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Management Accounting in the Manufacturing Sector: Managing Costs at the Design and Production Stages

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Abstract: This chapter analyzes the empirical research literature on management accounting in the manufacturing sector including the development as well and manufacturing phases of the product lifecycle. As managing product development has gained terrain in companies over the last 15 years, management accounting research has contributed to the advancement of this field of knowledge. Changes in the manufacturing environment, such as significant upfront investments and ongoing overhead costs, demanding performance criteria besides efficiency, or critical linkages across the value chain have contributed to a fruitful research in management accounting in manufacturing. The chapter identifies significant advances in this knowledge base and highlights future research opportunities.

1. Introduction

This chapter focuses on management accounting in manufacturing, whereby ''manufacturing'' refers to ''tangible'' products. We further focus on two stages of manufacturing processes: new product development (NPD) and modern manufacturing systems (MMS). We focus on environments characterized by (1) significant investments justified by intangible benefits, (2) high overhead costs because of innovation and product variety, (3) the use of non-financial performance measures, and (4) the existence of critical linkages across the value chain and product lifecycle stages.[1] To further limit the scope of the chapter, we look at empirical research; therefore leaving aside ''optimization papers'' that take cost information *as given* and look for optimal contracts (e.g., purchasing, labor, or management) or optimal decisions (e.g., investments, inventory management, or production scheduling) (Graves & De Kok, 2003).[2] We also briefly refer to topics that have been studied mostly in manufacturing settings but that are covered more in depth in dedicated chapters of this multi-volume series (such as activity-based costing or target costing). However, we do not limit our review to research published in management accounting journals.

The 1980s marked an important shift in the manufacturing field. Competition from Japan and other Southeast Asian countries threatened manufacturing industries in the United States and Europe. There was a sense of urgency and improving manufacturing was at the core of the threat (Hayes et al., 1988). The central argument was the need to excel in different dimensions of manufacturing at the same time, rather than thinking about tradeoffs. Competition required having both low cost as well as high quality. Customers wanted products with more functionality and adapted to their preferences. New technologies had to be incorporated fast in new products. The focus on manufacturing spurred research in management

[1]We also refer to the chapter by Anderson (2006) in this multi-volume series that reviews literature on strategic cost management. That chapter argues for management accounting research investigating decisions that impact cost structures in *radical* ways, and such decisions are often taken by non-accounting managers, and throughout the value chain and lifecycle of products and services.

[2]This reference is a recent volume within a collection of edited handbooks on operations management close to this topic. Other volumes also have information relevant to the reader interested in this topic.

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accounting (Kaplan, 1990), such as how advanced manufacturing changed the role of accounting regarding investment decisions, cost accounting, or performance measurement (e.g., Kaplan, 1984). The 1990s saw an emphasis on product development and R&D as the new source of competitive advantage and management accounting also devoted efforts to this stage in the product lifecycle (Cooper, 1995).

This chapter addresses these two broad topics: product development and modern manufacturing. Each topic is addressed using a simple framework that helps organizing the review. The review progresses from cost modeling (*ex ante*) and measurement (*ex post*)—the traditional focus of management accounting—to non-financial performance measures. Then, it moves to uses of management accounting information, from rewards to motivate social actors based on measures, to management accounting information for purposes other than motivation (decision-making, learning, or gaining power) and management control systems (see Table 1).

2. Management Accounting in Research and Product Development

In the late 1980s the view that researchers and practitioners had on NPD changed significantly. Before, NPD was seen as too uncertain with a large component of creativity. Management accounting and

Table 1. Framework for review.

Theories	Management accounting tools	Product development	Manufacturing
Measurement theory	Cost modeling estimating the future cost	Target costing Cost information Cost experts New cost management approaches	Intangible benefits Risk assessment MMS investment financial criteria
	Cost measurement measuring realized costs	R&D returns Budgets in R&D	Cost structures Cost drivers Cost system design Importance of cost accounting
	Non-financial performance measures reporting expected and realized non-monetary performance	Quantitative vs. qualitative measures Project-level measures R&D level measures Portfolio measures	Non-financial measures in MMS Design of management accounting systems:, scope, integration, aggregation, timeliness Fit with manufacturing strategy and impact on performance
Management-based Economics-based Sociology-based Psychology-based theories	Rewards motivating social actors based on measures	Extrinsic vs. intrinsic motivation Design of economic and social rewards	Non-financial measures in reward systems Group-based rewards Team-based and broader-based reward structures Impact of economic incentives on performance
	Management accounting systems using management accounting information for purposes other than motivation (e.g., decision-making, learning, gaining power)	Fit between management information and strategy	Management accounting differs to match the needs of different levels within the organization Management accounting as supporting learning, improvement Accounting information systems
	Management control systems designing the management infrastructure	Coercive vs. enabling control systems Types of control and performance	Impact of manufacturing strategy on budgeting process Completeness of non-financial performance measures Manufacturing strategy as a contingency factor to the design of management control systems

control systems were perceived irrelevant because they stifled creativity and innovation. They imposed a bureaucracy that could only be damaging. This assumption was not foreign to management accounting research; quite the contrary, it was a working assumption—accounting had nothing to do with NPD or R&D in general (Anthony, 1965; Ouchi, 1979). Then, the tide changed. Product development and soon research activities could benefit from management tools. The first hints of change came from practice and were picked up by operations researchers and a bit later by management accounting researchers.

2.1. Cost Modeling in Research and Product Development

A significant percentage of product costs are determined at the product development stage—80% has been frequently suggested (Cooper & Slagmulder, 1999a). Costs are designed into the product and become engineered once the product moves into manufacturing. Not surprisingly, the research literature has devoted efforts to understand how cost information is embedded in product design. Within management accounting, most of this effort has been invested in understanding target costing.

Target costing is a detailed technique to reduce costs during the product design stage (Koga, 1999). It is best suited for products for which price is a key competitive dimension. In these product markets, companies have little room to set prices and thin margins. Therefore, profits come from the ability to keep the functionality that the price point requires at the lowest cost. Market prices and required profit margins define a target cost that product development teams use as a target to be met. From this starting point, target costing provides the discipline and tools to bring the estimated cost down to the target cost though the product development process. Ansari et al. (2006) in this multi-volume series provide an overview of the development and state-of–art of the target costing literature. Accordingly, we do not devote space to this important cost management technique and refer the interested reader to the appropriate chapter. Instead, we present alternative approaches to manage costs during product development.

Target costing is better suited to environments where costs are a crucial competitive dimension and modeling costs is simple. When these two conditions are not met, and costs are not a critical competitive dimension—technology, time-to-market, or customer needs dominate the attention of the development team—but cannot be ignored, companies rely on alternative techniques to bring costs management to product development. For instance, the main challenge in the design of chip manufacturing equipment is to solve the technological problems associated with the physics of electrons. Once these challenges have been overcome and the product is in the market, competition shifts to cost reduction, which makes costs a secondary but important aspect of product development. In computer peripherals where the Christmas season accounts for almost half of the sales, time-to-market is the main focus of development teams. However, product costs cannot be fully ignored if companies want to make a profit.

These alternative cost management techniques can be classified into two groups—techniques at the product development project level and techniques at the product family level (Davila & Wouters, 2004).

At the project level, an alternative to raise the level of attention to cost considerations is to supply more relevant cost information: "to send specific messages to product designers and process engineers about how to improve the manufacturing capability of the firm" (Cooper & Turney, 1990). Rabino & Wright (1993) describe how activity-based costing (ABC) improves financial information for product introduction decisions. Anderson & Sedatole (1998) propose an advanced cost accounting system that brings together target costing, ABC, and traditional cost engineering estimation methods in product development to enhance design and manufacturing quality. Ben-Arieh (2000) and Ben-Arieh & Qian (2003) propose a hybrid of ABC and engineering cost estimation methods to enhance cost estimates in product design.

Another approach to achieve this increased level of attention to costs is assigning a management accountant to development teams (Hertenstein & Platt, 2000). These authors offer evidence that complements prior work (Nixon, 1998) that highlighted the role of management accounting as a language that brings together the different constituencies involved in product development.

Another alternative to manage costs at the project level is to use parallel cost teams (Davila & Wouters, 2004). Rather than integrating cost specialists into the product development team, these people work in parallel but outside the main team. Rather than trying to force cost criteria that may be ignored for the sake of technology or time, these parallel teams do not try to influence the main team but take sub-systems already designed and optimize them from a cost perspective. The timing of these parallel cost teams varies. In some cases, they may redesign the part before the product is released in the market; but often their cost reduction efforts come as engineering changes after product introduction and as part of the continuous cost reduction efforts.

Another approach to manage costs within projects is to leverage the concept of modularity (Baldwin & Clark, 2000; Schilling, 2000). Sub-systems that are not critical to the main competitive dimension of the project are designed as independent projects. As such, the team in charge of designing this particular sub-system can adjust the criteria to the characteristics of the project. Typically, cost considerations come higher in the priority list of these projects. Once designed, these sub-systems come as standard modules into the design of different products. This approach leverages the concept of modularity where the different sub-systems are designed as black-boxes and "plug-in" through detailed interface specifications.

The role of external networks in organizations and the integration of suppliers in product development are important ways of managing product lifecycle costs. Management accounting research has recently focused on understanding this relatively recent phenomenon and the particular challenges that it poses from an accounting perspective. Hakansson & Lind (2006) in this multi-volume series review this important line of research; from the perspective of management accounting and product development, research on how buyer–supplier cost systems integrate to manage costs during the design phase is sparse.

