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Abstract

Purpose – The purpose of this paper is to analyze the applicability of lean accounting and throughput accounting in a company with considerable investments in advanced manufacturing technology (AMT).
Design/methodology/approach – The paper compares lean accounting and throughput accounting with the traditional accounting system the company is using today. The authors investigate the differences between the three alternative approaches and use a case study approach to illustrate the effects of applying different modern accounting approaches in a complex manufacturing setting.
Findings – Pair-wise comparisons of the three approaches provide some interesting cost information as to the role of bottlenecks and value streams.
Research limitations/implications – The specific results of this study are limited to the case company, but can hopefully contribute to further research on how to combine lean and throughput accounting for mixed manufacturing environments, involving both value streams and bottlenecks.
Practical implications – Lean and throughput accounting provide other perspectives on cost information to traditional accounting, and can therefore be used in combination. The authors identify some issues and challenges involved in using lean accounting and throughput accounting in an AMT company.
Originality/value – This paper contributes with a comparison of traditional, lean, and throughput accounting in a specific industrial setting characterized by AMT and complex manufacturing.

Keywords Lean, Theory of constraints, Throughput, Advanced manufacturing technology, Bottleneck, Value stream costing
Paper type Research paper

1. Introduction

Manufacturing firms increasingly understand that their manufacturing strategy has to support their products in the marketplace, in order to stay competitive. Consequently, firms are looking at improvement initiatives to create a successively better alignment between their operations and markets. A wide range of improvement initiatives are available, including lean production and theory of constraints (TOC), to guide the manufacturing firms on the journey from "as-is" to "to-be." When such improvement initiatives are pursued, companies can find that their efforts are undermined by the legacy cost systems of another era (Hutchinson, 2007b; Plenert, 1999). Some companies have reported that implementation of a new strategy has had a negative effect on their performance, and in extreme cases some firms have even blamed such strategies for the company's demise (Hutchinson, 2007b). Quite often, the failure is due to the lack of appropriate control mechanisms after implementation, not due to flaws in the manufacturing strategy itself (Womack and Jones, 1996). Empirical research suggests

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that the management accounting systems rarely reflect differences in strategy, operating environment, or competitive pressures (Fry *et al.*, 1998; Hughes and Paulson Gjerde, 2003). If the firm changes its manufacturing strategy, changes in the management accounting system are required to continuously provide relevant information for manufacturing decision making. Consequently, firms that implement lean production or TOC find that other accounting principles are required.

The case company in this study identified a need to investigate newer approaches to management accounting, since they felt that their current system was not sufficient in providing manufacturing with relevant support for decision making regarding production investments, production allocation, product pricing, and production volume and mix decisions. The company is moving toward lean production, and has a few internal bottlenecks; wherefore both lean accounting and throughput accounting are of interest in this investigation. Also, lean accounting and throughput accounting are gaining interest in the research literature. However, we have been unable to identify research studies that compare lean accounting and throughput accounting in a practical setting. The purpose of this paper is to analyze the applicability of lean accounting and throughput accounting in a manufacturing firm with considerable investments in advanced manufacturing technology (AMT), producing complex components and products. This paper fills a gap related to both theory and practice, by providing a case study using real data that tests the applicability of lean accounting as well as throughput accounting.

This paper is organized as follows. First, we review lean accounting and throughput accounting. Then, we present the methodology and case company. The main section provides a discussion and analysis of the applicability of lean accounting and throughput accounting based on real data from the case company. The paper concludes by providing some implications, limitations, and suggestions for further research.

2. Related literature

2.1 Lean manufacturing and lean accounting

The source of the term lean production can be traced to the International Motor Vehicle Program (IMVP), and was first used by Krafcik (1988). However, the just-in-time (JIT) system or Toyota Production System (TPS) was the forerunner of lean manufacturing (Schonberger, 2007). The first research article on JIT/TPS appeared in Sugimori *et al.* (1977). Later, Womack *et al.* (1990) reported on the results from the IMVP study and offered lean manufacturing as a synonym for the practices pioneered by Toyota; the concepts and techniques under the lean label were the same as those of JIT a decade earlier (Schonberger, 2007). Womack and Jones (1996) provided five lean principles: first, value is defined by the ultimate customer; second, the value stream is the set of all the specific activities required to bring a specific product through the internal value chain; third, flow is about making the value-creating steps flow; fourth, pull refers to using a pull schedule; and finally, perfection is concerned with making improvement a continuous effort.

