The Routledge Companion to Production and Operations Management

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Management Accounting and Operations Management

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PART V

POM Interface with Other Functions
1 Introduction

In this chapter, we would like to outline the benefits gained for practice from looking at the
Operations Management phenomenon through multiple angles, in particular by including
Accounting, performance measurement, and incentives angles. Furthermore, we will explore the
opportunities for interdisciplinary contributions to both the academic Operations Management
and Accounting literature. Accounting focuses on the role of accounting information in assess-
ing, valuing, and predicting the performance of firms and individuals. Furthermore, Financial
Accounting is concerned with the role of such information to improve external (to the firm)
decision making such as lending decisions by banks and trading decisions by financial market
participants. Management Accounting, on the other hand, focuses on the role of accounting
information internally within the firm.

If the reader will allow us some sweeping generalizations, we would characterize Managerial
Accounting research as originally being very focused on the role of information to improve
internal decision making up until the mid-sixties (Kaplan 1984). Over time, the focus of this
research has shifted to the role of such information in measuring performance within the firm
and providing incentives to align employees’ actions with the firm’s strategy. We would argue,
however, that the pendulum has swung out a little too far. While the majority of what we teach
in our Management Accounting courses is decision-making oriented in order to prepare our
students for their roles in the workforce, the amount of research to support our teaching needs
and update our teaching materials on this front is much more limited. Operations Management
research, on the other hand, has continued to study the role of information in decision making
(e.g., how to reduce the bullwhip effect by improved information sharing), and it would be
valuable to bring some of that focus back to Accounting research.

Overall, Operations Management has typically been much more concerned with decision
making and, until fairly recently, usually not considered the behavior of humans under incentives
provided by performance measures. The main focus has been on accomplishing process and
operations improvement by dealing with exogenously imposed challenges such as, for example,
randomness of demand, outages, and defects. Operations Management research and practice
have not been focused on how to best measure aspects of an exogenously determined process.
Instead, the focus lands on the endogeneity that arises when measures are used not just to capture
the properties of the process but to incentivize and inform decision makers that are responsible for managing the process. As such, this perspective of Accounting research provides an important vantage point for thinking through the interactions among performance measurement options, human behavior when responding to these incentives, and the resulting optimal structure of operations. Given the readership of the book, our chapter will focus on what an Accounting perspective can signify for Operations Management. We argue that both areas are inseparable.

In Section 2, we will discuss the importance of considering incentives and performance measurement in Operations Management. Using the illustrative cases of two typical Operations Management settings (throughput maximization and the choice between push and pull production), we will outline how the performance measurement perspective adds many tools to the operations manager’s toolbox and how opportunities for joint optimization of operations and performance measurement arise. We will also discuss the role for Management Accounting in devising additional performance measures (such as those included in a balanced scorecard which typically reports performance measures for four different perspectives: financial, learning and growth, internal, and operational) to which incentives can be linked and how this affects how to best solve an operations problem.

In Section 3, we take the opposite perspective and discuss how the organization of operations affects what can and cannot be measured by Accounting. Here, our focus falls on cost measurement techniques such as Activity-Based Costing and Time-Driven Costing. We explain how Operations Management affects the accuracy of such cost measurement. This will in turn influence the operations management decisions based on these reported costs, suggesting that Accounting and Operations Management are joined at the hip. To be clear, some practitioners and researchers are already wrestling with issues on this interface (such as many of the works referenced in this chapter), and we do not aim to provide an exhaustive reference list of those that do (e.g., additional references include Hansen and Mouritsen (2007) and Chao et al. (2014)). Rather, we hope that our chapter will further stimulate Operations Management researchers and practitioners to consider Accounting and performance measurement issues, and vice versa, by outlining some avenues for research and practice which we believe will be most fruitful.

2 The Importance of Considering Incentives and Performance Measurement in Optimizing Operations

2.1 Introduction to Performance Measurement and Incentives

2.1.1 Agency Theory

Agency theory is the economic framework that underlies the majority of hypotheses building on performance measurement topics in Accounting research (with the next substantial theoretical framework used on this topic being behavioral/psychological). In its very basic form, a Principal with utility function $G$ contracts with a risk averse Agent with utility function $U$ to exert unobservable effort in return for a wage, which is a function of the observable outcome $x_i$.

