Become Lean With TOC, virtually

by VAIDEE SAMPATHKUMAR

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Profit = Selling Price—Cost Price. Elementary, you might say. But if you are a manufacturer trying to keep a lid on costs, take a re-look. Selling Price is fixed by market, by competition and is beyond your control unless you are a monopolist to boot. But cost is something you can control. Even the world's most efficient carmaker is clued into it. Toyota Motor Corp is working on a cost reduction initiative called CCC21 or Construction of Cost Competitiveness for the 21st Century. Toyota's highly effective lean initiative is continuing and they are looking for process improvements. They are trying to remove wastes, link it to their goals etc. But the questions that come to mind are: What are these Wastes?, Where are they?, How do we identify them?, How do we know that removing the waste is going to reduce the cost?, and 'How do we make decisions to invest?'

Dr Goldratt formulated the Theory of Constraints (TOC), which shows that there is always at least one constraint in a system that impedes the system from achieving its purpose. When this constraint is removed, another constraint shows up and impedes the system from achieving its purpose. TOC defines an approach that could be used to manage these constraints. These constraints are processes in which 'wastes' exist, which make the process a constraint. Identifying these processes and then investing in removing wastes from the process that maximum impedes the system is the key to success of Lean. In a complex manufacturing system, these decisions need to be information driven and hence statistical analysis is required. An interesting possibility is that TOC and computer simulation can be used to identify and eliminate wastes, in a complex manufacturing environment.

Lean philosophy

The philosophy of lean production was developed by Dr John Krafcik, based on the work done by him with the International Motor Vehicle Program (IMVP). Dr Krafcik coined the word 'lean' as the practice that provides a method by which an organisation can do more and more with less human effort, less equipment, less time, and less space (Womack, 1990). See *The Evolution of Manufacturing Practice.* Lean thinking provides a way to make work more effective by providing immediate feedback to convert the wastes into value. It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption, and perform them more effectively (Womack & Jones, 1996).

Value is the starting point for lean thinking. Lean thinking can be applied to the enterprise by identifying the value-stream, identifying the wastes and removing them from the system. Transforming a system into lean needs a structured approach (Liker, 1997). To implement lean principles, the wastes in the system have to be identified. The task of identifying the wastes is difficult especially in a high volume, highly automated manufacturing system. Wastes are of seven types (Askin, 1993)—Waste from overproduction; of material and material movement; of inventory; of correction; of processing; of waiting and of motion

According to Shanley, 1997, any change will create a waste and the waste may have a large or small effect on the system. The rate of growth of manufacturing innovations has not kept pace with the advances in the area of waste minimisation. Wastes in an organisation are typically treated as something that just 'exists'. It is often treated as a necessary evil that exists as part of the production process (Shanley, 1997). The causes for wastes as concluded by Shanley are:

- Non-steady state conditions
- Inadequate feedback controls
- Inaccurate measurements
- Failure in process integrity
- Untimely use of materials

Theory of Constraints

The essence of Theory of Constraints (TOC) lies in understanding cause and effect. The thinking processes associated with the TOC gives a series of steps, which combine cause-effect and experience and intuition to gain knowledge. The benefit of the thinking processes is that they provide the ability to recognise paradigm shifts that occur when times change and the assumptions and rules keep varying. It is not possible to constantly monitor every assumption in order to insure they are in line with constantly evolving reality.

Therefore, the ability to spot the shifts can be a real advantage (Goldratt, 1990). The core idea in the TOC is that every real system, such as a profit-making enterprise, must have at least one constraint. If that were not true, then the system would produce an infinite amount of whatever it strives for. In the case of a profit-making enterprise, it would be infinite profits. Because a constraint is a factor that limits the system from getting more of whatever it strives for, the manager who wants more profits must manage the constraints. Either the constraints in a system have to be managed or they will manage the system. The constraints will determine the output of the system. TOC defines the following method for managing constraints:

1. Identify the system constraints
2. Decide how to exploit the system's constraints
3. Subordinate everything else to the above decision
4. Elevate the system's constraints
5. If in the previous step a constraint is broken, go back to Step 1, but do not allow inertia to cause a system constraint.

