The Future of Industrial Engineering in Business is Speed, Innovation, and Creativity.

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Introduction

I come from a lucky country, Australia. I believe that an Australian perspective is somewhat different from those of you from other countries.

Life is really about passion, perceptions, and politics. Often we lose sight of scientific logic and real evidence.

Australia's history is steeped in the traditions of one of the oldest cultures in the world, our aboriginal people, who spoke in over 600 languages, and then the original boat people, British convicts. Now with every culture in the world, we are particularly rich in Asian cultures. If you walk down the main street of Sydney, George Street, you soon realise that we are now truly Asian.

I would like to talk to you about some aspects of the future of Industrial engineering and operations management as I see it and introduce you to two of many unique tools, both proven and successful. However to begin I would like to say that any vision forward rests firmly on the foundations laid in the past. As Isaac Newton said "I see further because I stand on the shoulders of giants." So, let us bask in the sunshine of our fathers.

Industrial Engineering is the heart of progress. The industrial revolution began with the spinning jenny and the steam engine. This in turn gave rise to the beginning of free trade and this led to the dominance of England and Scotland as economic powerhouses.

With the advent of the industrial factory then came new scientific management principles and new codes of factory discipline.

Now we are in the next wave of economic progress, innovation, creativity and speed. Digital data enables us to innovate faster than ever. The internet brings together a degree of teamwork and collaboration never before seen.

The breadth of Industrial Engineering, including Operations Management can be summed up in the following definition:

" industrial engineering may be defined as the design, improvement and implementation of integrated systems of men , materials and machines"

The next wave of change in all economies is the speed of innovation. Industrial engineers will be at the heart of the creativity and research needed to use new digital data more effectively to enhance standards of living, improve health and assist in solving all types of people problems as well as technical ones. New products and processes will evolve faster than ever.

So, let your imagination run wild.

- *Consider this. " The idea is there, locked inside, all I have to do is remove the excess stone"……Michelangelo.*
- *Or perhaps this gem: " Computers in the Future will weigh no more than 1.5 tonnes"……..Popular mechanics 1949.*
- *Here is another: " It is impossible for anything heavier than air to fly"….The Royal Society, London 1895.*
- *"640k should be enough"…..Bill Gates 1981.*
- *"I think there is a world market for maybe 5 computers"….Thomas Watson CEO IBM 1943.*

Albert Einstein postulated that there must be a "cosmological term", to explain the stability of the universe. Five years later he described this as the greatest blunder of his life. However with recent gains in string theory and parallel universes maybe Einstein was right the first time.

Why am I telling you this?

It is simply that even the best of us are unable to grasp the full significance of all the events of the world around us, but the scientific method, the foundation of industrial engineering will provide the best way forward as always.

Countries are becoming less important and companies more so. Multinational corporations have sales in excess of the GDP of most nations. Who rules the world?

All around us everything has suddenly become smaller, faster.

National boundaries are becoming less significant, small business can sell to the world, the "Instinet' is already here.

We may soon change our sleeping patterns to suit the moon rather than the sun or even Wall Street.

The industrial engineering profession needs to question old habits and face a fast future and recognise that while our profession is steeped in solid logic, perceptions often override scientific evidence…look at climate change or should I sat anthropogenic global warming? Animal spirits often prevail.

I have chosen two simple examples from my experience to illustrate the breadth of industrial engineering applications involving speed and creativity. There are of course many more.

But let us concentrate on speed with a well-defined strategic direction, which I will call "velocity" and use the Japanese lean manufacturing principles to illustrate the point.

Applications of Lean principles to Achieve Speed (Velocity)

As a consultant, the range of problems I am confronted with is extremely wide. It is this range – plus the excitement of being able to help people and businesses, then measure improvements – that motivates me. The US study of the International Motor Vehicle Program (IMVP), coined a word called "Lean" to describe Japanese manufacturing techniques. These methods were an extension of the work of Leonardo Da Vinci and Edwards Deming, hardly new.

Whilst lean to achieve velocity is not a quick fix for companies in distress, it does lead to agility which is mandatory for success in the future as the perceptions and demands of the people continue to change rapidly and more so in the future.

Many industrial processes are so far out of statistical process control as Deming would say, that it is prudent and sensible to introduce change in the process before many simple process control charts or even some shop-floor lean techniques are introduced.