A self-interested Agent will only behave in the way desired by the Principal when his pay structure is set up in such way that Principal’s and Agent’s incentives align. A discrete outcome ($N$ different $x_i$ values)—binary input measure ($a_h$ for high effort, $a_l$ for low effort) version of the classic agency model by Hölmstrom (1979) is specified as follows:

$$\max_{x \in \mathbb{R}} \sum_{i=1}^{N} G(x_i - S(x_i)) p(x_i | a)$$
Management Accounting and OM

\[
\begin{align*}
\sum_{i=1}^{N} U(S(x_i)) p(x_i | a_i) - V(a_i) & \geq U \\
\sum_{i=1}^{N} U(S(x_i)) p(x_i | a_i) - V(a_i) & \geq \sum_{i=1}^{N} U(S(x_i)) p(x_i | a_i) - V(a_i)
\end{align*}
\]

\(V(a)\) is the cost of effort of the Agent, and \(p\) is the conditional probability of achieving a particular outcome, given the level of effort exerted. The Principal’s (e.g., CEO or shareholders of the firm) objective is to maximize his residual, while offering the Agent (e.g., a worker in the firm) a wage that satisfies both his individual rationality (IR) constraint, which ensures that the Agent at least earns his reservation utility \(U\) and incentive compatibility (IC) constraint. This makes the Agent prefer to put in high effort rather than low effort (since the problem is set up such that the Principal always prefers high effort). Forming the Lagrangian for this optimization problem, and taking the first order condition (FOC) with respect to \(S(x_i)\), we obtain:

\[
\frac{dL}{dS(x_i)} = 0 \Leftrightarrow -G(x_i - S(x_i)) p(x_i | a^i) + \lambda U'(S(x_i)) p(x_i | a^i) + \mu U'(S(x_i))(p(x_i | a^i) - p(x_i | a')) = 0
\]

This expression further simplifies to:

\[
\frac{dL}{dS(x_i)} = 0 \Leftrightarrow \frac{G(x_i - S(x_i))}{U'(S(x_i))} = \lambda + \mu \frac{p(x_i | a^i) - p(x_i | a')}{p(x_i | a^i)}
\]

In this expression, the term \(\frac{p(x_i | a^i) - p(x_i | a')}{p(x_i | a^i)}\) is the likelihood ratio, which shows the precision with which the outcome \(x_i\) indicates that the effort level exerted was \(a^i\). Viewing \(x_i\) as a performance measure of the Agent’s effort, the precision of the performance measure determines its quality and hence impacts the weight placed on the measure in the contract \(S(x_i)\). All else being equal, a measure with higher precision is preferred since it reduces the risk that is imposed on the (typically considered) risk-averse Agent.

\section{2.1.2 The Sufficient Statistic Condition}

Holmström (1979) goes on to show that any publically observed piece of information that does not satisfy the sufficient statistic condition generates value for an agency. When \(y\) is publically observable, using both \(x\) and \(y\) (instead of \(x\) alone) in the performance evaluation will lead to a Pareto improvement, if and only if it is not the case that \(x\) is a sufficient statistic for \(y\). Mathematically, the sufficient statistic condition holds when \(p(x,y|a) = p(y|x) \times p(x|a)\). In this case, nothing is learned from observing the additional performance measure \(y\) that we don’t already learn from observing \(x\) and hence \(y\) will not be used. To see this, substitute the sufficient statistic condition in the likelihood ratio (Labro 2015):

\[
\frac{p(y_i | x_i) p(x_i | a^i) - p(y_i | x_i)p(x_i, a^i)}{p(y_i | x_i)p(x_i, a^i)} = \frac{p(x_i | a^i) - p(x_i | a^i)}{p(x_i | a^i)}
\]

This is good news for Accounting, since many of the accounting numbers (such as profit and cost) we provide do not satisfy the sufficient statistic condition. The availability of information
to populate particular performance measures will, as a result, have an influence on how incentives can be structured.

### 2.1.3 Implications for Operations Management

What does all this mean for Operations Management? Because the availability of information to populate particular performance measures affects the provision of incentives, it will also influence how operations should optimally be structured in conjunction with such optimal incentives. (Management) Accounting may help by removing information constraints and thus make particular Operations Management structures more effective. For example, throughput can be increased if measures and incentives can be established to work on the right parts at the right time (Hopp and Spearman 2000, 368). As explained in Section 3, Activity-Based Costing (ABC) and Time-Driven Activity-Based Costing (TD-ABC) improve measurement of costs while appropriate contribution margin calculations will support throughput optimization.

Furthermore, when ignoring incentives and performance measurement considerations, observations of production processes’ attributes such as capacity utilization, quality, and throughput volatility may lead to faulty conclusions about appropriate corrective actions. However, once incentives and performance measurement are considered, it becomes clear that aspects such as performance variance are endogenous responses to incentives embedded in the process design, and that the best way to deal with those is through changes in such incentives, rather than through Operations Management changes. As we will illustrate next, if we take the view that performance variance is created endogenously by incentives rather than exogenously, we will develop a comprehensive understanding of how to structure Operations Management practices optimally (Cachon 2012).

In the remainder of this section, we develop simple models of two typical Operations Management settings that illustrate the role of incentives and performance measurement outlined above in optimizing operations: throughput maximization with capacity constraints and push versus pull production. While the single-Agent, single-task model presented above is simplified, these two Operations Management settings introduce additional complexities that illustrate the continuing development of agency theory.

