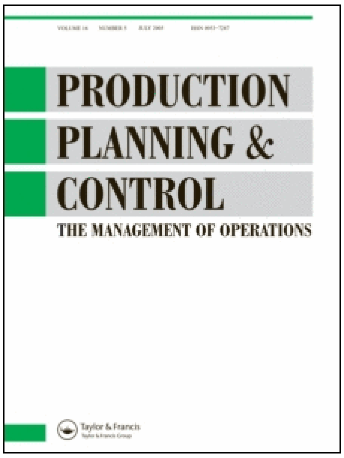

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A practical approach to achieving Agility-a theory of constraints perspective

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A practical approach to achieving Agility – a theory of constraints perspective

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This article documents an action research (AR) project aimed at identifying the practical steps needed to become an agile manufacturer through a combination of the theory of constraints (TOC) and resource- based view (RBV) approaches in a small to medium enterprise (SME) in the Australian manufacturing sector. To date, lean production has been highlighted as a possible catalyst for creating an agile manufacturer, despite the evidence suggesting that lean manufacturing lacks the responsiveness and adaptability to effectively handle a rapidly changing market place and only works well in a stable environment. A more flexible system of production is required to fully encompass the agile characteristics needed to attain a competitive advantage. This research provides empirical evidence that the TOC perspective can be used as a practical approach for becoming an agile manufacturer. The study provides a workable approach for small firms to achieve 'Agility' in practice.

Keywords: Agile; TOC; manufacturing; SME; action research

1. Introduction

The push towards a new paradigm of manufacturing has evolved from the dynamic forces present in today's global markets. Stalk (1998) identified response time as the single most important criterion for achieving a competitive advantage. Huang and Mak (1999) argued that the manufacturing environment is characterised by rapid changes, with these changes ultimately reflected in products and manufacturing processes. These rapid changes have rendered strategic planning alone inefficient due to a kaleidoscope of opportunities, threats, constraints and imponderables that occur in real time (Meredith and Francis 2000). Brown and Bessant (2003) describe today's manufacturing environment as a new competitive landscape that is characterised by ongoing and heightened levels of competition, which demands flexibility, delivery speed and innovation. One of the greatest challenges facing businesses in today's dynamic global competition is how to achieve and sustain a competitive advantage (Teece *et al*. 1997). The era of mass production is coming to an end with the changing nature of markets. Gagnon (1999) put forward that strategic management has moved from a market based to a resource based view of competition. Consumers are looking for customisation as opposed to standardisation and as such businesses need to have the capacity to produce customised products with the cost and efficiency of mass production.

Teece *et al*. (1997) argued that to attain and sustain the competitive advantage, firms could use a dynamic capabilities approach. By dynamic, they refer to the capacity to renew competencies so as to achieve congruence with the changing business environment. The term capability is defined as the key role of strategic management in appropriately adapting, integrating and reconfiguring internal and external organisational skills, resources and functional competencies to meet the requirements of the changing environment. The ability to adapt both the internal resources of a business and its behaviour in the market place can be achieved through the adoption of agile principles. While the literature has defined Agility and identified its characteristics, the question of how to become an agile manufacturer has not been addressed in any great detail. It is posited that through the adoption of the theory of constraints (TOC) as a method of on-going improvement, and the resource-based view (RBV) as a method of identifying strengths and weaknesses, an agile strategy can be achieved.

This article initially reviews the existing research on Agility for the purpose of identifying the gap in the

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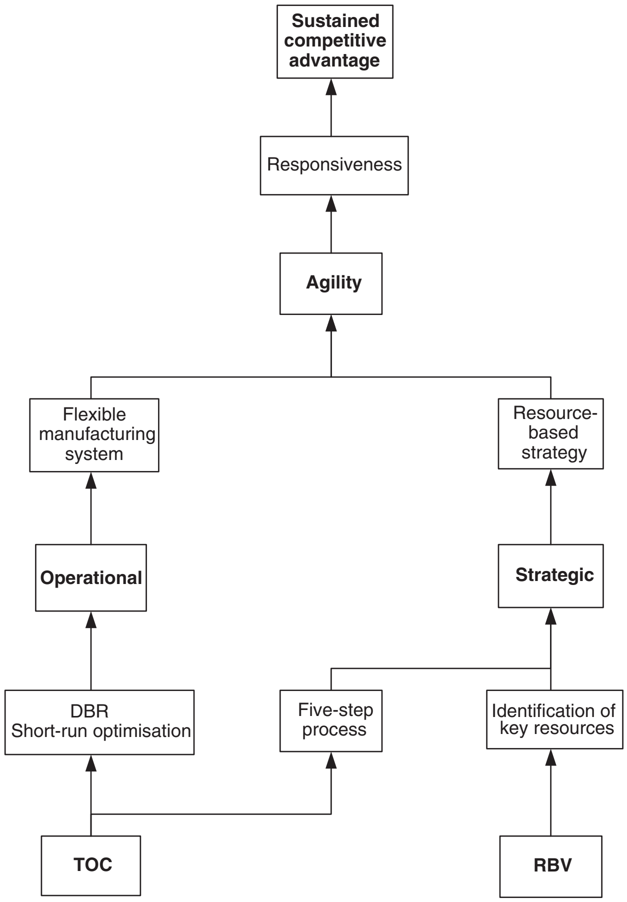