The evidence on these techniques is still limited and management accounting research has a fertile ground to advance knowledge in this area. Are there other techniques that have not been researched? How do cost specialists use cost information? Is it comparable to target costing? How do effective cost specialists interact? What is the influence of outsourcing certain modules to cost? Which of these techniques are complements/supplements to target costing? Why? How do companies model tradeoffs? These questions are just a sample of issues that have not yet been adequately answered.

Target costing loses some of its effectiveness in environments with complex cost behaviors, typically when indirect costs are a significant proportion of total costs and when direct costs depend on the interaction between products. In these environments, target costing is challenged with modeling such complex behavior. Often the solution is to limit cost models to direct costs rather than designing cost systems that design teams will have a hard time to understand and use. However, companies are left with the challenge of managing these indirect costs during product development.

These problems have been addressed mostly from an operations point of view where several practices have been examined. Design for X (DFX) techniques—for instance, design for manufacturing, design for recycling, design for usability, design for serviceability, etc.—have as their common denominator to maximize profitability over the lifecycle of a product often with a focus on cost reduction. These techniques provide heuristics to product design teams with the objective of reducing overall costs. For instance, design for assembly brings in rules intended to reduce costs at the manufacturing stage (Dalgleish et al., 2000).

Another significant thrust in this literature is parts and process commonalities. Both concepts are based on the idea that is the backbone of ABC, namely that complexity (and two of its manifestations—parts and process proliferation) is a significant driver of indirect costs. But instead of modeling this complexity—as cost systems attempt to do—commonality techniques posit that increasing commonality has a positive impact on profits (up to a point) and that most companies are far from this optimal solution. Parts commonality decreases complexity by decreasing the number of parts that a company works with—this is achieved through the sharing of designs and parts across products (Desai et al., 2001). Process commonality decreases complexity by decreasing the mix of supply chains. This is done through postponement—moving closer to the customer the point at which two products (usually from the same product family) differ (Fisher et al., 1999; Hillier, 2000; Lee & Billington, 1995).

This literature also investigates the use of platform planning as a way of managing costs over the lifecycle of product families (Robertson & Ulrich, 1998). Platforms are products designed taking into consideration that they are the basis for future derivative products and product redesigns. Platforms are designed not to reduce their cost but to minimize the cost of the product family.

Cost management of indirect costs during product development can also be achieved through the definition of cost strategies (Davila & Wouters, 2004). This technique defines an objective common to all product development efforts in the firm. For instance, an objective may be to eliminate manual adjustments to the finished product to configure to customer demands. This objective has almost no impact on costs if just one product achieves it, but significant consequences if all products do—for instance, an entire department is eliminated. Anderson (2006) in this multi-volume series further develops the topic of adopting a strategic perspective in managing costs.

Managing indirect costs during product development is also another rich field for research. How can cost information be designed such that project teams minimize indirect costs? How does the effect of commonality impact the design of cost systems? What is the role of cost information in deciding commonality policies? How do companies use cost information in designing their platform/product family strategies?

2.2. Cost Management in Research and Product Development

Measuring R&D has always been challenging (Hodge, 1963). But as R&D investments have become a more significant part of technology firms' income statements, the demand to measure the returns on those investments has become more acute. Researchers, responding to managers' needs, have addressed the problem of how to measure R&D performance. However, the challenges of measuring performance—timeliness (Hultink & Robben, 1995), completeness, noisiness, congruency, and risk considerations—are more pressing in R&D (Davila, 2003). The solutions proposed come short of fully satisfying managers' needs and highlight a fruitful path for future research.

Efforts to measure R&D performance include financial, quantitative and qualitative non-financial approaches. Within the financial measures, the most common one is planning and tracking project budget. Nixon (1998) describes a case study where the controller tracks the expenses associated with the project, estimation of product costs, and cost of resource usage. Budgets within R&D are also the focus of Rockness & Shields (1984, 1988) who conclude that the perceived importance of budgets "decreases monotonically from planning to monitoring, monitoring to evaluating, and evaluating to rewarding." Shields & Young (1994) study the attention to costs among R&D managers and find that budget participation and cost knowledge are positively associated with these managers' attention to costs while cost-based compensation has no effect.

Efforts to measure beyond development costs to include value creation have also been reported. For instance, Drongelen & Bilderbeek (1999) list expected or realized IRR, ROI, percentage of sales by new products, profits from R&D, and market share from R&D as financial measures intended to measure value creation. Hertenstein & Platt (2000) also include sales, sales to break even, profit percentage of sales from new/repeat customers, cash flow and economic value added as additional financial measures. McGrath & Romen (1994) propose a financial R&D effectiveness index to estimate the value that R&D generates. This index is the ratio of profits from new products (adding back R&D expenses which are considered an investment) divided by R&D expenses (treated as an investment). Alternative indexes include revenues from new products over R&D costs or over sales, or net present value of profits over investments (Werner & Souder, 1997a). Real options have also been proposed to assess the potential financial returns of R&D investments (Huchzermeier & Loch, 2001; McGrath & Nerkar, 2004; Worner & Grupp, 2003).

2.3. Non-Financial Performance Measures in Research and Product Development

Most of the work on R&D measurement has focused on non-financial performance measures—both quantitative and qualitative—and integrated performance measurement systems. The literature is large around this topic and we do not attempt to cover it all but to highlight the most important lines of research. However, there is still no accepted solution to the design of performance measures in R&D. Hertenstein & Platt (2000) examine a variety of measures both at the project level and the R&D level (but not at the portfolio level). They conclude that managers are not satisfied with the current state of performance measurement with a mean rating of 4.9 (1–10 scale) on current emphasis and of 7.2 on desired emphasis.

Performance measurement systems in R&D can be examined at four levels. The first one where more progress has been made is the project level. Next, measurement systems also need to address how these various projects combine with each other to create a portfolio that captures the strategy of the firm. A third level of analysis is the R&D function to understand whether technological capabilities are being developed in the right direction and fully leveraged. Finally, measurement systems are needed to assess the overall level of innovation of an organization.

At the project level, companies at the forefront use advanced measurement systems based on some model of project execution (such as the balanced scorecard methodology). These systems are used for upfront planning and on-going monitoring through stage-gate systems (Ulrich & Eppinger, 1995). These systems include input measures—costs associated with the project, scheduling of cross-functional experts; process measures—product cost estimates, time-to-market estimates, product specifications, customers' reactions to prototypes, and output measures. Meyer (1994), Bremser & Barsky (2004), and Curtis & Ellis (1997) are examples of integrated performance measures proposed.

Griffin and her co-authors have done extensive work on NPD measures at the project level (Griffin, 1997a). Her work encompasses detailed definitions of particular measures such as development time

(Griffin, 1997b) to summaries of associations' surveys on measures used in practice (Griffin & Page, 1993). She also presents evidence consistent with the idea that measurement systems for product development should be contingent on product strategy (Griffin & Page, 1996); a finding consistent with the idea of having a business model as the basis for designing performance measurement systems.

A more recent effort in designing measurement systems is the idea of metrics thermostat where the weights of the different performance measures vary with their impact on profitability (Hauser, 1998, 2001).

Measurement systems have also been examined beyond project level into three distinct directions: portfolio measures, R&D function measures, and innovation measures.

Measurement systems at the portfolio level are designed to give management an overview of how the various R&D efforts complement each other (Levine, 2005). Often, these systems are summarized in graphs that position projects along two dimensions. These dimensions vary from system to system but usually they include two of the following: time to value, risk, expected value, type of project, and implementation stage (Davila et al., 2005). In some cases, these various dimensions are combined to create an overall measure of project attractiveness that helps rank projects (Cooper & Edgett, 1999).

A further effort to measuring the interrelation among various projects is the concept of platform leverage (Meyer et al., 1997). This measure is based on the concept of platform product as the core of a multi-product family. The basic formulation of this measure compares the cost (or time) to develop a derivative product relative to the cost (time) of the original platform. Over time, this ratio increases as derivatives need more design to keep up with market changes until the ratio is high enough to signal the need of a new platform.

At the level of the R&D function, performance measures help coordinating and evaluating the overall performance of the R&D function. Feed-forward mechanisms coordinate the use of resources. For instance, the uncertainty associated with the process makes the scheduling of different types of expertise difficult—a project that ends up using more quality control expertise than expected may delay projects running in parallel that also need this type of expertise. R&D performance is also evaluated in terms of the exploration and exploitation of knowledge (Drongelen et al., 1999). These same authors in a study of R&D performance measures find that R&D departments doing external work use more objective measures. Furthermore, these authors report detailed lists of reasons why companies use measurement systems at the project and R&D level, of (financial and non-financial) objective performance measures and of qualitative performance measures. Werner & Souder (1997a, 1997b) provide further evidence on various metrics that are used to evaluate R&D performance (Brown & Svenson, 1998). Szakonyi (1994a, 1994b) suggests measuring R&D effectiveness relying on managers' opinions. Lin & Chen (2005) rely on patents—a common metric for R&D performance evaluation—to examine R&D success. Finally, Loch & Tapper (2002) provide case-study evidence on the implementation of a performance measurement system in an R&D setting.