Lean production differs from traditional manufacturing; consequently, other accounting principles are required. Therefore, a newer approach called lean accounting has been established, specifically for companies with lean operations. The term "lean accounting" appears for the first time in Maskell (2000), stating that "lean management accounting aims to provide information useful to the people in production plants who are actively implementing and sustaining lean manufacturing." Ruiz-de-Arbulo-Lopez *et al.* (2013) provided a review of the history of lean accounting. Lean accounting is not

a particular technique but an umbrella of methods (Maskell *et al.*, 2012), of which value stream costing (VSC) is a key concept. The value stream perspective is central to lean accounting, in that costs are related to the value stream, and the income (profit and loss) statements are established per value stream. Preferably, the value streams are distinctly different between product groups, implying that the individual value stream dictates the utilization of the resources in the value stream. The basic cost-related elements are: VSCs (i.e. material costs and conversion costs); value stream profit (i.e. sales – VSCs); and margin (i.e. value stream profit/sales). The conversion costs capture all other costs than material costs, and can be summarized overall departments that are involved in the value stream into four accounts per value stream: employee costs, machine costs, outside processing, and other costs (Maskell *et al.*, 2012). If needed, other cost types such as distribution costs, support costs, facilities costs, and external overheads can be added to the product cost. Ideally, each resource is assigned to a single value stream, rather than being split among several. If the latter is the case, allocation will be necessary (Ward *et al.*, 2003):

$$\begin{aligned}\text{Value stream cost} = {} & \text{Costs for single resources (materials, employees, machining, tooling)} \\ & + \text{Costs for shared resources} \\ & \times \text{(work centers, departments, production support)} \\ & + \text{Outside costs (subcontracting)}\end{aligned}$$

The cost is primarily established per value stream, but can be transformed to a product cost. The income statement also includes changes in inventory. Maskell *et al.* (2012) mentioned that a number of alternative common methods can be used; if inventories are low, the valuation of inventories is not a big issue wherefore simple methods can be used – however, if inventories are larger, then the valuation needs to be more traditional. Irrespective of method, both material cost and conversion costs are included in the inventory value. The continuous improvements associated with lean production include the systematic reduction of inventory levels, wherefore inventories are assumingly low in lean production systems.

The research literature has so far focussed on case studies, discussing the need and procedures for changing the management accounting system to better suit the lean philosophy (cf. Cooper and Maskell, 2008; Kennedy and Widener, 2008; Maskell and Kennedy, 2007). In some studies, lean accounting is compared with other approaches, such as traditional accounting (Kennedy and Brewer, 2006), and activity-based costing (ABC) as well as "resource consumption" accounting (Grasso, 2005). In a survey of US lean manufacturing enterprises, Rao and Bargerstock (2013) found that the accounting initiatives for lean implementation may be inadequate. However, in other surveys, Fullerton *et al.* (2013, 2014) found a positive relation between implementation of lean manufacturing and the use of lean management accounting practices.

2.2 TOC and throughput accounting

The origin of TOC can be dated to 1979 with the introduction of Optimized Production Timetables scheduling software by Eli Goldratt, with a focus on bottlenecks (Goldratt, 1980; Goldratt and Cox, 1984). Reviews of the TOC literature can be found in Gupta (2003) and Naor *et al.* (2013). The principal tenet of TOC is that within each system at least one constraint exists that limits the ability of the system to achieve higher levels of performance relative to its goal (Watson *et al.*, 2007). Inman *et al.* (2009) found that effective use of TOC elements can improve TOC outcomes and successively

organizational performance. Maximum utilization of the constraint therefore should lead to maximum output from the system. Thus, constraints determine the performance of a system. The constraint should be exploited to achieve the highest rate of throughput possible within the confines of the system's current resources and product demand, optimizing the short-run product mix. Non-constraining resources will by definition have extra capacity. All other resources in the system should be sub-ordinated to the constraining resource, i.e. working at the same rate as the bottleneck. In terms of economic performance, the profit contribution per constraint hour is important. This is similar to variable costing, for which the contribution margin and the ranking of orders in terms of contribution margin per time unit in the bottleneck are key. In both cases, fixed costs are expensed as a capacity cost and are not added to the unit cost. It should be noted that the constraint does not necessarily have to reside within the manufacturing system; it can be positioned in the market or at upstream suppliers (Corbett, 1999; Noreen *et al.*, 1995). In both these situations, the manufacturing system is capable of managing all demand that is put on the system. At the same time, it means that the system has overcapacity and would be capable to increase production if given the chance. A constraint in the market means the demand for the products are lower than the capacity of the manufacturing system, while a constraint in the supply network implies that there are problems in getting the materials in sufficient quantities for manufacturing. It is possible for one product line to have a specific resource constraint, and another product line to have different resource constraint, and a third a market or supply constraint.

