



The relationship between developments in modern manufacturing and management method and the use of management accounting techniques

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Abstract

This paper highlights the relationship between developments in modern manufacturing and management methods and the use of management accounting techniques.

A considerable number of scholars have conducted studies focused on management accounting, which emphasizes, for example, the implementation of activity-based costing by a local government (Gosselin and Journeault, 2022) or a review of the literature on management accounting innovations during the period 2000-2008 (Zawawi and Hoque, 2010). Other perspectives have highlighted management and accounting innovations, examining why they are adopted, with insights from adoption case studies (Busco et al., 2015), as well as the role played by external pressures, such as fads, focusing on institutional variables (Abrahamson, 1991).

This study contributes to the management accounting literature by investigating the relationship between developments in modern manufacturing and management methods and the use of management accounting techniques. More specifically, we discuss the way in which new manufacturing and management methods are influenced by the new business environment and how they support competitiveness. Drawing on the previous insights, this study highlights the linkages between management accounting techniques and the development of modern manufacturing and management methods. Overall, the research provides insight into the debate that management accounting techniques and practices must change when modern manufacturing and management methods change.

Keywords: Business Environment, Technological Change, Management Innovations, Management Accounting Techniques

1. Introduction

Managerial theory focuses on company managers who use the right of decision-making. In managing, the evolution of the macro-environment (political, economic, social, technological, ecological, and legal) and the business environment (BE) both play a relevant role. The BE, as a combination of relevant conditions and economic phenomena, influences firms' structures and dynamics. The BE, in which companies develop their activities, also includes innovations. The way in which a new BE influences new manufacturing and management (MM) methods requires an explicit analysis of the external factors with a focus on innovation. Examining how new MM methods support competition involves organizational strategic choices vital to the company's survival as well as initiatives that align strategy with new methods. The implementation of MM methods requires significant changes to organizational architecture (OA) that affect the organizational structure (OS), performance reward system (PRS) and the performance measurement systems (PMS) that include management accounting (MA) systems. This implies that the development of new MM methods influences new MA techniques (Zimmerman, 2017).

For example, Kaplan (1983) reports that manufacturing performance measures differ for existing product lines (mature products and technologies) and new products in the earliest stage of their life

cycle¹. While measures of cost minimization are appropriate for mature products in the manufacturing stage, new products in the earlier stage of their life cycle are measured by the ability to produce innovations and implement new MA techniques.

While many scholars have conducted studies focused on MA, few scholars, to our knowledge, have conducted research on MA with a specific focus on the relationship between developments in modern MM methods and the use of MA techniques. Improving MA techniques is particularly relevant for senior managerial accountants. For example, when the chief executive officer (CEO), working with strategists, seeks to develop and implement a business strategy (BS) based on product (or process) innovation with the acquisition of advanced manufacturing technologies (AMT), the MA must provide information for decision-making and control over the total life cycle cost of the new product (or process) and appropriate justification for AMT techniques. Therefore, the chief financial officer (CFO) must intervene in changing MA. This means that the CFO explicates the terms of new MM methods and, in particular, the implications for the MA. Next, intervention to re-design traditional MA techniques and practices is required.

This article is application-oriented. The following section stresses the influence of BE on MM methods. In particular, we examine how new BE influences new MM methods and how they support competition in the company's specific market. Section three discusses how MM methods have shaped new MA techniques through an explicit analysis. The conclusion summarizes the previous sections' discussions, brings together the relationship between new MM methods and the use of MA techniques, indicates this study's limitations, and offers potential avenues for future research.

2. Business environment

2.1 The way in which new manufacturing and management methods are influenced by new BE

The evolution of the BE in which the companies develop their activities is very important for management. As a combination of relevant conditions and economic phenomena, the BE influences company structures and dynamics².

Within relevant condition and economic phenomenon, the BE promotes, as a significant group of influences that give rise to adopting MM methods and using MA techniques, invention, and innovation³. With different investments and risks, the purpose of invention and innovation is to create competitive advantages, allowing BE innovations to influence new MM.

Strategic literature identifies four combinations of innovation: (1) technological innovation; (2) product or process innovation; (3) business model innovation; (4) open or closed innovation.

A review of this literature shows that technological innovation concerns both technology push and market pull. The technology push reflects new knowledge developed by scientists and technologists involved in research and development (R&D) activities to create new products, processes, or services. In contrast, market pull reflects, in many markets, the lead users. Whiting market pulls innovation, market experts, such as marketing and sales managers, identify and develop a relationship with lead users.

¹ See, for a discussion, Richardson and Gordon (1980).

² See, Porter (1985) on the analysis of competitive forces and the dynamics of industry structure.

³ 'Invention involves the conversion of new knowledge into a new product, process or service. Innovation involves the conversion of new knowledge into a new product, process or service and the putting of this new product, process and into actual use' (Johnson et al., 2014).

Summarizing the literature, product innovation emphasizes the attributes and attractiveness of the new product to be sold. In contrast, process innovation relates to how the product is produced and distributed with cost reductions. Frequently, developing industries tend to create product innovation, while mature industries tend toward process innovation to increase efficiency. (see Figure 1).

INSERT FIGURE 1 ABOUT HERE

Regarding business model innovation, some authors (see, e.g. Johnson et al., 2014) have questioned that adoption involves a radical repercussion on a range of company activities, not only technological change as the pure digitalization of certain business activities⁴.

Open or closed innovation is seen as having a positive effect on competitiveness. The closed approach to innovation is based on the company's internal resources, such as R&D or marketing departments. At the same time, an open approach to innovation intends to produce better products more quickly by exchanging ideas and visions regarding the future competition. In this open model, there is, regarding an internal closed approach, a lower level of obsession with secrecy.