At a broader level, measurement systems are of interest beyond the R&D function to encompass the innovation performance of an organization. The topic of innovation management and innovation measurement has been gaining interest. However, measuring innovation presents the challenges outlined for product development (Davila, 2003) plus the empirical fact that innovation is a multi-dimensional concept. Green et al. (1995) and more recently Gatignon et al. (2002) have shown that measuring innovation in a single dimension is bound to be too simplistic and provide evidence of the various dimensions that characterize the variable. Davila et al. (2005) provide an empirical application of innovation measurement.

The interest in measuring return to R&D is not limited to projects, portfolios, and companies but is also of much interest at the level of regions and countries. For instance, Archibugi & Coco (2005) compare five different metrics of technology capabilities at the country level and rank 47 countries according to them. These metrics have been introduced by the World Economic Forum, the United Nations Development Program, the United Nations Industrial Development Organization, RAND Corporation, and the authors. While the correlation among these metrics is high, they face the same challenges as non-financial measures at company level but at an even higher level; in particular, what is their relevance to economic performance and are higher technological capabilities always better.

2.4. Incentives in Research and Product Development

Incentive design is an important application of performance measures and as such it has a prominent role in management accounting research. Product development presents unique challenges from this perspective. Namely, creativity and intrinsic motivation have a relatively more relevant role to the success of development efforts. Organizational behavior researchers have examined this topic because of the intersection between creativity and the need for performance. Overall, their conclusion is that economic incentives—the traditional focus of incentive design in management accounting—drive away intrinsic motivation and reduce performance (Amabile, 1997). This conclusion is at odds with traditional agency theory predictions which rely on the assumption that actors will react to external incentives—typically to economic incentives (Baiman, 1982).

This tension has driven the sparse empirical research on this topic. Eisenhardt & Tabrizi (1995), using a sample of companies in a fast-moving industry, investigate whether greater variable rewards for schedule attainment are associated with shorter development time. They conclude that rewards (and planning) are ineffective ways to motivate faster execution. Davila (2003) addresses this tension and examines the relationship between the intensity of economic incentives (percentage of variable pay linked to performance) and performance in a sample of product development managers in the medical devices industry. He finds a non-linear relationship where smaller percentages of variable pay are associated with higher performance at a decreasing rate until a point where further increases in variable pay are associated with lower performance.

These studies provide some initial evidence on the role of incentives in NPD. However, they leave significant questions unanswered. The studies do not address how performance variables come into determining the bonus of the managers. They do not examine how bonuses interact with alternative rewards—from salary raises, promotions, peer recognition, outside market opportunities, multi-period contracts, etc. They do not address how organizational structure—heavyweight vs. lightweight project manager (Clark & Fujimoto, 1991)—interacts with performance measures and incentives.

2.5. Management Control Systems in Research and Product Development

The broader topic of management control systems has received attention in product development. Underlying this topic is the tension between two views as how these systems interact with innovation and creativity. On the one hand, formality constrains freedom to experiment and therefore these systems are detrimental to innovation performance. Damanpour's (1991) meta-analysis of this interaction confirms this argument reporting a negative association between administrative intensity and innovation. Abernethy & Brownell (1997) confirm but qualify this conclusion and find that personnel controls are effective mechanisms in R&D settings, while behavior and accounting controls are detrimental.

Bonner et al. (2002), in a study of 95 product development projects, show mixed results on the relevance of management control systems to performance; they conclude that the use of upper-manager-imposed process controls and the degree to which upper-managers intervene in project-level decisions during the project have a negative effect on project performance, but early upper-management involvement in defining operating controls has a positive impact.

In contrast to this view of management control systems as constraints and blocks to innovation, the concepts of enabling bureaucracy (Adler & Borys, 1996) and interactive systems (Simons, 1995) argue for a supportive role of these systems in innovation. Cardinal (2001) examined the use of input, behavior, and output control in the pharmaceutical industry with the expectation that some of these controls would be detrimental to performance. She finds that the three types of controls are positively associated with performance. Bisbe & Otley (2004) find mix results, with interactive systems enhancing performance in low-innovation firms and hurting performance in high-innovation firms. Davila (2000) highlights that the information reported through management accounting systems interacts with product strategy to enhance (cost and design information) or worsen (time information) product development performance. Bajaj et al. (2004) find that oversight from upper-managers has a negative impact on development costs lead time but a positive effect down the value chain on manufacturing costs and lead time.

In addition to the empirical work that addresses the impact of management control systems on product development performance, another line of empirical work has taken a more descriptive approach to the topic. Hertenstein & Platt (2000) describe how product development process is structured around well-defined stages. Stage-gate management processes divide product development projects into stages with milestones to be accomplished at the end of each stage and an evaluation at these points (gates) where projects are given funding for the following stage or killed (Cooper, 1990; McGrath, 1995). This approach to product development management was a significant change to a process where formalization was absent.

3. Management Accounting and Modern Manufacturing

The modern manufacturing environment, also labeled advanced manufacturing systems, encompasses production technology (such as robots, numerically controlled manufacturing equipment, and computer-integrated manufacturing) and management technology (such as total quality management, TQM, and just-in-time, JIT). Several characteristics make MMS challenging from a management accounting perspective:

MMS involve large investments with intangible benefits such as higher quality, shorter lead-times, or more reliable production processes that are hard to translate into financial measures. This characteristic raises the question of whether ‘‘traditional'' decision-making management accounting tools are appropriate in MMS settings.

MMS is a more complex manufacturing setting because of rapid product and production process innovations, product variety, flexibility, and demanding requirements for quality, throughput times, and inventory levels. A consequence is that overhead costs become a significant proportion of overall costs, displacing direct manufacturing costs. This characteristic has led management accounting to provide better costs measures throughout products' lifecycles and methods for better tracing and allocating costs.

Other aspects of performance are important besides low costs. Modern manufacturing operations need to comply with demanding requirements regarding costs, quality, throughput times, etc. Achieving good performance on these various dimensions not only requires high investments leading to higher overhead costs, but it also means that skills for team working and problem-solving are important. Interdependencies across functions and organizations compound this challenge. TQM, JIT, Kanbans, advanced planning systems (such as MRP), and flexible manufacturing systems are used to reduce inventories (that act as buffers) in the supply chain, without compromising responsiveness to customers. These operations management techniques demand higher collaboration within and across organizations. Management accounting research has studied performance measurement systems that pay attention to behaviors and performance characteristics pertinent in modern manufacturing operations, which can also be linked to performance-dependent reward systems.

Other parts of the value chain and of the product lifecycle become more important for success of manufacturing firms. Having an efficient, flexible, and innovative factory is not enough. It is also important to change the ways of working with suppliers and with customers to incorporate new technology and develop new products. The linkage between product development and manufacturing operations needs to improve to better understand relationships between decisions made during product development and performance later in the product lifecycle. These developments have led to research on management accounting in NPD and in supplier–buyer relationships, and management accounting research has started to pay more attention to costs throughout the product lifecycle.

Young & Selto (1991) provide an excellent review of the literature about the early research on management accounting in relation to modern manufacturing operations. There are several in-depth case studies investigating implementation of modern manufacturing and the implications for accounting which also provide a good background to ‘‘set the stage'' for this section, e.g., Jazayeri & Hopper (1999), Lind (2001), and Ezzamel & Willmott (1998).

3.1. Cost Modeling in Modern Manufacturing

Cost modeling refers to *forecasting future costs*. In the pervious section we reviewed how it has been addressed in product development; here cost modeling refers to calculating the economic impact of changes in the manufacturing system. The key issue is how to account for the intangible manufacturing benefits (related to factors such as quality, throughput times, manufacturing flexibility to quickly change to other products, or additional production capacity to allow volume flexibility) when initial investments in MMS are high, while direct (in monetary terms) and monetarily quantifiable effects (such as lower material costs and lower labor costs) are not sufficient to justify the investment,[3] but qualitative and quantitative non-financial criteria suggest that the investment may still be economically beneficial for the firm. We assume that potential changes in manufacturing have been analyzed and that information about required investments and change costs is given, as well as information about benefits.[4] We also refer to Haka (2006) for a review of the literature on capital budgeting and investment appraisal.

[3]Other research areas also look at investment appraisal and address many of the same issues, but with different emphasis. For example, corporate finance pays more attention to the question of risk and the appropriate discount rate for investments in modern manufacturing operations; engineering economy look at how to estimate and evaluate the financial consequences of engineering decisions.

[4]It is worthwhile to consider that behind the analysis of these benefits there may be a whole engineering exercise that is far more comprehensive than the ‘‘final'' financial analysis. We refer to Kumar et al. (1996) for a description of the larger decision-making process. We also refer to Raafat (2002).

Before we discuss empirical studies, it may be helpful to discuss approaches to this decision problem (see also Lefley, 1996). One alternative is to be disciplined at including and valuing all the alternatives (e.g., the "do nothing" may actually require investments). This implies translating every potential benefit into economic terms, even if the translation is only a rough approximation. The idea is that financial evaluation methods such as Discounted Cash Flow (DCF) methods are not wrong, but they should be applied with care (Kaplan, 1986). For example, an investment that enables a reduction in throughput time may have cash effects through lower inventories and shorter delivery times that translate into higher sales (Corbey, 1991; Krinsky & Miltenburg, 1991; Miltenburg, 1987; Son, 1991; Wouters, 1991). Yet some benefits might be concrete and quantified but it still may be considered too speculative to put a monetary value on it. A firm could then use multi-attribute decision-making methods to combine "apples and oranges" (cash flows and intangible benefits). See, e.g., Bhimani & Bromwich (1991), Abdel-Kader & Dugdale (2001), and Angelis & Lee (1996).