The earliest reference to "throughput accounting" as a concept can be traced to a series of four articles in 1988-1989 by Galloway and Waldron, published in the *Management Accounting* journal (Hutchinson, 2007a). Waldron worked for Goldratt's consulting firm, and contributed to the development of TOC, but would later diverge from Goldratt in attempting to reconcile its principles with more traditional accounting analyses (Hutchinson, 2007a). Thus, the idea of throughput accounting originates from the manufacturing philosophy developed by Goldratt. Goldratt and Cox (1984) introduced three plant-level performance measurements: throughput, inventory, and operating expense. Throughput is defined as the contribution that is left after a product's price is reduced by the amount of its totally variable costs. Totally variable costs are those costs that are incurred if a product is created, which typically only includes direct materials, but can include subcontracting costs, commissions, customs duties, and transportation costs. Inventory is defined as all the money the system invests in purchasing things the system intends to sell (Lockamy, 2003). The operating expenses (unlike traditional cost accounting) include direct labor, manufacturing overhead as well as sales and administrative costs. These are treated as period expenses, and are not allocated to products. The operating expenses incurred in a period must simply be covered by the throughput the system generates (Sheu *et al.*, 2003). Later, Bragg (2007) converted these three measures for throughput accounting purposes to five key terms, adding investment and net profit. The definition of investment is the same as for standard accounting rules, and net profit is defined as the throughput minus totally variable cost minus operating expenses. Products that are produced and put in inventory do not count as throughput. The investment in inventory only includes the cost of materials consumed in the production. This approach eliminates any incentive for managers to produce excessive quantities of inventory because they can no longer improve the financial result by "storing operating expenses in inventory" (Bragg, 2007, p. 54).

There is a gradual process of acknowledging the qualities of throughput accounting among practitioners and research society (Naor *et al.*, 2013). The research literature comprises of a variety of comparisons between throughput accounting and other accounting systems. For example, Hilmola (2005), Mehra *et al.* (2005), and Taylor *et al.* (2004) compare throughput accounting with traditional accounting, while Baxendale and Raju (2004), Kee and Schmidt (2000), and Sheu *et al.* (2003) compare throughput accounting with ABC. Some studies even compare all three, i.e. throughput accounting, ABC, and traditional accounting; see e.g. Boyd and Cox (2002), Lea and Fredendall (2002), Lea and Min (2003), and Lockamy (2003). These studies provide perspectives on the relationships between these accounting systems, typically proposing that throughput accounting is generally preferable.

2.3 Comparison of lean accounting and throughput accounting

Two notable similarities can be identified. First, both systems make a distinction between material costs and other costs. Both accounting approaches consider material costs to be the core costs that must be accounted for in the manufacturing system. Throughput accounting considers these to be the only totally variable costs, while lean accounting also includes costs that can be associated with the particular value stream. Second, both systems take bottlenecks into account. For example, Maskell *et al.* (2012) state that: "Generally, the rate of flow through the value stream is determined by the rate of flow of the product through the bottleneck operation within the value stream flow" (p. 205). Thus, the concept of bottlenecks has a role in lean accounting as well, in limiting the flow of the value stream, even though it is not the focal point as in throughput accounting. Still, if the value stream has a bottleneck it must be recognized.

The two approaches differ in terms of the support for decision making in the short and long term. Throughput accounting has been criticized for lacking information for sufficient long-term decision making (Kaplan and Cooper, 1998, p. 135; Kee and Schmidt, 2000; Lea and Fredendall, 2002). Without the full information on product and manufacturing costs it is difficult to make decisions about long-term capacity investments. Throughput accounting is more about getting as much as possible out of the existing production system in the short term with respect to the current customer demand. Lean accounting on the other hand contains costs for the entire product value stream, including all the costs that can be related to the product. Thus, while throughput accounting is limited to short-term decisions, lean accounting is covering the entire spectra from short to long term, with a stronger focus on medium to long term through its philosophy of continuous improvements. Another difference is concerned with the production organization. Lean accounting assumes that product manufacturing is organized in value streams, whereas throughput accounting does not require an organizational change of the production system.