2.2 Interpreting how the development of modern MM methods supports competition

This study examines how the development of modern MM methods is influenced by BE and how they support market competitiveness. In the present sub-section, we discuss how the development of modern MM methods supports competition.

Research shows that it is challenging to find the same manufacturing and management methods implemented in different companies using the same techniques and addressing the same problems (Busco et al., 2015) to support competitiveness by improving economic decision making to affect profitability and shareholder value positively. Our contribution leverages the most recent manufacturing and management methods implementation, focusing on two key categories: technological change and manufacturing innovations.

2.2.1 Technological change

Regarding technological change, the literature identifies the following four levels of advanced manufacturing technology (AMT): stand-alone, cells, linked islands, and full integration. The purpose of using these levels is to analyse, for each AMT, the different aim, benefit, organizational impact, and implementation risk when a firm evaluates making these technological changes in the transition to a modern manufacturing environment. In particular, the benefits can be not only financial but also strategic.

Stand-alone includes robots and numerical controlled (NC) machines, and the main purpose is to replace traditional existing machines to increase efficiency and safety. Benefits are tangible, the implementation creates a limited organizational impact, and the risk is slight.

Cells include group technologies (GT), flexible manufacturing systems (FMCs) and computer-aided engineering (CAE). The main purpose is to increase manufacturing technology. The benefits are identified, such as greater flexibility, less lead time and work-in-progress, better quality, but at

⁴ A typical example is Ryanair. In this case, the business model innovation involves: (1) ticket (revenues) and related payment online (internet) with cards; (2) cutting variable costs by not using travel agents; (3) reducing fixed costs using a secondary airport. The low-cost model's repercussions include impacts on ticket prices, which affects competitiveness and provides an effective business model innovation. See also Chesbrough (2010) for a discussion on business model innovation.

the expense of the ability to measure less tangible considerations. While the organizational impact will be moderate, the risk is high.

Linked islands include computer-assisted design (CAD), computer-aided manufacturing (CAM), automated storage (AS), and computer-aided process planning (CAPP). The main purpose of the linked island is to support better competitive advantages to quickly generate new products. Organizational impact is extensive, and the primary benefits are synergies in the production process. However, the benefits are very difficult in terms of measurement and consequently need appropriate value analysis and robust risk analysis.

Full integration, commonly known as computer-integrated manufacturing (CIM), requires many organizational changes. While the principal purpose of CIM acquisition is a total change, to become or remain a leading company, the strategic benefits are relevant and difficult to quantify; therefore, managers must develop quantitative financial and qualitative non-financial analyses. The organizational impact is extensive and the risk substantial⁵.

2.2.2 Management innovations

The more relevant changes in modern MM methods include the following management innovations (MI): Just-in-time (JIT), Total quality management (TQM), Lean thinking (LT), and Balance scorecard (BSC). Drawing on a brief literature review, in listing these four new modern MI, we explore, for each MI, the different features in implementation of these MI while transitioning to a modern manufacturing environment.

The JIT method, as some scholars have already suggested, has been described as a revolution of production systems (e.g., Bromwich and Bhimani, 1994). JIT manufacturing is a production system pull-through distinct from the traditional push-through. The installation of a JIT system involves a significant change in underlying operations and, in contrast to the push approach, these innovations guide the demand that supports production. Therefore, a company purchases a quantity that is useful only to satisfy customers' just-in-time needs. In general, the major benefits include lower inventory investment, reduction in carrying and handling costs, and reductions in inventory obsolescence risk and total manufacturing costs (Horgren and Foster, 1987). Nonetheless, the literature shows that the companies achieving considerable cost reduction seek the *quality of conformance* by stopping their subassembly line (*Jidoka in the Japanese term*) at the production stage. Yet, through the introduction of the pull approach, the adoption of a Kanban system has significantly contributed to inventory control⁶.

Total quality management (TQM) is a management approach to ensure high quality and/or low defect rates (Simons, 2014). TQM influences all aspects of company activities and seeks to improve quality control processes while emphasizing customer requirements. The literature highlights that the service gap (the comparison between what the customer wants and what the customer is promised) and the quality gap (the comparison between what the customer is promised and what the customer is given) are relevant in monitoring performance. In this context, the key factors include quality level, service, and quality costs.

⁵ Empirical evidence suggests some criticism regarding the implementation of full integration. For example, Electrolux Italy introduced in its refrigerator division level 4 of integration. However, after some important factory production problems, due to new manufacturing system rigidities, the division abandoned CIM and opted for level 3 with fewer links in manufacturing functions. Consequently, with new investment, the company radically changed the computerized information network of this division.

⁶ See Fox (1982) for a comparison of inventory control systems (Kanban, OPT and MRP).

Lean Thinking (LT)'s vision is that companies in industrialized countries are in a world of radical change from traditional mass production to lean production⁷. The authors of LT (Womack and Jones, 2003) suggest that companies create enormous waste. The considerable reduction of waste generates benefits in terms of profitability and long-term growth. Creating lean firms requires a new way of thinking about firm-to-firm relations and identifying the five lean principles fundamental to eliminating waste. The components of the five lean principles are: (1) specify value; (2) identify the value stream; (3) flow; (4) pull; and (5) perfection (Hines et al., 2002). Lean thinking (LT) philosophy is based on two fundamental concepts: (a) value creation and (b) waste elimination. Value is what the customers need, and waste does not add value in any way.

