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ORIGINAL ARTICLE

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Supply chain management program first- and second-order effects model: a new strategic tool

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Abstract Utilisation of supply chain management (SCM) strategies have an implicit objective of gaining an advantage over one's business arena partners, whether they be competition or supply chain partners; an SCM-derived competitive advantage. A literature review accentuated four bases of strategic competition (cost-based, resource-based, time-based and knowledge-based), upon which, such an SCM-derived competitive advantage might be built. A Monash University qualitative research study found that the majority of small- to medium-sized firms have found this to be a risky and unprofitable endeavour. In response, this paper explores the four bases of strategic competition through an exemplary success case found within the Australian textiles, clothing and footwear (TCF) industry. The research raised a proposition stated as "effective supply chain management increases shareholder value (SHV)." An effective SCM program influences key success drivers (e.g. expenses, asset utilisation and process cycle time) available to it in a manner that maximises the firm's competitive position, given its chosen strategy. This paper presents a first- to second-order SCM effects matrix model as a small step towards the mainstream achievement of current world-wide best SCM practice. The matrix can be utilised by individuals planning supply chain change processes or teams evaluating potential change initiatives within their supply chain operations. The substructure of the matrix is examination by isolating just the time-based strategic key success drivers, as found in the literature. The matrix's utilisation methodology is detailed to enable its application by practitioners.

Keywords Supply chain management · Competitive strategy · Program implementation

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1 Introduction

Ongoing research on supply chain management (SCM) at Monash University, Australia, shows that a major share of the Australian firms surveyed implementing SCM programs failed to achieve positive cost/benefit outcomes. In an endeavour to remedy this issue, a very simple technique was generated that facilitates practitioners' efforts to create positive SCM program cost/benefit outcomes. The simple technique was developed upon other contemporary SCM tools found in lean production tool kits, such as the fishbone diagram, and a literature review of SCM development. Management of a firm's supply chain has been known to mitigate various issues, such as revenue leakage, poor resource allocation and market response inertia. It is only prudent to manage a firm's cost drivers at their source throughout the supply chain to optimise the firm's fiscal/operational benefits/risks. An intrinsic functionality of SCM, be it implicit or explicit, is to increase shareholder value at the firm level; namely, generating risk-homeostatic increases in returns, growth and capital through increasing total revenues and decreasing costs relative to revenues [1]. Contemporary SCM strategies to accomplish this function include concurrent engineering in new product development (NPD), electronic commerce/business, lean/agile manufacturing, mass customisation, strategic alliances and value stream integration [2–8]. SCM programs must exhibit scope in addition to depth [9] and create economic value for shareholders while crafting an open, trusting corporate culture [10] to achieve strategic, sustainable value-adding changes. SCM as a firm-level strategy has been commonly practised for more than two decades [11]. However, only a few leading firms have developed their SCM models to become sophisticated enough to operate at the value stream level [12], such as the global automotive industry that utilises keiretsu supply partnerships [13].

Pine [6] argues that markets are becoming so significantly turbulent, that these SCM models, which originated from either Henry Ford's mass production or Toyota's lean production paradigms, are having their validity challenged by the mass customisation paradigm. This is not the first

time a supply chain/manufacturing paradigm has had its validity challenged. Womack et al. [11] explained lean production's encroachment on and superiority over mass production during the 1960s to the 1990s. Pine [6] parallelled this event with the American System of Manufactures' advance and dethroning the European artisan craft production system during the 1850s to the early 1900s, which, in turn with Taylor's *Principles of scientific management* [14] and Henry Ford's work on the assembly line in the early 1900s, gave rise to contemporary mass production [11]. History also shows that England's artisan craft production, or the "mechanised factory system" as it was known, overwhelmed medieval rural manufacturing techniques during the industrial revolution between the 1760s and the 1850s [15]. Pine [6] wrote, "A paradigm is a powerful tool for ordering information and focussing goals, yet it automatically filters out information contradictory to its world view," and added, "When one paradigm fails, it is time to shift to another." Because of this issue, it is important for practitioners to maintain the various paradigms within the original scope as they address salient supply chain agendas.

