., 2011). As a holistic business strategy, lean thinking, thus, encompasses a change in mindset that extends beyond operations. In particular, management accountants should be part of the lean transformation team since they are charged with supplying operations personnel and executives accurate, appropriate, and timely internal information. As a critical support function, lean management accounting practices (MAP) provide the financial control essential for internal decision making in lean organizations. An empirical question that has not been clarified is the role lean MAP have in a lean manufacturing environment and whether operations management need to be concerned with the implementation of lean accounting practices. The purpose of this study is to shed insights on these issues.

In this study, we use three components to represent lean MAP: value stream costing (VSC), simplified and strategic MAP, and visual performance measures. We develop hypotheses predicting that lean manufacturing positively influences lean MAP, and that there is a systematic structure among the lean MAP. We also hypothesize that the lean MAP positively influence operations performance, which in turn, positively influences financial performance. We control for the direct effect of the extent of lean manufacturing implementation on operations performance in order to sort out the performance effects due to the lean manufacturing implementation versus the lean MAP.

We examine our hypotheses using a structural equation model populated with survey data from 244 U.S. manufacturing firms. Not surprising, we find that the extent of lean manufacturing implementation is positively related to lean MAP and operations performance. We further find that lean MAP are related in a systematic way: simplified, strategic MAP positively influences the use of VSC, which in turn, positively influences the use of visual performance measures. In addition, the use of visual performance measures positively influences operations performance, and in turn, financial performance. Thus, simplified, strategic MAP and VSC indirectly influence operations performance (and subsequently, financial performance) through the use of visual performance measures. What is new and interesting is that after accounting for the effect of lean manufacturing on operations performance, lean MAP also positively influence operations performance. Moreover, some of the effects of lean manufacturing practices on operations performance are translated *through* lean MAP.

Our findings expand lean understanding for researchers and practitioners in two key ways. First, we provide some of the initial empirical evidence of the relationships among lean MAP, operations performance, and financial performance. Thus, we respond to calls by Ahlstrom and Karlsson (1996) and van der Merwe and Thomson (2007) to provide empirical research that investigates if and how lean MAP integrate with operations. Second, and most importantly, we contribute by providing a more complete look at how a holistic lean strategy can enhance firm performance (see Camacho-Minano et al., 2013). Our results support prior evidence that firms can increase their operations and financial performance by implementing lean manufacturing. Further, our results suggest that firms can leverage their returns from a lean manufacturing strategy by also implementing lean MAP. This implication is consistent with researchers and practitioners who have argued that traditional MAP motivate behaviors detrimental to the success of lean because of their focus on cost reduction rather than process improvement and customer value, and, thus, need to be updated to reflect the strategic objectives inherent to lean manufacturing (e.g., Ahlstrom and Karlsson, 1996; Chiarini, 2012; Johnson and Kaplan, 1987; Li et al., 2012; Maskell et al., 2012; Ruiz-de-Arbulo-Lopez et al., 2013). We show that strategically integrating both lean manufacturing and lean MAP provides a greater return to the firm (in the form of increased operations and financial performance) than does the implementation of only a lean manufacturing strategy, consistent with the notion that lean is a holistic business strategy (e.g., Camacho-Minano et al., 2013). This finding suggests that operations management should not implement a lean strategy solely on the manufacturing floor. Rather operations managers need to partner with accounting personnel to ensure that lean MAP such as value stream costing (VSC) and visual performance measures are implemented in support of the lean manufacturing processes. This will result in more positive effects on operations performance, and in turn, financial performance.

The remainder of this paper is organized as follows. Section 2 develops the hypotheses and discusses the related literature. Section 3 outlines the research study, and Section 4 discusses the results. Finally, Section 5 provides a summary of the study, limitations, and suggestions for future research.

2. Literature support and hypotheses development

Lean thinking is arguably the most important strategy for achieving world-class performance. Womack et al. (1991) first coined the term "Lean production" in their seminal book, *The Machine that Changed the World*. However, the origin of lean thinking is generally attributed to Toyota, whose production system was originally referred to as just-in-time (JIT), but is now commonly called the Toyota Production System (TPS). Lean thinking emphasizes excellence through the elimination of waste and a focus on continuous improvement. Referring to JIT/TPS, Schonberger, 1987, 5) called lean "the most important productivity enhancing management innovation since the turn of the century." Prior empirical research has often linked lean manufacturing to operational (e.g., Cua et al., 2001; Hallgren and Olhager, 2009; Narasimhan et al., 2006; Shah and Ward, 2003) and financial (e.g., Fullerton et al., 2003; Fullerton and Wempe, 2009; Hofer et al., 2012; Kaynak, 2003; Kinney and Wempe, 2002; Yang et al., 2011) performance.

2.1. Literature support

Lean is most well-known as a manufacturing system, but many argue that to be successful it has to be applied much more broadly as a complete business system (Grasso, 2005; Kennedy and Widener, 2008; McVay et al., 2013; Solomon and Fullerton, 2007; Womack and Jones, 1996). The essence of lean thinking is that all business processes and functions integrate into a unified, coherent system with the purpose of using lean principles and tools to provide better value to customers through continuous improvement and elimination of waste (Grasso, 2005; Shingo Prize, 2010). Since all business processes are interrelated, some argue that lean manufacturing cannot operate in isolation to realize its potential (Maskell and Kennedy, 2007).

Empirical research has taken steps in examining the holistic strategy. In their longitudinal study of core operations and human resource management practices in British manufacturing firms, de Menezes et al. (2010) find that firms with integrated advanced manufacturing practices consistently outperform others. Moreover, a 2006 Aberdeen study (Aberdeen Group, 2006) reported that there was a large performance gap between those manufacturing firms that had applied lean practices solely on the shop floor, as opposed to those that had developed a lean culture throughout the organization. In their case study, Benders and Slomp (2009)

which experienced Shingo examiners use to determine the selection of Shingo Prize recipients. The website for the Shingo Prize is www.shingoprize.org.

explain lean manufacturing as a long, arduous process that can be both problematic and beneficial depending on differing contextual factors. However, in their review of empirical studies on lean implementations and their effects on performance, Comacho-Minano et al. (2013) conclude that evidence examining how and whether contextual factors impact the relationship between lean practices and financial performance is inconclusive. Further, Sila (2007) found no performance difference among subgroups distinguishing five contextual factors – TQM implementation, ISO registration, country of origin, company size, and scope of operations. In extending this literature stream, we examine lean MAP, an important component of a successful lean transformation that is often overlooked.

This study uses a contingency framework, which has often been used in the literature to examine the effectiveness of MAP in various business environments. Contingency-based research assumes that certain types of MAP are more suited to certain strategies and that managers will adapt their organizations accordingly to achieve fit and enhance performance (Chenhall, 2003; Gong and Tse, 2009). Contingency theory also assumes that there is no one best way to structure a firm; rather, firms must adapt their structure to fit their environmental contingencies (Chenhall, 2003; Gerdin and Greve, 2004, 2008). It is important for firms to find the right combination of contingencies, since lack of alignment will lead to dysfunctional consequences (Fry and Smith, 1987). Many argue that MAP are a significant element of a firm's organizational structure and must be designed to fit the context in which they operate (Chenhall, 2003; Otley, 1980). Different types of MAP are associated with different organization strategies, and the methods for managing workflow in a JIT/TQM environment, for example, are best aligned with MAP that have been adapted to fit advanced manufacturing strategies (Gerdin, 2005).

For a lean thinking firm to achieve strategic fit, we thus argue that accounting as an integral aspect of any business must be a part of its lean transformation. Traditional MAP were developed for a different landscape – one where continuous product flow was not critical and labor was a significant portion of product costs. Management accounting information has supported this traditional environment with information extracted on the shop floor, and then calculated and reported under parameters separate from the shop floor. In contrast, many contend that the information flow and physical flow in lean operations need to be intertwined (Huntzinger, 2007, 6). In fact, several contend that most lean initiatives will fail if the traditional management accounting system is left unchanged (e.g., Ahlstrom and Karlsson, 1996; Li et al., 2012; Meade et al., 2006). For example, traditional accounting reports are not timely, they are too complex for most operations personnel to understand, they encourage meeting standards rather than customer demands, and they fail to provide information about process improvements achieved through lean.