The model of throughput maximization with capacity constraints centers on a multi-tasking extension of the agency model whereby the role of information in providing performance measures of the different tasks is key. The multi-tasking literature was jumpstarted by Hölstrom and Milgrom (1991). In essence, this literature extends the basic agency model where the Agent chooses the amount of effort to provide on a single-task to a model where the Agent not only chooses his level of effort but also the allocation of effort to multiple tasks. Of crucial importance in the Principal’s ability to motivate both high effort levels and effort allocation to the appropriate tasks is the quality of the available performance measures of each task.

In a multi-tasking setting where there exists a precise performance measure of one task, yet the precision of the performance measure of the other task is very low, the Agent will choose to only exert effort on the task that is accurately measured where his effort level has a high likelihood of impacting this task’s performance measure positively (if observed and rewarded by the Principal). The Agent will exert little, if any, effort on the task with an imprecise performance measure, since it is highly likely that even if he puts in high effort, this performance measure may not reflect that. Hence, the Agent will not provide a “balanced” effort on both tasks. Management Accounting can play an important role here, in that it can construct more precise performance measures of various tasks, allowing for a more appropriate effort allocation. It is this idea that inspired Management Accounting researchers to think about the role of the Balanced Scorecard...
Management Accounting and OM

(which reports scores on a set of “balanced” performance measures) in facilitating such effort allocation.

The model of push versus pull production, on the other hand, is exemplary of a multi-agent extension where multiple employees exert effort to produce an output. In the model presented in Section 3 of the seminal Hölmstrom (1982) paper that jumpstarted this literature, multiple Agents chose their effort levels, each obtaining a score on an observable, yet uncertain, performance measure of their output. Hölmstrom (1982) shows that something similar to the sufficient statistic result on the value of additional performance measures that we introduced earlier holds in this multi-Agent context. Say there are two Agents that provide effort $a_1$ and $a_2$, respectively, and each Agent’s performance is reflected in their performance measures, $y_1$ and $y_2$, respectively. Unless you can write that $g(y_1, y_2 | a_1, a_2) = h_1(y_1, y_2 | a_2) \times p_1(y_1 | a_1, a_2)$, it is optimal to also base Agent 1’s compensation on the performance measure of Agent 2, as this improves risk sharing.

For each of these Operations Management settings, we first derive insights from a view without incentives and performance measurement (traditional view) and discuss the decisions an operations manager in this firm may take. Next, we derive the insights from a perspective that includes incentives and performance measurement (a view through an Accounting lens) discussing the avenues that are suggested before comparing and contrasting these with the earlier recommendations.

2.2 Throughput Maximization and Capacity Constraints

2.2.1 An Operations Management Perspective on Throughput Maximization Under Capacity Constraints

The first Operations Management example of throughput maximization under capacity constraints models a firm (Principal) with a production technology that relies on some unlimited production factors, such as materials which can be bought at any point in any quantity and two potentially constraining production factors, labor $L$ and machine space $M$, which are batch resources. The laborer (Agent) exerts efforts on multiple tasks (say, two: $L_1$ and $L_2$). Two types of outputs of differing size are created: $q_s$ is the quantity of the (physically) small product, and $q_b$ is the quantity of the big product, which is twice as high as the smaller product. The machine produces a batch of products at the time and is configured with adjustable shelf space to allow for different combinations of product sizes to be combined during the batch processing. The firm’s objective is to maximize contribution margin, and the decision variables are the quantities of each product produced and the shelf configuration. In particular, the operations manager has to choose how many shelves that can hold big ($M_b$) versus small products ($M_s$) are put in the machine. Each shelf can hold $a_i$ products. The following linear program is solved:

$$
\text{Max}_{a_i, M_s} \sum_i (p_i - \nu c_i) q_i
$$

subject to

$$
\sum_i (l_i + l_s) q_i \leq L
$$

$$
m q_s \leq a_i M_s
$$

$$
m q_b \leq a_i M
$$

$$
2M_b + M_s \leq M
$$
whereby $p_i$ is the price of product $i$, $v_c^i$ is the variable cost of product $i$ such as materials used, $l_j$ is the units of labor capacity resource of task $j$ consumed by one unit of product $i$, $m_i$ is the units of shelf space consumed by one unit of product $i$, and $L$ and $M$ are the labor and machine capacity resources currently in place.

To make the model more concrete, you can think of an example of a clay pottery where an artist (the Agent) uses clay and other unlimited materials to create outputs like vases (big size) and bowls (small size). The Agent’s two tasks are creatively coming up with original designs ($L_1$) and shaping the clay ($L_2$) readying it for placement on the shelves that are subsequently put in the oven (the machine) for baking. Solving this linear program, the firm finds that the shadow price to the labor constraint is zero (the labor constraint is slack) and hence that the Agent has some idle capacity. However, the machine space constraint is binding and has a positive shadow price. This is the result of the vases and bowls needing a very long time in the oven and the inability of the artist to produce any further outputs while he waits, as the quality of the products decreases dramatically if they cannot immediately enter the oven.