The Balanced Scorecard (BSC) is divided into four categories of perspectives on organizational performance such as financial, customers, internal business process and growth (innovation) and learning (Kaplan and Norton, 1992). The main characteristic of the BSC is the linking of the four measurement perspectives in a causal chain that involves financial and non-financial measures⁸. Whiting the BSC framework, the selected measures differ across organizations⁹. The original BSC conceptual framework has evolved, including a subsequent research paper reflecting how organizations use their scorecard to align key management processes to the strategy (Kaplan and Norton, 2001).

Section 2's purpose is to advance this study by investigating the implementation of new MM methods, assuming the strong influence of the new BE. We discuss how new manufacturing and management methods are influenced by the new BE (Section 2.1.) and how they support competitiveness in specific markets (Section 2.2).

To interpret how the development of modern MM methods supports competitiveness, this study brings together technological change and management innovations as internal factors relevant to the argument developed here regarding modern MM methods and MA techniques.

3. The relationship between developments in modern manufacturing and management methods and the use of management accounting techniques

Drawing on insights about technological change and management innovations to support competitiveness, and assuming the influence on the new BE, in this section, we examine linkages in the development of modern MM methods and MA techniques. The purpose is to explain why some new MA techniques are relevant to the relationship between developments in modern MM methods and MA techniques. Through an explicit literature analysis, we attempt to explain the following new MA techniques associated with the justification of AMT systems, new product evaluation, the measurement of quality costs, the reduction of operational defects, and the enhancement of customer satisfaction.

3.1 MA techniques and the justification of AMT

Focusing on technological change's impact on investment justification, the literature highlights growing dissatisfaction with traditional capital budgeting methods. Using only these methods, the quantitative analysis discounted each net cash flow (NCF) at the firm's weighted average cost of

⁷ See Holweg (2007) for the genealogy of lean production.

⁸ These observations are taken from Kaplan and Norton (1996.)

⁹ See Malmi (2001) for a research note on BSC in Finnish companies and Norreklint (2000) for a critical analysis of some assumptions of BSC.

capital (k) and summed them back to the present. Mathematically, the net present value (NPV) of the investment decisions, at time 0, is shown as

$$NPV = \sum_{t=1}^N \frac{NCF_t}{(1+k)^t} - I_0 \quad [3.1]$$

The net cash flow (NCF_t), in each year t , is free operating cash flow ($FOCF_t$) minus the tax on operating income ($TOCF_t$).

Bruggeman and Slagmulder (1995, p. 241) note in this respect that:

'It has been argued that in many companies existing management accounting systems, especially costing and investment appraisal systems, significantly handicap the implementation of new technologies and are the major impediment to realizing the firm's competitive advantage'.

Further, Kaplan and Atkinson (1998, chapter 12) suggest that the return-risk theoretical framework reveals many flaws, such as excessively high discount rates, incorrect net cash flows forecasts for new technology investment, and failure to recognize the benefits of new technologies.

Many theoretical models (e.g. Meredith and Hill, 1987) suggest that investment in AMT must be justified by integrating financial and strategic considerations with quantitative financial analysis and qualitative non-financial analysis because various and different benefits are associated with AMT.

In conclusion, the theoretical model suggests a relationship between financial analysis and strategic analysis in evaluating an investment in AMT; it indicates that traditional financial analysis can be used when conducting stand-alone evaluations. By contrast, strategic analysis becomes most appropriate in assessing full integration systems¹⁰.

3.2. MA techniques and new product evaluation

Intense competition has forced many companies to quickly provide product and service innovations to the market at lowest costs. Simultaneously, new MA methods are also being developed as innovative ways of measuring and managing new products over their life cycle. A key aspect to change the traditional costing system, that emphasizes manufacturing costs, is the consideration that the new product implementation involves high R&D costs.

Indeed, recent innovations in MA for managing new product cost use the life cycle model. These organizational frameworks consider three life cycle concepts and total life cycle costs (TLCC). The TLCC considers the costs incurred before, during, and after the manufacturing cycle. The three life cycle concepts include: (1) the research, development, and engineering (RD&E) cycle, (2) the manufacturing cycle and (3) the post-sales service and disposal cycle. RD&E is the cycle in which firms estimate and assess customers' needs and design new products with contributions from scientists and engineers. Contemporary MA techniques apply Target Costing (TC) and Value Engineering to the RD&E cycle, while Activity-Based Costing (ABC) and Kaizen Costing is used in the manufacturing cycle.

In the RD&E cycle, life cycle costing helps scientists and engineers design new products that meet customers' and manufacturers' needs at the desired target costs. The measurement is shown in equation 3.2:

¹⁰ See Abdel-Kader and Dugdale (1998) for an interesting study on investment in AMT in large U.K. companies.

$$C_{ts} = S_{tc} - P_{tc} \quad [3.2]$$

where:

C_{ts} = Target cost;

S_{tc} = Target selling price;

P_{tc} = Target profit margin.

While traditional JIT production systems are acknowledged as achieving considerable inventory and cost reductions in the production (manufacturing) stage, applying TC provides a cost management tool that controllers can use to consider the RD&E stage with an aim to reduce the total life cycle costs (TLCC) of new products (see, e.g. Kato, 1993).

After summarizing the literature and given the problems emerging today in the new BE, this study recommends reassessing the use of JIT methods at the production stage and pursuing cost reduction in the R&D phase to develop TLCC in the new product life cycle process.