In this study, we examine three lean MAP. First, supporting the strategic objectives of lean MAP, s*implified and strategically aligned management accounting practices* represents accounting practices that mirror the lean manufacturing concepts of waste elimination, efficiency, and simplicity. Second, managing value streams is critical to successful lean enterprises, which makes v*alue stream costing* (VSC) an important component of lean MAP (Li et al., 2012; Ruiz-de-Arbulo-Lopez et al., 2013). VSC recognizes the new structure of the manufacturing organization and records and tracks actual costs for each individual value stream. This simplifies the reporting system by significantly reducing the number of transactions recorded and reported. Accounting reports are simpler to prepare, easier for shop-floor decision makers to understand, and more useful for decision making (Fullerton et al., 2013; Li et al., 2012; Maskell et al., 2012). Third, lean MAP are concerned about communicating clear and timely information through *visual performance measures* that provide key operational and financial metrics linked to the manufacturing strategy of continuous improvement, quality first-time through, and low-levels of inventory (Fullerton et al., 2013; Kennedy and Maskell, 2006). The measures are provided in a visually simple way, rendering the information useful for all employees. Since lean relies on worker involvement, the workers must be able to clearly see and understand the information they use to make and evaluate process improvements (Ruiz-de-Arbulo-Lopez et al., 2013).

Extant research has provided empirical evidence that implementation of lean manufacturing is positively related to the use of lean MAP (Fullerton et al., 2013; Kennedy and Widener, 2008). Kennedy and Widener (2008) found that the firm in their case study changed its MAP to be better aligned with its lean manufacturing initiative. Operations managers were able to better understand how to manage their inventory levels and maximize their capacity to exploit additional business opportunities. Fullerton et al. (2013) empirically demonstrated that the extent of a lean manufacturing implementation was related to a package of five MAP.[3] They concluded that lean firms relied more on lean MAP, including simplified, strategic MAP, visual performance measurement, empowerment of employees, and VSC; and relied less on traditional inventory tracking. Neither of these studies, though, shed insight on how the lean manufacturing strategy and related MAP influence performance. While the potential benefits from implementing lean accounting in lean environments have been noted in two recent IMA statements and practitioner literature (Cunningham and Fiume, 2003; Kennedy and Brewer, 2005; Kennedy and Maskell, 2006), there is limited empirical evidence related specifically to lean MAP and their effect on operations and financial performance. A few studies, though, have examined the relationships among financial performance, the expanded use of nonfinancial performance measures, and advanced manufacturing practices such as lean, just-in-time (JIT), and total quality management (TQM) (Baines and Langfield-Smith, 2003; Callen et al., 2000, 2005; Durden et al., 1999; Fullerton and Wempe, 2009; Kaynak, 2003; Perera et al., 1997). For example, Perera et al. (1997) found that changes to MAP had no effect on firms adopting advanced manufacturing technologies. Similarly, Callen et al. (2000) found that the use of nonfinancial performance indicators did not affect the performance of either JIT or non-JIT firms. On the other hand, Kaynak (2003) finds that practices such as the reporting, monitoring, and use of quality data ultimately positively impact financial and market performance. Further, Baines and Langfield-Smith (2003) and Fullerton and Wempe (2009) find that adapting MAP to better align with advanced manufacturing practices ultimately positively affects organizational performance.

In sum, the literature reveals two important insights. First, the evidence is mixed on how more non-traditional MAP, such as the use of non-financial and quality indicators as compared to the more traditional financial accounting measures, impacts the relationships among manufacturing strategies, operational performance, and firm performance. Second, there is no direct evidence on how the use of specific lean MAP affects performance. Thus, our intention is to examine whether lean initiatives can be successful by focusing efforts solely on the shop floor, or whether operations management must work with accounting in order to extract greater benefit from their lean manufacturing strategy, consistent with the

[3] Fullerton et al. (2013) examine two additional accounting and control practices. Inventory tracking is a traditional accounting practice, as opposed to a lean accounting practice. Empowerment is a control technique that results from the information provided by the lean accounting practices. We do not examine either inventory tracking or empowerment in this study as we are interested in the three primary lean MAP touted for tracking and providing accounting information in a lean environment.

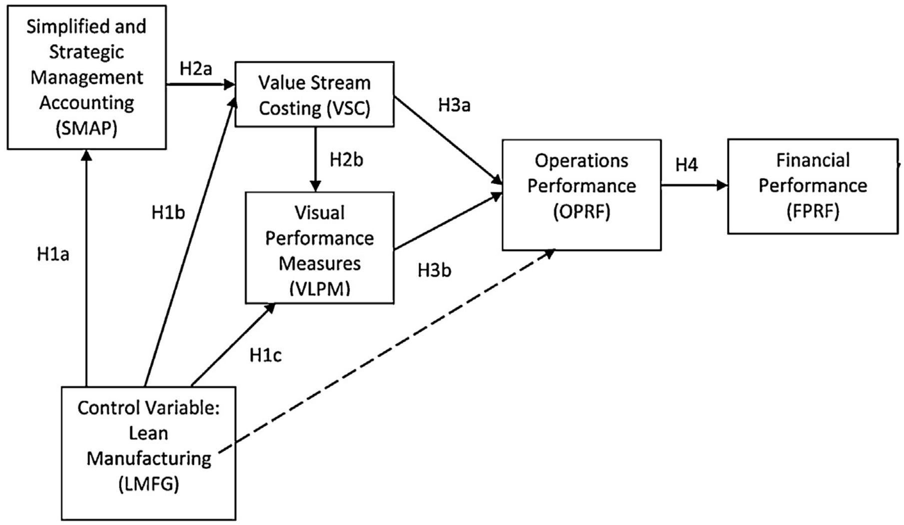

Fig. 1. Theoretical model. *Note*: The dotted line represents the control path. The solid lines represent the hypothesized paths.

Shingo Prize premise (2010) that lean thinking represents deeply embedded principles throughout the business processes.

In conclusion, we hope to shed insights on whether and how operations managers and accounting personnel will need to coordinate work activities. We hope to fill this gap in the literature stream through a more rigorous examination that: (1) uses data from firms interested in lean manufacturing; (2) controls for the extent of the lean manufacturing implementation on operations performance; (3) examines the relations between the extent of lean manufacturing implementation and usage of lean MAP; and (4) examines both operations and financial performance.

In the next section, we first develop our expectations about how the extent of lean manufacturing implementation is related to lean MAP[4] (H1a–H1c). We then develop the relations among the lean MAP (H2a–H2b). Finally, we theorize how lean MAP will impact operations performance (H3a–H3b), and in turn, affect financial performance (H4).

2.2. Hypotheses development

We begin our hypothesis discussion by developing the relations between the extent of lean manufacturing implementation and lean MAP. Our theoretical model is illustrated in Fig. 1.

Lean thinking creates major changes in an organization's way of doing business. Consistency in operating practices suggests that the same efforts made to eliminate waste and inefficiencies on the shop floor should be extended to accounting practices. This would allow the accounting system to be more supportive and strategically aligned with operational objectives (Maskell et al., 2012). Cunningham and Fiume (2003) also stress that the accountant's responsibility is to provide accounting information to operations personnel that is simple, timely, and easy to understand – information that supports the company's strategy and motivates the right behaviors. That is, the information should support the smooth flow of quality product with minimal waste. In their in-depth case study, Kennedy and Widener (2008) found that lean manufacturing initiatives influenced the use of lean accounting practices (i.e., use of streamlined transaction processing, use of actual costs, and use of kanbans). Thus, consistent with the findings of Fullerton et al. (2013) and the discussion above, we propose the following hypothesis:

H1a. The implementation of a lean manufacturing strategy is positively related to the use of simplified and strategically aligned MAP.

A lean manufacturing firm organized into value streams needs MAP designed specifically for a lean organization (Brosnahan, 2008). In lean manufacturing, operations are refocused from a task or product to a value stream. Operations personnel seek the relevant information contained in VSC to manage bottlenecks and capacity so as to maintain smooth production flow. VSC also provides capacity information which allows value stream managers to better understand the costs relevant to expansion and production decisions such as whether to take on special orders or in-source rather than out-source. In accordance with this discussion and the empirical evidence provided by Fullerton et al. (2013), we hypothesize the following:

H1b. The implementation of a lean manufacturing strategy is positively related to the use of VSC.

In a lean manufacturing environment, employees working in cells need information with which to facilitate their work activities (Cunningham and Fiume, 2003; McGovern and Andrews, 1998; Zayko and Hancock, 1998). Traditional financial measures provide high-level information on outcomes that are not detailed or simple enough to be relevant to shop-floor workers. Instead, operational information that communicates real-time results in a visual way provides the simple, relevant information shop-floor workers can use to help ensure that the objectives of a lean manufacturing strategy are met (Cardinaels, 2008; Galsworth, 1997; Maskell et al., 2012). In accordance with this discussion and with the empirical evidence provided by Kennedy and Widener (2008) and Fullerton et al. (2013) we hypothesize the following:

H1c. The implementation of a lean manufacturing strategy is positively related to the use of visual performance measurement information.