Note that the optimal solution will result in a restriction on small and big products sharing the same shelf since that would entail suboptimal shelf space. However, this could potentially stifle the artist’s creativity, as it constrains the products that the artist can design. For example, if the shelves allocated to vases are already filled, the artist has no choice but to come up with a design for a bowl. From a traditional Operations Management perspective, the manager of this firm may want to expand the capacity on the constrained machining resource. However, because this is a batch resource, it may be very costly to do so, and a cost-benefit analysis would need to be provided. Furthermore, if the operations manager is concerned about reduced creativity in the designs, he may relax the constraints on size-allocated shelf space, which would result in an even bigger need to buy additional oven capacity, as combining big and small products on the same shelf makes suboptimal use of the existing capacity.

2.2.2 A Management Accounting Perspective on Throughput Maximization Under Capacity Constraints

Next, consider this situation from the perspective of the incentives of the Agent who provides the effort on multiple tasks ($L_1$ and $L_2$). The artist has incentives to minimize throughput in the oven, as the artist is a batch resource that is left idle at the end of their shift each time the oven resource constraint binds, as it is the firm’s policy that the artist can go home because clay cannot be molded that long prior to baking. If the Agent deliberately uses the shelf space sub-optimally, he can shorten his time at work. Incentives are such that idle labor capacity is created. (See Boudreau et al. (2003) for the example of a power plant where throughput was much lower than predicted by the operations model because human factors were overlooked.) Can these incentives be changed by tying the Agent’s pay to performance measures such as volume? The Agent performs effort on multiple tasks. $L_2$, the task of shaping clay to put on the oven shelves is fairly and easily measureable. In addition, using the volume of objects produced as a performance measure would incentivize the Agent to make many products. However, the task of coming up with an original design for the products ($L_1$) is very hard to measure and the Principal is unable to assess the level of creativity applied until he learns of the customers’ reaction to the designs in the future and their willingness to pay. As explained earlier, in a multi-tasking setting where there exists a precise performance measure of one task, yet the precision of the performance measure of the other task is very low, the Agent will choose to only exert effort on the task that is accurately measured (Hölmstrom and Milgrom 1991). So, when the Principal incentivizes volume, the Agent will not spend any time to come up with creative designs.
2.2.3 Alternate Solutions Proposed by the Management Accounting Perspective

When approaching the issue from an incentives perspective, the solutions that the manager may consider are very different from the solution proposed by an Operations Management perspective, where the plan is to increase the capacity on the bottleneck resource, and may indeed not require such investment.

2.2.3.1 Profit Sharing

Because the creativity in the design will affect the quantity of the products sold and the price at which they are sold, a profit sharing arrangement may offer appropriate incentives to the Agent since profit will drop if creativity in the designs decreases. Profit provides an aggregate performance measure that encompasses both tasks of the Agent, creativity, and volume of production, and incentivizes both as a result. The drawback of this solution, though, is that many other things that are outside of the control of the Agent will also affect profit (e.g., the state of the economy). As a result, the Principal will have to pay a large risk premium to the risk-averse Agent under such an agreement. In particular, this may be prohibitive in very large organizations with many employees.

2.2.3.2 Performance Measurement and the Balanced Scorecard

An alternate solution is to have the management accountant of the firm devise a reasonably precise performance measure of the hard to measure task. In our example, this task involved the creativity of the worker, a hard to measure aspect of performance. However, it would be possible to organize focus groups of customers that provide a bi-yearly assessment of the creativity of designs of the products that workers produced. Such measures can then be incorporated, next to volume, in the incentive pay offered to the Agent. In another setting, one could think about the quality of the produced output being harder to measure than the quantity of the output, yet measures of defects per million in a manufacturing setting or patient satisfaction in a healthcare setting can be collected next to product or patient volume.

Balanced Scorecards will incorporate a measure of each task the Agent is requested to work on (Kaplan and Norton 1992). The Balanced Scorecard is a strategic performance management tool that defines what the Principal defines as “performance” (the tasks to work on) and the target level of achievement on each task, providing a quantification of strategy. Of course, while the Balanced Scorecard offers an excellent way to clearly communicate the company’s strategy to employees, there are some complications that may result in implementation problems. First, it is hard to achieve the right “balance” in assigning appropriate weights to each of the performance measures. The Balanced Scorecard typically includes performance measures of tasks in four different perspectives (financial, learning and growth, internal processes, and customers), but assigning weights to each of these perspectives remains more of an art than a science. Second, even if the management accountant is able to devise a performance measure of each task, it is highly unlikely that every task is measured with the same level of precision. Therefore, the Agent will still prefer to spend more effort on those tasks that are measured with more accuracy, as his effort will directly translate into his performance measurement score.