With the ascension of each superior paradigm, the dominant interactions between numerous co-dependent variables shifted, giving rise to new forms of competitive strategies and increasing the complexity of practitioners' decision-making:

- During the industrial revolution, England saw surplus labour, surplus capital and accessible supplies of raw materials, which made possible an unprecedented expansion of industry: new markets provided an outlet for its products, the new steam power revolution for manufacturing machines increased a worker's productivity, canal and mechanical transport allowed the rapid and easy transit of heavy commodities at negligible cost and made labour mobile [15]. These forces enabled the English supply chains to develop factory-style towns based on craft production that dominated European markets.
- During the American system ascension, North America saw an explosion of innovation in terms of patents and business ideas with the introduction of interchangeable parts, specialised machines, reliance on suppliers, focus on the process of production, division of labour, flexibility in products due to its focus on processes and continuous technological improvement; the most significant of innovations being the milling machine that progressively eliminated highly expensive manual processes [6]. These factors enabled the American system to enter and dominate international markets in a similar manner as the Japanese manufacturers did during the 1970s and 1980s. As the American system slowly became mass production, a number of new factors were introduced: flow of production, focus on low costs and low prices, economies of scale, product standardisation, degree of specialisation, focus on operational efficiency, hierarchical organisation with professional managers and vertical integration [6, 11].
- Post World War II, Japan could not sustain a mass production supply chain, since its war-ravaged economy was starved of finances for huge capital investments; the USA introduced labour laws which empowered employees, unions and severely restricted managements' right to lay off employees; the domestic market was tiny, especially for the automotive industry, of which, it demanded a huge variety of vehicles; foreign automotive producers were huge and anxious to enter the Japanese market, yet, they were jealously protective of their established markets against Japanese imports [11]. This environment generated lean production that aims to eliminate excessive labour, excessive facilities, excessive inventory, overproduction and unnecessary capital investment, while focussing on creating value-adding activities, achieving economies of scope, process standardisation, multi-skilling, focus on process efficiency, flat organisation with teams of professionals and strategic supply chain alliances [16].

All of these paradigms are fundamentally based on predominately stable market demand characteristics, yet, Pine's [6] research survey shows that this structure is failing. Pine's suggested new paradigm of agile production/mass customisation creates a hybrid between the favourable attributes of craft production, such as the customisation of each product to customer specifications, of mass production, such as economies of scale, and of lean production, such as economies of scope, while introducing new attributes of speed, flexibility, responsiveness and competency [17]. Although the theory of agile manufacturing is suggested as being better suited to the more turbulent markets, its application has not yet been comprehensively tried and tested within the Australian business environment. The Monash University survey also found a number of the other supply chain/production paradigms that have not yet been comprehensively tried and tested either. In a recent government-founded SCM program, a number of firms attempted to implement lean manufacturing principles throughout their supply chain with partial successes. A primary source of SCM program failure was the managers' inadequate knowledge of how co-dependent performance measurement variables (cDPMVs) interacted and the subsequent consequences of their SCM program upon these cDPMVs decisions. These findings have lead to the following two conclusions:

1. There is a need within Australian firms attempting to practise SCM for a management tool that decreases the risk of SCM implementation failure due to inadequate knowledge of cDPMV first- and second-order effects interactions
2. There is a need for an SCM utilisation methodology for the management tool mentioned above

For this purpose, a literature review of current world-wide best practices was undertaken to source the necessary knowledge for the introduction of such a tool and supporting methodology. While practicality was, and still is, a main concern of ongoing research, a preliminary

attempt has been made to examine SCM application and verify validity by analysing case studies found within the survey by Laulund et al. [18]. This paper will discuss the manner in which the research survey was conducted, present the best case study found within the survey, analyse the case study against salient contemporary strategies to draw out the necessary knowledge for the introduction of the management tool and then explain its utilisation methodology.

2 Research method

The research survey's mission was to gain a qualitative cross-sectional analysis of salient SCM issues within the Australian market. Of the 50 firms initially targetted, only 30 (60% of total) were identified as suitable. The firms consisted of one or more of the various echelons throughout Australian supply chains: foundries, fabricators, assemblers, brokers, wholesalers, retailers and service providers. The sample comprised large, medium and small firms within various Australian industries, such as restaurants, consulting, logistics, consumables, automotive, textiles, clothing and footwear. Semi-structured interviews were conducted with each senior manager addressing the issues surrounding the motivation, design, deployment, consequences and future direction of the SCM programs. Outstanding issues raised within these interviews were resolved in follow-up interviews with other senior or middle managers. Consequently, an average of four managers per firm were interviewed. Twenty-seven firms (90% of 30) facilitated site and document inspections to validate qualitative interviewee assertions.

2.1 Research proposition

Although the research study focussed on a number of subjects, this paper will only address the proposition that affirms, "effective SCM increases shareholder value (SHV)." An effective SCM program influences the cDPMVs available to it in a manner that maximises the firm's competitive position, given its chosen strategy. For SCM practices to be considered effective, they must achieve the goals to which they were designed. It is assumed that the goals of SCM practices are strategically aligned with the firm's current competitive position and, therefore, creates greater economic value within the firm. This paper will draw upon the best example found in the research study as a reference frame in which to explore literature and present a tool by which the managers could attempt to validate the proposition within their own business situation.