We are also interested in how lean MAP are related to one another. First, we hypothesize that simplified, strategic MAP is positively related to VSC. Second, we hypothesize that VSC is positively related to the use of visual performance measures.

Fullerton et al. (2013) provide evidence that the objectives of lean manufacturing are more likely to be achieved when

[4] We do not claim that these hypotheses (i.e., H1a–H1c) make a contribution to the literature since they are replications of Fullerton et al. (2013). However, we include them as part of our theoretical development because we are interested in exploring whether some of the effects of a lean manufacturing implementation on operations performance are transmitted through the lean MAP.

simplified, strategic MAP are adopted. As the extent of emphasis on lean manufacturing increases and lean thinking infuses the culture, it becomes easier and more compelling for management to encourage accounting and other support functions to begin adopting lean tools that simplify and streamline processes in their own areas. As accountants recognize the value of simplifying their own accounting practices to support strategic lean initiatives, they are more likely to directly interact with operations personnel. This will improve communication and help accountants better understand how to satisfy management's information needs and design MAP that are aligned with strategic objectives. Empirical evidence supports this argument, as (Cadez and Guilding, 2008, 840) find that as non-accounting personnel build stronger relationships with accountants, the accountants become "more active players in the strategic management process."

A key strategic information need for lean manufacturers is the aggregation of costs by value stream. Accountants are essential for designing the internal reporting system that supports the new organizational structure and facilitates decision making within the value stream. VSC has a fundamentally different purpose from traditional MAP that center on allocating costs to products (Kennedy and Maskell, 2006); instead, VSC charges all direct product costs to the "value stream" and attempts to capture actual costs with minimal allocations (Kennedy and Widener, 2008; Solomon and Fullerton, 2007). VSC is a more straightforward accounting system that conveys the continuous improvement and reduction of waste principles embodied in lean thinking – supporting a strategically "fit" application. Li et al. (2012) conclude that a VSC approach bridges the information gap between operations and financial reporting. Ruiz-de-Arbulo-Lopez et al. (2013) use a case study to demonstrate how VSC is better able to model the processes on the shop floor, give relevant cost information, and simplify the accounting process in comparison to traditional costing and activity-based costing. However, in her case study of a small manufacturing firm in its first year of lean implementation, Chiarini (2012) suggests caution in adopting VSC for small companies in the early stages of lean.

In sum, we argue that accountants who have followed the lead of their company's lean transition by simplifying their accounting processes become more involved as strategic business partners and participants in continuous improvement initiatives. They are more likely to understand the necessity for changing their MAP to better support lean principles. Thus, as the lean culture begins to mature and more emphasis is placed on simplified and strategically aligned MAP, we expect that VSC will emerge to support the objectives of lean. This leads to the following hypothesis:

H2a. Simplified and strategically aligned MAP are positively related to the use of VSC.

To support lean manufacturing objectives, all employees need accessible, timely, and relevant information in an easy-to-use format (see Johnson, 1992). Performance measurement information about the value stream is critical, not only for management, but also for shop-floor workers, who need to assess in real time how well the processes are working (e.g., on-time delivery, first-pass yield, day-by-the-hour) so that they can immediately respond to changing customer needs (Ruiz-de-Arbulo-Lopez et al., 2013). The value stream performance measurement information is often updated daily to inform employees, signal a need, and control production processes (Galsworth, 1997).

Visually presenting the operational performance measurement information is an effective way to facilitate quick and easy understanding by non-accountants. Li et al. (2012, 36) infers that VSC is the "best [accounting system] alternative for lean companies because it simplifies management and provides visibility for managing continuous improvement." In their study on visualizing multi-dimensional information, Dull and Tegarden (1999) concluded that the form of information affects the accuracy of predictions using that information. Cardinaels (2008) provides empirical support on the use of visual information and concluded that graphical cost accounting data are better than tabulated numbers at informing users with limited accounting knowledge. In their case study, Kennedy and Widener (2008) found that VSC performance metrics are normally provided on a daily or weekly basis, made available to all operations team members, and often displayed on metric boards. Using visual data, lean production workers can readily identify problems and practice better communication (Kennedy and Widener, 2008).

In sum, once a firm begins to rely more on VSC, it is likely that operational and cost metrics reporting on the value stream activities will increase in relevance and visibility. We expect to find that as the extent of VSC increases, visual performance measures will be more available. This leads to our next hypothesis:

H2b. The use of VSC is positively related to the use of visual performance measures.

We next turn our attention to how both VSC and the use of visual performance measures will result in a desired outcome – increased operations performance. We begin with VSC.

Relative to accounting practices focused on the use of standard costing and allocations, VSC is a simpler accounting process that accounts for all direct product costs incurred in the individual value streams. The use of VSC eliminates most allocations and many of the transaction costs associated with tracking labor (Apreutesei and Arvinte, 2010; Kennedy and Brewer, 2005). Unlike traditional accounting, VSC focuses on minimizing inventory rather than producing to capacity (Yu-Lee, 2011). Thus, there are two primary reasons that manufacturing results are enhanced from the use of VSC. First, due to the simpler nature of VSC, the financial reports and accounting information are easier for production managers to understand, which facilitates decision making (McVay et al., 2013). Better decision making leads to reduced costs, increased quality and efficiency, and more likely achievement of aligned business strategies. Second, firms that manage and report by value streams concentrate on increasing the flow of the product through the value stream, rather than building product regardless of demand and optimizing individual department performance (Kennedy and Maskell, 2006). This makes all members of the value stream accountable for their value stream's performance related to quality, cycle times, and on-time deliveries (Maskell et al., 2012). VSC is a lean accounting technique that encourages continuous improvement in lean environments because it more accurately reflects operational improvements (Ruiz-de-Arbulo-Lopez et al., 2013). In sum, since VSC is easier to understand and provides a focus more strategically aligned with lean principles, we expect operations performance to improve. This leads to the next hypothesis.

H3a. The use of VSC is positively related to increased operations performance.

In addition to the positive effects from VSC, we argue that the use of visual performance measurement information will also enhance operations performance. Organizational behavior literature has suggested that appropriate feedback facilitates goal attainment (Erez, 1977; Ilgen et al., 1979; Locke and Lathan, 1990, 2002; Neubert, 1998) by motivating workers to adjust their strategies and the level and direction of their efforts, which can positively affect performance (Earley et al., 1990; Ilgen et al., 1979; Locke and Lathan, 1990, 2002). Flynn et al. (1994) found that visual charts and information controls containing performance metrics had a strong association with quality performance. Lean manufacturing processes require efficient distribution of information. This includes improvement-oriented performance measures and visual control techniques. "Visual performance measurement boards and posted continuous improvement projects provide control and motivate ongoing analysis of problems leading to waste reduction, improved productivity, and faster, better service to the customers" (Kennedy and Maskell, 2006, 14–15). Lean manufacturing utilizes simple, clear, visual communication tools to motivate higher worker productivity. In their case study of three aerospace firms, Parry and Turner (2006) conclude that visual management systems can make significant contributions to the achievement of each firm's business goals. A well-accepted idiom is "what gets measured gets managed." If the measures are visible on the shop floor, readily available, easy to understand, and related to lean objectives of quality and flow, then operations performance is likely to show substantial improvement. This leads to our next hypothesis:

H3b. The use of visual performance measures is positively related to operations performance.

In our final hypothesis, we broaden our focus to firm financial performance. Improving operations performance leads to cost and waste reduction, which should positively affect financial performance (Gustafsson and Johnson, 2002; Sila, 2007). Reducing waste in scrap and rework and improving productivity lowers the cost structure of a firm (Mackelprang and Nair, 2010) and increases return on assets (Fullerton et al., 2003; Yang et al., 2011). Shetty (1987) found that as reputations for quality are established, companies can build market share and demand higher prices for their products. Improving cycle times has been tied to increased financial performance in several studies (Gunasekaran, 2002; Kim et al., 2002; Omachonu and Ross, 1994; Rogers et al., 1982). Contrary to the results in most studies, Inman et al. (2011), in their study of JIT and agile manufacturing, did not find a direct relationship between operational performance and financial performance. Rather, the impact of operational performance on financial performance was mediated through marketing performance. However, Kaynak (2003) found in her examination of TQM practices that quality performance had a robust relationship with financial and market performance. Overall, we posit that operations performance will be directly related to financial performance, and hypothesize the following:

H4. Operations performance is positively related to financial performance.

3. Methodology

3.1. Survey design and sample

We designed a detailed survey instrument to collect specific information about the manufacturing operations, organizational culture, top management leadership, performance measurement system and broader management accounting control system, financial and operational performance changes, and general demographics used by managers of U.S. manufacturing firms. Only a portion of the 125 survey questions are applicable to the relationships examined in this research project. The majority of the survey questions are either categorical or interval semantic differential scales (see Appendix A for a description of the questions used in this study). We conducted a pretest by soliciting feedback from several colleagues, as well as four operations managers working in firms that were in the process of implementing lean. We asked them to evaluate the survey instrument for readability, completeness, and clarity. We made appropriate changes to the survey in response to their feedback.