2.4 Synthesis of previous literature

The conclusions that we can draw from the literature review are threefold. First, both lean accounting and throughput accounting are gaining attention in the research literature. Second, while both accounting approaches have been compared with traditional accounting and ABC individually, we have been unable to find research that compare and apply lean and throughput accounting to real situations. Third, there are

few comparative case studies in general that compare two or more accounting approaches. Therefore, this paper contributes with a comparison of lean and throughput accounting in a specific industrial setting.

3. Case study

3.1 Research methodology

This research explores alternatives to a traditional accounting system in a real company. Voss *et al.* (2002) describe case research as an excellent mean to study emerging practices in such a dynamic field as operations management within a company. Yin (2009) suggests that case studies are suitable for this kind of research. Previous research that compare different accounting methods (e.g. Hilmola, 2005; Lea, 2007; Taylor *et al.*, 2004) utilized theoretical scenarios, imaginary manufacturing examples, or simulations to illustrate the differences. This research contributes with a real example from a case company. The company initiated this research to understand what newer approaches to management accounting methods could bring. This is a real company with a real problem related to accounting, looking for new perspectives, and approaches to manufacturing accounting. Therefore a case study approach is suitable from the research perspective.

3.2 The case company – manufacturing and accounting

The case company is active in the civil and military aerospace industry, and develops and produces components in partnership with customers as well as suppliers. The headquarter lies in Europe and the company has a global manufacturing footprint. This study is concerned with the main production site that is co-located with the company headquarters as well as the research and development site. This production site has around 2,000 employees. The facility includes more than 200 machines that are organized into 30 departments. There are five to 15 machines in each department. The company has a broad product mix with about 100 different end products. Many of the products require the machines to be certified to produce a particular product. The company provides maintenance services to its installed base of products worldwide. Consequently, the manufacturing site produces not only regular products but also spare parts for the service division, as well as new prototypes in close collaboration with research and development.

The managerial accounting system is fundamentally the same as when the company was founded in the 1930s. Costs are allocated by labor hours, which have been the most common way of cost allocation during the entire twentieth century. The strategic planning process is budget driven, and actual costs are analyzed in terms of variances from the budget. The annual manufacturing cost per machine is deployed to the planning and control function in terms of the number of production hours that is expected for the year. This implies that the manufacturing cost and production hours per machine derived from the budget dominate the planning and control decisions. Fewer work hours lead to higher costs per hour, while more work hours than budgeted lead to lower costs per hour. Thus, increasing the number of production hours becomes a strong driver for planning and control decisions. However, the company operates fundamentally on a make-to-order basis, which leads to some planning and control problems in a budget-driven setting with a traditional cost accounting system.

3.3 Data collection

One of the authors holds a research position at the company, which greatly facilitated the collection of data. Three products were selected for detailed analysis to represent

diversity with respect to complexity and product demand volume (cf. Table I). Relevant manufacturing and accounting data for an entire year were collected from the enterprise resource planning system, to be applied according to the principles of lean accounting and throughput accounting. The bills of material for these products are shown in Appendix 1, which also displays the number of operations per item number, ranging from one to 39. The total number of operations for these products ranges from 15 to 118. Appendix 2 contains a representative routing example, in terms of the routing for part 284, which belongs to the BOM, level one, of product A306. It should be noted that the product A306 has a total of 62 operations, of which 17 belong to part 284.

4. Applying lean accounting and VSC

Maskell *et al.* (2012, pp. 181-182) state six key requirements for applying lean accounting and VSC. These are listed in Table II, along with the practical aspects for the case study company. As can be seen, the case company has only begun its journey to become lean, even though requirement five is fundamentally fulfilled already.

A few departments can be characterized as having clear and stable flows, a key requirement for lean accounting or VSC. Thus, the current complexity of products and departments inhibits a straight-forward application of lean accounting. Nevertheless, since the company has started a broad-scale implementation of lean manufacturing, it is of considerable interest to the company to understand how lean accounting will work and which requirements it might set on the organization of the production system.

With respect to the high number of products and operations per product, machines and departments, considerable assumptions and adjustments have to be made to apply lean accounting. A lean value stream is defined as a set of processes through which similar products flow. A product will typically visit a few departments; the product is a dominant product for some departments, while for others the product is one of many products. Departments of the first type can be included in the value stream for the products, while departments of the latter type have to be considered as monuments that are shared by a few value streams.

