THEORY OF CONSTRAINTS: A REVIEW OF PILOT IMPLEMENATIONS IN MANUFACTURING

P. O'Gorman, M. Morgan and J. Neill
School of Engineering, University of Ulster, Shore Road, Newtownabbey, Co. Antrim.

ABSTRACT

Manufacturing organisations are under increasing pressure to compete and survive in the global marketplace. The Theory of Constraints (TOC) has been widely reported in the literature as offering a conceptual framework, methodology and tools for improving an organisation's performance. TOC and its key principles and components are described. The paper then analyses case survey results from a pilot implementation programme in Northern Ireland that commenced in 2000. A new recent survey designed to determine the current commitment levels of those original participants is reported. Results show that of the original devotees in 2000, only a small percentage remains fully committed to the approach. Reasons for the decline in the popularity of TOC are discussed.

KEYWORDS: manufacturing systems, theory of constraints, competitiveness

1.0 INTRODUCTION

Manufacturing organisations in Ireland are under increasing pressure to compete and survive in the global marketplace [1]. The economic well-being of any country is very much dependent of the performance of its enterprises [2]. The Theory of Constraints (TOC) has been widely reported in the literature as offering a conceptual framework and methodology for addressing many of the challenges and problems facing manufacturing industry. This paper presents a case survey analysis of a pilot TOC implementation programme in industry in Northern Ireland and examines its longer-term impact and status.

2.0 THE THEORY OF CONSTRAINTS

2.1 Evolution of the approach

What is now known as the Theory of Constraints (TOC) has evolved through a number of stages over the past thirty years [3]. It has its roots in a scheduling software tool, Optimized Production Timetable (OPT) that was released by Goldratt in 1978 but which reportedly met with modest success [4]. The lessons learned from actual implementations led to the publication of *The Goal* in 1984 in which a more generalised set of tools and principles for managing manufacturing systems was presented [5]. One of the key ideas presented in *The Goal*, the drum-buffer-rope (DBR) concept, appeared in a more detailed format in *The Race*, first published in 1986 [6]. The realisation that problems in the production system may not be solvable independently of the rest of the organisation, in other words the 'problem' may not be a machine but a policy, resulted in the Theory of Constraints [7]. Essentially, TOC consolidated the insight that successful scheduling solutions require that processes be improved and stabilised. Stabilisation of operations requires that counterproductive policies be altered and before that can

be done, these counterproductive policies have to be clearly identified [8]. The late 1980's saw the concept emerging into an even more generalised methodology known as the *Thinking Process* (TP).

Mabin and Balderstone [9] have suggested that TOC consists of two main components:

- performance measurement – operational and financial metrics, and
- performance improvements – the five focussing steps for continuous improvement
  – TP tools for problem solving.

2.2 The TOC Approach

Fundamentally, the TOC approach is the systems approach and it leads the user to adopt a holistic systems view of the organisation. As such, it emphasises 'global' over 'local' issues. Traditionally in most organisations, the emphasis has been on measuring and improving local efficiencies at the expense of the performance and health of the entire system. Systems concepts and thinking can be quite difficult to articulate and relate to everyday systems. It has been argued that one of Goldratt's significant contributions has been to introduce a common vocabulary that shop floor personnel through to senior management can use. This vocabulary is used in the 'throughput world'.

The *goal* for the organisation is to make money now and in the future. Progress towards the goal is measured by three performance measures that are based on the principles of throughput accounting [8, 10]:

- Throughput - the rate at which the system generates money through sales, or revenue less direct materials
- Inventory - all the money the system invests in purchasing things it intends to sell
- Operating expenses - all the money the system spends in turning inventory into throughput.

Progress towards the goal, i.e. system improvement, is achieved by increasing throughput while simultaneously decreasing inventory and operating expenses.

Throughput is typically limited by constraints or bottlenecks in the system. What makes TOC appear such an attractive approach to measuring and improving performance is that, compared with the total number of workcentres, a typical production system has relatively few constraints or bottlenecks. These bottlenecks limit the performance of the system as a whole. Scarce management time can therefore be devoted to these few key constraint resources. The process of continuous improvement is embodied in the five focussing steps:

1. Identify the system's constraint
2. Exploit the system's constraint
3. Subordinate everything else to the above decision
4. Elevate the system's constraint
5. If a constraint is broken, go back to step 1.