Figure 1. Achieving Agility.

literature, which is proposed to be the practical attainment of Agility. The literature on the TOC and RBV is considered in order to assess their contribution to Agility. The methodology of action research (AR) is briefly defined with an explanation of the specific model used. A conceptual model (Figure 1) is presented outlining the relationship between Agility, TOC and RBV for the purpose of attaining a sustained competitive advantage. This is followed by a case study of a small to medium enterprise (SME) that has achieved Agility through the adoption of the TOC approach. The development of the conceptual model and the case study data collection and analysis was an iterative process with each contributing to and informing the other along the way. The implications for practice derived from the conceptual model and case study are identified and finally the areas for future research are incorporated in the conclusion.

2. Literature review

The literature is presented in two parts. The first section outlines the literature on Agility. The characteristics of Agility as well as its position in a globalised market as a possible strategy for sustaining the competitive advantage are identified. The lack of any research that clearly defines an approach to achieving Agility is highlighted as the gap in the literature addressed through this research. The second section aims at defining the key strategies of the TOC and RBV. The three theories are brought together and evaluated within the conceptual framework.

3. Agility

Economies of scale and the 'low cost' order-winning criterion epitomised under mass production approaches are no longer the best approaches for competitive advantage. Meredith and Francis (2000) found that the price alone is not sufficient to sustain a competitive advantage, stating that new order-winning criteria include the rate of innovation, fitness for purpose, volume flexibility, variety, extreme customisation and above all rapid responsiveness. This view is shared by Soliman and Youssef (2001) who argued that low cost and high quality are merely qualifying criteria and not order-winning criteria in today's markets. Within this dynamic environment, Sharifi and Zhang (2001, p. 773) state that, 'Surviving and prospering in these turbulent situations will be possible if organisations have the essential capabilities to recognise and understand their changing environments and respond in a proper way to every unexpected change'. Thus, a shift in the market preferences has caused a shift in the manufacturing operations due to the new criteria for order-winning.

The view that the era of mass production is coming to an end and is being replaced by a modern, agile manufacturing approach is held by a number of academic theorists. Lampel and Mintzberg (1996) described the environment that led to mass production and noted that management scholars have proposed that we are now entering a new age that involves customisation, new technologies, increased competition and more assertive customers. Sharifi and Zhang (2001) supported the view that manufacturing is facing dramatic changes at an accelerated rate and noted that research has revealed the symptoms of a new era. The inappropriateness of mass production to deal with this changing environment has resulted in the emergence of a new manufacturing paradigm, consisting of lean and agile production and mass customisation (Lamming *et al.* 2000). The shift from mass production to a more agile/flexible system was noted by Duguay *et al.* (1997, p. 1187) as a result of:

> The globalization of markets has created entirely new dynamics of rapid environmental change. Faced with

> these changes, modern mass production today is helpless, notably because of the rigidity associated with several of its distinctive practices.

Sharifi and Zhang (2001) agree that a new paradigm known as Agility is being promoted as the solution for achieving and sustaining a competitive advantage in today's markets. The paradigm shift from mass production to agile manufacturing was noted by Burgess (1994) who, at the time, also noted that the agile paradigm was still ill defined.

Agile manufacturing systems have arisen due to the shortcomings of mass production in dealing with a dynamic and global market. While Agility is still an emerging field, there is a strong body of research that has defined what Agility means and its relative characteristics. McCullen and Towill (2001) trace the origins of the agile manufacturing movement to US defence manufacturing companies switching their no-longer-required capacity to produce commercial products but maintaining the ability to switch back to defence manufacturing in the event of an emergency. McCullen and Towill (2001) also attributed the emergence of Agility to US firms' need to develop strategies to compete with Far Eastern firms that could not be easily copied. The operational origins of Agility as a business concept lie in flexible manufacturing systems, as flexibility is the key characteristic of Agility (Christopher and Towill 2000). Power *et al.* (2001) argued that the concept of Agility is holistic rather than functional and of strategic rather than tactical importance. The view that Agility is holistic was supported by Christopher and Towill (2001, p. 236) who stated that, 'Agility is a business-wide capability that embraces organisational structures, information systems, logistics processes and in particular, mindsets'.