A key idea in lean accounting is to present the profit and loss statement (income statement) in plain English. Furthermore, it is suggested that the number of departments (or similar) is reduced to a few value streams (and one administration department) and that the number of accounts is reduced to a few. Maskell *et al.* (2012) suggest that only five accounts per value stream are used: materials costs, employee costs, machine costs, outside costs (such as subcontracting), and other costs. The case company makes a distinction between raw materials and purchased components for material costs, and specifies tooling costs and production support for other costs, wherefore it was reasonably straight-forward to identify the cost elements for lean accounting. Table III exhibits the total VSCs associated with the value streams of the three sample products. Due to confidentiality, the data in Table III has been scaled.

Table I.
Key characteristics for the three sample products

Characteristic	Product A306	Product B884	Product C305
Demand volume	High	Medium	Medium
Demand variability	High	Low	Medium
Sales revenue (annual)	High	High	Low
Lead time (days)	57	95	25
Number of operations	62	118	15

Lean accounting principle	Case study aspects
1. Reporting needs to be by value stream, not by departments	The reporting is currently done by departments and not by value streams. However, some departments resemble value streams. With respect to the lean implementation at the company, the number of departments that can be treated as value streams is expected to increase over time
2. The people in the company must be assigned to value streams with little or no overlap	Most people working in the production organization at the site are organized into departments (see above). The areas may borrow resources from each other, wherefore individuals are not assigned to a particular value stream
3. There should be few (or no) shared services departments and few monuments	There are a few departments with common resources that are used by all the production departments at the site: welding, washing, and surface treatment
4. Production processes must be reasonably under control and have low variability	There are ongoing improvement projects related to process control
5. There must be thorough tracking of "out-of-control" situations and of exceptions like scrap, rework, etc.	The case company produces components to an industry with heavy worldwide regulations from several different authorities. These regulations force the company to work with a real thorough tracking system for all deviations appearing on the products
6. Inventory must be reasonably under control, relatively low, and consistent	Inventory is reasonably under control and consistent, but not low. There are several reasons for this; complex and expensive products, long production lead times, and contracts with the customers leading to large finished goods inventory

Table II.
Lean accounting principles and the corresponding practical aspects of the case company

Factor	Product A306	Product B884	Product C305
Material costs			
Raw materials	8.761	40.839	20.921
Purchased components	18.543	9.916	0
Conversion costs			
Employee costs	6.369	22.350	3.651
Machine costs	3.613	13.210	1.882
Outside costs: subcontracting	0	250	0
Other costs: tooling cost	112	246	97
Other costs: production support	2.464	5.643	2.129
Total value stream cost	39.864	92.457	28.682
Revenue	45.899	114.335	29.613
Profit	6.035	21.878	931
Profit margin (%)	13.2	19.1	3.1

Table III.
Value stream costing data (all costs are in euros)

Lean accounting provides simplicity in the accounting system for manufacturing systems that can be described as value streams. A particular aspect is the use of "plain language" rather than traditional accounting terminology (such as variance analyses), which is appreciated by non-accounting people. Also, the cost of goods sold is split up into a variety of categories, and in particular between material costs and conversions costs. This strongly facilitates the understanding of how value is added to the products

being manufactured. However, shared resources need to be given specific consideration, since these are not explicitly accounted for in lean accounting.

5. Applying throughput accounting

There seems to be no particular requirements for applying throughput accounting. Instead, it is assumed that all manufacturing systems exhibit some constraining resource, which should be the focal point for planning as well as accounting. For the identification of bottlenecks in manufacturing, all master planners were asked to identify the constraining machine or work center in each department. The identification of bottlenecks was not clear-cut. It turned out that a useful approach was to identify the work center that the department focussed on having up and running as much as possible. Five departments are characterized as having a clear and dominating bottleneck, which is a key requirement for throughput accounting. For these departments, the amount of time that each product requires for processing in the bottleneck is determined. The other departments are treated in a similar way to "emulate" that there is a bottleneck in the department. Even though no machine in these departments is restricting the overall flow in the plant, a "local" bottleneck was chosen as the one needing most careful scheduling.

Only material and outside costs are deducted from the revenue per product to calculate the throughput margin. The throughput margin is then divided by the time required in the bottleneck, which yields the throughput value per time unit in the bottleneck. This value can be used in the short term to evaluate the contribution of each product relative to the utilization of the bottleneck. It should be noted that operating expenses are excluded in these calculations, since operating expenses are considered to be the price a company pays to ensure that it maintains its current level of capacity (Bragg, 2007). Since materials costs are the only costs that are considered to be truly variable, this approach is similar to variable costing with respect to the contribution margin per time unit in the constraining resource.