Implementation in manufacturing of these five steps is known as the drum-buffer-rope (DBR) production management technique. Once the system's bottleneck is identified, it becomes the *drum* that beats out the pace for the production system as a whole. Since this drum resource determines the throughput of the whole system, step 2 ensures that it is used to its full available capacity by ensuring that is never starved of work. This work-in-progress is the *buffer* shown in Figure 1. Step 3 synchronises the release of raw material onto the shop floor with the beat of the drum, so preventing excessive work-in-progress building up on the floor. The *rope* limits the size of the buffer and the size of the buffer is usually expressed in terms of the time that the bottleneck would take to process it all. To increase the system's throughput, step 4 means that

attention can be focussed on this key resource to increase its rate. Step 5 highlights that this is a continuous improvement approach.

The DBR technique improves the performance of the system in a number of ways. Primarily, it keeps the bottleneck running thereby increasing throughput. In addition, the 'rope' reduces inventory by controlling the timing of the release of WIP onto the shop floor, resulting in shorter lead times and better due date deliveries. Shortened lead times and better due date performance confer a competitive advantage [11]. Since variability and disruptions can not be totally eliminated from the system, others types of buffers are also recommended. One such buffer is the finished goods or shipping buffer. Scheduling is also simplified since, at its most basic, only two key events need be scheduled: the release of the job onto the shop floor and its start time on the bottleneck, as seen in Figure 1.

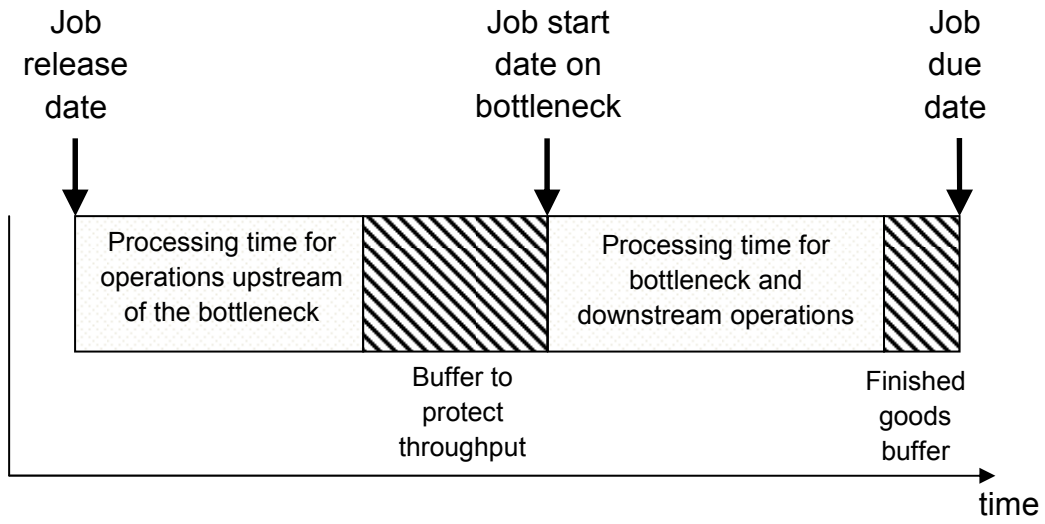

Figure 1 DBR buffers and key scheduling points

3.0 BUSINESS IMPROVEMENT PROGRAMME CASE SURVEY

In 2000, industry in Northern Ireland was invited to participate in an Industrial Development Board (IDB) sponsored Business Improvement Programme that centred on the implementation of the Theory of Constraints [12]. Approximately twenty companies expressed an interest and half became actively involved in the pilot programme. The programme was structured to provide participants with TOC education, help in developing an implementation plan, on-going support and verification of improvements, aided by outside consultants. The programme was funded by the IDB, with participating companies making a lump sum contribution on the achievement of agreed results.

The organisations that participated in the programme were both indigenous and local sites of multinationals. They represented a wide range of industrial sectors including OEM electro-mechanical components, apparel, household furniture, automotive components, customised conservatories, electronic assembly subcontracting and materials for construction/DIY. Company sizes ranged from approximately eighty to six hundred employees.