3.3 MA techniques and the measurement of quality costs

The correlation between TQM, accounting quality, and the benefits is not linear. In general, adopting TQM involves all company functions. It is essential to reflect whether the degree of quality increases the value of products and services a company provides to its customers. Further, when the firm competes on quality, many different dimensions are emphasized in quality programmes. Accounting quality programmes depend on the kind of TQM and provide specific measures, such as the number of reworks, the number of customer complaints, delivery time, and quality inspections. Therefore, an organization must be monitoring quality through an appropriate information system to eliminate the causes of quality failure and reduce quality costs. It is important to note that improving the quality of products and services requires resources; therefore, ensuring quality is often costly. Quality costs (QC_t) can be categorized into prevention, appraisal, internal failure, and external failure costs. Mathematically the quality cost (QC_t), at time t , as shown in equation 3.3:

$$QC_t = P_t + A_t + IF_t + EF_t \quad [3.3]$$

Where:

P_t = Prevention Costs,

A_t = Appraisal Costs,

IF_t = Internal Failure Costs,

EF_t = External Failure Costs.

Prevention costs (P_t) include investment in technology and education programmes designed to reduce the number of defective products during production. Appraisal costs (A_t) typically include costs for monitoring and inspecting products based on standards before the products are released to customers. Internal failure costs (IF_t) usually include failure costs discovered before the product is delivered to customers. External failure costs (EF_t) involve failure costs found after the product is delivered.

The information about quality costs is relevant for senior managers. Still, it is difficult to insert these quality costs into a quality measurement system without the operating manager's cooperation. In addition, TQM has been accused of sapping innovation. Among other criticisms, managers should be aware of possible problems because quality costs at the production stage serve as a feeble argument for long-term competitiveness.

3.4 MA techniques and the reduction of the operational defect and enhancing customer's satisfaction

In the accounting literature, the six-sigma is portrayed as a tool for reducing operational defects, improving financial returns, and enhancing customer satisfaction (Busco et al., 2006).

Various studies have analysed the adoption of six-sigma practices. Many large firms adopt both lean production techniques and six-sigma to eliminate waste and increase quality as well as cut costs and process time¹¹. The term 'lean six sigma' is a methodology that combines the implementation of two management and accounting innovations, such as lean production and six-sigma approaches. While lean practices identify and eliminate non-value-added activities, six-sigma increases the processes to increase a product's value-added.

Focusing on six-sigma, the implementation project is built with five steps known by the acronym DMAIC: Define, Measure, Analyse, Improve, and Control. In this context, the analysis and control steps are most relevant. In the analysis stage (what is wrong?), the firm identifies the causes of defects with tools (e.g. zone of tolerance, gap analysis, benchmarking). In the control stage, the firm often develops a statistical process control (SPC) to achieve measurable outcomes related to quality and its costs using charts on which process performance is plotted (see e.g. Bicheno, 2002, p. 37). In the statistical literature, six-sigma can be defined as a data-driven procedure based on statistical tools aiming to improve business processes (Montgomery and Woodall, 2008). This result can be obtained by standardising the productive process by applying the DMAIC phases and various statistical diagnostic tools, ranging from basic descriptive to advanced multivariate methodologies, to maintain control over the process.

The term six-sigma originates from the statistical quality control field applied to process capability. It refers to the comparison of a specific, measurable phenomenon with its reference distribution. The idea is that the manufacturing should compare production performance with upper and lower limits determined by the mean of the observed phenomenon and a variability measure (such as the standard deviation). Thus, these limiting values are determined considering six standard deviations from the mean of the reference phenomenon.

For instance, we can consider the case of the manufacturing steel plates. The target thickness of the final product is 10 mm, and the producer decided that acceptable products must present a measure between 9.85 mm (Lower Limit – LL) and 10.15 mm (Upper Limit – UL) to respect the production requirements. The two limits must correspond to the following equations to meet six-sigma requirements.

$$UL = \mu + 6 \sigma \quad [3.4]$$

$$LL = \mu - 6 \sigma \quad [3.5]$$

For this reason, by fixing UL to 10.15 and μ to 10, the variance of the production process results is

$$\sigma = \frac{0.15}{6} = 0.025,$$

meaning that the variance of the production process must be very small. Under these conditions, the probability of observing a value between the two limits is very close to one (the tails' probability is

¹¹ See, for example, the description about the implementation of Lean Six Sigma in ARAG Italy by Busco and Riccaboni (2010).

$9.866 \cdot 10^{-10}$); hence, improvements in the production process involve reducing results variability under the assumption of fixed average behaviour.

From the process performance perspective, we can consider the six-sigma condition depending on the number of defects per million observed in a productive process. Within this framework, the researchers observed that the production processes do not perform as well in the short term (presenting some biased measure of the mean performance) as in the long term. To account for this evidence, a ± 1.5 sigma shift in reference distribution is introduced. Under this empirical shift assumption, a six-sigma level of performance is reached when the expected number of defects per million is 3.4, with a proportion of non-defective products equal to 99.99966%. This probability corresponds to one minus the probability of the tails defined by LL and UL. Still, it refers to the Gaussian distribution presenting an expected value of $\mu + 1.5$ or $\mu - 1.5$. In fact,

$$P(-6 < X - \mu - 1.5 < 6) = P(-4.5 < X - \mu < 7.5) \cong 1 - P(Z \leq -4.5) = 0.9999966,$$

or equivalently

$$P(-6 < X - \mu + 1.5 < 6) = P(-7.5 < X - \mu < 4.5) \cong 1 - P(Z \geq 4.5) = 0.9999966,$$

with $X \sim N(\mu \pm 1.5, 1)$ and $Z \sim N(0, 1)$.