Table IV presents the costs and margins for the three sample products according to throughput accounting. It shows that all three products have considerable throughput value per bottleneck hour, and are therefore profitable in the short term.

6. Comparing accounting approaches at the case company

Tables III and IV show that VSC and throughput accounting have different foci and are used for different purposes. While VSC aims at capturing all costs that are relevant to the value stream to be used for product costing, throughput accounting does not allocate costs to products, except for material costs. Instead, throughput accounting focusses on cash conversion at the bottleneck, aiming at maximizing the throughput

Table IV. Throughput accounting data (all costs are in euro)

Factor	Product A306	Product B884	Product C305
Revenue	45.899	114.335	29.613
Material costs			
Raw materials	8.761	40.839	20.921
Purchased components	18.543	9.916	0
Throughput contribution	18.595	63.580	8.692
Time in bottleneck resources (hrs)	74.9 hrs	71.9 hrs	14.0 hrs
Throughput contribution/bottleneck hour	248	884	621

contribution per bottleneck hour. The ranking of products differ between the two approaches (cf. Tables III and IV). According to VSC, product B884 has the highest profit margin (19.1 percent), followed by product A306 (13.2 percent), and product C305 (3.1 percent). The throughput contribution per bottleneck hour is highest for product B884 (884 euros/hour), followed by product C305 (621 euros/hour) and product A306 (248 euros/hour). Both approaches thus rank product B884 highest, which indicates that this product is prioritized both in the long term (according to VSC) and in the short term (according to throughput accounting). However, VSC and throughput accounting rank products A306 and C305 differently. Product C305 has a low-profit margin, but a high throughput contribution per bottleneck hour, which is a result of having a much shorter processing time in bottlenecks (compared to the other products) and comparatively extensive processing in non-bottleneck resources (captured by VSC when computing the profit margin). Finally, product A306 has the reverse situation, i.e. relatively long processing time in bottlenecks and less processing in non-bottleneck resources, resulting in low throughput contribution per bottleneck hour but a relatively high-profit margin.

This comparison clearly illustrates that these alternative methods offer complementary perspectives on manufacturing costs. Lean accounting relates the cost to the time spent in the entire flow, while throughput accounting relates operational costs in the production system to the bottleneck. The throughput contribution at the bottleneck is a key aspect for short-term operations planning, primarily the short-term optimization of the product mix. In addition, it does not require that the manufacturing system or organization is designed in a particular way; rather, it can be applied to any manufacturing environment. However, a problem arises when there is no dominant bottleneck or moving bottlenecks that are dependent upon the product mix, as is typically the case in a job shop.

Traditional accounting, lean accounting, and throughput accounting provide three different perspectives on which cost elements are relevant and how to structure the product cost calculations. Even though these three approaches use slightly different terminology, it is possible to compare all three approaches structurally (see Table V). Table V shows the costs for Product A306 in order to illustrate the comparison with real data.

Table V shows that throughput accounting provides the baseline with the material costs. In addition, lean accounting use the conversion costs, concerning employees, machines, subcontracting, tooling, and production support. The current management accounting procedures at the case company further add other costs related to work repair, work modification, and production overhead, as well as surcharges for material, subcontracting, and tools. Consequently, the product costs according to throughput accounting is a subset of the product costs according to lean accounting, which in its turn is a subset of the product costs according to the current accounting approach. This relates to the cost concepts that each approach employ: throughput accounting uses variable cost, lean accounting VSC, while the current traditional accounting approach aims to include the total product cost.

A visual comparison of the full costs according to the three accounting approaches is displayed in Figure 1. Traditional accounting tries to capture any cost that can be related to the product, of which some are related to the product via surcharges. Lean accounting suffices with those costs that can be regarded as VSCs, while throughput accounting focusses on material costs only as being the only truly variable costs.

The cost differences between the three accounting approaches can be interpreted as gaps. Gap 1 is the cost difference between lean accounting and throughput accounting,

and corresponds to the conversion costs. These costs can be fully related to the value stream, according to lean accounting. Gap 2 is the cost difference between the current traditional accounting approach and lean accounting, and corresponds to the costs that the traditional approach captures outside the VSCs. These costs cannot be directly related to the value stream according to lean accounting, but are costs that the company needs to include in the product cost in order to get an appraisal of the full product cost.