3 Case study

A firm within the textiles, clothing and footwear (TCF) industry, renamed *Metamorphous Inc.* for the purposes of this paper, was selected as the best example to serve as a frame of reference for further exploration of the literature. *Metamorphous* was a family owned and run manufacturing business, located in the northern suburbs of Melbourne, Australia. *Metamorphous* had experienced declining profits and increasing pressure to decrease their costs with the government's partial deregulation of the TCF industry. The company was hours away from bankruptcy when a large conglomerate purchased it.

First- and second-order effects found within the case study will be listed throughout this example and explained further in the latter parts of this paper. Most first- and second-order effects listed have been explained in great detail within the literature [2, 5, 6, 8, 9, 11, 12, 16, 19–22].

The conglomerate saw great potential profits in modernising *Metamorphous*' operations:

- Traditionally, senior management had always been family, which allowed the rise of poor management practices. Over the last few years, the conglomerate's own people had replaced the senior management personnel and introduced responsible management practices.
- Consultants audited *Metamorphous*' processes and radical improvements had been implemented. The so-called white-collar workers had been relocated to a new building within the same suburb to allow a more effective and efficient lean manufacturing layout within the confining factory.
  Note that the first-order effects included: ↓ supply lead time and ↓ process cycle time.
  Note that the second-order effects included: ↓ expenses, ↑ financial productivity, ↑ inventory productivity, ↑ HR productivity, ↑ asset productivity, ↑ asset utilisation and ↑ delivery on-time in-full.
- To improve upon the antiquated, mechanised bobbin–gear–pulley mills and traditional-paper-based product design, *Metamorphous* implemented solid, standard operating procedures (SOPs), knowledge-management systems and modernised computer-integrated manufacturing (CIM) mills with computer-aided product design.
  Note that the first-order effects included: ↑ HR productivity, ↑ asset productivity, ↓ process setup time, ↓ process cycle time and ↑ knowledge management effectiveness.
  Note that the second-order effects included: ↑ revenue, ↓ expenses, ↑ financial productivity, ↑ inventory productivity, ↑ HR productivity, ↑ asset productivity, ↑ delivery on-time in-full, ↓ process cycle time, ↑ total quality management (TQM) effectiveness and ↑ total productivity maintenance (TPM) effectiveness.
- Professional policies between supply chain partners and computer-aided ordering (CAO) through electronic data interchange (EDI) systems had been established and strong strategic alliances with rival companies had been fostered to desensitise the firm from the industry's widespread poor supplier service levels [23].

Note that the first-order effects included: ↓ expenses, ↑ inventory productivity, ↑ HR productivity and ↓ supply lead times.
Note that the second-order effects included: ↑ profit, ↓ expenses, ↑ financial productivity, ↑ inventory productivity and ↑ delivery on-time in-full.

– The old make-to-stock operations involved pushing 5,000 stock-keeping units (SKU) to stock orders. The new just-in-time (JIT) operations utilised postponement strategies to reduce make-to-stock SKUs to just 500 items for the first half of the company's internal value stream and then make-to-order operations jump to the 5,000 SKUs of finished goods [8, 24].
Note that the first-order effects included: ↓ expenses, ↑ financial productivity, ↑ inventory productivity, ↑ delivery on-time in-full and ↓ supply lead time.
Note that the second-order effects included: ↑ profit, ↓ expenses, ↑ financial productivity, ↑ inventory productivity, ↑ HR productivity, ↑ asset productivity and ↑ delivery on-time in-full.

– The setup time was traditionally 6±2 h and had been reduced to just 30 s. This first-order effect of reducing the setup time also caused the second-order effect of quality defects falling to 6% and a fall of a further 2% was expected as the firm increases its experience with the new SOPs. Another second-order effect involved the reduction of the firm's minimum economic order quantity (EOQ). The firm was traditionally constrained by a minimum EOQ of 800 units, as compared to the new process, which could now economically sustain an EOQ of 6 units. Although rarely is such an order requested due to freight costs, it does demonstrate how focussing on process flexibility through minimising machine setup times could cause substantial operational performance benefits [20].
Note that the first-order effects included: ↓ process setup time.
Note that the second-order effects included: ↓ expense, ↑ financial productivity, ↑ inventory productivity, ↑ asset productivity and ↑ delivery on-time in-full.