Manufacturing systems

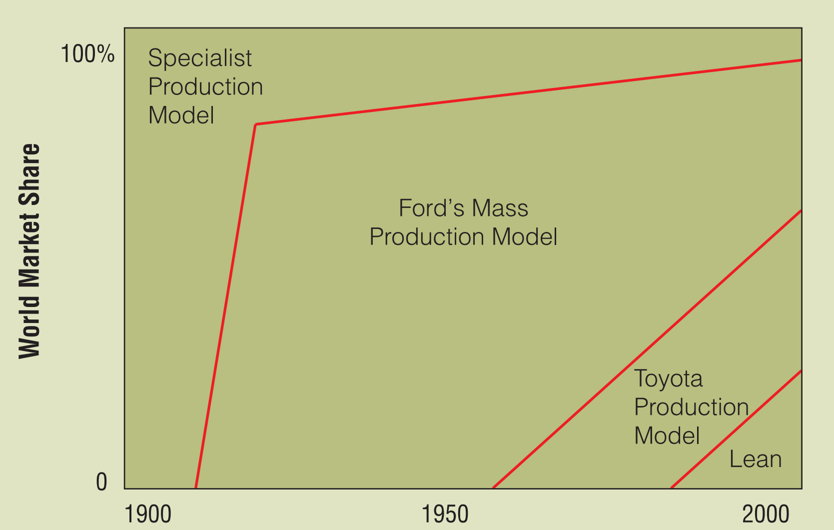
A manufacturing system is any system in which man, machine, materials, and methods are integrated to produce a product or a service. A manufacturing system can be divided in to five interrelated functions (Askin, 1993):

- Product design
- Process planning
- Production operations
- Material flow and facilities layout
- Production planning and control

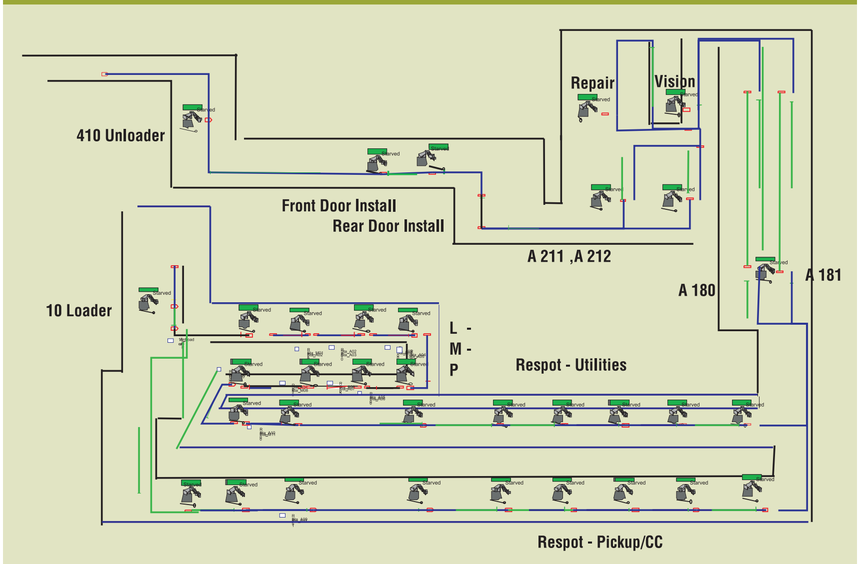
Information is the umbrella that drives the five functions, oversees their coordination, and measures the compliance with the objectives. Two manufacturing facilities with the same number and type of machines could vary a lot in the performance. The following are the principles of manufacturing systems (Askin, 1993):

1. WIP = Production Rate X Throughput Time (Little's Law)
2. Matter is conserved
3. The larger the system's scope, the less reliable the system: Large systems are inherently difficult to design, coordinate, and maintain
4. Objects decay
5. Complexity grows exponentially: If there are 'M' machines and there are 'N' states for each machine, then the system has NM possible states
6. Technology advances
7. System components appear to behave randomly
8. Limits of (human) rationality

The Evolution of Manufacturing Practice



A Simulation Model - Animated 2-Lane Assembly



9. Combining, simplifying, and eliminating will save time, money and energy

Each of the principles applies to every function of a manufacturing system.

Simulation

Simulation is a mathematical tool used to 'think ahead' and to identify oncoming constraints and then optimise them (Kelton et al, 1998). A valid simulation model usually directs the planning engineers to think in the correct direction. The proposed system may be animated to insure that everyone in the multifunctional planning group understands the implications of the simulation study and thus reacts fast.