On the other hand, effort on less precisely measured tasks entails more risk, as there is more noise in the translation from effort to the performance score, and the Agent will choose to spend less time on this task. (The earlier example where there was no performance measure available of the creative design task is an extreme example of this case since the performance measure of this task exhibits infinite noise.) In mathematical terms, the numerator of the likelihood ratio

351
(p(x_i|a^h) - p(x_i|a^l)) is smaller for tasks with less precise performance measures since the performance score $x_i$ is not a good reflection of the level of effort put in. If the difference between $p(x_i|a^h)$ and $p(x_i|a^l)$ is small, an Agent who puts in very little effort can score almost as high on the performance measure as an Agent who puts in high effort. Hence, the Principal cannot distinguish the high effort Agent easily from the low effort Agent, which is very risky for the high effort Agent. Measures with a smaller likelihood ratio are receiving less weight in the incentive pay structure of the Agent, since they attract a larger risk premium.

### 2.3 Push Versus Pull Production

Next, we enhance the basic agency model by introducing multiple Agents, based on a simplified version of the model in Hemmer (1998). Two Agents are working in sequence to produce a finished product. Agent I performs the initial tasks, passes the intermediate product onto Agent F, after which F performs the final tasks.

#### 2.3.1 An Operations Management Perspective on Push versus Pull Production

To the operations manager, the natural question is whether a push or a pull system is preferred. In a push system, Agent I initiates production, while Agent F is simply responsible for keeping up with the flow. In a pull system, the responsibility to initiate production rests with Agent F, while Agent I is responsible for meeting the demand from F. The parameters that enter a decision on whether to organize the production as push versus pull from a traditional Operations Management perspective are the benefits of low inventory holding costs and the ability to rapidly adjust to demand shocks versus low risk of stock-outs and improved information flow. The first two are typically better under a pull environment, while the latter two are typically better under a push environment.

#### 2.3.2 A Management Accounting Perspective on Push versus Pull Production

The incentives and performance measurement perspective may get the operations manager to think about other parameters that impact the choice between a push or pull environment. Typically, the quality of the work of Agent I on the intermediate product affects Agent F’s ability to finish the product. For example, think about Agent I sanding chairs, while Agent F paints them. The smoothness of the sanding and thoroughness of the dusting by Agent I affect not only the quality of the final products, but also the speed with which Agent F can paint the chairs. Under which production organization would it be easier to give Agent I incentives to do a quality job on the intermediate product? Let Agent I be a multi-tasker, who allocates effort to both speed and quality, while Agent F can only supply speed. As before, Agent I’s tasks have different levels of measurability. While the time that each Agent spends is a very precise measure of speed, it is very hard to measure intermediate quality.

Whether or not the operation is organized as a push or a pull system will affect the options management has to incentivize the Agents.

#### 2.3.2.1 Incentives Under the Push System

Under a push system, time is a highly accurate measure of whether Agent F meets contractual obligations, so he can be paid a risk-free flat wage if he keeps up with Agent I’s production. However, since no measure of quality exists, Agent I can only be paid based on volume. Hence, he will
not allocate much effort to quality as that doesn’t impact his incentive pay positively. Following the assumption in Hölstrom and Milgrom (1991), Agent I is benevolent, which entails that he will supply some limited effort on quality “for free,” up to a certain level. This is a natural way to think about Agents allocating effort to things that are not contractually part of their incentive pay. Most humans do wish to be at least somewhat of a good “citizen” in the workplace and will allocate some effort to parts of their job that are not strongly incentivized.

2.3.2.2 Incentives Under the Pull System

Under a pull system, Agent F is assigned the responsibility to initiate production. However, Agent I controls the choice of quality of the intermediate product supplied, thereby affecting the speed of Agent F. Hence, the expected production volume is determined jointly by Agent I’s choice of quality supplied and Agent’s F choice of speed. This means that the production volume now becomes a measure of quality as well. By offering both Agents a contract that is increasing in volume, the Principal can incentivize quality input by Agent I. (One could interpret this as a group incentive whereby the entire team gets paid on the same measure: volume.) Contract parameters can be chosen in such a way that Agent I will exert more effort on quality than the level he benevolently supplies. Because there is no measure of quality in the push system, it is impossible for the Principal to get more than such benevolent level under that production organization. In sum, other parameters than those considered in the traditional Operations Management view now enter into the decision of how to organize production optimally as either push or pull: the level of quality benevolently provided by I, the benefit to the organization of I allocating more effort than this benevolent level to quality, and the productivity of I’s quality enhancing effort.