Because of the limited number of firms that have actually changed their MAP in support of lean initiatives, collecting data related to lean accounting is particularly difficult. However, interest in designing more relevant MAP is becoming more widespread, which encouraged the formation in 2005 of the first annual Lean Accounting Summit (LAS), a conference venue focused on various aspects of accounting for lean operations. The Summit attendees were invited to leave their contact information on the LAS website for future professional exchanges. The researchers were given permission to contact attendees that participated in the 2005–2008 annual LASs. A total of 1389 names appeared on the contact lists. However, over one-third of the names were either duplications of people who attended more than one Summit or attendees from the same plant, which we eliminated from the sample.[5] We also eliminated potential contacts due to the following reasons: (1) they were employees of non-manufacturing entities; (2) they were employees of international firms (which is outside the scope); or (3) the contact information was incorrect. After adjusting for all of the above reasons, the remaining sample size was 476. We contacted respondents a maximum of four times (three were by e-mail and the last contact was by mail) and asked them to complete a detailed, 15 min on-line survey reflecting operations at their facility. We received 265 responses from U.S. managers. Six responses were largely incomplete and eliminated from the testing, leaving a relevant sample response rate of 54 percent (the high response rate was deemed to be primarily due to a personal phone contact with the potential respondent prior to initially e-mailing the survey). Fifteen responses were received from duplicate plants. The answers from those duplications were averaged together, which resulted in a testable sample of 244. The large majority of the respondents had accounting and finance backgrounds, with titles of controller, CFO, and VP of finance. The distribution of the respondents and other sample characteristics are shown in Table 1.

We investigated non-response bias by comparing early respondents to late respondents, based on return date. We classified early responders ($n = 134$) as those that responded following the first contact and late responders ($n = 110$) as those that answered on the following three contacts. We found no statistically significant differences between early and late respondents for any of the variables included in our research model. We also compared the groups on sales and again found no significant differences. Overall, the results support the absence of significant non-response bias.

3.2. Survey constructs

The study has six primary constructs (extent of lean manufacturing, simplified and strategically aligned MAP, visual performance measures, VSC, operations performance, and financial performance). While we drew on general concepts from previous studies, the majority of the constructs were purpose developed. We used the Shingo Prize 2006 guidelines to develop the scales for lean manufacturing and visual performance measurement information. The nine elements representing lean manufacturing (LMFG) – standardization, manufacturing cells, reduced setup times, kanban system, one-piece flow, reduced lot sizes, reduced buffer inventories, 5S, and Kaizen – are representative of lean in the Shingo Prize Guidelines and several related studies (e.g., Fullerton and McWatters, 2002; Fullerton et al., 2003; Sakakibara et al., 1993; Shah and Ward, 2003; White et al., 1999). We adapted visual performance measures from the Shingo Prize Guidelines, the 14 principles described in the *Toyota Way* (Liker, 2004, 38–39), and the case study of Kennedy and Widener (2008). The eight-item visual performance measures scale (VLPM) includes making the information

[5] Although it would be helpful to have multiple responses from the same plant, it was not considered practical, and even detrimental to obtaining responses. In fact, when this occurred accidentally, some complaints were received from contacts saying that either they or a colleague had responded previously. Attendees from the same firm were contacted as long as they represented different manufacturing plants.

Table 1
Sample characteristics.

Sample characteristic	Number of responses	Classifications	Totals	Percent	Mean
Respondent positions	239	Controller	73	30.5	N/A
		Finance/Accounting Mgr	37	15.5	
		V/P/Director Finance	31	13.0	
		CFO	29	12.1	
		V/P/Director Operations	18	7.5	
		Cost Accountant	18	7.5	
		Operations Manager	12	5.0	
		Lean Specialist	10	4.2	
		President/COO/Plant Mgr	6	2.5	
		Miscellaneous	5	2.1	
Gender	239	Male (0)	134	56.1	0.44
		Female (1)	105	43.9	
Unionized	231	Non-unionized (0)	116	50.2	0.85
		Partially unionized (1)	33	14.3	
		Fully unionized (2)	82	35.5	
Respondent's years of experience with firm	236	0–3 years	72	30.5	7.8 years
		4–6 years	57	24.2	
		7–10 years	49	20.8	
		22–45 years	58	24.6	
Respondent's years of management experience	237	0–9 years	55	23.2	15.96 years
		10–15 years	77	32.5	
		16–20 years	45	19.0	
		21–48 years	60	25.3	
Firm employees	146	5–175	37	25.3	4956
		180–300	36	24.7	
		310–750	37	25.3	
		784–160,000	36	24.7	
Firm sales	164	$100–$36,000,000	40	24.4	$4998 M
		$38,000,000–$116,000,000	42	25.6	
		$120,000,000–$650,000,000	41	25.0	
		$800,000,000–$100,000,000,000	41	25.0	

visual, readily available, and aligned with strategic goals. We developed the measures for a simplified, strategic MAP (SMAP) from the management accounting practices described in the Kennedy and Widener (2008) lean accounting case study. These are also conceptually supported by Maskell et al. (2012) and Cunningham and Fiume (2003). The four-item measure captures the use of streamlined MAP designed to provide relevant strategic information.

We adapted our operations performance construct (OPRF) from the operational performance measures used in Shah and Ward (2003) and a related literature review. The six-item scale consists of self-assessed improvements of scrap and rework, setup times, queue times, machine downtime, lot sizes, and cycle time over a three-year period. We adapted our financial performance construct (FPRF) from Kaynak's TQM study (2003) and a related literature review. The four items include self assessments of changes in net sales, ROA, profitability, and market share over a three-year period.

3.2.1. Exploratory factor analysis

In order to develop a parsimonious representation for the various constructs in the survey, some of which are new constructs, we conducted an initial principal-components-based exploratory factor analysis for each set of questions that we planned *ex ante* to represent a separate construct. We eliminated items that loaded greater than 0.40 on more than one construct or that loaded onto a factor that did not make logical sense. After all of the survey instrument constructs were defined, we performed another factor analysis to verify the initial exploratory results. Using the principal components method, the same five constructs emerged with eigenvalues greater than 1.0, accounting for 59% of the total variance in the data. These factors were in general alignment with a priori expectations. The VARIMAX rotation resulted in the following factors:

LMFG:	The extent to which the facility has implemented various Lean manufacturing tools such as cells, a *Kanban* system, one-piece flow, 5S, and *Kaizen*.
VLPM:	The availability and visibility of strategically aligned performance measures on the shop floor.
SMAP:	The efforts made in the accounting system to simplify and align it with strategic initiatives.
OPRF:	The changes in operations performance over three years.
FPRF:	The changes in financial performance over three years.

These factors along with VSC represent the variables used in the testing of the research model. The results of the factor analysis are shown in Appendix B.[6] VSC is a single five-point semantic differential scaled question that asked respondents to assess the extent to which they used VSC from 1 "not at all" to 5 a "great deal." While most variables used in SEM are latent variables, it is also acceptable to use observed variables (Kline, 2005, p. 12). An observed variable captures the construct when it is sufficiently narrow or unambiguous to the respondents (Sackett and Lawson, 1990; Wanous et al., 1997). Rossiter (2002) argues that a single-item measure is sufficient if the construct is singular and concrete in the minds of the raters, and Drolet and Morrison (2001) recommend the use of single-item measures that meet Rossiter's criteria. Bergkvist and Rossiter (2007) demonstrate how some single-item concrete measures can be superior to multi-item measures. We contend that our measure of VSC is unambiguous, singular,

[6] Note that the positive anchor of the 5-point Likert scaled survey questions for LMFG, OPRF, and FPRF is "5," and for VLPM and SMAP, the positive anchor is "1." To make the interpretation of the results more intuitive, we subtracted the responses to the questions representing VLPM and SMAP from 6 so the higher the value of each construct, the greater is VLPM and SMAP.

and concrete in the minds of our responders.[7] It is a costing system that is directly related to the operational activities of a value stream. Even though not all of our respondents have implemented lean MAP, they were all attendees of the LASs, where VSC was consistently discussed and clarified.

The factor solutions for the defined constructs support the construct validity of the survey instrument. Multiple-question loadings for each factor in excess of 0.50 demonstrate convergent validity (see Bagozzi and Yi, 1988). In addition, discriminant validity is supported, with none of the questions in the factor analyses having loadings in excess of 0.40 on more than one factor.