– Traditionally, the dye process was subject to extreme quality variations. The knowledge of dye element mixtures was kept in the memory of specific team leaders. Since customers would reject an order if the SKUs were just a few shades off, this presented unacceptable risks on such issues as customer serviceability, quality control, product innovation and succession planning. These inefficiencies demonstrated the need for the implementation of a simple knowledge management system, which consisted of quality being managed by standardised sample comparison and dye preparation techniques. A sample is manufactured in the first run of a given SKU. This is then stored in a folder with a specification sheet. The specification sheet records the exact mix of dye elements among other knowledge elements for other processes. The next time that SKU is run, the operators simply utilise the same dye element mixture and then compare the sample with the first few units through the process.
Note that the first-order effects included: ↑ knowledge management effectiveness.
Note that the second-order effects included: ↓ expenses, ↑ HR productivity, ↑ asset productivity, ↑ TQM effectiveness, ↑ TPM effectiveness, ↑ delivery on-time in-full, ↓ supply lead time and ↓ process setup time.

Metamorphous had been a turn-around success. The firm's customer service had sky-rocketed to the industry's best practice, with increased market share came increased sales volumes and alongside decreased operations' costs came increased net profits.

The *Metamorphous* case clearly demonstrated that various variables depended upon one another and that controlling these variables created unprecedented operational performance for their industry. *Metamorphous* targetted their significant strategic leverage points to capitalise on opportunities and threats within their marketplace. *Metamorphous*' initial work focussed upon refining the few mass production technologies that still presented value-adding potential and planned how to best eliminate the technologies that did not. As a good global citizen, *Metamorphous* sent the antiquated mechanised bobbin–gear-pulley mills to third-world textile mills for less than the price of the logistics. The processes were mapped with an understanding of the new agile production technologies that were to be introduced. A lean production system was established to generate quick performance improvements and allow more time to integrate the agile production technologies and systems with current processes. All of this activity was governed by sound asset-based financial engineering to maintain activity funding [25]. The learning outcomes of this case study and simular SCM success stories are analysed next.

4 Analysis against salient SCM strategies

From this case study, it can be concluded that there was more than one form of SCM strategy implemented. The four main forms of SCM strategy found in the literature include cost-based, resource-based, time-based and knowledge-based strategies. The following section will briefly introduce and analyse *Metamorphous*' performance against each of these strategies.

4.1 Cost-based strategies

The concept of cost-based strategies comprises two main factors [26]: (1) input resources and (2) output resources. Moden [16] reasoned that Toyota's supply chain was a viable business model because it was extraordinarily effective in producing profit via cost reduction and productivity improvement strategies. Toyota implemented a JIT manufacturing system that integrated with CIM

technologies and a strategic electronic commerce system [16]. These systems reduced or eliminated wastes within production, logistics, sales, planning, research and development processes, causing fundamental cost structures to exponentially diminish [16]. These cost-based strategies gave Toyota two forms of cost-based competitive advantage: (1) Toyota generated greater margins per unit than any other firm, so much so that, during the 1973 oil shock, unlike its counterparts, Toyota still generated profits by completely eliminating excessive inventory and labour and (2) Toyota successfully entered international markets by sustaining its sales price lower than overseas competition for prolonged periods. Australian efforts in utilising simular cost-based strategies, such as quick response (QR) has shown significant increases in shareholder value within both the retailing and the TCF industries [27].

Metamorphous' cost-based strategic investments included: the elimination of non-value-adding activities (about 1/3 of all activities) that simply generated costs, the introduction of CIM/CAD technologies that allowed greater production smoothing and flexibility from *production schedule firming* to decrease from 5 days to 8 h, a simple knowledge-management system that eliminated huge quality costs and a reduction in workforce to right-sizing it to the new efficient production system. These investments caused *Metamorphous*' costs to decrease and revenues to increase, which, in turn, generated new economies of scale and scope.

4.2 Resource-based strategies

The concept of resource-based strategies comprises three main factors [26]: (1) resources, (2) capabilities and (3) strategic assets. Resource-based strategies encompass all financial, physical, human and organisational assets used by a firm to develop, produce and deliver its products and services [28]. Lean production or value stream management as an SCM practice presents what could be described as the most comprehensive resource-based SCM program available within the literature to date, as it encompasses all forms of development, planning, implementation, management, strategy, tactics and maintenance [2, 8, 16, 29, 30].

Metamorphous' resource-based strategic investments incorporated: the introduction of a number of new technologies, including a new production layout; experienced professionals from the head office moving into senior management positions; a CAD system for pattern making; CIM mills for the production of sock tubes, high-speed sowing machines in sock assembly; the eventual relocation of the production plant to gain increased capacity in the dye process; and a fundamental shift in supplier relations from antagonistic to synergistic. These investments caused *Metamorphous*' various cycle time elements to diminish, process efficiencies to escalate, costs to decrease, revenues to increase and profits to explode. *Metamorphous* knew that they required flexibility within their resources to compete against domestic and international competition. All of the processes needed to generate good products first time and every time, as the dye process was operating at full capacity. Either the Environmental Protection Agency (EPA) and local council would have to allow an expanded dye process facility or *Metamorphous* would have to relocate their manufacturing plant (which is what they eventually did). By transforming antagonistic supplier relations into synergistic ones, options for sourcing raw materials become available for when suppliers failed to attain a 100% service level. Evidence of the benefit from the synergistic supplier relations filtered through the entire value stream until reaching the retail customer on a number of critical product seasons.