2.3.2.3 A Measure of Intermediate Product Quality

So far, we have assumed that the quality of the intermediate product is impossible to separately measure. Hence, in the push system no measure of quality is available, whereas in the pull system volume can serve as a measure of quality. Imagine that the company’s management accountant can produce a measure of intermediate quality, such as the evenness of the chair’s surface or the amount of dust remaining on the chair. The noise in this performance measure will determine whether this additional information is of value. However, the level of precision required for the measure to be of value and the yardstick to compare it to are different in a push versus a pull organization. In the push system, the new measure of quality can potentially complement the volume measure of speed. However, the higher the benevolent level of quality provided by Agent I in the push system, the more precise the performance measure of quality should be before the Principal will use it. In the pull system, the new measure of quality is a substitute for the volume measure, which already provides information about intermediate quality. Hence, for the Principal to wish to make this substitution in the incentive pay scheme, the new intermediate quality measure needs to be a more precise measure of this construct than volume.

Consequently, the availability of such a performance measure of intermediate quality (or the creation thereof by the management accountant) determines how operations should be organized. If performance measurement can be done right, pull production outperforms push production, as it can create higher value to the organization by incentivizing more effort on quality. If not, push production outperforms pull production. Hence, performance measurement and incentive systems need to be optimally matched with how production is organized. Empirically, we observe substantial cross-sectional variation in success or failure of companies that adopt pull production, even though the Operations Management mechanics of their implementation are the
same (e.g., Shah and Ward 2003). The (in)ability to match a pull production environment with the right performance measurement system can potentially explain such variation.

### 2.4 Implications for Practice

Broadening the operations manager’s perspective to include incentives and performance measurement increases the number of tools in his toolbox that he can use to improve operations. Operations Management tools such as capacity acquisition and allocation, production scheduling, throughput planning, and organizing production to be pulled or pushed are to be complemented with performance measurement and incentive pay tools, and jointly optimized. Furthermore, variation that may seem random when considering a narrow Operations Management perspective may actually be predictable when the human incentive side of the issue is also considered. The construction of (accounting) performance measures may increase the degrees of freedom that the operations manager has to organize production processes.

### 3 The Importance of Considering Operations When Designing Cost Measurement Systems

Section 2 described how accounting performance measures affect the optimal design of Operations. This section reverses the causality, and develops on how Operations Management choices affect the accounting measurement function. In particular, we will illustrate how the way in which operations are managed can affect the accuracy of cost measurement. Before doing so, we first need to introduce the mechanics of cost measurement.

#### 3.1 The Mechanics of Cost Measurement

In most organizations, costing systems serve many different needs such as product pricing, product line decisions, capacity planning and allocation, performance measurement and control, project scheduling, project selection, and benchmarking. In order to improve decision making and performance management, managers try to understand how costs behave and how cost objects consume resources by means of cost functions. A cost function is a mathematical description of how cost changes with changes in volume or in the level of an activity or process relating to that cost (Labro 2006). Cost objects are the products, services, distribution channels, customers, or any other part of the business that a manager may wish to understand how much of the firm’s resources it consumes. Costing is therefore in essence an estimation or approximation exercise: within a relevant range, management accountants seek to derive a linear function that approximates the underlying true cost behavior. Various cost measurement techniques have been developed to make this approximation.

#### 3.1.1 Traditional Costing Methods

Traditional costing methods estimate cost as a linear function of volume (Horngren et al. 2014). Along with other management experts, Kaplan and Johnson (1987) and Cooper and Kaplan (1987) have claimed that these traditional costing methods were systematically distorting product costs, leading to wrong decisions being taken on the basis of these costs. They critiqued the simplicity of only considering costs to be either variable with volume or fixed and disapproved of the exaggerated use of direct labor hours as an allocation base for the indirect costs in a “new” production environment where fewer hours of direct labor were used. In addition, a bigger share...
of the costs in this “new” production environment was indirect and therefore had to be allocated using some allocation base. Picking the wrong allocation base in this setting has disastrous consequences.

### 3.1.2 Activity-Based Costing

Activity-Based Costing (ABC) was coined as a more accurate costing method where allocation bases are chosen to better reflect the cause and effect relationship in resource consumption patterns. ABC estimates changes in cost as a function of changes in level of activity, where an activity is any discrete task that an organization undertakes to make or deliver a product or service. New cost drivers (factors that cause or drive an activity’s cost; in essence the same as the old term “allocation bases”), other than volume-based drivers such as direct labor hours and direct machine hours, were now used to allocate the cost of the resources aggregated in these activity cost pools. Examples include the number of set-ups to allocate the cost of the set-up activity, the number of purchasing orders to allocate the cost of the procurement activity, the number of machine insertions to allocate the cost of the machining activity, the number of inspections to allocate the cost of the inspection activity, and the number of different components to allocate the cost of maintenance of the Bill of Materials.