From my experience it all depends on the size of the company. Large multinationals are generally much further advanced than small and medium sized enterprises but it is these latter companies and start ups that are the future. They are the ones with the really big ideas. However, even some large companies need a lot of help.

This was the case for a client of mine in 1999. This was a company with a multi-million dollar turnover employing thousands of people. The board and management did not understand the link between processes and the necessity to reduce the time between forecast and manufacture and how to link this with demand. They did not understand how important cycle time reduction was to their business. Over-production of many products was so high that over $2.5 million of write-downs were made each year. On-time deliveries were only 33% and the customers were so unhappy that they placed orders in advance and asked the company to hold them before delivery, hence extra inventory, greater errors in measuring real demand, extra space in the warehouse and extra insurance and interest on borrowed capital.

The overseas-based owners believed that the way to solve the problem was to immediately introduce lean manufacturing techniques to the shop floor. I thought otherwise, since there was a quicker way to achieve their objectives of releasing the A$40M of working capital they desired using the 26 rules I had developed as recorded in Table 1.

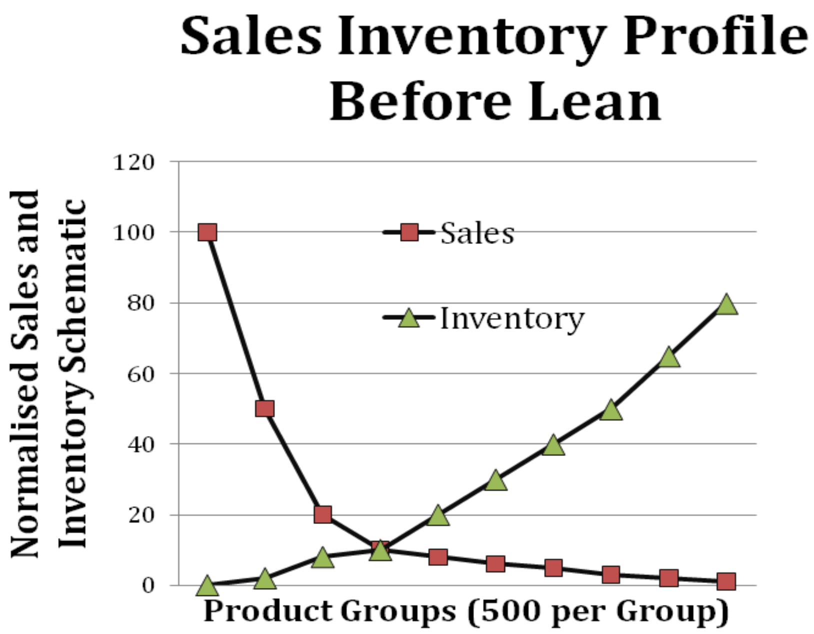
Table 1. 26 Rules aimed at Velocity.

People	
1.	Continuously improve the culture
2.	Team-up
3.	Optimise customer response
Integration	
4.	Supply equals demand
5.	‘Pull’ for minimum cycle-time
6.	Apply to supply chain
7.	Minimise variation
8.	Shorten the financial cycle
9.	Apply 6S System
Planning	
10.	Demand to bottleneck
11.	Even mix for production
12.	First in first and prioritise
13.	Optimize supply
14.	Load-levelling
15.	Equal batches at the Economic Production Run (EPR)
16.	Optimise sequencing
Operations	
17.	Minimize waste
18.	Aim for continuous flow
19.	Maximise value-added
20.	Link processes
21.	Match processes
22.	Minimise hold points
23.	Prevention not rework
24.	Use Statistical Process Control (SPC) to improve control to Six Sigma
25.	Use Single Minute Exchange of Dies (SMED)
26.	Use quality systems as part of the business processes

After an audit, the management and the owners were convinced to change the way they planned production and shorten the timeframe between demand and production by applying the appropriate rules of the 26 Rules for process flow as above. This was only the first step.

The audit revealed the following relationship between sales and inventory as shown in Figure 1.

Figure 1: Before 26 Rules aimed at Velocity



When you analyse Figure 1, you wonder why anyone would continue to make those products where there is a lot of inventory and poor sales, but this is what the marketing department and executive were demanding. A culture change was needed.

This company had been working on removing A$40 million of working capital for five years and yet had made no progress. When I produced the above graph, not easily done, it was clear what new strategies were needed. The first problem was to change the planning cycle. The errors created by simply forecasting from shipments, was first removed by feeding back actual orders into my new algorithm into the IT system and compressing the time for implementation…basic industrial engineering.