4.3 Time-based strategies

The concept of time-based strategies comprises five main levels [2, 3, 19, 31]: (1) new product development cycle time (NPDCT), (2) total information flow cycle time (TIFCT), (3) total production cycle time (TPCT), (4) total order delivery time (TODT) and (5) total cash cycle time (TCCT). It is assumed within each of these five levels that erroneous or defective flow of processes, tangible goods or finances is precluded. The first three levels operate in parallel with one another and have been one of the foundation pillars of Toyota's competitive advantage [2, 30]. With the advent of new affordable electronic commerce and business information technology systems, TIFCT and TPCT compression became available to firms of smaller capital funding [3, 4], enabling agility in the form of QR within Australian supply chains [27]. TODT compression is a prerequisite for firms intending to establish an agile supply chain [19]. TODT compression enables reductions in inventories, labour, robustness against market demand turbulence, forecasting errors, capital investments and increases alternative business models, make/buy decisions, market responsiveness, customisation alternatives and potential profits within a finite time period [3, 5, 19]. TCCT extends on the TODT by including accounts receivable, as it concludes the firm's cash flow cycle [31]. A firm that can leverage its TCCT could effectively generate benefits similar to Toyota when they reduced total costs relative to revenue under the cost-based strategies.

Metamorphous' time-based strategic investments involved: the introduction and training of new SOPs, new production layout, CIM/CAD technologies, a knowledge-management system and supply chain partnership fostering. The most immediate effect was the reduction in setup time from 6±2 h to just 30 s. The flexibility and production smoothing this availed provided an unprecedented resource-based competitive advantage within the industry. In terms of customer service, for the EOQ to fall from 800 units to just 6 units and its associated lead time reduction benefits generated an overwhelming cost-based competitive advantage within *Metamorphous*, their suppliers and, most of all, their customers that, in turn, generated significantly increased demand.

4.4 Knowledge-based strategies

The concept of knowledge-based strategies comprises five main factors: (1) auditing knowledge, (2) collecting knowledge, (3) nurturing knowledge, (4) disseminating knowledge and (5) creating environments conducive to knowledge development and management [32]. Knowledge-based strategies are the least developed in terms of theoretical basis when compared with the other three SCM strategies. Industry best practice can be found in a number of industries. Toyota utilise a strategic information system that maintains a myriad of market knowledge, such as customer lifecycle milestones, to enable sales representatives to call upon past customers when their children are old enough to drive and offer suitable deals [16]. Toyota also utilised an incentive paper-based ideas generation system within production facilitates to leverage worker knowledge that yielded thousands of profitable ideas per year [16]. A number of the largest consulting firms utilise similar knowledge management information technology systems, which enable every employee to ask every other employee globally for a solution to their customers' problems. *Gatekeepers* manage this knowledge management system by nurturing and disseminating the proprietary knowledge to enable more effective deployment of core business resources. This strategy has created considerable competitive advantage over non-knowledge-management-focussed organisations. A significant number of firms surveyed in the Monash University study were chronically failing to establish contingency knowledge resources within their critical processes. One foundry in the south-eastern suburbs of Melbourne had employees in their late 50 s in all six critical process positions, with no persons being groomed for succession, failing safety protection and no means by which to recover if one of the six should happen to become unavailable for work. The risks associated with such a blatant disregard for knowledge-based strategies created an overwhelming threat, which would only need to take effect, to bankrupt the foundry.

Metamorphous' knowledge-based strategic investments involved: the introduction and training of new SOPs, a simple knowledge management system and a fundamental shift in supplier relations from antagonistic to synergistic. Quality and process timeliness were now known and sustained with minimal effort. As a result, the workers, senior staff and supplier staff were all continuously seeking to the improve time-based, resource-based and cost-based competitive situations. Product designed on the CAD system was offline, simulated and integrated with the CIM mills. This generated an ever-growing resource of knowledge that accelerated future innovations, designs and production routes. The dye process team leaders were no longer restricted to work when customer orders corresponding to their particular production knowledge arrive, nor was production planning constrained to match production schedules to team leader work shifts. Within *Metamorphous*' experience, a hybrid of the four SCM strategies is apparent.