One year into the programme, improvements were quantified and reported. As part of this current research, anonymised data on the companies that participated were obtained and analysed to assess the impact of the programme overall. Data at the one-year point was available for six of the companies. The findings are summarised in Table 1. The measures of performance for which data were commonly available were; lead times, cycle times, due date performance and inventory. Data on the principal throughput world measures such as throughput and operating expenses, for example, were very sporadic.

	n	Min	Mean	Median	Max
Lead time	5	18	48	50	80
Cycle time	2	10	11	11	12
Due date	5	15	43	40	70
Inventory [a]	4	10	28	52	70

[a] WIP but RM+WIP+FG in one case

Table 1 Summary of reported percentage improvements

Many impressive results were reported, especially considering how early a stage in the programme that the data were recorded. Improvements in these performance measures typically confer significant competitive advantage. However, these improvements are not surprising or exceptional when compared with results from international studies as shown in Table 2. Five out of the six companies reported an improvement in lead time, a much greater proportion reporting this than in Mabin and Balderstone's international survey [9]. The reduction ranged from 18% to 80% with the mean being reported at 48%. A similar proportion to that found in the international survey reported improved cycle times, although the gains were not as significant. As for lead time, a very high proportion of the companies reported improvements in due date performance, the improvements ranging from 17% to 70%. Although the basis on which the metric was compiled has not been clearly explained, the mean improvement, 43%, is very similar to that recorded for other studies, as can be seen in Table 2.

	International Case Survey [a]		Japan [b]	NI
	Mean improvement reported (%)*.	Cases reporting improvement (%)	% improvement after one year (single company)	Mean improvement reported (%).
Lead time	70	50	50	48
Cycle time	65	17		11
Due date	44	37		43
Inventory	49	52	50	28

* quantifiable data was not available for all the cases that indicated an improvement
[a] Mabin and Balderstone [9]
[b] Umble [13]

Table 2 Comparative benefits reported

Results also show two-thirds of companies in the programme reporting a reduction in inventory, the median improvement being 52%, with a mean improvement of 28%. This is somewhat smaller that the mean reduction determined by Mabin and Balderstone. However, the proportion reporting improvements was greater than found elsewhere.

As has been the experience in other surveys, data is not always expressed and presented in throughput accounting measures and this was also the case for the Northern Ireland programme where very little financial data was recorded. This is understandable because transforming a company's systems and procedures to throughput accounting requires a much more significant commitment from the organisation.

It must also be remembered that these improvement data were determined after a relatively short time into the pilot programme. The data relate to companies that were already motivated to seek change and improve their performance. The results should be treated with some caution as there may well be a positive reporting bias inherent in the assessments - not an uncommon phenomenon. It is notable that no TOC failures have been reported in the literature. Despite these points, it is clear that the participants reported positively on the programme.

4.0 SURVEY OF CURRENT STATUS

A follow-up survey was conducted in 2010 to assess the status of TOC implementation in the companies that had participated in the original programme. Three were found to be no longer trading or no longer engaged in manufacturing. In total, five organisations participated in our survey. This survey revealed that although all had used DBR and TOC manufacturing tools, only one was now fully committed to running the organisation according to TOC principles.

Three of the five were very positive about the benefits accrued in the early stages. All reported that TOC was still relevant and useful in their companies but, with the exception of the one noted above, this was largely limited to use of selected TOC manufacturing tools or TOC insight to bottleneck management. Only one company has actively striven to run the plant fully in accordance with TOC principles, including a switch to throughput accounting. This particular owner-managed company has a very successful track record in a competitive high volume market. It is characterised by a strong engineering-led senior management team.

Multinationals, in particular, resisted the transition to throughput accounting which, besides the effort required, would have put the locally-based plants' financial systems at odds with the parents' systems. Respondents generally reported that they considered the programme beneficial in that it acted as an impetus to the introduction of a culture of change and improvement.

Several commented that the lack of a well-established, successful company that they could benchmark against was a significant handicap. This is in marked contrast to the situation with lean manufacturing. All the respondents are now also using elements of the lean approach. When asked to recommend continuous improvement approaches for local industry, the survey showed that there is a clear preference for the effectiveness of the lean approach over TOC as can be seen in Figure 2. TOC is, however, considered an easier system to implement.