Gap 2 provides a measure of the gap from becoming fully value stream oriented. Consequently, the company should strive to minimize or eliminate these cost elements. If this can be achieved, all remaining costs can be considered as conversion costs, wherefore lean accounting can be fully applied.

Table V.
Comparison of the cost structure and elements for product costing for the current approach (traditional accounting), value stream costing (lean), and throughput accounting; the costs for product A306 (in euros)

Factor	Traditional accounting	Lean accounting	Throughput accounting
Cost concept	"Total product cost"	"Value stream cost"	"Variable cost"
Material costs			
Raw materials	8.761	8.761	8.761
Purchased components	18.543	18.543	18.543
Conversion costs			
Employee costs	6.369	6.369	–
Machine costs	3.613	3.613	–
Outside costs: subcontracting	0	0	–
Other costs: tooling cost	112	112	–
Other costs: production support	2.464	2.464	–
Other costs			
Work repair, work modification, production overhead	12.800	–	–
Surcharges			
Material	2.480	–	–
Subcontracting	0	–	–
Tools	0	–	–

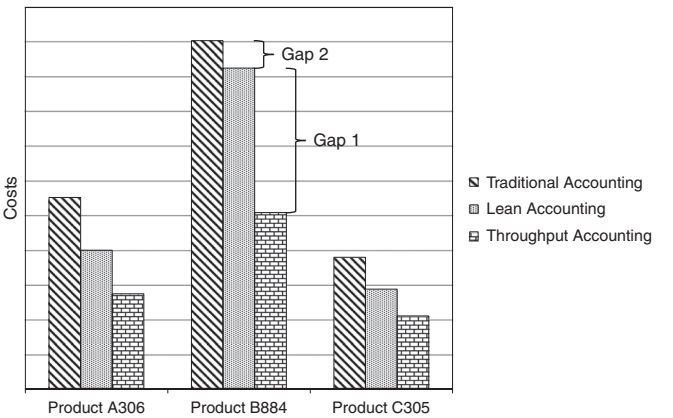

Figure 1.
Cost comparisons between current, lean, and throughput accounting for three products; the two gaps are commented in the text

Gap 1 provides a measure of the cost of running the value stream. These cost elements need to be controlled, such that the throughput contribution (revenue minus material costs) always will cover the conversion costs.

Interpreting the costs from the case company perspective, we see that product B884 can almost be considered as a value stream product, since Gap 2 is relatively small. For product A306 on the other hand, Gap 2 is larger than Gap 1, i.e. the lean conversion costs are proportionally small compared to the "non-lean" conversion costs. This implies that a lot of manufacturing costs are taken outside the value streams, indicating that the process planning of this product need to be rethought in a lean implementation. A similar argument can be made for product C305, since there are a considerable amount of non-VSCs. The material costs are about 50-55 percent of the total product cost for all three products, indicating a high level of value added.

In general, graphs such as the ones in Figure 1 should be of interest to any manufacturing firm that wants to move from traditional accounting toward lean accounting or throughput accounting. Gap 2 indicates the costs that need to be addressed in order to develop value streams, while Gap 1 indicates the costs of operating the value stream.

7. Concluding remarks, limitations, and further research

This paper contributes with a case study where lean accounting and throughput accounting are applied and compared in a real manufacturing company with AMT and complex products. The case illustration shows that neither lean accounting nor throughput accounting provides the full product cost information that the company deems necessary for product cost accounting. The company has decided to continue with the current, traditional accounting approach for internal management accounting. However, separate investigations and analyses that utilize lean accounting and throughput accounting are made on a project-by-project basis. Besides the analyses reported in this research, two recent examples are: first, effect analyses of improvement initiatives; and second, proposals for how to measure and evaluate flow efficiency and resource efficiency. Thus, the company has realized that lean accounting and throughput accounting can provide additional insights that are relevant for manufacturing.

The results of this research are limited to the case company. However, other companies with similar product and manufacturing system characteristics may experience similar problems and may find that both lean accounting and throughput accounting can provide interesting perspectives on product costs and manufacturing-related accounts.

This investigation at the case company raises the question if a combination of these two systems is possible or suitable. Different sections at the case company have different characteristics; some have an established stable flow suitable for lean accounting, while others have dominant bottlenecks suitable for throughput accounting, but with variable flow. Thus, further research is needed on how lean accounting and throughput accounting can be combined, particularly for production systems that are partly lean and partly bottleneck-dominated. A hybrid solution with elements from different accounting approaches may well provide fuller cost information, and is of interest for further research.