4.5 Hybrid strategies

Utilisation of SCM strategies has an implicit objective of gaining an advantage over one's business arena partners, whether they be competition or supply chain partners; an SCM-derived competitive advantage [6–8, 13, 15, 16, 29, 30, 33]. Each strategy herein influences its own set of the cDPMVs and each strategy's set overlaps with each of the other strategies' sets [26]. When the strategy's influence over the set of cDPMVs is successfully leveraged in alignment with the firm's ultimate strategic plan, given the business situation that the firm operates within, a competitive advantage is achieved [33, 34]. Effective SCM strategies nominally consume significant capital reserves, hence, it would be expected that the gained competitive advantage be prolonged for an extended period [1, 33, 34]. This extended period would allow the capital consumed in the implementation of the SCM strategy to be retrieved, along with further economic profits. As the four SCM strategies herein are all successfully leveraged, as was the case with *Metamorphous*' experiences, each of the competitive advantages re-enforce one another, creating a new level of SHV (Fig. 1).

5 A new management tool: the hybrid matrix

During the Monash University survey, it was observed that managers sought single cDPMV changes in their initiatives, such as reduced setup time or increased return on inventory investment (inventory productivity). Survey analysis indicated that this issue stemmed from managers' difficulty in picturing, understanding or forecasting multiple-schools-of-thought approaches or multiple follow-on effects from their initiatives [26]. Managers were not simply lazy; they were highly skilled proactive professionals who achieved their goals where most would fail; however, their specialities did not include specific actions associated with holistic productivity performance improvement within an SCM context. When the single cDPMV initiative's goal was successfully achieved, the firm

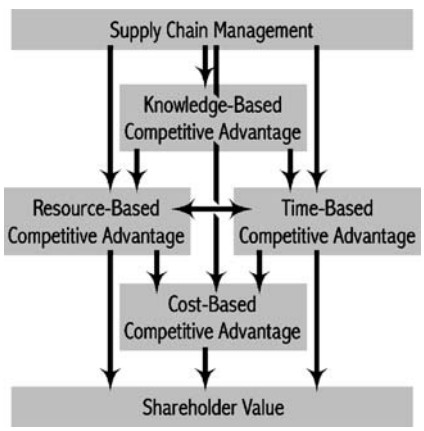

Fig. 1 Supply chain management (SCM) strategies influencing inter-dependent competitive advantages to generate a new level of shareholder value (SHV)

Table 1 Hybrid co-dependent performance measure variables matrix illustrating the potential first- to second-order effects of an SCM program

	Potential second-order effect of an SCM program															
Potential first-order effect of an SCM program	Revenue	Profit	Expenses	Financial productivity	Inventory productivity	HR productivity	Asset productivity	Asset utilisation	TQM effectiveness	TPM effectiveness	Delivery on-time in-full	Supply lead time	Process setup time	Process cycle time	Knowledge-management effectiveness	HR turnover
↑ Revenue	–	3	2	1	1	1	1	1	1	1	1	−1	−1	−1	1	−1
↑ Profit	2	–	−1	1	1	1	1	1	1	1	1	−1	−1	−1	1	−1
↓ Expenses	1	−3	–	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	−1	1
↑ Financial productivity	2	3	−3	–	1	1	1	1	1	1	1	−1	−1	−1	1	−1
↑ Inventory productivity	1	2	−3	3	–	2	2	1	2	1	2	−2	−1	−1	1	−1
↑ HR productivity	1	2	−3	3	2	–	3	1	3	3	3	−1	−3	−2	3	−3
↑ Asset productivity	1	2	−3	3	2	3	–	2	2	2	3	−1	−2	−3	1	−1
↑ Asset utilisation	3	2	−3	3	2	2	2	–	2	2	3	−1	−2	−2	1	−1
↑ TQM effectiveness	1	2	−3	3	3	3	3	3	–	2	3	−2	−3	−3	2	−2
↑ TPM effectiveness	1	2	−3	3	2	2	3	3	3	–	3	−1	−2	−2	2	−2
↑ Delivery on-time in-full	3	2	−3	3	3	3	3	2	2	2	–	−1	−1	−1	1	−1
↓ Supply lead time	−2	−2	3	−3	−3	−2	−2	−2	−1	−1	−3	–	2	2	−1	1
↓ Process setup time	−2	−2	3	−3	−3	−2	−3	−2	−2	−1	−3	1	–	2	−1	1
↓ Process cycle time	−2	−2	3	−3	−3	−2	−2	−1	−1	−1	−3	1	1	–	−1	1
↑ Knowledge management effectiveness	3	2	−3	1	2	3	3	2	3	3	3	−3	−3	−3	–	−1
↓ HR turnover	−2	−2	3	−1	−2	−3	−2	−2	−2	−2	−3	1	2	2	−3	–

nominally failed to leverage new arising benefits with subsequent initiatives. This occurred because managers saw their roles not as entrepreneurial, zealously seeking greater productivity performance, but rather as maintenance of a static enterprise, keeping performance inline with budgetary expectations. Thus, SCM program changes were long, drawn out processes of removing the proverbial onion peel layers of waste and preparing new SCM change programs layer by layer. On the other hand, as compressed changes are completed, they would reveal the ineffectiveness of layer-by-layer approaches.