The key characteristic of Agility is to have flexible operations that are able to respond rapidly to the changing environment. Crocitto and Youssef (2003) define agile manufacturing as a relatively newer form of advanced manufacturing technology, with the attributes of flexibility and versatility, increased product development, process modelling capabilities, rapid parts acquisition and adaptation to continually changing customer specifications. This definition is similar to that offered by Mohamad *et al.* (2001, p. 707) in their definition of flexible manufacturing systems, 'Flexible manufacturing systems are state-of-the-art production systems designed to emulate the flexibility of job shops while retaining the efficiency of dedicated production lines'. Having flexible manufacturing, while not fully encompassing the holistic nature of Agility, is the cornerstone to an agile strategy.

With the call for firms to be more responsive to the changing environment, a strategy such as Agility that is based on speed can provide a sustainable competitive advantage (Youssef 1992). The view that through the process of rapid response, Agility could achieve a competitive advantage was supported by McCullen and Towill (2001). Furthermore, Crocitto and Youssef (2003) claimed that this competitive advantage could be sustained through a reputation of innovation and quality, which comes from the implementation of an agile strategy. Furthermore, Meredith and Francis (2000) identified two independent aspects of Agility, one being strategic, which is outward looking in approach; and the second being operational that looks inwardly at processes of production, maintenance and process innovation.

The call for more research on the affect Agility has on the competitive position of a manufacturing firm was made in 1992 by Youssef and to date a complete framework that defines Agility and develops models for its implementation has not been achieved. As Burgess (1994, p. 23) states, 'Despite academic involvement agile manufacturing has not yet entered the literature in any great depth and where it has done so the concept, reflecting its recent origins, remains ill-formed'. Lampel and Mintzberg (1996) acknowledged the shift from mass production to mass customisation and warned that we may be replacing one extreme for another and posited the need to set a strategy along this continuum, with a call for management writers to provide the conceptual tools to aid in this endeavour. With the dynamic, global environment requiring a rapid response for production, specifically for custom products to specific customer requirements, it would appear that manufacturing strategy, Agility and mass customisation would be well documented in the literature. However, as Brown and Bessant (2003) found, to date the link between manufacturing strategy, Agility and mass customisation has not been addressed. These authors (Brown and Bessant 2003) have put out a call for future research including the, 'identification/development/elaboration of tools and techniques to help configure the organisation to deliver the requisite Agility'. Research reported herein is based on the proposition that by adopting the TOC the operational side of Agility can be met. Furthermore, by adopting an RBV of the business, the strategic side of Agility can be achieved.

The merging of lean production and Agility has been put forward as a solution to the problem of implementing an agile strategy. A working definition of lean production is provided by Mason-Jones *et al.* (2000, p. 54), 'Leanness means developing a value stream to eliminate all waste, including time, and to enable a level schedule'. Duguay *et al.* (1997) argued that in a stable environment, lean production would out-pace its flexible/agile competitor as there is no need to adapt. Once the environment shifts to unstable or dynamic the flexible/agile manufacturer would out-pace its lean counterpart through the deployment of extra resources. Agility is focused on rapid responsiveness and mastering the market turbulence and requires specific capabilities above and beyond those that can be achieved using lean production. Mason-Jones *et al.* (2000) note that the drive to reduce waste and to maintain level schedule means that the lean companies tend to operate with little spare capacity. And as such, surges in demand will be costly to meet since all the resources along the lean manufacturing plant will need to be increased. It is argued that by replacing lean production with the TOC, a better system of production will ensue. The sprint capacity within the TOC and the identification of the constraint gives the business a greater capacity to meet fluctuations in the market.

4. Theory of constraints and the resource-based view

The TOC is a theory developed by Goldratt and brought to public attention through the 1984 novel 'The Goal'. The underlying process for implementing a TOC approach involves repeating applications of five key steps, ensuring on-going improvement. The five steps consist of: (1) identify the system's bottlenecks, (2) decide how to exploit the bottlenecks, (3) subordinate everything else to the decision in step two, (4) elevate the system's bottlenecks, and (5) if, in a previous step, a bottleneck has been broken go back to step one (Goldratt and Cox 1993, p. 297). The benefits achievable through adopting this approach are reported as being a reduction in lead-time, cycle-time, lowering inventory and improving productivity and quality (Goldratt and Fox 1987, Razaee and Elmore 1997). Balderstone and Mabin (1998) conducted a detailed survey of actual applications of the TOC. This survey of over 100 cases found a mean reduction in lead times of 69%; a mean reduction in cycle times of 66%; a mean improvement in due date performance of 60%; a mean reduction in inventory levels of 50%; and a mean increase in throughput of 68%. Implementing the TOC approach clearly generates significant benefits in key operational variables.