To provide additional assurance on the suitability of our measures, we undertake a rigorous examination of common method bias utilizing both procedural and statistical remedies (Podsakoff et al., 2003). Although respondents were aware that they were answering questions about lean accounting, lean manufacturing, and performance, they were unlikely to guess our specific research model. If the research question is unknown, respondents have less ability to manipulate their answers in an attempt to meet some presumed expectations of the relationships. We used various response formats (e.g., not at all to a great deal; strongly agree to strongly disagree; significant increase to significant decrease) and did not group questions by construct. We protected the respondents' anonymity and carefully pre-tested the survey to ensure that we avoided ambiguity, while using simple, easy-to-understand language. To assess the extent of common method bias that may remain after implementation of procedural remedies, we ran a Harman's one-factor test on the survey questions that form the primary constructs in our model. If the majority of variance is explained by the first factor, then there is significant bias (Podsakoff and Organ, 1986). In this analysis, only 17.3% of the variance is explained by the first factor, and the balance of the variance is explained by the remaining variables (13.7%, 10.2%, 8.8%, 8.6%). Overall, we conclude that the potential for common method bias is low.

3.2.2. *Confirmatory factor analysis*

We evaluated the measurement model with a confirmatory factor analysis (CFA) (Gerbing and Anderson, 1988). Schumacker and Lomax (1996, 72) recommend a two-step modeling approach, proposed by James et al. (1982), that first evaluates the measurement model to assure its fit and then examines the full model. The measurement model provides an assessment of convergent and discriminant validity, while the full model provides an assessment of predictive validity. Jöreskog and Sörbom (1993, 113) indicate that the measurement model must be tested independently to ensure that the chosen indicators for a construct are appropriate. The maximum likelihood (ML) approach in AMOS 18 was used to test the measurement model and full structural model. Among the 244 responses, most measures have a full response, with no more than five responses missing for any single measure. AMOS does not evaluate missing data, but provides a theoretical approach to random missing data that is "efficient and consistent, and asymptotically unbiased" (Byrne, 2001, 292). Where covariances were suggested by AMOS and justified theoretically, we included them between error terms of the same construct (see Baines and Langfield-Smith, 2003; Fullerton and Wempe, 2009; Jaworski and Young, 1992; Shields et al., 2000). All of the structural models are over-identified and recursive.

We evaluated the measurement model using a number of fit indices, including: X^2 and the ratio of X^2 to degrees of freedom; Root Mean Square Error of Approximation (RMSEA); standardized root mean square residual (SRMR); Bentler–Bonett normed fit index (NFI) (Bentler and Bonett, 1980); incremental fit index (IFI) (Bollen, 1989); Tucker–Lewis Index (TLI) (Tucker and Lewis, 1973); Comparative Fit Index (CFI) (Bentler, 1990), and Akaike Information Criterion (AIC) (Akaike, 1987). While there are no minimal established guidelines for what constitutes an acceptable fit (Schermelleh-Engel et al., 2003), there are several suggested parameters in published reference and academic works for what represents acceptable and good fit. Small p-values for the X^2 indicate that the hypothesized structure is not confirmed by the sample data (Hughes et al., 1986). However, Jöreskog and Sörbom (1989) note that this statistic should be interpreted with caution, and that other measures of fit should be considered, such as the ratio of X^2 to degrees of freedom, which should be less than 2.0. RMSEA is one of the most informative criteria in assessing model fit (Byrne, 2001), with a built-in correction for model complexity (Kline, 2005, 137). A RMSEA value of less than 0.08 is reasonable, although many view a value of 0.05 or less as indicating a good fit (Browne and Cudeck, 1993; Byrne, 2001; Kline, 2005). An SRMR less than 0.05 (Schermelleh-Engel et al., 2003) to 0.10 (Kline, 2005) is considered favorable. The other ratios (NFI, TLI, CFI, and IFI) are evaluated for their closeness to 1.0, with values over 0.90 (Bentler, 1992, Byrne, 2001; Kline, 2005) or over 0.95 (for the CFI; Hu and Bentler, 1998; Schermelleh-Engel et al., 2003) representing good fit. In addition, we used the AIC, which compares the hypothesized sample model to a hypothetical random sample (saturated) model, to measure model parsimony (Kline, 2005, 142). The AIC of the hypothesized model should be less than that of the saturated model, since the model with the smallest AIC is the one most likely to replicate (Byrne, 2001; Hu and Bentler, 1995; Kline, 2005). The measurement model has good fit indices, with the exception of NFI, as shown in Table 2. However, NFI often underestimates fit in small samples (Byrne, 2001; Kline, 2005), whereas TLI, CFI, and IFI are preferred fit indices for small sample sizes (Shah and Goldstein, 2006). Thus, we feel the overall model fit for our sample is reasonable.

Discriminant validity assesses the extent to which the individual constructs are discrete (Bagozzi et al., 1991). Crocker and Algina (1986) indicate that discriminant validity is shown when the correlations of individual factors do not exceed the alpha (reliability) coefficients. Another measure of discriminant validity is to compare the square root of the average variance extracted (AVE) to the correlations between constructs (Braunscheidel and Suresh, 2009; Chin, 1998; Fornell and Larcker, 1981). The square root of AVE is indicated on the diagonal of Table 3 and is greater than the construct correlations.[8] Table 3 shows that all of the correlation coefficients are less than the alpha coefficients. The alpha coefficients are used to test for the internal consistency of the constructs (Cronbach, 1951); they all exceed the acceptable standard of 0.70 for established constructs (Nunnally, 1978; Nunnally and Bernstein, 1994). In addition, we looked at the composite reliabilities, which unlike

[7] For additional reassurance that our results are not affected by using a single-item measure, we run the following sensitivity analysis. We relaxed the assumption of zero error variance and included the parameter for the error variance as (1-average reliability) × (actual item variance). In doing so, our results were almost identical to the original model and the qualitative inferences were unchanged, giving us more comfort in the use of the single-item measure.

[8] We also compared the AVE to the inter-construct correlations produced in the AMOS confirmatory factor analysis. We find that all of the correlations are less than the square root of the AVE as recommended by Fornell and Larcker (1981) with one exception, the correlation between LMFG and OPRF (0.73). Even though Schumacker and Lomax (1996) recommend the Pearson correlation for testing SEM models (which is less than the square root of the AVE), we turned to Kenny (2012) – http://davidakenny.net/cm/mfactor.htm to gain further assurance about our model. He suggests that discriminant validity among latent factors in SEM is poor if the correlations ⩾.85. Although all of our correlation coefficients <0.85, we perform an additional recommended test that restricts the correlation between LMFG and OPRF to 1 in the CFA. We find that model fit is worse (e.g., SRMR increases from .05 to .15, and ILI, CFI, and CFI drop to barely over 0.90). We, thus, conclude that our discriminant validity is acceptable overall (Kenny, 2012).

Table 2
Results from confirmatory factor analysis summary data for individual construct indicators.

Construct indicators	Standardized coefficients (loadings)	*t*-Values (all significant to $p < 0.000$)
Lean manufacturing practices		
LMFG1	0.654	–[a]
LMFG2	0.741	9.978
LMFG3	0.705	9.573
LMFG4	0.681	8.498
LMFG5	0.720	9.719
LMFG6	0.791	10.425
LMFG7	0.684	9.259
LMFG8	0.642	8.813
LMFG9	0.709	9.541
Visual performance measures		
VLPM1	0.525	–[a]
VLPM2	0.606	6.911
VLPM3	0.652	7.839
VLPM4	0.680	7.302
VLPM5	0.695	7.457
VLPM6	0.725	7.568
VLPM7	0.712	7.572
VLPM8	0.656	7.215
Simplified and strategic management accounting practices		
SMAP1	0.636	–[a]
SMAP2	0.511	8.080
SMAP3	0.880	9.922
SMAP4	0.792	9.711
Operations performance		
OFPR1	0.613	–[a]
OFPR2	0.631	7.914
OFPR3	0.776	9.123
OFPR4	0.551	7.126
OFPR5	0.712	8.631
OFPR6	0.551	7.126
Financial performance		
FPRF	0.652	–[a]
FPRF	0.727	9.463
FPRF	0.906	9.566
FPRF	0.588	9.582

Notes: $n = 244$.
Measurement models are estimated using maximum likelihood.
See Appendix for definition of individual indicators from survey data.
Model fit indices: Chi-square, 630.072; degrees of freedom, 440; *p*, 0.000; Chi-square ratio, 1.432; NFI, 0.833; IFI, 0.943; TLI, 0.934; CFI, 0.942; RMSEA, 0.042; SRMR, 0.052; AIC, 870.072 (saturated model, 1120.00).
[a] Indicates a parameter that was fixed at 1.0.