The same procedure can also determine the number of defects for 1, 2, 3, 4 and 5 sigma levels. It is necessary to consider that as the sigma number is lowered, the relevance of the left tail of the distribution grows. For example, assuming the two-sigma solution, we can compute the following probability of non-defecting products

$$P(-2 < X - \mu - 1.5 < 2) = P(-0.5 < Z < 3.5) = 0.6912,$$

corresponding to 308770.2 defects per million.

These basic probability results can be considered to develop different statistical tools ranging from hypothesis testing procedures to the construction of so-called control charts (Deming, 1975) and applying many other possible statistical tools for business data analyses.

4. Concluding Remarks

4.1 Summary

Some studies have focused on management and accounting innovations. For example, the role of fads and external pressures, and more recently, what they are and why they are adopted.

Our study contributes to the literature on MA by analysing the relationship between developments in modern MM methods and the use of MA techniques. Hence, we provide insight into the assertion that MA techniques and practice must change when MM methods change.

Regarding the relevant analysis, this study discusses how new BE approaches influence new MM methods and support competitiveness. We then examine linkages between MA techniques and the development of modern MM methods.

Analysing the relationship between new manufacturing methods and the use of management accounting techniques indicates the complex nature of advanced manufacturing technology and management innovations and their impact on MA change (see, for instance, Davila et al., 2009). This

can be summarized as follows.

1. The literature criticizes the impact of technological change on MA. Indeed, technological change, like AMT, impacts investment justification, and the literature highlights growing dissatisfaction with traditional capital budgeting methods. Many authors suggest that good investment in AMT must be justified by integrating strategic and financial considerations because various strategic benefits are associated with AMT. Lessons include the close link between strategy and accounting as well as financial and non-financial information integration. Empirical research recommends introducing a strategic dimension of management accounting with more considerations.

2. Intense competition influenced by BE has forced many companies to quickly provide new products and service innovations to the market at the lowest cost. In parallel, new MA methods are being developed as innovative ways for measuring and managing how new products develop over their life cycle. In this situation, the impact of several product innovations causes high R&D costs that require changing traditional MA with the adoption of total life cycle costs (TLCC). The change considers the impact of different stages of cost information incurred in the production process before, during and after the manufacturing cycle. The literature illustrates that contemporary to remain competitive MA methods manifest the application of Target Costing (TC) and Value Engineering during the R&D cycle, while Activity-Based Costing (ABC) and Kaizen Costing is applied during the manufacturing cycle.

3. Given the problems emerging in the BE, many academic authors ‘frequently publish articles that establish the adoption rates of accounting information systems, such as the Balanced Scorecard’ (Wiersma, 2009). Further, the accounting literature recommends using JIT methods at the production stage to pursue cost reduction in inventory and product quality performance. In particular, the literature indicates that many companies in industrialized countries are adopting quality improvement as a primary corporate objective (Bromwich and Bhimani, 1994). Here, a challenge for the firms is to deemphasize the focus only on financial measures and develop appropriate non-financial indicators for monitoring the causes of quality failure to reduce quality costs.

4. The literature emphasises that six-sigma is a refined version of TQM; this tool aims to reduce defects, improve financial returns, and enhance customer satisfaction. In particular, evidence provided by the accounting literature indicates that some large international companies adopt both lean production and six-sigma (Lean Six-Sigma) to increase quality and eliminate waste as well as cut costs and process times. While lean production identifies and eliminates non-value-added activities, six-sigma increases the processes to increase value-added to the product. Six-sigma is built in five steps: Define, Measure, Analyse, Improve, and Control. Adopting the five steps is more relevant and consistent with customer satisfaction in the long-term, including the analyse and control steps. In the analysis step (what is wrong?), the firm identifies the causes of defects using tools (e.g. zone of tolerance, gap analysis, benchmarking). Regarding the control stage, the firm develops a statistical process control (SPC) to achieve measurable quality and cost outcomes using charts on which process performance is plotted.

4.2 Areas for future research

This study has certain limitations that show areas for future research. One is to develop more insight into the accounting literature that examines factors driving the adoption of new manufacturing methods. Of equal interest would be to explore the specific purposes for which managers use different

innovative management accounting techniques to support competitiveness. We suggest an international research project that empirically investigates lean six-sigma and six-sigma implementation.

Appendix

The specific analysis developed here discusses how modern MM methods are influenced by new BE (especially the effect of innovations and uncertainty) and how they support competitiveness. We then explore the impact of the modern MM change on MA techniques/practices. See exhibit A.1 ‘The Contingency model links BE change, MM change, and MA techniques’.

INSERT EXHIBIT A.1 ABOUT HERE

An empirical part of our study draws on questionnaire responses from a sample of senior managers and accountants and interviews held with two managers of large companies. Extending existing knowledge, an appendix provides empirical evidence of some illustrative cases related to the implementation of the six-sigma in Italian companies (there is no evidence in Italy). A short research with a specific exploratory investigation held with a survey questionnaire was followed by interview results regarding the implementation of Six Sigma.

1. Exploratory investigation

1.1 Questionnaire results and discussion

The aim of the questionnaire is to investigate the implementation of lean-six-sigma and six-sigma empirically. The investigation involves samples from different manufacturing companies operating in Italy.

The data, collected using a questionnaire survey, was previously pilot tested with three academics and two senior managers working for firms not included in the sample.

A letter explaining the research project’s purpose was sent to senior managers and accounting officers in 60 Italian large manufacturing companies. At the end of the letter, they were asked to indicate whether the firm would participate in the research project.

Fourteen companies accepted and identified the person and their email for the delivery of the survey. Ten usable questionnaires were returned.