Empirical studies have examined whether firms explicitly consider intangible benefits from their manufacturing strategy. Abdel-Kader & Dugdale (2001) based on a survey in large UK companies, found that analysis of non-financial investment criteria had become more important in MMS investment and significantly so in four cases: quality and reliability of outputs, greater manufacturing flexibility, reduced lead-times, and reduced inventory levels. In a case study of Caterpillar, Miller & O'Leary (1997) showed that the firm reviewed investments in manufacturing to ensure that every proposed investment program conformed to the firm-level vision of modern manufacturing. Based on a series of case studies, Lee (1996) provided evidence that performance expectations at the investment justification stage reflected accurately the different companies' manufacturing strategies.

Are intangible benefits included in the *financial* analysis, and if so, how? There are indications that firms include intangible benefits as part of the financial analysis—even if the exact value is uncertain—rather than excluding them and then having to do qualitative, multi-attribute tradeoffs. Abdel-Kader & Dugdale (1998) found that while strategic analysis became more important for MMS companies, this was not at the expense of financial analysis, which MMS companies found at least as important as non-MMS companies. They further found that most firms quantified seven benefits of MMS investments in financial terms: reduced labor costs, reduced material costs, reduced inventories, reduced scrap and rework costs, increased sales volume, savings from less frequent setups, and increased manufacturing capacity. The benefits considered on a non-financial basis by the majority of respondents were improved product quality, faster response to market needs, consistency with corporate strategy, improved competitive position, greater manufacturing flexibility, reduced lead-times, improved company image, easier production scheduling, retention of market share, and increased market share.

The incorporation of intangibles in the financial analysis was also investigated by Wilkes et al. (1996). In a survey they asked companies how they considered intangible factors when evaluating MMS investments. Firms used different approaches: placing a value on them and including this in the financial appraisal (21%), making a judgment about the worth of these intangible benefits compared to any shortfall on a narrower financial appraisal (do we think they are worth the X Euros negative NPV?) (24%), 19% made a judgment by other means, 8% used a mixture of methods, and 32% did not include any allowance for such effects. The majority of firms (87%) felt that existing methods allowed a fair comparison of MMS investments with conventional alternatives.

Another empirical study is reported by Lee (1996), who provided case studies of firms translating the benefits into financial numbers based on an analysis of the firms' intended usage of the system. For example, firms that introduced flexible manufacturing systems to increase production volume were more likely to quantify reductions in labor, increased output arising from reducing machining time and changeovers, and reductions in sub-contracting costs. Similarly, savings in work-in-progress feature most prominently in financial justifications when the objective is reducing inventories. See also Jones & Lee (1998).

In a study of illustrative case studies of Advanced Manufacturing Technology (AMT) investments in six Belgian manufacturing firms, Bruggeman & Slagmulder (1995) describe a number of examples where firms were able to include relevant "intangible effects" in the financial analysis, but only if the firm had a clear manufacturing strategy and clear objectives for what they wanted to achieve through the AMT investment. Similarly, Miller & O'Leary (1997) found that the firm in their study considered investments in MMS as "bundles" of projects, and in this way it wanted to ensure that the full impact of the related costs and benefits was captured in investment analysis process.

What kind of *financial criteria* are used? More general surveys on investments evaluation (not specific to modern manufacturing technology) indicate that discounted cash flow measures (NPV, IRR) are the most common investment criteria (Arnold & Hatzopoulos, 2000; Bruner et al., 1998; Farragher et al., 1999; Graham & Harvey, 2001; Payne et al., 1999; Trahan & Gitman, 1995). The use of these criteria has increased over time (Klammer et al., 1991; Pike, 1996; Ryan & Ryan, 2002), and large firms use them more than small firms (Graham & Harvey, 2001; Payne et al., 1999). Small firms often use payback time as the most important criterion (Block, 1997). However, the accounting rate of return still plays an important role as an investment criterion, often in combination with other methods (Arnold & Hatzopoulos, 2000; Block, 1997; Pike, 1996; Ryan & Ryan, 2002; Trahan & Gitman 1995). There is not much empirical evidence for how firms appraise MMS investments, and this suggest that MMS investments are probably evaluated on basis of the same criteria as other investments (Abdel-Kader & Dugdale, 1998; Lefley & Sarkis, 1997; Low Lock Teng & Seetharaman, 2004). Lefley & Sarkis (1997) found that the payback method (either without or with discounting the cash flows) was the most widely used and it was considered to be the most important by both US and UK respondent companies. Internal rate of return was the second most used method, followed by NPV.

How is financial *risk and uncertainty* of MMS investments accounted for? The results of Abdel-Kader & Dugdale (1998) do not support the hypothesis that more sophisticated treatments of risk are employed in the evaluation of MMS investments. Only the relatively unsophisticated technique of sensitivity analysis was considered to be important by respondents, and the MMS companies were just as reluctant to use sophisticated methods such as simulation and the capital asset pricing model as non-MMS companies. In general, sensitivity and scenario analysis were the most important ways for handling risk (Arnold & Hatzopoulos, 2000; Farragher et al., 1999; Payne et al., 1999; Pike, 1996; Ryan & Ryan, 2002; Trahan & Gitman, 1995).

Corporate finance theory indicates that the *discount rate* should reflect the risk of the project (Brealey & Myers, 2000). If MMS investments are relatively risky, a higher discount rate should be used. However, this practice amplifies the potential problems with financial justification of MMS investments because they become less attractive in the context of procedures for financial investment appraisal. This reasoning leads to the empirical question of what discount rates firms use. There is some empirical evidence that firms tend *not* to adjust the discount rate to reflect the risk of individual investment opportunities (Akula, 2003; Bruner et al., 1998; Graham & Harvey, 2001; Seal et al., 1999). Abdel-Kader & Dugdale (1998) also found no statistical difference between the financial hurdles in MMS vs. non-MMS firms. Drury & Tayles (1997) found that half of the respondent organizations in their study used discount rates in excess of 19%, but they found no different rates from non-MMS firms; yet they also found that firms allowed longer payback times for MMS investments. Carr & Tomkins (1996) reported payback as the most important financial criterion for MMS investments, and found that firms played these down in the light of other non-financial considerations. However, Lefley & Sarkis (1997) found that investments in MMS are seen as more risky than conventional investments, and if the financial analysis is adjusted for risk, firms placed *more stringent* requirements on financial criteria by expecting a higher rate of return, using a higher discount rate, or shortening the required payback period. Slagmulder et al. (1995) also found that risk analysis led to shorting the required payback period or increasing the required hurdle rate.

However, imposing stringent financial criteria may be particularly difficult if projects are surrounded with much uncertainty. Carr & Tomkins (1996) found that when financial targets imposed on MMS investments were tough and seriously imposed, financial calculations were frequently based on very questionable assumptions, and cheating sometimes occurred. In a similar vein, Lefley & Sarkis (1997) found that if projects did not meet the financial requirements, a large majority of companies re-evaluated projects. They also found considerable concerns with short-term bias and giving appropriate weight to intangible benefits.

Do accounting methods hinder MMS investments? Selection bias makes it hard to investigate whether accounting methods have led to rejection of MMS investments that should have been accepted. It would be possible to study the reverse, but we are not aware of objective studies doing so: do accounting methods lead to investments that should have been rejected? Abdel-Kader & Dugdale (1998) provided perceptual evidence relevant to these questions. They asked respondents whether: ‘‘It is difficult to get MMS investment proposals approved because of stringent financial criteria.’’ Only 15% of respondents agreed or strongly agreed with this statement; the vast majority of respondents was either neutral or disagreed. Lee (1996) is also not ‘‘pessimistic.’’ Based on a study of 21 MMS investments, he found that companies introduced their systems to realize the manufacturing objectives of volume production, JIT production, or flexible manufacturing. In all of these instances, the companies were able to adapt their investment appraisals to reflect their proposed use of MMS.

3.2. Cost Measurement in Modern Manufacturing

Cost measurement refers the *ex post* monitoring of *actual* manufacturing costs. The key issue here is how to measure indirect manufacturing costs, especially in settings where this is not trivial because of circumstances such as high product variety and demanding requirements for quality, lead-times, inventory control, etc. We will first discuss studies on cost drivers in manufacturing, then studies on design choices for cost accounting systems, and conclude with a section on the role of cost accounting in manufacturing. We also refer to Gosselin (2006) in this series for a review of the literature on ABC.

3.2.1. Cost Drivers in Modern Manufacturing

Are cost structures different in firms with modern manufacturing operations? Kerremans et al. (1991) investigated the impact of automation on costs and on cost accounting systems using survey data from 90 companies. They found no difference between high and low automation firms with respect to the percentage of fixed vs. variable costs, but they did find a significantly higher percentage of *indirect costs* vs. direct costs in firms with high level of automation. They also found that the proportion of *direct labor cost* is lower in such firms. (They did not find differences regarding management's perception of limitations of cost accounting systems and of uses of cost accounting information.)