A production system based on the TOC approach is characterised by the implementation of Drum–Buffer–Rope (DBR). DBR is a production process that dictates what, when and how to schedule the production in order to increase the sales and reduce inventory. The drum is the constraint that sets the pace of production, the buffer insulates the constraint from disruptions and the rope is a signalling mechanism that causes materials to be released into production (Blackstone 2001). The rate at which a business can produce goods is subject to the constraint. Assuming that the constraint is a machine, any machine or process before the constraint that produces more parts than the constraint can process will result in a build-up of work-in-process (WIP) inventory before the constraint (Coughlan and Darlington 1993). Scheduling the pace of production to the drum and releasing materials by the rope ensures that production before the constraint is producing enough WIP to keep the constraint working to capacity (Goldratt and Fox 1986). The buffers work as time buffers to protect the constraint by placing enough work in front of the constraint and after the constraint to allow constant production and a buffer of finished goods to ensure on-time delivery (Smith 2000, p. 55). What sets this system at odds with other systems of production is that the non-constrained resources are working below capacity, causing local efficiency ratios to suffer. Yet it is the excess capacity in the non-constrained resources that provides the sprint capacity to adequately respond to a rapidly changing environment, and thus allows the TOC approach to create the flexibility required in truly agile systems.

The merging of lean production and Agility was put forward as a solution to the problem of implementing an agile strategy (Christopher and Towill 2001). While lean production and TOC are congruent in many ways, their greatest difference lies in their opposing view of excess capacity with lean production viewing excess capacity as waste (Mason-Jones *et al.* 2000, McCullen and Towill 2001). Lamming *et al.* (2000) argued that the requirements for Agility might call for extra resources to be made available, which lean production (through waste elimination) does not possess. The sprint capacity and the detailed knowledge of capacity inherent in the TOC production system makes it an ideal candidate to respond to the fluctuations in market demand by maximising the capacity of scarce resources.

The view that resources could dictate strategy was touched upon by early writers (Penrose 1959, Williamson 1979) but the term RBV was coined in Wernerfelt's (1984) article. Wernerfelt (1984) posited that by specifying a resource profile for a firm, it is possible to find the optimal product/market activities as opposed to working from current products/markets to determine resource commitments. Furthermore he argued that looking at a firm in terms of its resources would shed a different light with respect to strategy formulation. Towards the later part of the 1980s and the early 1990s the RBV received increased academic attention (Barney 1991, Barney 2001), with the effect being the mushrooming of the RBV into an accepted view of the firm (Fahy 2000). The view that the competition is based on resources as opposed to products is not a recent idea and was put forward by Mintzberg *et al*. (1998, p. 275):

> The idea that it is not products which compete in the marketplace but systems of production is not new. Economists have long held that the efficiency of a production system plays a central role in competition. What few economists fail to appreciate, however, is the degree to which such advantage could be firm specific – that uniqueness may be at the root of strategic advantage.

With the adoption of the TOC, a business is maximising the return of its scarce resources (Noreen *et al*. 1995) and gaining the benefits of a reduction in lead-time, cycle-time, lowering inventory and improving the productivity and quality (Goldratt and Fox 1987, Razaee and Elmore 1997). By identifying the production system as a source of competitive advantage and aligning this resource with the market by highlighting the management processes that facilitate this alignment, a business can gain a long-term competitive advantage by combining the TOC and the RBV to form an agile strategy.

5. Methodology

The research methodology adopted in this project was action research (AR). It can be defined as 'a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview' (Reason and Bradbury 2001, p. 1). Thus, AR allows the construction of theoretical solutions and the testing of these solutions. Vinten (1994) described AR as a grounded method rooted in the realities of a situation and is best described as a concept, a philosophy, an emancipatory process and a methodology of learning. The essence of AR is to solve a practical problem and develop knowledge through a process of action. The dual cycle presented by McKay and Marshall (2001) recognises these dual goals by providing two cycles that can be superimposed to satisfy the practical problem and the research output. The cycle involves the following iterative cycle: problem identification, reconnaissance/fact finding, planning, action steps, implementation, monitor in terms of problem solving efficacy and evaluation. Following the evaluation step a decision is then made to exit the cycle if the outcomes are satisfactory or amend the plan and initiate the action steps. AR is eclectic by nature as there is no one method to follow (Badger 2000, Mumford 2001). The data collected for this research utilised a mixture of observation, interviews and cooperation, and document review. One of the authors spent considerable time working with the firm in question (AEM Pty Ltd), for, as Kock (2003) argued, an organisation can be more deeply understood if the researcher is part of it.

6. Conceptual model

The two interlinked research questions driving the research reported herein are as follows:

RQ1: Can a strategic performance measurement system, consistent with the TOC, focus on Agility as a long-term strategy?

RQ2: Can a management framework consisting of the TOC, RBV and Agility perspectives provide a framework for process improvement and innovation?