Cronbach's alpha do not assume equally weighted measures. The composite reliabilities are also above the acceptable standard of 0.70 (Chin, 1998; Fornell and Larcker, 1981), as shown in Table 3. In Table 3, we also see many significant correlations as expected. Indeed all of the constructs are significantly correlated with the exception of the relations between VLPM and VSC with FPRF. Due to the voluminous number of factors that impact FPRF, it is not surprising that a univariate effect for these two constructs is not revealed. Moreover, this is consistent with our hypotheses that VLPM and VSC affect FPRF through OPRF. Given the many significant univariate correlations, we assessed multivariate multicollinearity in the measurement model by examining tolerance and variance inflation factors. None of the variance inflation factors exceed 2.0 and the tolerance statistics are all under 1.0, indicating multicollinearity is not a concern.

4. Research results

4.1. Descriptive statistics

We asked the survey respondents to indicate whether or not ("yes or no") they had formally implemented lean accounting at their facility. The results show that 119 of the 244 plants have some form of lean accounting in place, and all 119 of those plants indicated that they have formally implemented lean manufacturing.[9] Fig. 2 depicts the distributions for the implementations of lean practices (lean manufacturing, lean accounting, JIT, TQM, and TPM) for all respondent firms.

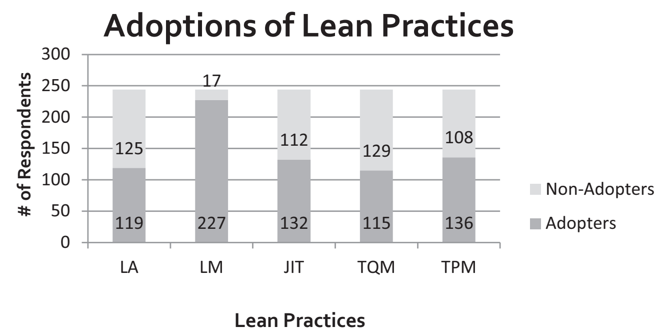

Fig. 2. Description of sample. LA, lean accounting; LM, lean manufacturing; JIT, just-in-time; TQM, total quality management; TPM, total productive maintenance.

Table 4 presents descriptive statistics for the test model variables for the full sample, the plants indicating they had adopted lean accounting, and the plants that had not adopted lean accounting. The mean ratios for the lean accounting plants versus the non-lean accounting plants are all in the directions expected. Interestingly, the ANOVAs show that the means for all of the variables are significantly different for those plants that have adopted lean accounting versus those that have not, except for operations performance. While it is higher for lean-accounting plants, it is not significantly so.

4.2. Fitness of the structural equation model

Before the path coefficients can be assessed, the fitness of the structural model must be evaluated. As shown in Table 5, the goodness-of-fit statistics generally indicate a good fit to the data. Although the X^2 is significant, the X^2 ratio is less than two, indicating an acceptable fit (Kline, 2005). Each one of the remaining model fit indices shown in Table 5 (NFI, IFI, TLI, and CFI) exceeds the acceptable fit level of 0.90, with the exception of NFI, which often underestimates fit in small samples (Kline, 2005). The RMSEA does not exceed the acceptable fit measure of 0.08 (Browne and Cudeck, 1993), nor does the SRMR exceed 0.10 (Kline, 2005). The probability value that the model is a close fit is convincing at 0.950. Jöreskog and Sörbom (1996) suggest that the *p*-value for this test should be >0.50. Further, parsimony is demonstrated by an AIC that is lower than that for the saturated model.

4.3. Hypothesized findings

Table 5 and Fig. 3 show the results of the structural model. We are interested in the incremental effects of lean MAP on operations performance. Moreover, we are interested in whether lean manufacturing affects operations performance through lean MAP. Thus, we control for the direct effect of lean manufacturing on operations performance. This relation is well-established in extant literature (e.g., Hallgren and Olhager, 2009; Narasimhan et al., 2006; Shah and Ward, 2003, 2007) and accordingly, we find that

[9] Note that this sample does not approximate a representation of the percentage of lean accounting adopters in the general population, since the sample was taken from attendees at Lean Accounting Summits, where the interest in lean accounting and percentage of adoption would be much higher.

Table 3
Correlation table.

	# of measures	1	2	3	4	5	6	Mean[a]	S.D.	Cr. α	Comp. reliability
1. LMFG	8	**0.71**						3.673	0.79	0.90	0.90
2. VLPM	8	.54**	**0.66**					2.601	0.74	0.86	0.86
3. SMAP	4	.31**	.36**	**0.72**				2.806	0.90	0.71	0.80
4. OPRF	6	.63**	.49**	.32**	**0.64**			3.747	0.61	0.81	0.81
5. FPRF	4	.15*	.10	.13*	.15*	**0.73**		3.668	0.78	0.82	0.81
6. VSC	1	.38**	.39**	.35**	.33**	.08	N/A	2.440	1.21	N/A	N/A

Notes: $n = 244$.
Square root of AVE on diagonal in boldface.
LMFG, implementation of lean manufacturing practices; VLPM, the visibility and strategic alignment of performance measures; SMAP, the simplification and strategic alignment of management accounting practices; OPRF, the change in operations performance over the last 3 years; FPRF, the change in financial performance over the last 3 years; VSC, the extent of use of value stream costing.
* Significant at the .05 level (2-tailed).
** Significant at the .01 level.
a All measures are a Likert scale from 1 to 5.

Table 4
Descriptive statistics for comparison of variable means between lean accounting plants and non-lean accounting plants.

	Full sample means	LA plant means[d]	Non-LA plant means	ANOVA F-value	Sig. *F* (2-tailed)
Variables					
LMFG[a]	3.758	4.099	3.603	4.326	.042
VLPM[b]	2.411	2.558	2.283	4.998	.027
SMAP[b]	2.194	2.533	1.860	38.182	.000
VSC[a]	2.440	2.940	1.970	45.227	.000
OPRF[c]	3.747	3.802	3.693	1.811	.180
FPRF[c]	3.668	3.777	3.559	4.483	.035
Other descriptives[d]					
JIT	0.540	0.690	0.400	22.215	.000
TQM	0.487	0.590	0.360	13.337	.000
TPM	0.560	0.660	0.460	9.331	.004

Notes: $n = 244$.
LMFG, implementation of lean manufacturing practices; VLPM, the visibility and strategic alignment of performance measures; SMAP, the simplification and strategic alignment of management accounting practices; VSC, the extent of use of value stream costing; OPRF, the change in operations performance over the last 3 years; FPRF, the change in financial performance over the last 3 years; LA, the adoption of lean accounting; JIT, just-in-time; TQM, total quality management; TPM, total productive maintenance.
Note that responses for VLPM, SMAP, and FPRF were reverse coded to make all positive anchors at "5".
a Possible responses: Not at all = 1; Little = 2; Some = 3; Considerable = 4; Great Deal = 5.
b Possible responses: Strongly agree = 1...2...3....4...Strongly disagree = 5.
c Possible responses: Significant increase = 1; Moderate increase = 2; Little or no Change = 3; Moderate decrease = 4; Significant decrease = 5.
d Possible responses: (yes = 1; no = 0).

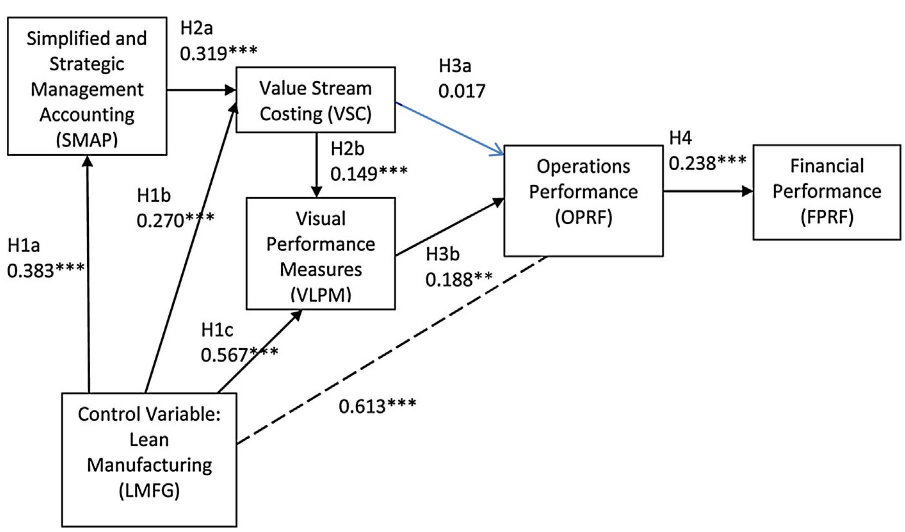

Fig. 3. Depiction of results. *Note*: The dotted line represents the control path. Solid lines represent hypothesized paths. ***, **, * indicates the significance of the *p*-value at <0.01, 0.05, and 0.10, respectively. We report one-tailed *p*-values for all hypothesized relations.

the extent of lean manufacturing is positively related to operations performance ($p < 0.01$). This is consistent with theory that argues that in order to sustain a competitive advantage in today's market, streamlining processes and focusing on objectives such as continuous improvement and quality first-time through are important.