Also, research is needed that can identify the problems with applying either approach to a physical manufacturing system that is not fully aligned with the

particular approach, to provide a fuller understanding on the relative merits of each particular approach. In particular, more research is needed to better understand the problems and possibilities of using different accounting approaches for different manufacturing processes.

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Appendix 1

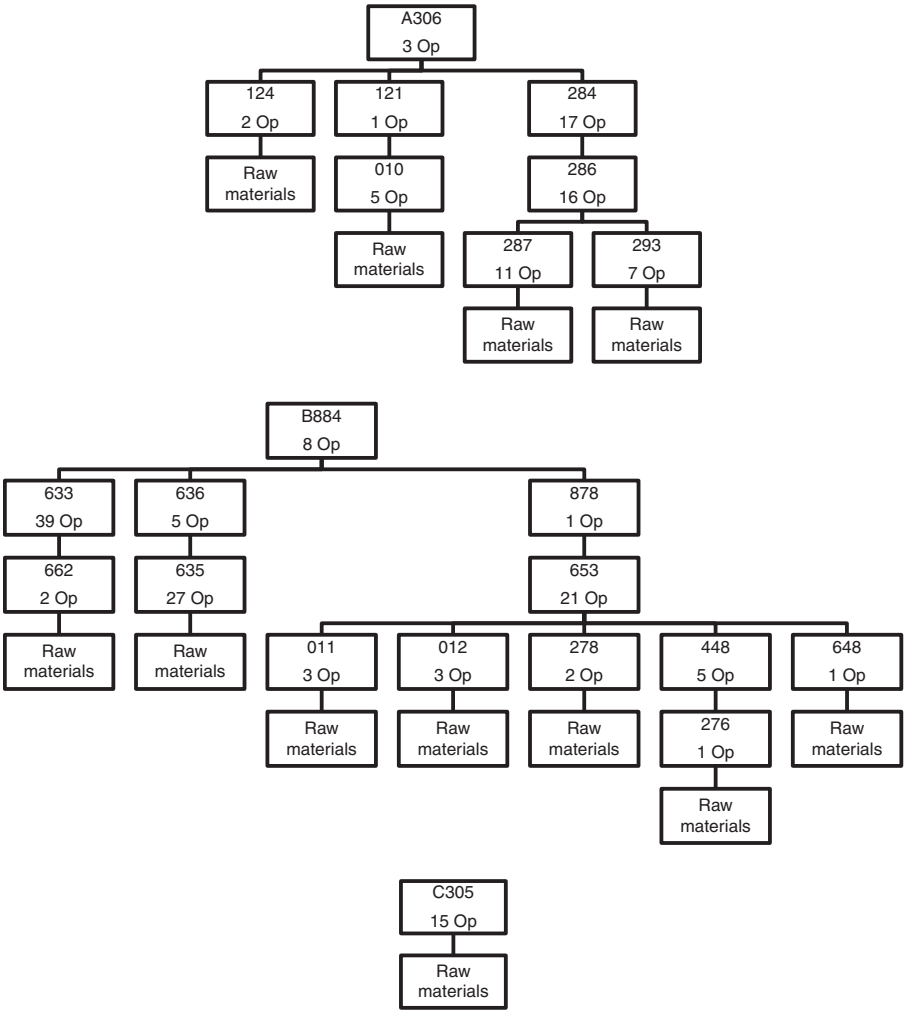

Figure A1.
Bills of material for the three selected products (including the number of operations per item number)

Appendix 2

Table AI. Routing for part 284 (at level one in the BOM of product A306)

Operation	Resource/Department	Processing time	Set up time
100	499/743	0.1	0
200	484/745	7.9	0.5
300	684/745	9.5	0.5
400	734/333	1.0	0
500	497/743	2.3	0.2
600	662/743	1.1	0.5
700	954/333	0.7	0
800	970/340	1.7	0
900	931/332	4.0	0.5
1,000	499/743	3.5	0.5
1,100	497/743	0.2	0.1
1,200	498/743	1.4	0.2
1,300	488/743	3.5	1
1,400	734/333	1.0	0
1,500	946/333	1.3	0
1,600	498/743	1.8	0.2
1,700	499/743	3.0	0.5

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