Combining the concepts of TOC, RBV and Agility creates the necessary direction needed to drive the process improvement towards Agility. It identifies the key resources vital to sustainable competitive advantage and identifies the necessary improvements and innovations through the RBV. The five steps of the ongoing improvement within the TOC provide the practical steps for achieving process improvement and innovation. The theoretical progression from the gap in the literature to the research problem of achieving a sustained competitive advantage is presented in Figure 1. A further explanation of the relationships between these concepts follows.

The operational aspect of Agility (Figure 2) can be achieved through the implementation of the TOC via DBR and the short-run optimisation of the scarce resources. AEM showed improvements to lead times, throughput, quality and delivery performance congruent to that found in the literature (Goldratt and Fox 1987, Razaee and Elmore 1997, Balderstone and Mabin 1998). Adding to these improvements in short-run characteristics, DBR creates a flexible production system, which is noted as the cornerstone of an agile strategy (Christopher and Towill 2000, Crocitto and Youssef 2003).

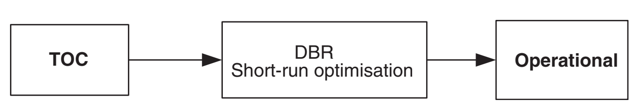

Figure 2. TOC–Operational.

The use of throughput information to make tactical decisions as set out in RQ2 adds to this link. By focusing on constraints, AEM was able to harmonise the part and product variations, which led to both time and cost savings. Time savings occurred through the outsourcing of constraint time. Prior to the improvement projects carried out in the outsourcing strategy, it was not price competitive to outsource the parts and process them due to the variation of parts. By harmonising the variations, similar processes could be outsourced to companies with laser cutting, casting, and machining centre technologies. These changes resulted in numerous cost savings, which had a direct impact on the bottom line. More importantly these changes increased available constraint time and by definition the total capacity of AEM. An improvement process that increases capacity and reduces costs was a win/win strategy that improved the operational effectiveness of AEM. It is through understanding the constraint and the ability to exploit and elevate it that drives flexibility, which is crucial to the operational aspect of Agility.

The TOC focuses on the bottleneck and subordinates all other resources to improving throughput at the bottleneck. It is this narrow scope that led to the criticism of the TOC as just a short-run optimisation tool (Kaplan 1990, Yahya-Zadeh 1999). One of the difficulties in applying the TOC is to know when to improve non-constrained resources that are not easily related to the bottleneck. The RBV may be able to prioritise improvement projects and areas for improvement. The project to streamline the order cycle time example presented in the case study provides evidence to support this view. The nature of the improvement project will in effect determine whether it is operational or strategic; however, the framework for improvement remains unchanged.

The strategic aspect of Agility can be achieved through a combination of the TOC five-step process and the identification of key resources via the RBV (Figure 3). Resources identified as key to sustaining the competitiveness of the business can be improved via the five-step process long before they become bottlenecks. This process not only increases the scope of the TOC, but also provides a strategic continuous improvement plan. The identification of key resources took place during the creation of a balanced scorecard where employees were asked to list the resources that they believed created a sustainable competitive advantage. These key resources are also discussed at the board level. The TOC five-step process of: (1) identifying the constraint, (2) exploiting the constraint, (3) subordinating all the resources to the decision made in step two, (4) elevating a constraint and (5) repeating the process can be applied to the key resources as follows. A key resource will only be advantageous to a company if it can be engaged for the purpose of achieving the organisational goals. In the case of AEM, the goal is akin to the TOC goal of making money now as well as in the future. To engage a resource which involves the implementing processes, the TOC can be applied to speed up that process by applying the five steps. This process can be performed systematically on the key resources to maintain these as opposed to waiting until they become constrained resources. This moves the TOC away from purely reactionary bottleneck management to a strategic tool designed to strengthen the organisation's key resources.

By both identifying and improving the key resources, AEM is able to build on its strategic strengths. This ensures that the characteristics that create a competitive advantage are sustained. It is this process that was successfully applied to AEM that has led to the attainment of Agility and the continuous improvement process of sustaining the key resources that provide a competitive advantage.

Agility has two independent aspects: operational and strategic (Meredith and Francis 2000). Both aspects need to be fulfilled in order to attain Agility (Figure 4). The operational aspect provides the flexible manufacturing system that includes the processes surrounding production. The reported success in terms of lead-time reduction, visibility, delivery performance, and cost savings are typical of the TOC success stories in the literature (Goldratt and Fox 1987, Razaee and Elmore

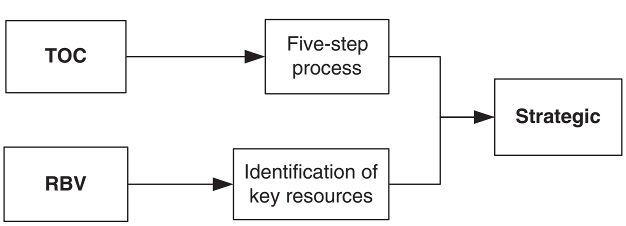

Figure 3. TOC/RBV–Strategic.