Do non-volume variables drive indirect costs? ABC systems are based on the premise that variables other than production volume drive indirect costs. At the conceptual level, cost drivers include unit level (''traditional'' production volume driver), batch level, product sustaining, and facility sustaining. Several empirical studies support the existence of non-volume drivers of overhead costs (Anderson, 1995; Banker & Johnston, 1993; Banker et al., 1995; Datar et al., 1993; Dopuch, 1993; Dupoch & Gupta, 1994; Fisher & Ittner, 1999; Foster & Gupta, 1990; Ittner & Macduffie, 1995; Ittner et al., 1997). We refer to Banker & Johnston (2006) for a literature review on cost driver research.

What is the behavior of *quality-related costs*? Kim & Liao (1994) discussed and illustrated (with numerical examples) several possibilities for non-conformance costs as a function of the difference between the target value and the actual value of a quality characteristic. Ittner (1996) found empirical support for the premise in the quality literature relating improved quality management with ongoing reductions in non-conformance costs *without* an increase in prevention and appraisal costs. Foster & Sjoblom (1996) examined drivers of quality improvement in the electronics industry. Based on archival data from a case-study company, they concluded that improvement rates were not well explained by either production volume or number of components—traditional ''learning by doing'' variables. On the basis of the survey data gathered both in the case-study company and in the electronics industry, they suggested that variables related to product design, production infrastructure, supplier and customer relations are drivers of quality improvement.

Which cost drivers are related to *congestion* in manufacturing systems? Another group of studies has investigated stochasticity—variability and its impact on queues—as a cost driver in manufacturing systems (e.g., Banker et al., 1988; Leitch, 2001; Srinidhi, 1992). As products move from one activity to another they may have to wait in a queue before being processed. Queues impact work-in-progress (WIP) inventory (hence costs), throughput times—which may affect product availability—and throughput volume—which may affect total sales. The impact of stochasticity on throughput volume extends traditional bottleneck analysis. Without considering variability, the bottleneck resource can easily be identified and the maximum output volume can be calculated. However, production capacity on the bottleneck resource might be lost if variability and queues in upstream activities cause some idle time on the bottleneck resource. Furthermore, there could be a reduction in quality or efficiency due to having to rush orders in congested systems. Analytical models (e.g., Banker et al., 1988; Srinidhi, 1992) and simulation studies (e.g., Balachandran et al., 1997; Leitch, 2001) found support for effects of variability on congestion in production systems. Variability may be caused in several ways, such as variability of set-up times and processing times (Banker et al., 1988). Empirical studies in this topic are scarce, but Balakrishnan & Soderstrom (2000) found empirical support (in a healthcare setting) for a relationship between congestion and a proxy for the cost of congestion (caesarian section rates in a maternity ward).

Studies have also investigated the relationship between costs of congestion and cost allocations. Zimmerman (1979) argued that resource allocation decisions may involve hard-to-measure opportunity costs and suggested that cost allocations may serve as an approximation of those costs. In the context of manufacturing systems, decisions about accepting orders and using resources may increase congestion and associated costs. Are these opportunity costs approximated by cost allocations? Balachandran & Srinidhi (1988) modeled a service center where potential users arrive whenever they have requirement, and they incur costs of delay if the service center is busy. It was assumed that an external service facility could not be used, so that all users had to rely upon the service center. The users determined the total demand for the service center. Their model demonstrated that a fixed charge on all users based on allocated fixed capacity costs was needed to achieve a firm-wide optimal demand. No allocation led to a sub-optimal, too high demand rate (from the viewpoint of the firm) because it was beneficial for the individual user to increase his demand, even when this benefit would be more than offset by the increased waiting costs of other users. Other papers within this line of research include Banker & Hughes (1994), Dewan & Mendelson (1990), Hansen & Magee (1993), Stidham (1992), Whang (1989), Dickhaut & Lere (1983), Miller & Buckman (1987), Gietzmann & Monahan (1996), Cohen & Loeb (1982, 1988), and O'Brien & Sivaramakrishnan (1996). Findings in this literature suggest that cost allocations can be approximations of the costs of congestion, but with varying degrees of accuracy.

3.2.2. Cost Accounting Practices in Modern Manufacturing

What kinds of cost accounting practices are used in manufacturing? Brierley et al. (2001) provide an excellent overview of descriptive research based on surveys of cost accounting practices in the manufacturing sector in Europe. The results of prior research are examined in seven areas: how many accounting systems firms use, product cost structures, the application of blanket overhead rates, the bases used to calculate overhead rates, the use of product costs in decision-making, the use of product costs in product pricing, and the application of activity-based costing (ABC). Examples of studies about cost accounting practices in other parts of the world include Boer & Jeter (1993), Guilding et al. (1998) comparing New Zealand and UK; Wijewardena & De Zoysa (1999) comparing Australia and Japan; and Al Chen et al. (1997) comparing US and Japan. Chenhall & Langfield-Smith (1998a) also review the empirical literature on management accounting practices when presenting their findings of a survey of manufacturing firms in Australia. Fry & Steele (1995) and Fry et al. (1998) investigated differences between users and non-users of standard costing. Using survey data they found no statistically significant differences between these two groups in terms of production environment. However, they did find that manufacturing companies that did *not* use standard cost systems had a better performance on non-financial criteria for inventory turns, scrap reduction, quality complaints reduction, and delivery complaints reduction, and fewer situations of dramatically increased shipments near the end of the financial reporting period.

What kind of "technical" changes do firms make to adjust cost accounting to modern manufacturing operations? Patell (1987) studied the impact of manufacturing changes on cost system design. In a case study of the implementation of JIT, he found that more effort was directed to understanding the causal structure of indirect manufacturing costs, moving away from using direct labor as the only basis for allocating these costs. Also, the accounting system was simpler as it evolved from product batches to process costing. The study highlighted the interplay of cost accounting and quality control and suggested that the design and role of the cost accounting system should be interpreted in the context of the information gathered from other sources, such as quality control systems. For instance, higher level of cost aggregation may come with increasing detail of non-financial information from such systems. Also using a case study, Ahlstrom & Karlsson (1996) found that the modernization of manufacturing led to simpler and less detailed formal reporting, and easier cost tracing.

Other studies looked at multiple companies (either on the basis of a limited number of site visits or on the basis of a survey) and generally found little support for a systematic relationship between manufacturing changes and accounting change. Gosse (1993) investigated how the integration of manufacturing processes and the application of computer-aided technology affected the design of cost accounting systems (cost identification, cost entry, cost assignment, and cost reporting). Contrasting four computer-integrated manufacturing plants and four traditional plants, he found some support for the hypotheses that firms adjusted their cost center structure, cost allocation basis, and reports (financial and non-financial) to computer-integrated manufacturing systems. Using survey data, Karmarkar et al. (1990) investigated the relationship between cost accounting design and characteristics of the firm's output market and production technology. The cost accounting characteristics were number of overhead cost pools, number of standard cost variances reported, frequency and reporting lag of accounting reports, and degree of reporting performance evaluation data. The independent variables were type of production process (continuous, batch, or custom), production complexity (measured by variance of production lead-time), number of products, instability of production process (measured by number of engineering changes), relative importance of overhead, and extent of competition in the product markets. All these variables were expected to lead to more elaborate cost accounting systems. However, they found limited empirical support for these hypotheses. The number of observations being rather low may explain the lack of stronger findings.

Also based on survey data, Durden et al. (1999) investigated the effect of JIT production on cost accounting and performance measurement. They obtained data from 85 manufacturing companies in New Zealand. Overall, they found no significant difference between JIT and non-JIT companies regarding to the level of accounting modification. However, JIT companies that redesigned their costing systems had better performance than JIT companies that had not made these changes. They also found that non-financial performance indicators—supplier quality, supplier on-time delivery, scrap, set-up times, and inventory turnover measures—were used to a significantly greater extent in JIT companies. However, they also found that greater use of non-financial performance indicators was associated with performance irrespective of the production management system adopted.

3.2.3. Need for Cost Accounting Information in Modern Manufacturing

Are more sophisticated cost accounting systems considered more important for modern manufacturing operations? If modern operations have more indirect costs, then more elaborate cost accounting information could expected to be used for understanding and managing these costs. Alternatively, the availability of *alternative* sources of information and control mechanisms—such as computer systems for process control (e.g., numerically controlled production systems) and for planning (e.g., ERP systems), or mechanisms for quality and materials management (such as JIT)—may reduce the need for sophisticated cost accounting systems.

The empirical evidence on this question is mixed, but it becomes clear that modern manufacturing operations are not clearly associated with more sophisticated cost information: Lee & Monden (1996) described a field study of Daihatsu in Japan. The company put a lot of emphasis on cost reduction during product development and during production (target costing, kaizen costing), using techniques for value engineering, JIT production, TQM. The company did not use ABC. The analysis of the case suggested that because this firm had so many other tools that focused on cost reduction more directly, it did not need comprehensive ABC systems. We will discuss more studies in the remainder of this section.

Many different characteristics of manufacturing have been investigated in relation to the usage and importance of cost accounting information. In an early study, Kaplan & Mackey (1992) used survey data, and they found that organizations using a flow manufacturing process (in contrast to job shops) were more likely to rely on accounting numbers for evaluating the performance of production managers. Results for two other characteristics (use of work-in-progress inventories; accounting for set-up costs) were only marginally significant.