The growing influence of the lean approach over the past decade raises the question as to what TOC's role will be in the future. None of the respondents considered that TOC would be central to continuous improvement activity in industry in Northern Ireland. This reinforces the view expressed earlier that they consider lean to be more effective. Research elsewhere has raised concerns that TOC lacks the tools and techniques that are widely used in the lean approach such as 5S, visual management and SMED [14]. However, new hybrid methodologies are emerging that seek to combine the best elements of TOC, lean and other approaches [15].

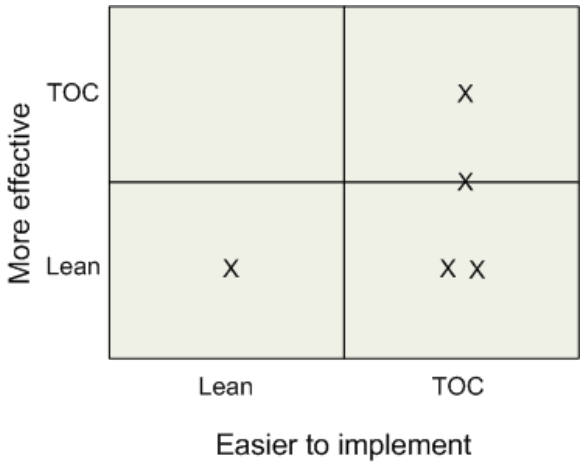

Figure 2 Effectiveness and ease of implementation

5.0 CONCLUSION

Internationally, there are many reported cases of successful TOC implementations. An analysis of data suggests that local companies in Northern Ireland who participated in a pilot programme beginning in 2000 witnessed improvements in key performance indicators, namely, lead time, cycle time, due date and inventory. However, a recent survey has revealed that although TOC thinking and principles still inform to some extent how their plants are run, the majority now see lean manufacturing as a more popular way forward. Rather than regarding TOC, lean and other philosophies as mutually exclusive, it appears that there is now an on-going synergy where industry combines elements of each approach to suit its own particular needs and strategic direction.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the help provided by Invest NI in this work.

REFERENCES

[1] IMD World Competitiveness Yearbook 2010, http://www.imd.ch/research/publications/wcy/upload/PressRelease.pdf, accessed 3/6/2010.
[2] D. Hughes, Ireland's Experience with Measuring and Benchmarking Competitiveness, http://www.oecd.org/dataoecd/56/0/44965470.pdf, accessed 3/6/2010.
[3] S. Rahman, Theory of constraints- A review of the philosophy and its application, *International Journal of Operations and Production Management,* Vol.18, No.4, (1998), 336-355.
[4] T. Fry, J. Cox and J. Blackstone, An analysis and discussion of the Optimized Production Technology software and its use, *Production and Operations Management*, (1994), 229-242.
[5] E. Goldratt and J. Cox, *The Goal*, North River Press, (1984).

[6] E. Goldratt and R. Fox, *The Race*, North River Press, (1986).
[7] E. Goldratt, Computerised shop floor scheduling, *International Journal of Production Research*, Vol.26, No.3, 443-455.
[8] E. Noreen, D Smith and J Mackey, *The Theory of Constraints and its implications for management accounting*, North River Press, (1995).
[9] V. Mabin and S. Balderstone, The performance of the theory of constraints methodology – Analysis and discussion of successful TOC applications, *International Journal of Operations and Production Management*, Vol.23, No.6, (2003), 568-595.
[10] D. Smith, *The Measurement Nightmare: How the Theory of constraints can resolve conflicting strategies, policies and measures*, CRC press, (2000).
[11] G. Stalk, The time paradigm, *Forbes,* New York, (1998), 213-214.
[12] M. Dinham, Bringing TOC to the Celtic Countries, The TOC Times, (2000) available at http://www.goldratt.com/toctquarterly/idb.pdf, accessed 27/05/2010.
[13] M. Umble, E. Umble and S. Murakami, Implementing theory of constraints in a traditional Japanese manufacturing environment: The case of Hitachi Tool Engineering, *International Journal of Production Research,* Vol.44, No.10, (2006), 1863-1880.
[14] R Pirasteh, K. Farah, The top elements of TOC, lean and six sigma (TLS) make beautiful music together, *APICS*, May 2006.
[15] D. Jacob, S. Bergland and J. Cox, *Velocity: Combining Lean, Six Sigma, and the Theory of Constraints to Achieve Breakthrough Performance*, Simon & Schuster, (2010).