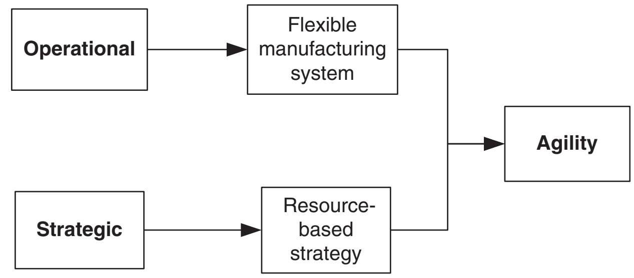

Figure 4. Strategic/Operational–Agility.

1997, Balderstone and Mabin 1998). Without the addition of an agile perspective, AEM's production system would continue to be classified as a flexible production system for the fact that it produces customised products at mass production rates. The benefit of incorporating the TOC philosophy to all operational decisions enables AEM to make fast tactical decisions in response to the market forces.

The strategic aspect is achieved through the adoption of resource-based strategies to maintain and exploit the characteristics of speed and responsiveness. The performance measurement principle of what gets measured gets done (Smith 2000) is highly relevant in this argument. By identifying the key resources and measuring, it communicates what aspects of the company are deemed important to all employees. The reduction of order cycle time (time from the receipt of an order until it is ready to be scheduled) from 16 to 3.5 days as well as the reduction in issuing schedules from 1 week to 1 day highlights the increase in responsiveness of AEM. This increase in responsiveness was a result of a performance measurement system that identified order cycle time as a key resource.

Finally the research question of achieving a sustained competitive advantage is addressed by adopting an agile strategy, with the key characteristic of responsiveness paramount in a business adapting to its environment. The push towards a new paradigm of manufacturing has come from competitive pressures in global markets. Response time was noted as the cornerstone for achieving a competitive advantage. The manufacturing environment is now characterised by rapid changes, which need to be reflected in products and manufacturing processes. Heightened levels of competition places flexibility, delivery speed and innovation at the forefront of management strategy. The ability to adapt both the internal resources of a business and its behaviour in the market place can be achieved through the adoption of agile principles. While the literature has identified what Agility is and its characteristics it has not addressed, with any great detail, the question of how to become an agile manufacturer. The conceptual model presented in Figures 1–4 addresses the question of how to become an agile manufacturer. This conceptual model was both created and implemented via an iterative process with the key outcomes presented in the following case study.

7. Case study

AEM Australia Pty. Ltd is a small manufacturer of custom-built electrical components and is situated in the outer western suburbs of Sydney. Over the last 8 years the firm has successfully adopted optimised production technology (OPT) software and implemented a TOC approach to production. The firm has also managed to implement a cultural change to fully embed the TOC principles into the company culture. The initial adoption of the TOC and the implementation of OPT software occurred in 1998/99. Since the installation of OPT software AEM was able to iron out the teething problems that were experienced and has now moved to a sophisticated system of manufacturing, marketing and customer service that places it as a leader in its field. Under traditional manufacturing planning, AEM was battling to meet its orders for electrical equipment; with TOC it was able to double its sales and have spare capacity to take on export markets. Inventory was slashed and cash flow dramatically improved. Although TOC has typically been used by large companies, here was a small enterprise successfully implementing the methodology. The reductions in lead times together with the increased control were the two main benefits experienced. For example, products that used to take 20–24 weeks to manufacture are now produced in 6 weeks. Even though the disconnectors and earthing switches (the main product lines) consist of approximately 300 parts and 5000 manufacturing operations it is possible to monitor the progress of these products, even with multiple products being produced at the same time. Towards the end of 2002, AEM had reached a point where it had outgrown existing markets and began implementing an agile strategy in order to increase sales. By 2005, AEM had increased sales by 75% ($7.1 million) and by the end of 2006 sales had reached $12.5 million, an increase of 60%.

As mentioned in the literature (Stalk 1998, Huang and Mak 1999, Brown and Bessant 2003) rapid responsiveness was identified as a key factor for competing in a dynamic market place. Through the adoption of the TOC, AEM has created a flexible manufacturing system that is able to handle a product mix of dozens of custom made electrical switches at any one time; however, the support services such as order processing were not at the same level. Managerial time was spent on reducing the amount of time taken to ready an order for production. It was found that an order spent a great deal of time waiting to be processed and this was overcome by implementing guidelines that dictated the flow of an order and highlighted the priority it should take. As a result order cycle times (time from the receipt of an order until it is ready to be scheduled) were reduced from 16 to 3.5 days for orders not requiring significant engineering design.