The survey consisted of four sections:

- (a) principal strategic business unit (SBU) and principal critical success factors (CSF);
- (b) financial planning and control;
- (c) management accounting and lean-six-sigma and six-sigma implementation;
- (d) effects of the six-sigma usage on the organizational structure.

The questionnaire was semi-structured, and most items used answers on a Likert scale ranging from 1 to 5. The survey’s main goal was to provide insight into practices. The survey was targeted at top managers and senior accountants who volunteered to participate in the research project as respondents. Table A.1 provides information on the companies involved in the survey.

INSERT TABLE A.1 ABOUT HERE

In 2018, the sales (in millions) of the ten companies ranged from € 30 (a medium-sized national company) to € 29.706 (a large international company). At the end of the questionnaire, the respondents were encouraged to discuss the survey using suggestions and comments and to clarify the process involved with lean-six-sigma and six-sigma implementation in their company.

All the descriptive statistics were developed in R (R Core Team, 2021).

In presenting the results and discussion, we follow the questionnaire layout below. The questions did not ask for detailed sensitive data.

1. Principal strategic business unit (SBU) and critical success factors (CSF)

The company's main characteristics were determined using two key questions focusing on the principal SBU and the related primary CSF. The results indicated that the keywords of the CSF for the principal SBU are: product quality, product and process innovations, efficiency, technology, costs, R&D, and supply chain (see Table A.2).

INSERT TABLE A.2 ABOUT HERE

2. Financial planning and control

The majority (80%) of the respondents indicated that their organization adopted financial planning and controls in profit planning and financial forecasting. Only a minority (20%) shows minor financial planning and control usage (see Table A.3).

INSERT TABLE A.3 ABOUT HERE

3. Management accounting, Lean-Six-Sigma and Six-Sigma implementation

While the respondents indicated that lean-six-sigma implementation is equal (50% and a mean of 2.9) in terms of frequency, most respondents (60%) reported minimal six-sigma usage (see Table A.4).

INSERT TABLE A.4 ABOUT HERE

The results indicated that the first DAIMC step in Six-Sigma usage is analysed (70% and a mean of 3.7). The criteria for define, measure, improve, and control were regarded as almost equally important by the majority. The main values were 3.3, 3.3, 3.3, and 3.2, respectively (see Table A.5).

INSERT TABLE A.5 ABOUT HERE

4. The effects of Six-Sigma implementation on the organizational structure

Only 30% (and a mean of 2.8) of the respondents believed that the effects of Six-Sigma implementation on the organization structure are relevant for their organizations (see Table A.6).

INSERT TABLE A.6 ABOUT HERE

The respondents' comments at the end of the survey indicate that most organizations believe that the competitive marketplace has now made it necessary for companies to re-examine their MA practices, including lean-six-sigma usage. For many respondents, with continuous improvement becoming the standard in a constantly changing environment, it is unsurprising that they indicated Six-Sigma should be more structured and formal to improve the operations product quality to a certain standard, reducing operational defects, and enhance customer satisfaction.

1.2 Interview questions and results

Interviews were held, using email and Microsoft Teams, with the head of Word-Class Manufacturing (WCM) in Europe at CNH Industrial and the Electrolux Manufacturing Systems (EMF) manager in Europe at Electrolux. The interview was semi-structured and included the following questions.

1. What does the company do?
2. What does the company consider the aim of Six Sigma? Please indicate your company's implementation (year) of Six Sigma.
3. Does the benefits of Six Sigma play a role in the company? Please describe your company's implementation of Six Sigma in terms of changes.
4. Who uses (functions) the Six Sigma information?
5. Please describe, with examples, your company's use of Six Sigma.

The interview results are discussed below.

1.2.1 CNH Industrial

CNH Industrial is a large global company working in production for the capital goods market through brand machinery for agriculture and construction, commercial and industrial vehicles, buses, and special vehicles powered by its engine and transmission products. The ownership model is an entrepreneurial business, and strategy tends toward a diversified conglomerate.

Regarding the question about the aim and the year of implementation of Six Sigma, the Head of the WCM in Europe of CNH Industrial stated:

'We monitored government thinking on manufacturing and implemented a programme of operational excellence starting in 2008 and introduced statistical tools based on Six Sigma starting in 2014'.

He then stated:

'The operational excellence name world class manufacturing (WCM) adopts as a general logic PDCA (the equivalent of DMAIC) and use specific statistical tools 6 Sigma as the DOE (Design of Experiment)'.

The Head of the WCM in Europe explained:

'The benefits observed with the implementation of Six Sigma mainly include cost efficiency and waste reduction in production'¹².

Regarding the use of Six Sigma information, the Head of the WCM in Europe at CNH Industrial observed that such information had to be designed from other available systematized data.

'The uses of Six Sigma information involve, in particular, some functions such as production quality, logistics, and the launch of new products'.

Regarding Six Sigma at CNH Industrial, the company's practices were indicative of a high degree of refinement and application of sophisticated statistical tools. However, it is relevant that Six Sigma is considered at the company level as a part of a Tool kit, despite strategy, prioritizations, financials are following the WCM framework. (Financial information is tracked and formal but is removed for confidentiality).

A specific example illustrates how the Six Sigma process is a good example for the manufacturing arena. The example, the launch of a new marine engine, was provided by email and discussed using Microsoft Teams. The informal process involved with the new marine engine, which followed the five steps of DMAIC, are illustrated below.

1. Define: in the preliminary phase, the company identified a problem in the production of the connecting rods that strengthen the marine engine.