The planning cycle method was then analysed and the models below considered. The product range was first stratified into A and B. Product group A could be supplied either from stock to the distributor in 2 to 5 days including transit time, or had to be produced from the numerous inventory points in 21 days but to this was added the 42 days it took to plan the work. The 42 days to plan was an incredible waste and could be eliminated as shown in Stage 1 as illustrated in Table 2.

The results would be spectacular as shown in Table 2. A supermarket holding point for an intermediate stage of production was set up and the production time to satisfy orders was reduced to one-to-five days and the delivery to the distributor reduced to 10 to 17 days by simply applying the 26 Rules. Stage 3 could reduce it further to 4 to 11 days into the distributor's store.

Table 2 Staged planning cycle changes for A and B showing increased velocity…Lead time in Days.

Group	A	A	A	B	B	B
	Before	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Planning	42	7	1	42	7	1
Production	21	1 to 5	1 to 5	70	14	7 to 14
Shipment	2 to 5	2 to 5	2 to 5	2 to 5	2 to 5	2 to 5
	65 to 68	10 to 17	4 to 11	114 to 117	23 to 26	10 to 20

Product Group B was a lot more complicated, but the 26 Rules to achieve velocity still applied and as shown in Table 2 the 114 to 117 days could be reduced to 10 to 20 days with the correct parameters in place. This was all done without value stream maps and shop floor control and was only the beginning of the improvement. The next stage was to increase the value-added component by optimising batch sizes and minimising setups using Single Minute Exchange of Dies (SMED), and the 22 Creative Ideas for Innovation as shown in Table 3 and application of Rule 25 and 19.

There were other improvements that could be made, such as synchronising planning cycles between suppliers and later customers. For another of my clients when the plan was implemented the raw material inventory at the customer was reduced from A$1.5 million to A$100,000 and the supplier reduced his price by 5%, the holding cost at his plant was reduced enormously.

The 26 Rules, when used in a common sense fashion, will always lead to significant improvements in productivity and profit. By speeding up the planning system and using the correct input data, the velocity had increased. Having implemented successfully a very good profitable system based on these rules what would happen if the rules were broken?

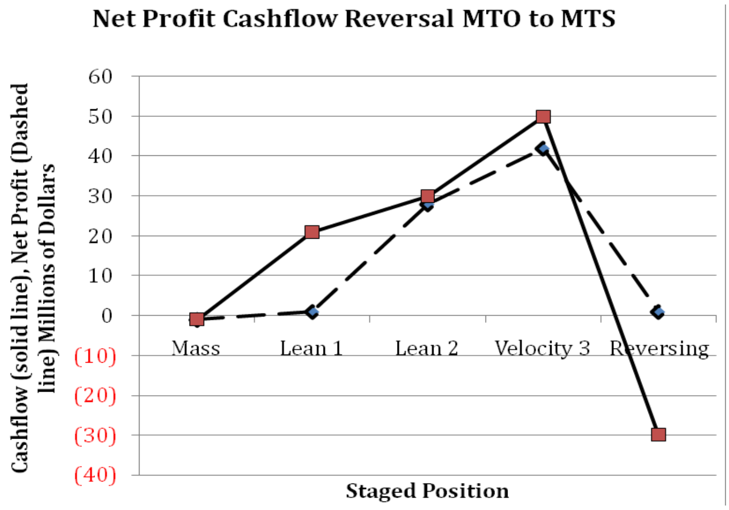
Imagine that the company decided to completely change direction based on the marketing department's perceptions without trial, and they decided to make a completely new product range and the marketing department, for the launch, decided that the product in all permutations must be in stock if they were going to sell it. Disaster struck when the CEO changed his strategy.

The company traded at an EBITA of A$40M per year for 2 years after the improvements I forced through, and after I left the company and then the CEO in his wisdom changed direction. The result of the change in direction is illustrated Figure 3.

I watched this from afar in amazement. When disaster struck the Chairman rang me to basically apologise after the CEO had been fired but the damage was enormous and it was too late to save the company without a massive injection of capital. This disaster should not have happened if common sense was applied and the correct modelling and industrial engineering principles adhered to.

Even from my very first research experiments, I have always believed that a new idea should be piloted more than once before production is commenced. It was common for my research programs to start with a primitive laboratory mock up and then pass through four or five minor pilot stages even before the real pilot plant was built. The same philosophy applies to market research. Test the market before committing the investment.