Furthermore, by taking a TOC perspective the bottleneck activity in the processing of an order was identified and acted upon. Each manufacturing operation is performed according to an engineering drawing that contains the relevant information on the process as well as the details necessary for control such as part, order and customer numbers. Previously each drawing had to be printed out and then individually marked with the necessary details in order to maintain control. This was a week-long process (for a 6–8 week schedule) that hampered the speed at which orders could be sent to production. Printing technology together with internal IT development was implemented to reduce the time taken to produce drawings with the result that the operation is now being performed in 1 day. Using the TOC alone would not have resulted in the identification of this bottleneck due to scope. Similarly, merely adopting an agile strategy does not provide the necessary steps to identify and solve bottleneck activities. By identifying the agile characteristics of responsiveness as a key resource under the RBV, it enabled the business to consider the ways of improving this resource. Using a combination of these approaches provides the flexibility required for rapid response to rapidly changing customer requirements and simultaneous demands for reducing lead times.

In the pursuit of growth AEM identified its strength via an RBV and highlighted product innovation as a source of competitive advantage. Through the culture of innovation AEM has been able to hold several patents, particularly those for dropout fuselink technology that has been a source of sustained competitive advantage. Following on from this technological innovation, AEM developed and tested a new product for the distribution market while continuing to grow in the existing transmission market. The new product was a simpler design and required a T-plant manufacturing system as opposed to the A-plant system already in place. Under TOC terminology, an A-plant system involves numerous unique parts all coming together to form one final product similar to the shape of the letter A. Alternatively, a T-plant involves the manufacture of common components which break away at or near the final assembly stage to form several products. Furthermore, the new products required a lead time of 10 days from order to receipt of goods and with raw material suppliers offering 14-day lead times a different system of handling the new products was needed.

AEM dedicated three machinists (the bottleneck resource) as well as factory space and a raw material bay for this new product line. Processing the orders in the existing way would have taken too long given the lead time of 10 days from receipt of order to the delivery of the finished product. The new product line required the repetitive manufacture of similar products as opposed to the custom built made to order products. Therefore, it was possible to begin production of the product line up to final assembly that is based upon a forecast. The process involved a continuous flow of raw materials and the manufacture of the product up to a certain point, since all the four variations shared identical base assemblies. At this point the products were completed according to real orders, thus being able to meet lead times that are shorter than the time taken to bring in raw materials.

To add to the complexity of the manufacturing floor AEM also manufactured off-the-schedule items. This term referred to products that were not part of the existing schedule due to the late placement of the order, but were nevertheless manufactured simultaneously. At any given time AEM was in the process of manufacturing a 6–8 week schedule of transmission switches (70% of production), distribution switch gear (20% of production), drop out fuselinks (that required one to two people with resources separate from the above two), as well as off-the-schedule transmission products, which were manufactured using the sprint capacity identified in the schedule. The manufacture of all these products would not be possible in a true lean production system as there would be no sprint capacity to handle the new orders once production is scheduled to capacity.

In a lean manufacturing plant, surges in demand are difficult and costly to meet due to the elimination of sprint capacity, which is erroneously identified as waste. The elimination of all waste to support a level schedule means that in order to increase the capacity, all resources need to be increased across the board. In the case of a TOC production system, such as the one at AEM, the bottleneck activity is identified and as such buying in extra capacity or outsourcing production solely for the bottleneck activity increases total capacity resulting in a more agile system that can handle surges in demand.

A great deal of the push towards Agility in AEM originally came from the managing director; however, recent developments, and calls for a more proactive approach to problem solving, has seen AEM adopt more agile principles throughout the organisation. Production is managed through a daily meeting of middle managers with the main focus on buffer management. The buffers represent WIP before the constraint and act as safety nets to any disruptions to production by providing time in which the problem can be rectified and the constraint can be kept working to capacity. Scrap, re-work, supplier reliability, breakdowns, absenteeism and other unforeseen circumstances disrupt the flow of production. As long as the constraint continues to work to capacity the total output remains unchanged. The sprint capacity of the supporting resources is used to replenish the buffers and overcome any disruptions to the constraint. The daily production meetings are focused on maintaining the buffers and at times require proactive decision making to keep production flowing.

Furthermore, with the exception of the distribution products, no product lines have trends or forecasts to predict the infinite number of product mixes that can arise as a result of a make-to-order business. In order to manage such an elaborate system AEM adopted agile principles through a TOC perspective. As a part of this development, AEM implemented an effective outsourcing policy. The aim of the outsourcing policy was to achieve cost reductions, improve on time delivery, reduce lead times, and increase labour efficiency and availability through standardising the components and assemblies to allow larger, cheaper batch quantities from suppliers and or the stocking of parts along the supply chain. Two examples of the approach adopted by AEM are listed below and involve the common components of disconnectors and switches produced as routine product lines by AEM. The procedure for implementing this strategy is set out below.