The influence of product diversity, production process, and the cost structure on costing systems was investigated by Abernethy et al. (2001). At five research sites, they examined the influence of these three variables on three dimensions of costing systems: nature of the cost pools (i.e. activity cost pools vs. responsibility cost pools), number of cost pools (single vs. multiple), and type of cost pool (whether the system had hierarchical cost pools). They evaluated a costing system's level of sophistication based on where it fitted on a continuum representing these three dimensions. The findings suggested that when product diversity was high and production process complexity was reduced by flexible MMS, there was less of a need for sophisticated costing systems; more specifically: multiple cost pool were relevant, but less relevant were hierarchical cost allocation keys (unit-level cost pools could be sufficient) and activity-cost pools (process cost pools around flexible equipment could be sufficient instead).

JIT, automation, and quality management practices may also impact the importance of cost information. Hoque (2000) investigated the impact of JIT production and automated manufacturing systems on cost allocation and the importance of cost information to management, based on a survey of New Zealand-based manufacturing firms. The findings supported the hypothesis that organizations operating in a JIT environment put less emphasis on the use of ABC systems, and this could reduce managers' need for detailed cost information for their day-to-day activities. The effects of automation were not as clear cut. Gurd et al. (2002) investigated the impact of implementing TQM on cost accounting systems, based on site visits to six different companies. They concluded that industry, management commitment, organizational structure, participation, and financial performance influenced the diffusion process, but in an inconsistent manner. Two companies in the automotive component-manufacturing sector cited that much documentation and performance measures were required to satisfy the requirements of customers. In both companies, powerful customers had a strong influence on the rate of adoption of performance measures. Daniel & Reitsperger (1992) studied whether a focus on quality reduced the need for short-term cost information for managers, because targets and feedback could be based on quality performance in non-financial terms (such as rejects, rework, scrap) that directly reduced costs. Using survey data from the US and Japan, they found that goal setting and feedback focused primarily on non-cost measures. However, a relatively large proportion of managers also received such feedback in cost terms. While cost feedback was seldom supplied on a daily or weekly basis, it was often provided to managers monthly.

Does ‘‘better’’ costing information contribute to better performance? Based on a survey of manufacturing companies, Foster & Swenson (1997) reported a positive association between ABC adoption and performance. In another study, Swenson (1995) investigated the benefits of ABC in 25 manufacturing firms. Respondents reported significant improvements in use of and satisfaction with cost management information. He also reported that ABC information was most frequently used for product pricing and product mix decisions as well as for process improvement decisions. Using survey data about reported financial and non-financial performance, Ittner et al. (2002) investigated the association between ABC and manufacturing performance. Extensive use of ABC was associated with higher quality levels and greater improvements in quality and cycle time. Also, ABC use was significantly associated with modern manufacturing practices. They found weak support for the association between ABC and profitability being a function of the ‘‘match’’ between a plant’s operating environment and ABC use.

3.3. Non-Financial Performance Measures in Modern Manufacturing

The basic proposition explored in much of the literature is that MMS need different performance measurement systems. Early research identified the need to broaden performance measurement systems to support new operations practices (Beamon, 1999; Eccles, 1991; Hall et al., 1990; Kaplan, 1990; Maskell, 1991; Nanni & Robb Dixon, 1992). Traditional performance measures in operations only emphasized direct costs minimization through low material costs, high capacity utilization, and high direct labor efficiency. MMS, however, need also clear measures on quality, throughput times, flexibility, etc., linked to the operational strategy of the firm. Non-financial measures provide information about manufacturing goals, causes of bad (or good) performance, and early warning signals (before financial results reflect changes). Ittner & Larcker (1998b) and Nagar & Rajan (2001) found empirical support for non-financial performance measures being leading indicators of financial performance. We also refer to Ittner & Larcker (2006) in this series for an extensive and more general review of the literature on non-financial performance measures.

As we will discuss below, there is empirical evidence for the relationship between manufacturing strategy and the use of non-financial performance measures (e.g., Carr et al., 1997; Daniel et al., 1995; Hoque et al., 2001) and for a link to overall performance—performance is enhanced when MMS are used together with non-financial measures. However, non-financial performance measures are not the only adjustment in management controls to MMS. In this section, we will review a number of studies about the use of non-financial measures in manufacturing without linking these to reward structures. That linkage is discussed in the next section.

One of the first empirical studies, to our knowledge, investigating the relationship between manufacturing strategy and performance measures was Banker et al. (1993). This study used survey data from 362 people in 40 different manufacturing plants in the US. They found a positive association between the adoption of new manufacturing practices (JIT, teamwork, and TQM) and reporting manufacturing performance measures (on productivity, quality, defects, schedule compliance, machine breakdown) to shop-floor workers. In another early study, Daniel et al. (1995) focused on electronics manufacturing, in Japan and the US. They found that the implementation of a quality strategy was associated with quality feedback (on rejects, rework, and scrap) and quality being more important for financial rewards. Daniel & Reitsperger (1991) reported that management control systems supporting an ambitious ‘‘zero defect’’ quality management strategy were more likely to emphasize quality in their goal-setting and feedback processes.

Another early study is reported by Abernethy & Lillis (1995). Based on interviews at 41 business units, they found that firms pursuing manufacturing flexibility placed less emphasis on efficiency-based measures, and used integrative liaison devices (in the form of teams, task forces, meetings, and spontaneous contacts) to a greater extent than non-flexible manufacturing firms. Using survey data, Perera et al. (1997) found that customer-focus strategy was associated with the use of non-financial (operations-based) performance measures (thus supporting the earlier Abernethy & Lillis (1995) results) but not with organizational performance. Chenhall (1997) investigated to which extent TQM should be developed together with managerial performance evaluation systems employing manufacturing processes measures. Based on a survey, he reported that TQM firms that also used manufacturing measures performed better than TQM firms without such measures. In contrast, results reported by Durden et al. (1999) do not support the need to adjust non-financial measures to manufacturing strategy. Rather, greater use of non-financial indicators was associated with higher performance irrespective of the production system (JIT) adopted.

More recently, Baines & Langfield-Smith (2003) examined organizational initiatives that lead to greater reliance on the management accounting systems, through the provision of a range of non-financial performance measures. These organizational initiatives were changes in organizational design (increased used of team-based structures), modern manufacturing technology (to meet customer preferences and improve product quality more efficiently), and techniques designed to support a customer focus. As a consequence of greater reliance on non-financial accounting information, they found improved organizational performance. The antecedent of these organizational initiatives was a changing strategy that emphasized customer service and product innovation. Maiga & Jacobs (2005) found that more communication about quality goals, more frequent feedback on achieved quality, and more usage of quality-related incentives were antecedents of better quality performance. As a consequence, this was associated with higher customer satisfaction and higher financial performance. Both Baines & Langfield-Smith (2003) and Maiga & Jacobs (2005) were based on survey data and used structural equation modeling.

The linkage between the use of performance measures and organizational performance has mostly been investigated using perceptual or survey data. However, Mia (2000) used interviews with controllers of 55 Australian organizations and information from annual reports, to find that JIT organizations with high (low) provision of information earn higher (lower) profits. Managers working in JIT manufacturing environments have little or no slack resources to cushion against the difficulties caused by defective raw materials, production errors, irregular supply and demand schedules, or to mask inefficiencies. This made management accounting systems' information—financial as well as non-financial information—critical in such environments. Said et al. (2003) looked at both accounting performance and stock market performance related to the use of non-financial performance measures in compensation contracts. As hypothesized, it was found that the use of non-financial measures was associated with higher stock market performance (but not with accounting performance) as well as with higher future market-based and accounting-based performance. They also found that performance was higher when the use of performance measures was consistent with company's operational and competitive performance (i.e., when there was a match between the use of non-financial measures and the firm's operational characteristics).

Non-financial performance measures are only one aspect of providing broader information in the context of MMS. Another line of research in manufacturing settings examines the contingencies that explain the design of management accounting systems. Chenhall (2006) in this series carefully reviews this research thrust. However, two studies are closely related to our focus on modern manufacturing operations. Bouwens & Abernethy (2000) investigate the relationship between four dimensions of management accounting information—scope, integration, aggregation, and timeliness—and the extent of customization and interdependence. Customization is of particular interest here, as it captures the degree to which a firm changes its product design to customer specifications. They find that a higher level of customization leads to more interdependence between departments such as marketing, product development, production, and purchasing. More interdependence leads to management accounting systems with more integration (information about how performance in different departments is related), aggregation (summary information), and timeliness (frequency and speed of reporting). Recently Gerdin (2005) investigated how "broad scope management accounting systems"—with frequently issued, detailed, non-financial information instead of standard costing with little non-financial information (labeled "traditional system")—are related to departmental interdependence and organizational structure. Using survey data from production managers, the study supports the hypothesis that the provision non-financial information depended on the type of interdependence and organizational structure.

3.4. Rewards in Modern Manufacturing

Working in a modern manufacturing environment requires different skills and behavior compared to traditional manufacturing. Tasks are highly interdependent because there are fewer buffers. Performance must be delivered on a range of—sometimes contradictory—dimensions. These conditions make knowledge, teamwork, and problem-solving skills important. The introduction of non-financial performance measures, as discussed in the previous section, makes it possible to introduce performance-dependent rewards that are linked to the realized performance on these measures. Other elements of the reward system (besides the measures used) are likely to be also adjusted to that environment, such as rewarding group performance rather than individual performance, and rewarding skills and knowledge and not only output volume. In addition to compensation, other human resource practices could also be affected such as staffing, training, and performance appraisal. In this sub-section, we discuss studies that examine relationships between modern manufacturing operations, performance measures, and rewards.