One avenue to compress the total SCM program change process would be to introduce a tool that imparts managers with the capacity to picture, understand or forecast multiple-schools-of-thought approaches or multiple follow-on effects from their initiatives. The sections that follow shall introduce one such tool, a matrix of salient cDPMVs, as found within the Monash University research study. The matrix was designed to facilitate the application of scope and scale to SCM program change processes. The matrix shall allow speed and knowledge management to govern SCM program productivity performance [34].

The matrix was designed to function as a tool for designers, managers and operators of SCM programs. The matrix has the following five objectives:

1. To increase the value (ROI) and reduce the failure risk of change initiatives within SCM programs
2. To increase the number of realised beneficial follow-on effects by enabling the identification of manageable relationships and the ratification of consequential change initiatives
3. To accelerate the follow-on-effect design process by illuminating key elements (the matrix's cell values) of the complex salient SCM cDPMV relationships in a simple, straightforward manner
4. To enable the various firm hierarchy levels to converse, concerning the complex relationships of the salient SCM cDPMVs within change initiatives by establishing a communication framework
5. To establish a work tool standard to facilitate the capture and nurturing of critical knowledge regarding the salient SCM cDPMVs

5.1 Matrix structural design

Table 1 exhibits 16 cDPMVs, which are vertically listed as first-order effects and horizontally listed as second-order effects of SCM. Each of these cDPMVs are vertically listed as causes of the relationship between themselves and the horizontally listed as effected cDPMVs. Dependent upon its relationship's consequences, a weighting is assigned from barely to highly significant: 1, 2 or 3. Hence, a number 3 weighting signifies that a change in the first-order effect cDPMV would result in a strong change in the second-order effect cDPMV. The weighting is then given a negative or positive sign to indicate a converse or parallel relationship, respectively. Hence, a negative weighting signifies a positive change in the first-order effect cDPMV, which would result in a negative change in the second-order effect cDPMV, and vice versa.

The substructure of the matrix can be understood through the examination of only the time-based strategic cDPMV, which focusses upon total time compression in terms of real time being divided into supply lead time (Eq. 1), idle time, setup time (Eq. 2), cycle time (Eq. 3) and downtime. One of the standard SCM time-based measures assesses the number of customer orders that were delivered on-time in-full (DOTIF) to evaluate the process' market demand sustainability (Eq. 4). The Monash University survey found that, traditionally, firms attempting to implement an SCM program tended to gain localised time compression. Only holistic or total time compression enabled the follow-on benefits of the successful SCM program firms [9]. Research showed that this approach enables the redesign of a number of other cDPMVs. Most of the time-based cDPMV herein have minimisation objectives, thus, achieving total time compression. The only time-based cDPMV that exhibits a maximisation objective is DOTIF.

$$\begin{aligned} &\textit{Supply Lead Time} \\ &\quad = \textit{Time}(\textit{Receipt of Material}) \\ &\qquad - \textit{Time}(\textit{Request Material}) \end{aligned} \tag{1}$$

$$\begin{aligned} &\textit{Process Setup Time} \\ &\quad = \textit{Time}(\textit{Attain Nominal Process Rate}) \\ &\qquad - \textit{Time}(\textit{Initiate Preliminary Process Setup Procedures}) \end{aligned} \tag{2}$$

$$\begin{aligned} &\textit{Process Cycle Time} \\ &\quad = \textit{Time}(\textit{Complete Process Run}) \\ &\qquad - \textit{Time}(\textit{Attain Nominal Process Rate}) \end{aligned} \tag{3}$$

$$\textit{DOTIF} = \frac{\textit{Orders Delivered On-Time and In-Full}}{\textit{Total Number of Customer Orders}} \tag{4}$$

Table 2 exhibits the relationship between these four measures. Specifically, maximising the DOTIF does not necessarily influence total time compression or any of its elements, such as supply lead time, process setup time or process cycle time [19]. However, minimising these time elements and leveraging the yielded time allowances significantly influenced DOTIF in a positive manner [19]. The time elements that constitute the total time are less interactive with one another than they are with DOTIF. Subsequent time elements are slightly influenced by previous time elements. For instance, minimisation of the supply lead time affords the process setup time to

streamline and achieve an overall time reduction. Similar interaction occurs between the supply lead time with the process cycle time and the process setup time with the process cycle time.