2. Measure: the company collected data to understand the factors involved (when, what, where, which) that influence the production problem and the potential risk for the new engine.

3. Analyse: the company analysed the fundamental causes of defects. In particular, the company found that three manufacturing parameters influenced production. Statistical analysis identified the optimal combination of the three manufacturing parameters to remedy the production problem.

4. Improve: the process was re-engineered to bring the number of defects within target limits. In particular, applying the new optimal combination of parameters, the production process showed a reduction in production problems using a before and after comparison.

5. Control: the improvement process was monitored through statistical process control, using the D.O.E technique, to ensure that the connecting rods were within a maximum profile tolerance.

1.2.2 Electrolux

Electrolux, one of the largest global manufacturers of household electrical appliances and professional products, uses an extensive Six Sigma programme to improve operating efficiency. The ownership model is an entrepreneurial business, and the strategy is a diversified conglomerate.

Regarding the aim and the year of implementation of Six Sigma, the Electrolux Manufacturing System (EMS) manager in Europe stated:

¹² Keith and Clement (2010) illustrate how Six Sigma has been applied successfully in the accounting and finance arena at Caterpillar.

‘Six Sigma was implemented in the manufacturing arena some decades ago. Today all plants worldwide, including the finished good warehouses, apply Six Sigma. Six Sigma refers to the ability to manufacture products with a level of a few defects per million, involving a structured project-based approach. A project team, led by internal Six Sigma experts, follows a methodology of defining the process of improvement goals (DMAIC).

Note that Six Sigma isn’t part of the lean production programme. At Electrolux, a lean production (lean) programme, that focuses on value added, eliminating non-value added and waste, started in October 2005’.

The EMS manager in Europe stated:

‘The major benefits observed with Six Sigma implementation, that include specific advanced tools, refers to product quality (production) with a defined, very low tolerance’s level for defects per million as well as cost efficiency’.

Regarding use of Six Sigma information, the EMS manager in Europe noted that:

‘A preliminary Six Sigma programme has been implemented for manufacturing functions, while the lean production programme started from EMS in the year 2005. The EMS later develop also two programmes, one for R&D (called Kaizen) and one for offices and services (called Continuous Improvement’ – On-Beat).’

One of the fascinating characteristics of Six Sigma is that can be combined, as an underlying approach, in many different ways to provide a lean production program.

Focusing on Six Sigma, this is influenced by the constantly changing business environment and were indicative of a good degree of refinement, especially for the quality and product cost improvement in order to maintain a competitive marketplace. At Electrolux, Six Sigma is structured, and formal and financial and non-financial information is essential for manufacturing departments. In this respect, the EMS manager in Europe suggests that:

“The Manufacturing Quality function is responsible for establishing criteria to ensure that the benefits of every project were rigorous, real and credibly. While, in parallel with Six Sigma, the principal task of the EMS department focuses on wastes elimination, new standard development in term of production flows, quality control whitening a set of measures under the Six Sigma process. The final goals are to remain in a range of minimal standard”.

A specific example, a relative project on a new process line, was provided by email and discussed using Microsoft Teams which describes the formal process of Six Sigma. A document provided by EMS, that shows the Lean programme, is illustrated briefly: (a) the factory and the team involved in the project; (b) the focus area and product; (c) the primary expectation of the company. The document (as a prologue of the project) indicated that:

- a) The factory involved in the project was Electrolux Home Product Italy and the team included the project manager (EMS manager in Europe), one facilitator, and fourteen change agents (who responded to the plant manager).
- b) The focus was the press line 1 for the production of washing machines (production: 800.000 WM/Yr.).

- c) The primary company expectation for cost improvement was: (1) C/O (change over in the hot-pressing) time improved by 10%; (2) ensure safety and standardize C/O.

The formal process involved in the new press line for washing machines in terms of DMAIC framework is synthesized below.

1. The project team identified the problem of the cabined production area and *defined* the primary goals of using a new production process for press line 1.
2. Next, the team *measured* the capability of the current process and statistically determined which process inputs caused the variation in realizing the goals, reducing the risk involved in the current process.
3. The team again *analysed* the data according to the following principal steps: (1) assess the current situation (actual C/O time: 36'); (2) separate (divide) the internal and external phases; (3) convert internal to external (C/O time: 28'); (4) process waste.
4. Once the project team *improved* press line 1's production process by eliminating the root causes of the problem, the company created an ideal cycle without waste with the following results: (1) the C/O time improved by 55%; (2) the C/O was made safe and standardized. For this improved stage, the organization used statistical tests to ensure that the improved process remained in control going forward. In this process, called set-up monitor, there was a comparison between targets and results.
5. In the *control* stage, the team recommended statistical tests to monitor the process to ensure the specified goals were met. In this process, called set-up monitor, there is a comparison between targets and results as well as variance analysis. This stage, which involved the EMS departments, examines the profile tolerance of the parameters.