Figure 2. Three Years after the Rescue



In the company at the executive level greed and animal spirits took over. My rescue assignment which started in December 1999 and finished in January 2003, left the company with a profit of $40 million EBITA and 95-99% on-time deliveries and a cycle-time reduction of 85% for A and 77% for B. The next stage planned was to further increase velocity to reductions of 94% for A and 91% for B. It was calculated that with every one day of reduction in the cycle-time the increase in profit would be approximately between $40,000 and $80,000 to the bottom-line as EBITA profit.

In Figure 2 "Mass" represents the company's position in 1999 when it was trading at a slight loss. At Lean 1 and Lean 2, the 26 Rules for Lean Systems had been applied and the company made approximately $40 million EBITA at the same time as deliveries were improved and the finished goods inventory reduced by $11 million and overall working capital reduced by approximately $40 million and the profit increased from a loss of $0.5 million to an EBITA of $40 million. The company travelled very profitable for two years after my contract ceased. At Velocity 3, the profit peaked, the inventory level fell and the on-time deliveries were excellent.

When the company decided to make a new product line it used production time for cash-flow products to make a new line for inventory for the worldwide launch. The warehouses were full, cash-flow dried up as no one would buy the product...unbelievable, but nonetheless true. When the Chairman rang me he apologised for supporting the CEO's change of direction.

Accelerating Processes

World trade is largely dependent on adding value to goods. The closer the company is to the end user the better the enterprise is able to control product and process flow and profit. Japan has shown us that new standards can be set by applying statistical tools to reduce variation. Before we can take advantage of statistical process control we must get the setup right and remove the special causes affecting the process. Lean aimed at cycle-time reduction and increased velocity uses team problem solving, the scientific method and practices process intent.

Creativity and Innovation

Innovation may be defined as the taking of opportunities and the creation of newness to improve existing services, products and processes. It involves the use of advanced conceptual thinking, and continuous improvement of existing processes, and applies to marketing, operations, service, products, finance and all parts of the business and every industry, in fact every walk of life. Innovation is newness and originality in doing things. It includes 'eureka ideas', research and development, commercialisation and Kaizen.

To be successful in the future, all parts of the business must undergo continuous innovation both explosive and incremental. A company's ability to innovate will depend on its capability, how it measures the opportunities both in the market internally and externally, and the general creativity that business can apply to a particular problem. It is incumbent on the people in the industry to use all idea-generating techniques that are available.

In particular, I have made frequent use of the following 22 Creative Ideas for Innovation developed while I was Chief Metallurgist Research and Development at a BHP subsidiary, John Lysaght Australia (now Bluescope Steel) in 1971. These ideas are not exhaustive and are similar to those developed by Altov and published in 1996. I have listed these in Table 3.

Other techniques include:

- Knowledge databases
- SPEED teams (Honda Japan)
- Staged innovation strategies with Kaizen (incremental)
- Risk management
- TRIZ techniques
- Rapid prototyping and tooling (SMED)
- Business process reengineering
- "Six Thinking Hats" (Edward De Bono)
- Reverse engineering
- Re-engineering .

Some sources of new ideas can be:

- Patents
- Trade shows
- Customers
- Journals
- Competitors
- All people
- Internet
- Overseas trips
- Brainstorming/Imagineering
- Annual reports of competitors
- Suggestion boxes

The 22 creative ideas are listed below.