5.2 Utilisation of the matrix

The matrix (Table 1) can be utilised by individuals planning change processes or teams evaluating potential change initiatives within their SCM operations. To utilise this matrix, the following methodology should be employed:

1. Map out local processes [8] while taking into account enough holistic processes to avoid local optimisation and holistic sub-optimisation [9, 35].
2. Target specific performance improvement opportunities and threats [9].
3. Identify which cDPMVs are directly influenced by the performance improvement changes. These *first-order effect* variables and their corresponding *second-order effect* variables are isolated on the matrix labelled *primary iteration*. The second-order effects of the primary iteration are the most commonly understood and anticipated, assuming that the performance improvement changes were successful.
4. Identify which cDPMVs are indirectly influenced by the performance improvement changes, namely, those influenced by the primary iteration second-order effect variables. These *third-order effect* variables are isolated on the matrix labelled *secondary iteration*.
5. Identify which cDPMVs are indirectly influenced by all of the *third-order effect* variables. There would be significant overlap of cDPMVs in the majority of performance improvement changes. These *fourth-order effect* variables are isolated on the matrix labelled *tertiary iteration*.
6. Weight the second-order effects with estimation figures. Note: a guess/estimation when the certainty is impossible is better than no guess at all. Weight the third-order and fourth-order effects of the secondary and tertiary Iterations in a similar manner.
7. Pool the weights together to give the anticipated follow-on effect of the performance improvement changes.
8. Measure and record the outcome of this process and the actual outcomes of the performance improvement changes. Over a number of utilisations, the managers' accuracy in estimating performance outcomes would improve relative to their learning curve.
9. Modify the matrix, with increased experience, to become more comprehensive (as this is a very simplistic model) or more focussed towards a particular industry or business situation.

To illustrate step 9, Table 3 shows how a retail store chain might modify Table 2 to consider their particular supply chain characteristics. A retail store chain implementing an SCM program would find that the first-order effects of decreasing the supply lead time (product transported to the store) and the process setup time (product moved onto the store's shopfloor) would generally cause a significant second-order increase in the DOTIF (product available to customer/no stock out). Differing from the matrix (Table 1), only a minor second-order effect increase in the DOTIF would be caused by first-order decreases in the process cycle time (customer picking up product, moving to point-of-sale and purchasing product).

The matrix (Table 1) has been developed from the literature and survey samples of manufacturing firms, for manufacturing firms under Australian conditions. The relationships between the cDPMVs are based on these assumptions and a generalisation of the conditions. For a firm to apply this matrix within their own supply chain requires due diligence regarding discrepancies between their current business situation and this matrix's assumptions. Further, the cDPMVs were selected by identifying salient issues discussed by research interviewees. For a firm to apply this matrix in its current form would be expedient, as the cDPMVs are well documented throughout the literature [1, 8, 16, 19–22, 31, 33, 34, 36, 37]. However, it is recommended that the firm should customise

Table 2 Time-based co-dependent performance measure variables (cDPMVs) matrix illustrating the potential first- to second-order effects of an SCM program

	↑ Delivery on-time and in-full	↓ Supply lead time	↓ Process setup time	↓ Process cycle time
↑ Delivery on-time and in-full	–	−1	−1	−1
↓ Supply lead time	−3	–	2	2
↓ Process setup time	−3	1	–	2
↓ Process cycle time	−3	1	1	–

Table 3 Retail store chain version of the time-based cDPMVs matrix

	↑ Delivery on-time and in-full	↓ Supply lead time	↓ Process setup time	↓ Process cycle time
↑ Delivery on-time and in-full	–	−1	−1	−1
↓ Supply lead time	−3	–	2	2
↓ Process setup time	−3	1	–	2
↓ Process cycle time	−1 (not −3)	1	1	–

or simplify the matrix to increase its ease of use or applicability within the firm's own business situation.

6 Conclusion

The first- to second-order supply chain management (SCM) effects model presented herein is a small step towards the mainstream achievement of current world-wide best practice. The matrix model presents clear distinctions of cause-and-effect relationships between the numerous significant co-dependent performance measurement variables (cDPMVs). It takes into account the inter-relationships between numerous cDPMVs under four bases of strategic competition: cost-based, resource-based, time-based and knowledge-based. Future research objectives includes: to develop a methodology to best disseminate this tool into Australian industries and have the tool provide a common platform upon which SCM firms can establish strategic and tactical SCM program decisions; to gain a deeper understanding of how management use of the matrix affects shareholder value (SHV) in the long term, then to enable accurate SHV benefit forecasting through integrating this understanding into the matrix; and to develop a matrix support management tool that enables the understanding of a firm's strategic competitive positioning in terms of the four competitive bases and facilitates an understanding of resource allocation to tactically achieve that position. Thereby, managers would be enabled with substantial tools in the pursuit of effective SCM outcomes, such as noteworthy SHV increases.

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