Turning our attention to our hypotheses, we find that the extent of lean manufacturing is positively related to

Table 5
Structural equation model results.

Relationships	Hypothesis	Standardized coefficient	*t*-Values
LMFG → SMAP	H1a	0.383	4.729***
LMFG → VSC	H1b	0.270	3.881***
LMFG → VLPM	H1c	0.567	5.690***
SMAP → VSC	H2a	0.319	4.379***
VSC → VLPM	H2b	0.149	2.323***
VSC → OPRF	H3a	0.017	0.287
VLPM → OPRF	H3b	0.188	2.234**
OPRF → FPRF	H3	0.238	3.028***
Control path			
LMFG → OPRF		0.613	5.783***

Notes: $n = 244$.
Measurement models are estimated using maximum likelihood.
***, **, * indicates the significance of the *p*-value at <0.01, 0.05, and 0.10, respectively. We report one-tailed *p*-values (for all hypothesized relations).
Model fit indices: Chi-square, 645.203; degrees of freedom, 446; *p*, 0.000; Chi-square ratio, 1.447; NFI, 0.829; IFI, 0.940; TLI, 0.932; CFI, 0.939; RMSEA, 0.043; SRMR, .056; AIC, 873.203 (saturated model, 1120.00).
LMFG, implementation of lean manufacturing practices; VLPM, the visibility and strategic alignment of performance measures; SMAP, the simplification and strategic alignment of management accounting practices; OPRF, the change in operations performance over the last 3 years; FPRF, the change in financial performance over the last 3 years; VSC, the extent of use of value stream costing.

simplified and strategically aligned MAP (coef. = 0.383, $p < 0.01$), VSC (coef. = 0.270, $p < 0.01$), and the use of visual performance measures (coef. = 0.537, $p < 0.01$). These results provide evidence on H1a, H1b, and H1c. They show that the extent of lean manufacturing positively influences the use of lean MAP. Thus, firms that are implementing lean manufacturing are realizing that they correspondingly need to adapt their management accounting system to be aligned with and supportive of their operations.

We next turn our attention to our hypothesized relations among the set of lean MAP. H2a predicts that simplified, strategic MAP are positively associated with VSC, and we find a positive, significant relation (coef. = 0.319, $p < 0.01$). Firms that have applied lean thinking to their accounting functions by simplifying and strategically aligning their MAP are more likely to see the value and need for VSC and provide direct product cost information for the value streams, supporting better decision making. H2b predicts that VSC is positively associated with the use of visual performance measures, and we find a positive, significant relation (coef. = 0.149, $p < 0.01$). As firms embrace VSC, they also see the need and benefit in providing more visual performance measures that support their internal accounting system and provide information that is easy for the operations personnel to use and comprehend.

Interestingly, there is no indication that operations performance increases because firms rely more on VSC; thus, H3a is not supported. Since VSC is more focused on a financial reporting of value stream product costs, there may not be a direct linkage between the use of VSC and operations performance, which is related to non-financial outputs. H3b predicts that the use of visual performance measures is positively related to operations performance, and we find a positive, significant relation (coef. = 0.188, $p < 0.05$). The results indicate that as firms use more visual performance measures, they have also increased their operations performance over the past three years in terms of quality issues, lot sizes, and cycle times. Operations personnel are able to use these visual measures to identify and respond to problems more quickly than information that is hidden in computers and compiled too late to be relevant. The results also indicate that while the information contained in VSC is not by itself associated with operations performance, translating it into visual performance measurement information that enables operations employees to be more efficient and/or effective results in enhanced operations performance. Finally, H4 predicts that operations performance is positively associated with financial performance. We find a positive, significant relation (coef. = 0.238, $p < 0.01$). As expected, the results demonstrate that when flexibility is increased through the elimination of production wastes and improvements in quality initiatives, financial performance improves.

4.4. Direct and indirect findings

To provide additional insights into the effects that lean MAP have on operations and financial performance, we run a trimmed structural equation model that removes the insignificant path hypothesized in H3a, providing more parsimony and clearer insight. The direct, indirect, and total effects of the trimmed model are shown in Table 6. The results demonstrate that lean MAP have both direct and indirect effects on operations and financial performance. The use of visual performance measures has a direct effect on operations performance ($p < 0.05$), while simplified, strategic MAP ($p < 0.05$) and VSC ($p < 0.05$) have indirect effects. Moreover, simplified, strategic MAP ($p < 0.01$), VSC ($p < 0.01$), and the use of visual performance measures ($p < 0.05$) indirectly influence financial performance. Although we do not find a direct effect of VSC on operations performance (see Table 5), Table 6 shows that VSC is important in translating the effects of simplified, strategic MAP to both operations and financial performance. Thus, it is likely that VSC does not directly influence operations performance, because the VSC information must be translated through the use of visual performance measures before the benefits of operations performance can be realized.

An important implication of Table 6 is that lean manufacturing has both direct and indirect effects on operations performance. By examining an integrated model that includes the manufacturing strategy as well as the management accounting support function, we are able to see *how* lean manufacturing affects operations performance. That is, as manufacturing operations focus on continuous improvement and quality first-time through, there is a direct improvement in operations performance. Further, it appears that when accounting personnel get on board with lean and implement lean MAP, operations managers and shop-floor employees tasked with making manufacturing decisions are provided with more concise, simpler, and relevant information that leads to an incremental increase in operations performance. In sum, lean MAP

Table 6
Trimmed model: standardized direct, indirect, and total effects.

Relationships variable	Direct effects	Indirect effects	Total effects
LMFG → SMAP	0.384***		0.384***
LMFG → VSC	0.271***	0.122***	0.393***
LMFG → VLPM	0.567***	0.059***	0.626***
SMAP → VSC	0.318**		0.318***
LMFG → OPRF	0.617***	0.121**	0.737***
SMAP → VLPM		0.048***	0.048***
SMAP → OPRF		0.009**	0.009**
SMAP → FPRF		0.002***	0.002***
VSC → VLPM	0.149***		0.149***
VSC → OPRF		0.029**	0.029**
VSC → FPRF		0.007***	0.007***
VLPM → OPRF	0.192**		0.192**
VLPM → FPRF		0.046**	0.046**
OPRF → FPRF	0.238***		0.238***

Notes: $n = 244$.
These are the standardized direct, indirect, and total effects from a structural equation model that trims the insignificant path from VSC to operations performance.
***, **, * *p*-values <0.01, 0.05, and 0.10, respectively. We report one-tailed *p*-values.
LMFG, Implementation of lean manufacturing practices; VLPM, The visibility and strategic alignment of performance measures; SMAP, The simplification and strategic alignment of management accounting practices; OPRF, The change in operations performance over the last 3 years; FPRF, The change in financial performance over the last 3 years: VSC, The extent of use of value stream costing.

provide financial control tailored to the lean environment, thus, supporting operations managers and shop-floor workers in their internal decision making, which leads to enhanced performance.

4.5. Robustness tests

Chiarini (2012) described VSC as an ineffective accounting system for the small company she examined that was in the early stage of lean implementation. In their literature review, Camacho-Minano et al. (2013) found that contextual factors of size, years of implementation, and sector in lean companies had mixed results with financial performance. In order to evaluate the robustness of our results, we run a series of models that control for size (sales), top management support, unionization, management experience (in years), years of lean manufacturing implementation, and years of VSC implementation. We implement these controls by modeling paths between each of the control variables and the six constructs in our model. In untabulated results, we find that our statistical inferences remain similar across the various tests.