Simulation is a dynamic process of formulating and experimenting with models of real-world systems, normally using high-speed computers and user-friendly software packages (Banks, 1999). It is used to describe and analyse the behaviour of a system, ask 'what if' questions about the real system, and aid in the design of real systems. Both existing and conceptual systems can be modelled with simulation (Banks, 1999).

In a manufacturing system, a sensitivity analysis with 'what if' scenarios needs to be done and a decision has to be made based on the effect that the implementation of that specific decision will have on the profitability of the plant (Goldratt, 1990). Changes will have to be incorporated in all the processes based on the decision. The information that would be needed may be the effect that a specific constraint would have on all processes. The constraint has to be removed by performing 'what if' analysis again.

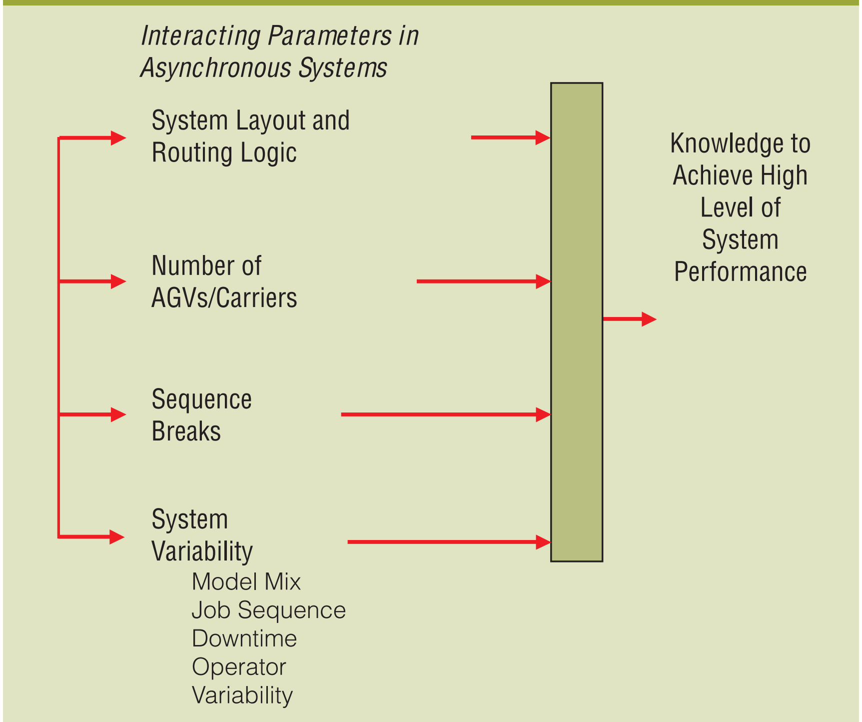
The simulation software industry has been developing more accurate and easier-to-use simulation software packages. The rate at which the software has developed is directly proportional to the rate at which hardware capabilities are developing. The number of businesses and industries that use simulation for solving manufacturing related problems continues to increase rapidly (Garnett, 1999). Managers are realising the benefits of using simulation for more than just one-time plant remodelling. The benefits of using simulation go far beyond simply providing a look into the future. Simulation allows companies to make critical decisions and understand a variety of manufacturing issues. In a complex manufacturing and business environment, the use of simulation may be an approach for problem solving (Banks & Norman, 1999). In most organisations, unlimited data is available. However, the conversion of this data into information is still a challenge. Simulation is used as a tool to analyse data and convert that into useful information. Simulation will be successful only if the data provided and the model that is used is close to accurate (Glover & Kelly, 2000). The assumptions made have to be understood. According to the Theory of Constraints, there will be at least two solutions to a specific problem, which will be in conflict. Decisions have to be made by optimising the available solutions (Goldratt, 1990). For example, staying close to suppliers in order to procure material may be better than staying close to customers. Such decisions may be controlled by a number of parameters. The more accurate such decisions are, the more profitable the company would be.

Simulation can be used to identify more constraints and optimise them to understand their impact on the goal of the organisation, which is usually to maximise profits. Simulation can handle statistical fluctuations and thus can help in capacity planning. Visualisation is the foundation to human understanding (Banks & Gibson, 1998). Simulation software gives the capability to give animated and graphical results, which are easy to understand. *A Simulation Model—Animated 2-Lane Assembly* shows a screen shot of a graphical layout that can be generated using a windows based simulation software package.