The final innovation of ABC was to introduce the ABC hierarchy: an understanding that costs are driven by (and hence variable with respect to) activities that occur at different levels. The typical hierarchy considers four levels: unit, batch, product- (or service-) sustaining, and facility-sustaining. The hierarchical level at which a particular cost is classified indicates when this cost becomes variable. Costs on the unit level are the costs that traditionally are called variable costs and are incurred per unit (e.g., price). Costs on the batch level are incurred each time a batch is delivered or brought to the production line (e.g., inspection and set-up costs). Product-sustaining costs are incurred to enable the production and sale of a particular product (e.g., product design and product advertising). Facility-sustaining costs are costs that are fixed in the short run. They only become variable when the facility is closed down or reduced in size.

This ABC hierarchy helps management identify which costs are incremental for different types of decisions. For example, if the decision concerns whether or not to produce one extra unit of a product, only the unit level costs (such as the material to use in the unit) are relevant. However, for the introduction of a new service to the firm’s service mix, all costs up to the service-sustaining costs (such as service development and service specific marketing) are to be considered.

### 3.1.3 Time-Driven Activity-Based Costing

A more recent cost method innovation is Time-Driven Activity-Based Costing (TD-ABC) (Kaplan and Anderson 2004). TD-ABC was introduced because of a perceived dissatisfaction with the complexity and low maintainability of ABC systems, which were argued to be particularly harmful in industries subject to rapid change. Two simplifications are proposed in this method. First, TD-ABC systems only use time as a cost driver, and hence are particularly suitable for businesses where time spent by the employees and human capital of the firm is a big percentage of resources, such as in the service sector. Cost rates per unit of time of each resource can then be calculated.

Second, TD-ABC introduces the notion of time equations. A time equation collects information on the quantity (in units of time) of each resource that supports an activity that is required to produce a unit of the cost object. Next, the cost rates per unit of time can be multiplied in
Thomas Hemmer and Eva Labro

to calculate the cost of the cost object. While no survey evidence is currently available about
the widespread adoption of this technique, case studies illustrating its use have been published.
The first TD-ABC implementations were mostly in the service sector, such as in healthcare and
banking. Also distribution features TD-ABC implementations, since an understanding of what
drives delivery time is crucial. (Like the number of deliveries, a transaction cost driver doesn’t
capture all the variation in delivery effort that a duration cost driver, like the time spent deliver-
ing, reports.) However, the idea of time as a cost driver can extend to time spent on machinery
or in facilities or warehouses. For more detail on the mechanics of each of these techniques and
numerical examples, we refer to Balakrishnan et al. (2012).

3.2 Operations Management Choices Affecting Cost Measurement Accuracy

With the mechanics of the cost measurement techniques explained, we are now ready to study
how Operations Management choices may affect the accuracy of these costing methods.

3.2.1 Validity of the ABC Hierarchy

Ittner et al. (1997) explain how Operations Management choices affect the validity of the ABC
hierarchy. From an Accounting perspective, the implication of the ABC hierarchy is that total
costs associated with product-sustaining activities are independent of any of the cost drivers
on lower levels in the hierarchy (batch or unit). Additionally, the setup cost of a single batch is
independent of the number of units produced in that batch. That is, for the ABC hierarchy on
which ABC cost measurement is based to be an accurate reflection of the truth, the batch-level
cost should not depend on the size of the batch (volume, or unit-level).

In contrast, decision rules used by operations managers introduce associations among the cost
hierarchy categories and between these classifications and total manufacturing costs. For exam-
ple, Economic Order Quantity (EOQ) models in their simplest form calculate optimal economic
order quantity in units as
\[
Q_0 = \sqrt{\frac{2DS}{H}}
\]
whereby D is demands in units over the time period, S is
the ordering cost per order in dollars and H is the inventory holding cost per unit over the time
period. That is, the optimal batch size \(Q_0\) is a function of trade-offs between order costs (which
are incurred at batch level) and inventory holding costs (which are incurred at unit level). Hence,
EOQ rules used by the procurement function entail that the number of batches is positively
associated with production volume since the total number of batches represents the product’s
production volume divided by the constant reorder point. This invalidates the assumption of the
ABC hierarchy that the batch and unit level costs are independent. Such endogenous produc-
tion scheduling based on EOQ models thus makes variation in costs associated with production
batches empirically indistinguishable from variation due to production volume (Anderson and
Sedatole 2013).

3.2.2 Cost of Product Variety

As a second example, consider the cost of product variety. A big proportion of product variety
costs are accounted for in the ABC hierarchy at product-level as they relate to the spending on
product-specific development resources and marketing campaigns, and as such should be cap-
tured by a well-specified ABC system. However, the choice of operations managers to invest
in flexible automation (or not) also affects a firm’s understanding of its cost of product variety
(Ittner et al. 1997). Firms that are making large fixed cost investments in flexible automation
systems (typically considered facility-level costs) reduce batch set-up costs to close to zero. Firms that are making no such investments and continue to rely on manual set-ups (the costs of which are measured at batch-level) are likely to see a strong association between product variety and batch-level costs.