4.6. Implications of the results

The results of this study are important because they provide evidence that performance is enhanced with a holistic lean strategy comprised of both lean manufacturing and lean MAP. It is not enough for operations management to implement a well-executed lean manufacturing strategy. Instead, operations management must work with accountants to ensure that the underlying financial control data are aligned with lean manufacturing initiatives. Management accountants should be encouraged to act more as coaches, rather than enforcers – providing more strategic analysis than transaction analysis. Anecdotal evidence from many discussions with operations managers indicates the critical need for accountants to become more involved in lean transitions. When accounting personnel implement lean MAP that are aligned with lean manufacturing initiatives, our results show that operations performance is enhanced. Further, the structural model provides evidence that supporting lean implementations with the appropriate management accounting and control systems will lead to increased financial performance beyond that which is derived from operations. Lean MAP play an integral part in the success of a lean implementation, as they provide the information to motivate appropriate behaviors. That is, lean MAP provide financial control that spurs operations managers to reduce inventory, make more efficient use of capacity, and strive for continuous improvement. Yet, the role of management accounting in lean implementations has often been overlooked, especially by researchers. The evidence in this study suggests that firms deriving the greatest benefit from using a higher level of lean manufacturing practices are those also adopting lean MAP – simplifying and aligning their MAP, reporting their lean operations through VSC, and using a more visual performance management system. These integrated lean strategies lead to improved operations and financial performance. Empirical studies such as this will hopefully initiate more interaction between operations and accounting functions. As operations managers encourage management accountants to take a more pro-active role with lean initiatives, firms should see an increase in their performance.

5. Conclusion

Lean pundits have suggested that in order to achieve its potential, lean must be a holistic business strategy engrained in all aspects of the organization. They argue that support systems, such as accounting, human resources, and information technology, should be both participating in and providing support for lean initiatives (Cunningham and Fiume, 2003; McVay et al., 2013; Solomon and Fullerton, 2007). It is particularly important to strategically align management accounting, since it provides the financial control necessary to support and facilitate effective performance-enhancing decision making. Traditional MAP focus on minimizing average product cost; thus, it is often argued that they lead operations managers to make decisions that are inconsistent with lean objectives. In contrast, the financial control provided by lean MAP is simpler and easier to understand. Lean MAP facilitate operations managers to make decisions that reduce inventory and better utilize capacity, shift their focus to maximizing customer value and the efficiency of the value stream, and motivate them to strive for continuous improvement. Thus, it is important to understand how and if lean MAP can better support and be integrated with operations. This research provides some of the first empirical evidence on these issues – how lean manufacturing and lean MAP working together can affect operations performance by having more relevant, visual, and actionable information.

Lean manufacturing has a significant relationship with operations performance as does lean MAP. Visual performance measures are directly related to operations performance, which in turn is directly related to financial performance. Further, simplified and strategically aligned MAP and VSC are indirectly related to operations and financial performance. The lean MAP work together as a package, and in doing so, both VSC and the use of visual performance measures act as performance mediators. VSC does not have a direct effect on operations performance, but it acts to mediate simplified, strategic MAP that enhance the use of visual performance measures, and visual performance measures mediate simplified, strategic MAP and VSC that ultimately enhance financial performance. Importantly, lean manufacturing also indirectly affects operations performance through lean MAP.

These results have important implications for operations managers and executives involved in developing and implementing lean strategies. A high-level implication is that lean thinking is indeed a comprehensive business strategy that not only involves operations, but also depends on lean managerial accounting practices for providing information in a timely fashion that motivates appropriate lean behaviors. Thus, a practical implication is that operations personnel cannot operate in isolation. They must develop good communications and a strong working relationship with management accountants in order to achieve their expected gains in efficiency and performance from lean initiatives. Through focusing on continuous improvement, reorganizing into cells, producing per customer demand, and ensuring quality first-time through, operations personnel may think they are getting the most benefit they can from implementing a lean strategy. But that is not the complete story. Some of the potential gains in operations performance will be foregone unless operations personnel join forces with their accountants to encourage them to lean their accounting processes, better communicate relevant information that facilitates sound decision making, and change their reporting system to better support lean initiatives. If accountants are excluded from being a fundamental part of the continuous improvement team, they can become barriers to change that they do not understand or have a vested interest in (Cunningham and Fiume, 2003, 3). Since our results indicate that lean manufacturing affects operations performance through lean MAP, there is also a practical, albeit self-interested, implication. Operations personnel that are incentivized on the basis of operations performance may realize greater incentive compensation when they partner with accounting personnel and encourage the implementation of lean MAP.

5.1. Limitations of the research

This study does not use a random sample, which reduces the generalizability and applicability of the findings. It is very difficult to find a sizable sampling of firms that have adopted lean MAP, so it was expedient to use a single venue for selecting respondents. It is assumed that all of the respondents were interested in lean thinking, and particularly lean accounting by their attendance at a Lean Accounting Summit. As in all survey research, a necessary assumption in data collection is that the respondents had sufficient knowledge to answer the items, and that they answered the questions conscientiously and truthfully. Another potential issue is the single measure of VSC. While it does measure gradients of VSC adoption, it would be helpful to identify specific practices that are used in relationship to VSC. Further, the performance measures were self-reported, which may introduce bias in the measures.

5.2. Future research

This study examines various aspects of the environment and characteristics that may encourage manufacturing firms to be willing to take the rather dramatic steps to change their accounting systems in support of other change initiatives occurring throughout their operations. In-depth case studies are needed to identify these characteristics more specifically. Long-term analyses would be helpful to evaluate the sustainable success of changes in MAP. Interdisciplinary research involving both accounting and operations researchers could be a fruitful partnership to provide further evidence and deeper insights on the complementary benefits that result from an integrated accounting and operations strategy. Further, survey studies that have a larger cross-sectional random sample may provide a clearer understanding of the results found in this study. Regardless of the research methods, it is evident that operations personnel need to join forces with their management accountants and enlist them in providing internal information that is timely, relevant, and valuable to the decision makers of today.

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Appendix A. Survey questions that support the variables used in this research

Lean manufacturing practices (LMFG)[a]

To what extent has your facility implemented the following:
- Standardization
- Manufacturing cells
- Reduced setup times
- *Kanban* system
- One-piece flow
- Reduced lot sizes
- Reduced buffer inventories
- 5S
- *Kaizen* (continuous improvement)

Visual performance measures (VLPM)[b]

Indicate your agreement to the following statements related to your management accounting system:
- Many performance measures are collected on the shop floor.
- Performance metrics are aligned with operational goals
- Visual boards are used to share information.
- Information on quality performance is readily available.
- Charts showing defect rates are posted on the shop floor.
- We have created a visual mode of organization
- Information on productivity is readily available.
- Quality data are displayed at work stations.

Simplified management accounting practices (SMAP)[b]

Indicate your agreement to the following statements related to your management accounting system:
- Our accounting system has been simplified in the past 3 years.
- Our accounting closing process has been streamlined.
- Our management accounting system supports our strategic initiatives.
- Our accounting information system facilitates strategic decision making.

Operations performance (OPRF)[c]

Indicate how your facility's operations have changed over the last three years:
- Scrap and rework
- Machine setup times
- Queue times and move times
- Machine downtime
- Lot sizes
- Cycle time

Financial Performance (FPRF)[c]

Indicate how your facility's operations have changed over the last three years:
- Net sales
- Return on assets
- Overall firm profitability
- Market share

Value Stream Costing (VSC)[a]

Indicate the extent to which your facility uses value stream costing.

[a] Possible responses: Not at all = 1; Little = 2; Some = 3; Considerable = 4; Great Deal = 5.

[b] Possible responses: Strongly agree = 1. . .2. . .3. . ..4. . .Strongly disagree = 5.

[c] Possible responses: Significant increase = 1; Moderate increase = 2; Little or no Change = 3; Moderate decrease = 4; Significant decrease = 5.

Appendix B. Exploratory factor analysis: factor loadings for explanatory variables

	Factor 1 LMFG	Factor 2 VLPM	Factor 3 OPRF	Factor 4 SMAP	Factor 5 FPRF
LMFG-standardization	0.599				
LMFG-cells	0.710				
LMFG-reduced setup	0.633				
LMFG-Kanban	0.739				
LMFG-one-piece flow	0.724				
LMFG-reduced lot size	0.760				
LMFG-reduced inventory	0.601				
LMFG-5S	0.728				
LMFG-Kaizen	0.716				
VLPM-collect shop floor		0.631			
VLPM-aligned measures		0.638			
VLPM-visual boards		0.616			
VLPM-quality info		0.753			
VLPM-defect charts		0.759			
VLPM-visual organization		0.560			
VLPM-productivity info		0.717			
VLPM-data work stations		0.683			
OPRF-scrap & rework			0.625		
OPRF-setup times			0.602		
OPFR-queue times			0.707		
OPRF-machine downtime			0.639		
OPRF-lot sizes			0.677		
OPRF-cycle time			0.555		
SMAP-MAS simplified				0.769	
SMAP-close streamlined				0.705	
SMAP-support strategies				0.794	
SMAP-decision making				0.764	
FPRF-net sales					0.816
FPRF-ROA					0.765
FPRF-profitability					0.848
FPRF-market share					0.789

Notes: $n = 244$.
All loadings in excess of 0.40 are shown.
Kaiser–Meyer–Olkin measure of sampling adequacy is good (0.87) and the Bartlett test of Sphericity is highly significant ($p = 0.000$).

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