Table 3. The 22 creative Ideas

	A: Change	B: Example	C: Result
1.	Properties	Bimetallic strips	Different coefficient expansions of metals enables temperature to activate switch
2.	Space	Fill sunken objects with foam to displace water	Steel ship recovery from ocean floor
3.	Order	High purity materials create new ordered structure	Self-Assembling Materials (SAMs)
4.	Energy	Use pre-energy in pre-loaded spring to overcome high loads	Self-activated doors with a minimum force to open
5.	Shape	Offset impellers for mixing chemicals/cakes	Better, faster and more uniform mixtures
6.	Movement	Energy from falling object used to feed another	Lifts
7.	Friction	Overcome friction with cushion of air or use point contact	Hovercraft (cushion) or sharp contact point (ball bearings)
8.	Magnetism (attraction, affinity)	Ferromagnetic iron becomes paramagnetic at Curie point	High temperature switch
9.	Gravity	Inertia reels in seat belts	Retractable belts that tighten under load
10.	Dissecting	Analysing causes of lack of tone quality – piano	Stuart piano has more precise tone
11.	Fragmenting	Modular computers	PC upgrades/plug and play
12.	Self-service	Eliminate action steps in process	JIT
13.	Copying	Resin copying of CAD/CAM	Stereolithography..3D printing
14.	Coatings	Zinc/aluminium coatings on steel	Strength of steel corrosion resistance of Al/Zn
15.	Blending	Micro-processors/ memory	High-speed devices
16.	Phases	Heat treat alloys in critical phase transformation zones	Special zinc coatings on intricate steel parts
17.	Solvent	Organic solvent added to polystyrene	Volume decreases markedly
18.	Oxidation	Use nitrogen instead of steam to strip liquid zinc off steel	BHP buys world-wide processes
19.	Potential	Use sacrificial anodes	Steel hulls protected
20.	Combination	Combining functions	Multi-purpose pen
21.	Multi-use	Hang glider become parachute	Life saver
22.	Prevention	Asymmetric plugs	Three-pin plugs/prevents loss of life

One of the biggest problems with ideas is evaluating them in terms of their probability of success. Numerous techniques have been devised to assist in this, but some of the essential elements that must be continuously measured for products and services and processes to enable implementation of the best innovation strategies are:

- Lifetime of products
- Processes
- Number of ideas generated
- Number of new products developed
- Total expenditure on research and development
- Number of new processes developed
- New technologies introduced
- Measurement against state of the art
- Sources of innovation data
- Surveillance methods

Application of the 22 Creative Ideas for Innovation and thinking outside the square..an example.

I was privileged to meet Ben Lexcen (originally Bob Miller), the designer of Australia II which won the Americas Cup for Australia from the USA in 1983, once – very briefly – just after he designed the revolutionary 18-foot skiff "Taipan", and later "Venom". This creative design revolutionised 18-footer sailing.

Australia II, was a revolutionary 12-metre yacht which defeated the USA's Liberty to win the America's Cup in 1983, even though it appeared that the skipper of Liberty, Dennis Connor, outsailed and out-manoeuvred Australia II's skipper, John Bertrand. The contest went to a full seven races and despite the greater manoeuvrability and going-about speed of Australia II John Bertrand lost six of the seven starts. However, after a fortunate clever manoeuvre of the last square turn, and with superior speed on the last windward leg, Australia II crushed the American boat and Australia II and Ben Lexcen wrote themselves, John Bertrand and the crew into the history books.

Analysts claim that the secret was the winged keel. Certainly this gave the Australian's a psychological advantage. How did Ben come up with the idea? Did the winged keel make the boat faster? If we use the 22 Creative Ideas for Innovation we can find out. An analysis of the most important variables affecting the performance of two yachts is given in Tables 4 and 5

Table 4: Design equation for a 12-metre yacht

$$\frac{(LWL+2(G1-G2)-F+\sqrt{SA}}{2.37} = 12$$

LWL = Length on Waterline (m)

G1 = Surface Girth at Beam (m)

G2 = Surface Girth Side Extrapolated (m)

F = Freeboard (m)

SA = Sail Area (square metres)

Table 5. Summary of important dimensions determining the speed of Australia II and Liberty

Australia II Liberty Comparison in the 1983 America's Cup

	Liberty	Australia II	Diff%	Australia II
LOA (m)	**19.3**	**19.6**	**1.53**	**Assist in increasing stem rake**
LWL (m)	**14.0**	**13.4**	**4.48**	**Disadvantage running**
Beam (m)	**3.6**	**3.6**	**0.00**	**Neutral**
Draft (m)	**2.7**	**2.6**	**3.85**	**Wing keel extra draft working**
Weight (Tonnes)	**25.2**	**23.8**	**5.87**	**Lighter**
Sail Area (metres sq)	**167.2**	**170.0**	**1.65**	**More power**

Ben Lexcen decided to make a shorter vessel on the waterline (LWL) and design against the well-known logic that for a displacement yacht, the ultimate speed is a function of the square root of the waterline length. It has been proven many times that the longer a displacement yacht is, the faster it will be. He therefore went against tradition. By sacrificing length he could increase the sail area, and build a smaller, lighter yacht. Now he had two factors assisting speed and one negating, but he realised that most of the time the boat would be heeling over as it sailed to windward.