Lean implementation in a manufacturing system

The goal of lean initiative tasks is to eliminate wastes in an existing system. These tasks, most times, utilise resources (man, money, time). Hence, the management should be able to decide on where to invest their limited

Some Parameters Affecting Throughput



resources. A waste or a 'muda' in a system could be defined as anything that impedes the system from achieving its goal. A manufacturing plant needs to produce goods at high quality and minimum cost. For this, the following are the wastes that need to be identified and eliminated:

1. Minimise line stoppages (remove bottlenecks)
2. Maximise utilisation of machines/ processes
3. Minimise rework

Many other initiatives could be formulated, but they may not directly impact the profitability of a manufacturing plant.

TOC-based approach

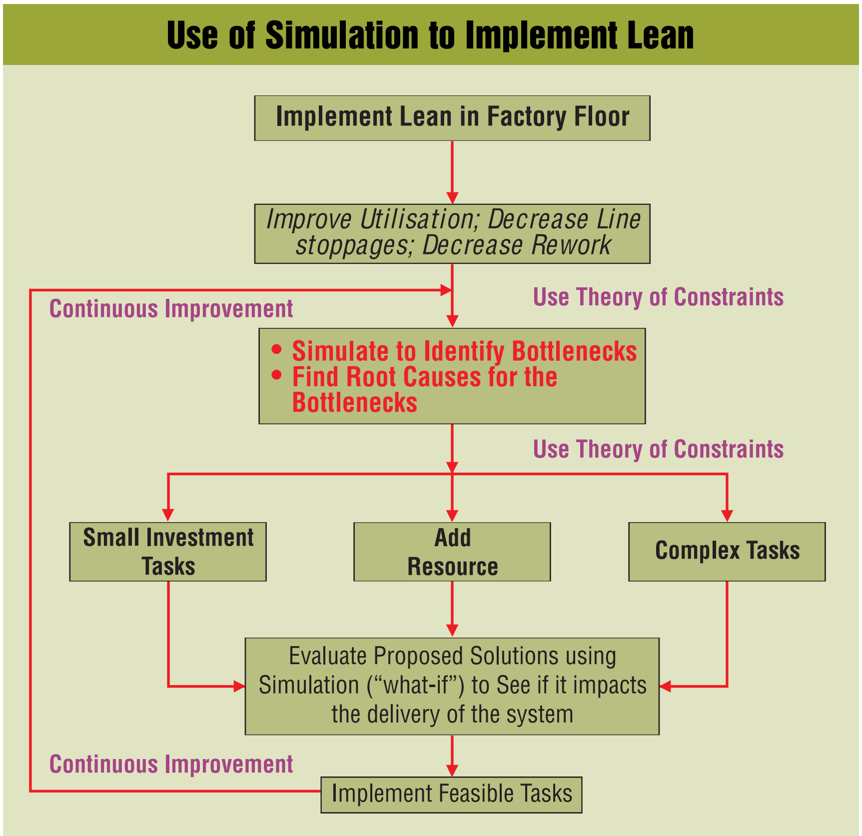
As per TOC, the following are the steps involved in making decisions on investments for lean initiatives:

1. Identify bottlenecks in the system
2. Focus on the top bottleneck. The 'top' bottleneck is the process that is the biggest cause for the system not achieving the goal. In another way, if this process had performed to its design capacity, then there would be maximum increase in the system's output.
3. Invest on the top bottleneck process and analyse to see how the initiatives will help remove the impact of the bottleneck on the system
4. Implement the effective initiatives
5. Go to step 1 and identify the next top bottleneck

In a complex manufacturing plant, identifying the bottleneck is an analytical task. It will not be obvious. The constraints of the system should be identified so that the limited resources that are available are focused on the correct tasks. The performance of the system is a result of several interacting parameters. *Some Parameters Affecting Throughput* (see previous page) lists an example related to throughput, which is one of the performance parameters. Based on the research work done by the author and chaired by Dr Srihari (Chairman, Systems Science & Industrial Engineering, State University of New York, Binghamton, NY) in June 2000, in an automotive assembly plant in the US, a standard approach has been suggested to make decisions on lean initiatives in a complex manufacturing environment. See *Use of Simulation to Implement Lean*. The following key points may be noted:

1. Define the manufacturing system under consideration. It could be the entire plant or an area in the plant
2. Define the required performance parameters of the system
3. Use simulation identify the 'top bottleneck'
4. Brainstorm with a multi-functional team, arrive at a list of tasks to evaluate
5. Evaluate the tasks using computer simulation
6. Look for investments in the area that is the biggest bottleneck.
7. The goal is not just to make investments to remove wastes, but to remove wastes and to enhance the system's output.
8. Computer simulation tools help to identify bottlenecks. The system has to be modelled accurately and the distributions of downtimes and cycle times have to be determined and validated
9. 'What if' analysis that could be performed using simulation tools will help us understand the impact a particular investment will have on the system.
10. Data collection methods have to be understood before the simulation is performed

Manufacturing systems are complex and dynamic. Two manufacturing systems with the same number of machines and manufacturing the same product could have different production rates, throughput times, and quality. The key to maximising the effectiveness of a manufacturing facility is to improve the effectiveness. The lean philosophy can be adopted to increase effectiveness of any manufacturing facility. The implementation of lean principles into an existing manufacturing system demands a focus on the key elements defined by lean philosophy: flow, pull, and striving for excellence. Implement-



ing lean philosophy in a manufacturing facility needs to have a structured data-driven approach. Some of the small improvements like cleanliness of work place, lighting etc may not need any investments in any form. But, beyond those, improvements in the process may require changes that would require investments in the form or man, money, or time. A structured data-driven method will help the management invest on the right tasks on the right process. Lean philosophy can be implemented using the thinking methodology provided by Theory of Constraints (TOC):

1. Define the performance measures of the manufacturing facility
2. Find the process that maximum impedes these performance measures (top bottleneck)
3. Invest on removing 'muda' from this top bottleneck
4. Again analyse and find the new top bottleneck

If the investment is made on a process that is not the top bottleneck, then the performance measures of the plant will not improve. Simulation could be used as a tool in case of complex manufacturing system.

Becoming lean is a continuous process of improving the effectiveness of any system. The methodology suggested is based on different best practices suggested by experts in the manufacturing arena and is proven and implemented in manufacturing plants in the US.

List of references

■ Srihari, Hari & Sampathkumar, Vaidee; 2000, Throughput Improvement in the Cab Shop of an Existing Automotive Assembly Using Computer Simulation as a Tool, State University of New York, Binghamton, NY ■ Askin, R. G. & Standridge, C. R., 1993, Modeling and Analysis of Manufacturing Systems, John Wiley and Sons, New York ■ Banks, J. & Norman V. B., November 1995, 'Justifying Simulation in Today's Manufacturing Environment', IIE Solutions, pp. 16 - 19. ■ Banks, J. & Gibson, R. R., January 1998, 'Simulation Input Data', IIE Solutions, pp. 29-36. ■ Banks, J., & Gibson, R. R, November 1998b, 'Simulation Evolution', IIE Solutions, pp. 26 - 29. ■ Banks, J. 1999, 'Introduction to Simulation', Proceedings of Winter Simulation Conference, pp. 7 - 13. ■ Cassidy, M. 1999, 'Throughput Initiatives in an Automotive Assembly Plant Body shop', Thesis, Sloan School of Management. ■ Goldratt, E. M. & Cox, J., 1986, 'The Goal: A Process of Ongoing Improvement', North River Press, Great Barrington, Massachusetts. ■ Goldratt, E. M., 1990, 'The Theory of Constraints', North River Press, Great Barrington, Massachusetts. ■ Goldratt, E. M., 1990, 'The Haystack Syndrome: Sifting Information Out of the Data Ocean', North River Press, Great Barrington, Massachusetts. ■ Goldratt, E. M. & Cox, J., 1986, 'The Goal: A Process of Ongoing Improvement', North River Press, Great Barrington, Massachusetts. ■ Goldratt, E. M., 1990, 'The Theory of Constraints', North River Press, Great Barrington, Massachusetts. ■ Goldratt, E. M., 1990, 'The Haystack Syndrome: Sifting Information Out of the Data Ocean', North River Press, Great Barrington, Massachusetts. ■ Rohrer, M., May 1997, 'Seeing is Believing: The Importance of Visualization in Manufacturing Simulation', IIE Solutions, pp. 24-27. ■ Womack, J. P. & Jones, D. T., Roos, D., 1990 'The Machine that Changes the World', HarperCollins Publishers Inc, New York, New York. ■ Womack, J. P. & Jones, D. T., 1996 'Lean Thinking: Banish Wastes and Create Wealth in Your Corporation', Simon & Schuster Inc, New York, New York. i2.0

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