Several survey-based studies investigating the relationship between manufacturing strategy and the introduction of non-financial performance measures, also explicitly address the usage of these measures as part of reward structures. Using survey data from manufacturing executives at 253 US firms, Fullerton & McWatters (2002) found empirical evidence relating the use of non-traditional performance measures (such as product quality and vendor quality), employee empowerment, and compensation rewards for quality production with the degree of JIT practices implemented. Sim & Killough (1998) used survey data from directors of manufacturing in 84 plants in the US and investigated the interactive effect of TQM/JIT and non-financial performance measures on performance. They found (as hypothesized) that the ''right'' combinations of TQM/JIT and (a) provision of customer-related performance goals and (b) usage of performance-contingent rewards were associated with high customer performance.

Case studies have been used to investigate relationships between manufacturing strategy and reward structures, and results demonstrated how some firms have broadened the basis for rewards in manufacturing. Wruck & Jensen (1994) describe a case study of the implementation of TQM at Sterling Chemicals. Training, more emphasis on teams to solve quality problems, and new performance measures used for day-to-day operations and problem-solving efforts became more important as part of the TQM implementation. Employee compensation was made of a base salary, stock ownership through an employee stock ownership plan, and a profit-sharing payout. Performance measures affected the subjective performance evaluations of employees and their base salary adjustments.

A case study in Sweden is the topic of the study by Lind (2001). He describes a longitudinal case study investigating changes in production systems and in control characteristics (performance measures, the level of information, timeliness of information, the use of performance standards, and rewards) associated with the implementation of MMS. Changes in control characteristics in the case supported propositions from modern manufacturing operations: non-financial measures became more important, cost accounting was simplified, information was available faster, standard costs were tied to continuous improvement goals for productivity, and the reward system for operators became a group bonus—based on labor productivity, throughput time, and yield.

Two longitudinal UK case studies are presented by Ezzamel & Willmott (1998). In the first one, the company changed its production technology and grouped machines to product-focused cells. The company also changed the reward scheme from the production volume attained by each operator to teams attaining target production levels measured over a longer time period. Also, jobs became broader and more money was spent on training. In the second study, production was redesigned and reconfigured to introduce flexibility and teamwork, and the organization structure was simplified by taking out many layers. The reward scheme changed from individual and piece-rate to a scheme that consisted of an individual element based on the skill band plus a bonus based on group performance.

In another study, Chenhall & Langfield-Smith (2003) examine the history of the development of a performance evaluation and compensation scheme in a manufacturing company. They focus on compensation schemes at the shop-floor level and investigate the extent to which a company used performance measurement and a gain-sharing reward system to achieve strategic change over a 15-yr period. The case examines the initial impact of the gain-sharing scheme in overcoming inherent hostility within the workforce, its continued success in gaining the cooperation of employees to work toward the successful implementation of strategic initiatives, and, finally, its limitations in sustaining ongoing strategic change after a 10-year period of apparent success. The firm eventually adopted team-based structures to complement gain sharing and sustain commitment to strategic change.

The case studies referred to above do not link the introduction of a new reward system to firm performance. However, in an early case study, Symons &

Jacobs (1995) investigated the effects of introducing an incentive system to support TQM. According to this reward system a bonus payment to operators in a paper manufacturing company was based on a limited number of performance measures for output volume, quality, and safety. Furthermore, a bonus could be earned by engaging in team-based problem-solving projects. Several performance measures improved significantly over time (comparing 26 months of data before, during, and after the introduction of the system).

However, some studies point to the benefits of "traditional" piece-rate reward systems. Lazear (2000) analyzed archival data from a case study and demonstrated positive effects on moving from hourly wages to piece-rate pay. However, this case study was not in a context requiring high levels of knowledge, teamwork, problem-solving, or other skills and behavior important in a context of MMS. Potential benefits of a piece-rate system were also discussed by Wruck & Jensen (1994) and Millgrom & Roberts (1995) based on the Lincoln Electric teaching case. In both papers, the piece-rate system is seen as successful because it was part of a more broadly based reward system that included an end-of-year bonus that depended on cooperation with others, quality, and creativity; employee stock ownership (employees own over 40% of the company's stock), and the fact that quality could be monitored effectively at the individual level.

Survey-based studies outside accounting have also examined relationships between manufacturing strategy and broader-based reward structures. Snell & Dean (1994) investigated the relationship between modern manufacturing—modern manufacturing technology, TQM, and JIT—and several compensation practices: group incentives vs. individual incentives, salary vs. hourly wage, and skill-based pay vs. seniority pay. They found virtually no direct effects of manufacturing characteristics on compensation practices. However, when integrated manufacturing is moderated by job uncertainty and interdependence (indicating that the work of operators required more knowledge), compensation systems emphasized group-based incentives (as expected), salary (as expected), and seniority pay (contrary to the hypothesis). Youndt et al. (1996) used survey data of 97 plants, and their results indicated that quality-manufacturing strategy moderated the link between human resource management systems (including staffing, training, performance appraisal, and compensation) and operational performance (employee productivity, machine efficiency, and customer alignment). MacDuffie (1995) reports similar results: firms combining modern manufacturing (low buffers in the study) and a variety of human resource practices (team-based work systems, contingent compensation, extensive training) outperformed mass production firms.

The purchasing function may provide a critical contribution to manufacturing firms' strategies, and Wouters et al. (2005) investigated antecedents of purchasing decisions based on total cost of ownership (TCO). The collected survey data and applied structural equations analysis. Their results indicated that stronger customer market pressure and a more strategic purchasing orientation were associated with more adequate TCO information, higher judged success of using TCO, and more use of TCO-based performance evaluation and reward.

3.5. Management Accounting Systems for Learning in Modern Manufacturing

In this chapter, we are gradually broadening the discussion of management accounting in manufacturing. We first talked only about the provision of data about cost and non-financial performance; then we discussed the use of such data for rewards. In this and the remaining sub-sections, we will discuss a number of broader topics related to the use of management accounting and control systems in manufacturing: learning in modern manufacturing, accounting information systems (this section), the impact of manufacturing strategy on budgeting, and using non-financial targets (next section).

First we will discus the role of accounting information for local learning to improve manufacturing (Lukka, 1998). Operations managers have various concerns, such as quality, safety, efficiency, and completing activities on time. For daily, short-term activities, managers generally use non-financial operating data on units of output, units of input, scrap, quality, order quantities, inventory availability, etc. "In twelve varied manufacturing companies, we found no instance of a key daily production indicator being a cost or other financial number" (McKinnon & Bruns, 1992, p. 42). However, accounting numbers become important as the horizon lengthens (e.g., to control budgeted expenses, to identify problems and opportunities for improvement). The performance of managers is often measured in financial numbers and managers build a mental model of how physical counts impact financial performance. For instance, Jönsson & Grönlund (1988) describe how operations managers in a production plant used cost data over a longer period to detect problems and to monitor the results of experiments. Such existing, informal, locally developed non-financial performance measures may also provide inputs to the development of centrally initiated, ''official'' performance measurement systems. Based on qualitative case-study data, Wouters & Sportel (2005) found that the development and implementation of new non-financial performance measures in the logistics department of a manufacturing company were strongly influenced by that organization's existing performance information that was largely developed by operational managers.

Managers are often dissatisfied with the accounting information they receive (McKinnon & Bruns, 1992). First, accounting recognition and measurement criteria delay the availability of information until uncertainties have been resolved. But, timely information is important for managers: to be informed about the status of operations and to be warned in case the need for action, because of unexpected events, arises. Second, reliability is often a problem. Managers need consistent definitions and accurate registration. Third, relevance of accounting data suffers because of sub-optimal categorization of data or the failure to present desired relationships in reports. Aggregation and allocation of costs often obscure details that are important to managers.

The case study of Jönsson & Grönlund (1988) focuses on different ways of learning by higher-level and lower-level managers. The authors conclude that output-oriented accounting numbers comparing plans against budgets are appropriate for higher-level managers' learning, which is based to a large extent on conceptual models. However, while these numbers provide signals if something is wrong, they do not provide causal information for taking corrective action. In contrast, lower-level operations managers need a few operating statistics to determine if things are out of control. Learning is more experiential and based on direct observation of processes. They focus on one problem at a time, take action, determine whether costs have improved, and then refocus on another problem (Jönsson & Grönlund, 1988, p. 524). Lower-level managers have an image of causal relations, and they try to complement that image with relevant operating statistics. Non-financial measures are developed at the local manufacturing units through experimental learning processes and more or less independently from the strategic goals of the firm. The authors suggest that information systems should be flexible to facilitate learning at lower levels, while being integrated with output-oriented information systems for higher levels. Higher-level managers need to be able to connect the measures with other sources of information, and to ''see with your own eyes and talk to the people closest to the events'' (Jönsson & Grönlund, 1988, p. 524).