To satisfy the equation, he would build a shallower keel but overcome this disadvantage by designing two wings that would actually increase the draft as the boat heeled whereas for the more conventional Liberty, the effective draft would decrease. Also since the Length Overall (LOA) was greater for Australia II than Liberty, the angle from stem to waterline was sharper and the extra benefit of an increase in waterline length could be realised as the boat heeled. The wings on the keel would also dig in as the boat manoeuvred at the start and give the helmsman, John Bertrand, an advantage of extra lift to windward. Despite this, Bertrand lost six of the seven the starts so it could not have been much of an advantage.

Ben clearly thought outside the square. He designed the boat to sail more effectively to windward and overcame the apparent disadvantage of a shorter waterline length with the sharper rake at the stem and stern but was able to have more sail area and therefore more power than Liberty. Australia II was faster for most of the course.

Numerous attempts to use wings on keels in Sydney have failed simply because they do not make the boat faster; they are purely a way to generate more lift in a yacht on heeling if there are formula imposed restrictions. As far as the 22 Creative Ideas for Innovation are concerned, what had Ben done? This is summarised in Table 6. Not all the ideas can be applied to all situations. In this case the ideas that can be applied are given in Table 6.

Table 6. Application of the 22 Creative Ideas to Australia II

	A: Change	B: Example	C: Result
1.	Properties	No change as far as we know. Both Liberty and Australia II were made from the same or similar materials.	No difference
2.	Space	Australia II was lighter than Liberty since she was a smaller boat and therefore would be faster. She would also have less wetted surface area partially negated by the surface friction of the wings which could supply lift not only to windward but also vertically.	Less volumetric displacement for Australia II therefore she would be faster
3.	Order	The major variables would have been listed and prioritised	Sail Area and weight are probably the most significant, so once again Australia II would be faster
4.	Energy	Greater lift to windward would be generated by the winged keel as it heeled since the Depth to width ratio would improve	Australia II would be faster to windward and suffer from less leeway
5.	Shape	Shape of the keel had to be downwards to gain maximum benefit	Better, faster and more uniform tacking by Australia II
6.	Movement	Keel would effectively act as a stored energy spring as the yacht heeled	Australia II would be faster
7.	Friction	Australia II as the smaller boat would have less wetted surface area therefore less friction	Australia II would be faster
8	Dissecting	Dissecting the major variables and prioritising enabled the analysis to come up with a superior design	Thinking outside the square and ignoring the age old idea that the boat had to be longer to be faster

The Dilemma of Made to Stock (MTS) versus Made to Order (MTO) at high-velocity….Inventory Control and Velocity.

When the manufacturing time, M, is greater than the expected delivery time demanded by the customer, D, then the enterprise has no choice but to make to stock (MTS). This is, of course, is the most expensive option, since holding inventory increases working capital, interest expenses, redundancies waste and write-downs and encourages over-production. However most companies do not allocate the inventory holding cost of the product to the actual product involved and instead spread it as a general overhead to all products.

Dell assemble from order and so hold components in stock and start assembling after the order is placed and the money received. This is good for the cash-flow of Dell, but not the customer.

ZARA International, led by the owner Amancio Ortega, use high-velocity supply chains from cheap labour areas all over the world to make fashion garments and 'push' new fashion to buyers with no redundancies in the store, since they always slightly undersupply. Their raw materials are sourced anywhere and shipped direct to the converter.

Toyota are currently trialling made to order for cars in Japan. My current Honda was ordered prior to manufacture but took 12 weeks to arrive.

Made to order books are a reality at Canon using their Omnipress. In fact, some of my books, up to 200 pages, have been produced in a batch size of 10. The batch size can be one. The maximum stock level will therefore be zero. The turnaround time for a batch is one day from order placed to production of a copy. The delivery time to the customer is therefore currently one day plus transit time to the customer. The customer can also place an order, pay into my account and then either receive a hardcopy or download a digital copy for a cheaper price.

Conclusion

Speed and creativity are the future. It is about lean velocity, people cooperating, process aimed at precision and high-quality, and perfect processes at six sigma, people, process and precision… the essence of velocity using lean systems and six sigma.

Process flow at high-velocity of the whole of the supply chain and in all internal functional groups is the way.

It is the CEO's responsibility to lead the restructuring and implementation of these new ideas and work practices and technology. The CEO must lead and innovate at an accelerated rate or his company will disappear in its competitive environment. Remember:

"***The idea is there trapped inside. All we have to do is remove the excess stone".***