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Figure 1 - A framework of product and process innovation over time for the industry

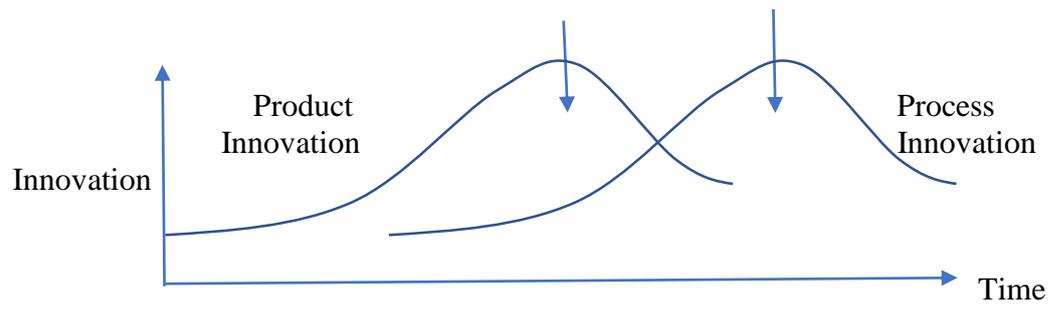


Exhibit A.1 - The Contingency model links BE change, MM methods, MA techniques

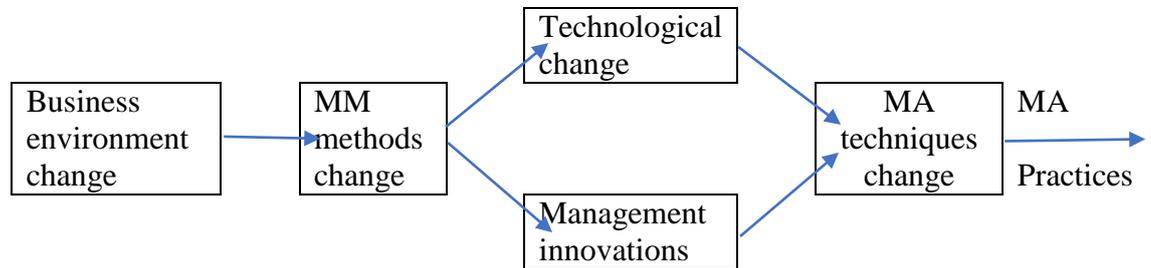


Table A.1 - Information of the companies involved in the survey

Sector	Company	Technological level	Respondents
Manufacturing	A	Medium tech	Head of Manufacturing and Services
Manufacturing	B	High tech	Chief Financial Officer
Manufacturing	C	High tech	Chief Financial Officer
Manufacturing	D	Medium tech	Head of Controlling
Manufacturing	E	High tech	Financial and Administration Director
Manufacturing	F	Medium tech	Chief Executive Officer
Manufacturing	G	High tech	Chief Executive Officer
Manufacturing	H	High tech	Group Administration and Finance
Manufacturing	I	Medium tech	Corporate Director
Manufacturing	L	High tech	Finance and Accounting Director

Table A.2 – Principal SBU and CSF

	Principal SBU	Principal CSF
A	Earth-moving, Agriculture and Building Machines.	Product quality, Post-sale service, Quality engineering and technology.
B	Cutting tools for wood manufacturing	Product and process innovations, Product quality, production efficiency
C	Steel manufacturing	Product quality, Service delivery
D	Furniture for kitchen/dining room	Manufacturing costs, Product quality, Supply chain
E	Iron and steel manufacturing	Technological know-how, Investment capacity, Production efficiency
F	Equipment production for manufacturing firms	Product and process innovations, Product quality
G	Precise sheet metal cut with laser.	Product quality, Supply chain, Investment capacity
H	Plasma gathering and distribution	Product quality, plasma security, plasma availability
I	Household appliance building and trading	Technological innovation, Production efficiency, Product quality
L	Building and installation of a control board	Research and development, Product innovation and patented.

Table A.3 – Financial planning and control

Financial Planning and Control	Frequency					Total	Mean
	Very Little	Little	Neither	Much	Very Much		
To what extent do the following apply to your firms?	1	2	3	4	5		
Profit planning (operating plan, cost behaviour and breakeven analysis) play a role in strategic decision- making.	0 0%	0 0%	2 20%	6 60%	2 20%	10 100.0%	4.0
Financial forecasting (cash budgets, cash flow cycle and expected financial results) play a role in strategic decision-making,	0 0%	1 10%	1 10%	6 60%	2 20%	10 100.0%	3.9

Table A.4 – Lean-Six-Sigma and Six-Sigma usage

Lean Six-Sigma and Six-Sigma usage To what extent do you agree with the following statements?	Frequency					Total	Mean
	Very Little	Little	Neither	Much	Very Much		
Lean Six-Sigma is structured and formal for the technology advantage, reduce cycle time and improve the operations from production to client services.	1 10%	4 40%	1 10%	3 30%	1 10%	10 100.0%	2.9
Six-Sigma is structured and formal to improve the operations product quality to a certain standard, reduce operational defects, and enhance customer satisfaction.	2 20%	4 40%	1 10%	2 20%	1 10%	10 100.0%	2.6

Table A.5 – Importance of DMAIC's steps in Six-Sigma usage

Six-Sigma usage	Frequency					Total	Mean
	Low importance		High importance				
What importance do you currently attach to the following DMAIC steps:	1	2	3	4	5		
Define?	2 20%	0 0%	2 20%	5 50%	1 10%	10 100.0%	3.3
Measure?	2 20%	0 0%	2 20%	5 50%	1 10%	10 100.0%	3.3
Analyse?	2 20%	0 0%	1 10%	3 30%	4 40%	10 100.0%	3.7
Improve?	2 20%	0 0%	2 20%	5 50%	1 10%	10 100.0%	3.3
Control?	2 20%	0 0%	2 20%	6 60%	0 0%	10 100.0%	3.2

Table A.6 – Effects of Six-Sigma implementation on the organizational structure

Six-Sigma Implementation How important are the effects of the Six-Sigma usage on the organizational structure?	Frequency					Total	Mean
	Unimportant		Crucial				
	1	2	3	4	5		
	2	1	4	3	0	10	2.8
	20%	10%	40%	30%			