Firms that have flexible automation systems are unlikely to observe such association between breadth of product offering and batch-related costs. However, in such firms, batch level and facility-level costs are negatively correlated, again invalidating the assumption of independence of levels in the ABC hierarchy. Furthermore, if firms endogenously respond to the need for offering product variety by adopting flexible automation systems, their cost measurement system may underestimate the resulting costs since a regression analysis will not document any batch cost level variation (as these are close to zero) nor any fixed investment cost variation (by definition, since these costs are fixed) that is associated with an increase in product variety.

The way in which operations are organized can also affect the general accuracy of the cost measurement system, defined as the level of error with which cost object’s costs are measured by the costing system. Consider the distinction between a job shop organization and a process shop organization. In a job shop, small batches of a variety of products are manufactured and most of the products produced require a unique set-up and sequencing of steps. In a process shop, larger batches of more similar products are manufactured using a similar setup and common sequencing of steps. These two ways of organizing production are typically considered the extreme ends of a continuum. In a production organization that leans more toward a job shop there is little sharing of resources across products, whereas a system that is closer to a process shop is characterized by a lot of resource sharing with most products making use of the same set of resources (even if the pattern of resource consumption varies somewhat across products).

Balakrishnan et al. (2011) find that in job shops, a more sophisticated cost system with more cost pools is required than in process shops in order to achieve the same overall level of cost measurement accuracy. The reason is the following: At every step in cost calculations, measurement errors can be made. However, some errors may offset. While one error over-costs a cost object, another error may under-cost it, resulting in an overall fairly accurate approximation of the cost of the cost object (Datar and Gupta 1994). The likelihood that costing errors offset each other is much higher in a process shop because the various products share resources, which means that over- and under-allocations are more likely to cancel out. In a job shop, however, the likelihood that errors offset each other is much smaller, and hence a more sophisticated costing system needs to be put in place to achieve the same level of accuracy.

3.3 Implications for Practice

The various prior studies and examples mentioned suggest that to understand the validity of costing assumptions and the accuracy of cost measurement, we must take into account the production environment that is being measured. The same cost measurement technique may produce more or less accurate cost numbers in different environments. Furthermore, operations managers may take deliberate actions to change the way in which production is organized. First, such decisions are likely based on reported costs and hence subject to this measurement concern. Second, these actions to change the Operations Management environment will in turn not only affect the actual (unobservable) resource consumption but also the accuracy and the bias with which the cost system can measure, approximate, and report this resource consumption. Managers should be aware that in some production environments costs are likely to be reported with higher inaccuracy than in others. For example, job shop environments and firms relying heavily on EOQ type ordering policies likely have a higher than average level of errors in reported costs.
4 Directions for Future Research

We see a lot of opportunities for academic research on both the performance measurement/incentives and Operations Management interface, as well as on the interface between cost measurement and Operations Management.

4.1 Service Sector Considerations

We surmise that the importance of performance measurement and incentives in Operations Management will increase even more with a shift away from research studying the manufacturing sector towards the service sector, which has increased significantly in economic importance over the last couple of decades. As a percentage of total inputs, material and machine cost make up a smaller amount than labor in the service sector, so incentives to align human behavior with the strategy of the firm are even more important. Time and cost measurement is of utmost importance in the service sector more generally. For example, they are crucial inputs to effective project planning (e.g., in construction and maintenance). Furthermore, most services resemble a pull environment with the arrival of the client triggering the service and decisions being made by people on the spot when serving these customers. We know from Section 2.3, that getting performance measurement right is of utmost importance in such pull environments. Opportunities for empirical work are potentially bigger in the service sector too, since many service industries are regulated, and regulation typically goes hand in hand with an increase in data availability. Prime examples are banking, healthcare, and airline travel.

4.2 Accounting Information Technology Advances

With rapid accounting information technology advances, informational constraints on what can be measured as a performance measure are relaxed, allowing for changing Operations Management structures that increase value generation. For example, do we empirically observe that when accounting performance measurement quality is improved, organizations shift towards more pull production? While a call for studying how performance measurement affects operations is not new (Melnyk et al. 2004), most Operations Management research has focused on how data quality affects operations decision making (e.g., Hazen et al. 2014).

4.3 Dynamic Cost Measurement in Specific Operations Environments

Further research on how to tailor cost driver analysis and cost measurement to particular operations environments will be fruitful. Here, too, the service sector poses a very different operations environment with different cost measurement implications that we have not studied sufficiently. For example, recently we started seeing more Time-Driven-Based costing implementations (with time spent by resources as the sole cost driver) in human resource intensive sectors such as healthcare and distribution.

Furthermore, Operations Management is in constant flux and over time many changes occur with how operations are organized in response to changing technological, environmental, or demand parameters. Cost measurement has historically taken a very static perspective and makes a snapshot of resource consumption patterns by products or services at a set point in time. Understanding the impact of operational changes on cost measurement and improving dynamic cost measurement are important to further both academic literature and practice.
References and Bibliography