7.1. *Procedure*

(1) Identification of similar assemblies
(2) Analysis of components
(3) Identification of dissimilar components
(4) Modification of dissimilar components to standard components
(5) Modification of bill of materials
(6) Entry into the system

7.2. *Projects identified*

A. Disconnector operating handles
B. Overcentres

The disconnector operating handle is a part that is used by every disconnector, the second was an overcentre that is also common in every switch. The engineering department then proceeded on the next step of reducing the number of variations in operating handles and overcentres to the minimum possible variations. The operating handle was redesigned so that one operating handle could replace the twenty plus variations that currently existed. The overcentre redesign led to the creation of five standard sub assemblies. Ninety per cent of the overcentres within the tender contracts could be made by using three to five of these sub assemblies. Material costs and time savings were analysed, which indicated that the strategic outsourcing policy would result in the stated aims of the project. Prototypes of the parts were made and tested and the bills of material were changed and the parts were introduced into the system.

The problem that was addressed in this cycle was how to meet the increasing customer demand given that internal capacity was full. The proposed solution was to implement a strategic outsourcing policy that raised total output and maintained profitability. The changes resulting from the modification of the operating handles and the overcentre reduced the constraint time by 5 hours per product for an increased cost of \$150. This translated to a cost of \$30 for every hour saved at the constraint. Prior to the changes AEM was able to produce 50 switches per month. Saving 5 hours out of every switch translated to 250 hours of spare capacity for that month for a total cost of \$7500. An extra 20 switches could be made in the time saved which would add approximately \$30–50,000 towards the bottom line. In effect these changes increased capacity by 10%.

The \$5.4 million (60%) increase in turnover between 2005 and 2006 was achieved with minimal increases in personnel or operating expense. The rapid growth in production and the administrative capacity was achieved through firstly the identification of key resources and secondly the strategy of making these resources agile through the application of TOC principles.

8. Implications for practice

The practical significance of this conceptual model is dependent upon a shift away from traditional accounting based information to a more dynamic view of manufacturing. With the call for firms to be more responsive to the changing environment, a strategy such as Agility can provide a sustainable competitive advantage. Agile manufacturing systems have arisen due to the shortcomings of mass production in coping with the rapid responsiveness that is demanded by customers. The key characteristic of Agility is to have flexible operations to be able to respond rapidly to the changing environment. A flexible manufacturing system is the cornerstone to an agile strategy; however, this flexibility needs to be present throughout the organisation. The implications for policy and practice are that organisations can replace cost based accounting information, which is incongruent with Agility and responsiveness, with throughput accounting. The use of constraint-based information is aligned with the concepts of time and responsiveness present within the agile perspective.

The idea that there exist alternative performances and accounting measurement systems that can be applied to operations management techniques provides the business environment with a broader range of tools. The practical significance of an SME that has adopted the TOC, abandoned all cost based accounting and has implemented Agility for strategic and operational decision making is of merit. The fact that this SME has experienced considerable growth and has increased its profitability throughout this endeavour is a sterling example of the beneficial financial implications that this research provides.

The conceptual model can apply to non-manufacturing sectors, as the principles of continuous improvement and focused responsiveness to customer demands are common. The notion of identifying the key resources that have the potential to or are currently providing a competitive advantage, applying a continuous improvement strategy and aligning these resources with customer demands is a concept that can be adopted across numerous sectors and regions.

9. Conclusion

The dynamic forces that characterise today's environment call for a new type of manufacturing process; that of Agility. The literature recognises that responsiveness, mass customisation, adaptability, speed and innovation are the characteristics that a business must possess in order to be classified as agile and more importantly the characteristics needed to effectively compete in the market place. This research has addressed a gap in the literature based on identifying the necessary steps and processes required to achieve Agility in a small-to-medium manufacturing firm. The conceptual model provided here is summarised in Figures 1–4 and can provide a roadmap to lead a business towards becoming an agile manufacturer. The case study information provides good evidence to suggest that this process is not only feasible but has been successfully implemented in an SME. The agile characteristics of responsiveness, mass customisation, adaptability, speed and innovation are present within AEM's processes, underpinned by a history of continuous improvement. This improvement was driven by the adoption of the TOC perspective for the purpose of becoming an agile manufacturer. There are two distinct areas for future research. Firstly there is a clear need to further examine the practical application of the conceptual model in both manufacturing and non-manufacturing settings through qualitative in-company research. The second area would be to identify companies who have successfully adopted the TOC and gather data on the comparative competitive strategies that have been adopted by these firms. Both avenues of research can contribute to knowledge in the areas of strategic management, performance measurement and operations management, as well as providing improved pathways for practical implementation of TOC to achieve operational Agility.

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