Van der Veeken & Wouters (2002) also examined how lower-level managers used accounting information for cost control and learning. In a case study of a road building company, they found that lower-level managers did not make much use of a computer-based system for reporting and analyzing actual costs. Rather, these managers were involved in project budgeting and they could translate the budget to observable milestones for project progress and resource consumption. The study also points to the kinds of action-centered skills that lower-level managers used for project management, where computer-based reporting system was of less support. Most of the accounting information was designed for higher-level managers who did not observe work on-site and had to rely on formal reports for identifying problems and finding solutions.

Other studies investigate characteristics of *accounting information systems* to advance our understanding of what accounting is used for in manufacturing. Libby & Waterhouse (1996) in a survey study of Canadian firms looked at the relationship between capacity for change, size, intensity of competition, and decentralization, and the number of changes to management accounting systems. The management accounting included 23 different systems grouped around planning, controlling, costing, directing, and decision-making. The greatest number of changes occurred in systems that supported decision-making. Organizational capacity for change was the best predictor of accounting system change. Williams & Seaman (2001) replicated this study with data from firms in Singapore in three sectors (manufacturing, industrial, and service), and they found different results due to cultural and cross-sectional differences.

The accounting information system may also be related to manufacturing characteristics, such as JIT manufacturing. Nicolaou (2002) investigated factors associated with a broad scope of the cost management system—defined as its use for supporting a broad spectrum of operational as well as strategic decisions necessary for the implementation of manufacturing strategy (make or buy decisions for component parts; product pricing decisions; decisions to discontinue existing products; decisions relating to post-manufacturing, customer-related costs; identification of areas for process improvements; product design decisions; performance measurement and evaluation decisions). He hypothesized that the adoption of JIT and electronic data interchange (EDI) affects the scope of the cost management system, but that environmental uncertainty, product standardization, and the cost structure moderate the relationship. The findings indicated that the cost management system had broader scope when JIT was combined with a low environmental uncertainty, more standardized products, or lower fixed factory overhead and indirect costs. As for EDI, the relationship between broad scope and the adoption of EDI was found to be moderated by product standardization and cost structure.

Who changes management accounting systems? Various studies investigated the contribution of management *accountants* to management accounting systems. However, it is clear that measurement of costs and performance is not the exclusive domain of the accounting function. Sillince & Sykes (1995) present a case study where operation managers did some of their own cost accounting and the accountant's data was separate from the production data with little dialogue between these professional groups. Jönsson (1996) presents several studies exploring the complex interplay between accountants and other professionals in preparing measurements and analyzing performance data. Chenhall & Langfield-Smith (1998b) propose, based on a case study, five interrelated factors that may explain the extent to which management accountants contribute to the development of integrated performance measures and change programs: a shared view of role of accounting within change programs; senior management support for accounting innovations; accounting champion; accountants have well-developed technical and social skills; and authority of accountants derived from formal hierarchy.

3.6. Management Control Systems in Modern Manufacturing

This sub-section discusses the role of accounting information for control purposes. Relationships between accounting and manufacturing are particularly interesting because the accuracy of cost targets and non-financial targets may depend on the manufacturing environment.

Relationships between *budgeting* and manufacturing characteristics are the topic of a number of early studies. Merchant (1984) investigated whether differences in departmental budgeting were related to differences in production technology, market factors, and organizational characteristics. Production technology that is more routine and repetitive makes it possible to put more emphasis on costs, both *ex ante* when setting goals and *ex post* when reporting actual costs. It was found that degree of automation of the production processes was associated with greater requirements to explain variances and react to budget overruns. Also, managers responsible for highly automated production processes met less frequently with their superiors and their subordinates regarding budget matters, and they felt they had greater influence over their budget plans. Moreover, performance was higher where there was a fit between automation and the use of budgeting.

Brownell & Merchant (1990) investigated whether process automation and product standardization enhanced the accuracy of manufacturing cost budgets. When the levels of these characteristics are low, budgetary participation may become more important for resolving uncertainties. When automation and standardization are high, flexible budgeting is more accurate. They found that when product standardization is low, high participation and use of budgets as static targets were each significantly more effective in promoting departmental performance than where product standardization was high. They did not find such a moderating effect of process automation. However, Dunk (1992) found a moderating effect of automation: reliance on budgetary control in the evaluation of production sub-unit performance was more strongly associated with performance as the manufacturing process became more automated.

The introduction of non-financial measures brings up the question of *completeness* in the context of implementing manufacturing strategies. Non-financial measures need to help top management to get an overview, to drill down, and to compare. Consistency, transparency, and comparability are key elements. However, disaggregating these measures into partial sets of measures in functional manufacturing sub-units may lead to incompleteness. Operational processes involve trade-offs between various dimensions of performance, such as efficiency, productivity, quality, customer service, and responsiveness (Lillis, 2002). For instance, responsiveness may lead to more changeovers, shorter lead-times, and higher inventories. Without a well-designed system, trade-offs are not considered in setting targets for financial and non-financial measure, leading to frustration. Thus, it remains difficult to design measurement systems that capture these effects in setting targets. Solutions rely on dialogue, the use of explicit or implicit weightings on measures (Ittner & Larcker, 1998a), or slack in budgetary controls (Davila & Wouters, 2005; Lillis, 2002; Van Der Stede, 2000).

The above discussion on the completeness of budgets and non-financial performance measures suggests that the effect of budgets and performance measures depends on how these are used as part of a larger *management control system*. Some studies have looked at the fit between management control and manufacturing strategy. Selto et al. (1995) examined whether a fit between manufacturing practices and management control explained performance of workgroups in a case-study company. Fit between JIT/TQM and management control was examined in various ways, but the central theme was that manufacturing practices required elements such as high worker authority, horizontal communication, high task difficulty, and variability for operators. They found that the firm had strong vertical dependence, which was not compatible with the concept of worker empowerment. However, they were unable to explain workgroup effectiveness with contingency theory.

A second study is by Kalagnanam & Lindsay (1998), who investigated management control in JIT manufacturing. Using three case studies and survey data from Canadian manufacturing plants, they found that mass production organizations that pursue JIT used an organic model of control to a greater extent than traditional firms. That is, these firms increasingly used informal and cross-functional communication, teams composed of individuals from different functional areas, and decentralization of decision-making to lower levels in the organization.

Ittner & Larcker (1997) investigated relationships between quality strategy and management control systems. They found that organizations supported their quality strategies with at least some quality-related strategic control practices for strategy implementation: reward (making quality performance important for compensation), internal monitoring (providing feedback, having meetings to discuss quality, the board of directors frequently reviewing plans, problems and achievements), and external monitoring practices (extent of benchmarking operations, frequency of external research and audits). However, a match between the organization's quality strategy and its use of these formal quality-related control practices was not associated with higher performance. In fact, they found negative associations between control practices and performance, as a direct effect or as moderated effect (the relationship between a quality strategy and performance being less positive as formal controls were used more). In another study using data from the same sample, Ittner & Larcker (1995) performed different analyses and found that TQM practices were associated with greater use of nontraditional information and reward systems. However, there was only mixed support for the claim that organizational performance is a function of the interaction between adoption of TQM practices and the use of non-traditional information and reward systems.

Finally, Chenhall & Langfield-Smith (1998a) used survey data from Australian manufacturing firms to examine the benefits of a variety of management techniques and management accounting practices, as well as the firms' strategic priorities. They expected "traditional" techniques to benefit firms that place a strong emphasis on low-price strategies, while other techniques benefit firms placing a strong emphasis on customer service and flexibility. They found that strategy did not matter very much. Many firms across the sample gained high benefits from both traditional and contemporary management accounting practices, and traditional techniques ranked as providing the highest benefits.

4. Conclusions

The large changes in manufacturing in the 1980s and in product development in the 1990s have been fertile ground for research in management accounting. The move toward modern manufacturing and related forms of NPD puts new demands on management accounting information. Significant developments out of this need are new ideas about cost allocation (activity-based costing), relevance of non-financial measures, valuation of intangible benefits, accountants as suppliers of cross-functional information, real options, cost of quality, or lifecycle costing. While the consequences have been examined to a significant extent, this paper outlines empirical results that are still mixed or against expectations that require more research.

But research is needed to better understand what the new manufacturing environment demands from *internal* accounting because new developments in manufacturing are putting new demands on external information such as customer satisfaction or partners' information to be part of management accounting information. For instance, globalization has enhanced the importance of logistics' costs and supply chain costs. Supply chain management has become an important research topic in operations, but it is only now starting to attract management accounting research (e.g., Cooper & Slagmulder, 1999b). The growing importance of externalities on the environment is also enhancing the importance of lifecycle costing and extending management accounting to the recycling or reusing stage of products (e.g., Epstein, 1995). These are only examples where new research opportunities are emerging; other chapters in this series review emerging fields of research such as inter-organizational relationships or service firms.

The chapter also attempts at summarizing the current state of research in management accounting and NPD. This organizational function is also going through a significant transformation, which is having a large impact in the field of management accounting. From being perceived as detrimental to performance, management accounting is becoming a central piece to enhance performance. Product development started the revolution when it moved from being seen as a black box where money came in and hopefully a product would come out to being interpreted as a process to be measured and managed. Research in product development is still a fruitful area for management accounting researchers as new approaches to improve this process rely on techniques that are common to the accounting knowledge and as the process becomes more complex through dispersed development teams, cross-functional integration, customers and suppliers voices, etc. But fundamental and applied research are emerging as processes where research is scarce and becoming more relevant not only for the advancement of knowledge but also for the advancement of practice.

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