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FORMAL PAPER REVIEWS

Leading papers published in this Journal are usually fully refereed. This service is available through the **New Engineer JOURNAL**. Papers which are to be fully refereed for formal publication may be submitted at any time.

Industrial Engineering in the Brave New World

We live in extraordinary times. Never in the history of mankind has the world faced more challenges, (and possibly more opportunities), than what appears before us in the closing stages of the first decade of the 21st Century. "May (you) live in interesting times" is a Chinese proverb that, of late, appears to have taken on 'more potency' than usual.

The theme for this edition of the ***New Engineer*** was inspired by the same idea of '*New*ism'. Not newism for its own sake but of necessity. The world has changed and, along with it, so has the need for IE to change too. Not to say that the IE of old with its emphasis on 'tools' (means) to achieve a single objective of higher productivity (end), is obsolete, but to suggest that new challenges require new approaches. The dawn of a *New Industrial Engineering* may be upon us in which the emphasis becomes excellence in achieving superior organisational performances (multiple ends) and how these goals inform the means by which such results are to be achieved. That is, the *New Industrial Engineering* may be more objective-focused than the means-focused Traditional IE.

The articles in this edition have been contributed by some of our IIE (Australia) Directors – both 'old' and new, and Dr. John Blakemore. They explore possible future directions for IE within Australia and possibly also throughout the rest of the world in the decades to come.

New IIE Director Chin Wong introduces the reader to the TRIZ approach of finding new technological solutions to both existing and new problems. He emphasises the particular need for modern organisations to continue to grow their Knowledge Capital.

John Blakemore's article on 'Management Solutions to the Current Financial Crisis' continues his theme of the need for Australian companies (particularly those in manufacturing) to emulate Japanese icons Honda, Toyota, Panasonic, Canon, etc. in their continuing growth of intellectual-capability, and their proven approach to 'creative innovation using the principles of lean manufacturing'. John argues this is not a 'culture' thing, but a very logical, long-term approach to realising superior organisational performances.

Lex Clark looks at the role of the industrial engineer as it has evolved both in Australia and overseas to date in his article 'The Industrial Engineer – Technical Specialist and Team Member or "Why doesn't everybody love me?'. He sees a metamorphosis in the role of the IE from that of management-sponsored, technical-specialist to (multidiscipline) team leader / facilitator of change. Through their training and multidisciplinary practical-experiences, Lex argues that this as a logical and natural step in the continuing evolution of industrial engineering in general, and in the role of the IE in particular.

The final article in this edition of the **New Engineer** is a reproduction of a research paper written and presented by this author, in April 2009 at Dunedin, NZ. The occasion was the 2009 Performance Measurement Association conference chaired by Prof. Andy Neely of Cranfield and Cambridge Universities UK.

The paper, although written for a performance measurement audience, may help in formulating the above suggested *new* objective-focused approach to industrial engineering. It develops a theoretical formulation linking superior organisational performance in a particular performance-parameter – (p = *productivity*, in the case of the paper), with the means of setting new utility of input resource goals and the subsequent attempted traditional IE approach to improvement in the productivity of actual process(es). That is, through the development of the utility–productivity performance equation, a link has now been established between the traditional approaches to IE and, what may be called, the objective(s)-based *New Industrial Engineering*.

Dr Damian Kennedy
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Acting Federal President's Report

Following the tragic Black Saturday Victorian bush fires, Federal President Dr. Damian Kennedy telephoned and requested I act as Federal President as he had lost his house in Flowerdale along with twenty years of accumulated effects and memorabilia. The night before Damian's call I had attended a bushfire appeal evening in Mandurah not knowing how close I was to the tragedy.

At the September 2008 Federal Council meeting I accepted the role of Senior Vice President on the understanding I was to be available if the Federal President was hit by a Melbourne tram. As the Black Saturday event surpassed the force of a Melbourne tram here I am writing this report.

Damian and your family, on behalf of the members of the Institute, our thoughts and good wishes are extended.

As it is possible there may be other members in Victoria and New South Wales affected by the bushfires and the Queensland floods, please accept the Institute's concern for your plight. In the collegiate spirit of our Institute, I request the Divisional Directors to communicate to any of our members who are in need from these national disasters and assist where possible.

I am mindful of another category of desperation being faced by not only Australians at large but also our members who, as Industrial Engineers, are vulnerable to unemployment in this economic down turn. There are many recorded cases where organisations, faced with economic crisis, target the strategic, wrong staff to terminate. These being productivity sustainers and improvers including Industrial Engineers. To counter this possibility, I believe the Institute and individual members must make a concerted effort to market the skills of Industrial Engineers more in order to assist individual enterprises survive the recession.

As you are aware the IIE is a Society within Engineers Australia (EA). I am pleased to report that the EA has generously offered to assist in the redesign and part production of our information brochures and also a review of our website. Your Federal Directors are working as a team with EA on this review.

Finally, Federal Council has a new Director, congratulations Chin Hak Wong. Chin resides in Singapore and his appointment recognises his Industrial Engineering professionalism and the importance of our overseas members.

Bob Watson, Acting Federal President

Introducing New IIE Director: Mr Chin Hak, Wong

Research Director Asia Pacific Research Centre and APRC Productivity Centre SdnBhd

Dr Damian Kennedy

Chin Hak, Wong, based in Singapore, has been active in the profession of industrial engineering for some 38 years to date and, in March of this year, was unanimously elected as a new Director and member of the IIE (Australia) Board. The Board of IIE (Australia) welcomes Mr. Wong and looks forward to his valuable contributions to the Institute over the next two years of his tenure.

Chin Wong has established a strong reputation in Asia for his value steam mapping approach to Cycle Time Engineering, specializing in Lean Line Design for one-piece flow configurations. He has also undertaken extensive work in waste elimination and use of the TRIZ approach to innovation in problem solving.

Chin started his working career in Teledyne Semiconductor (General Electric) as an Assistant Industrial Engineer (Methods Analyst) in 1971. During three subsequent years, Chin completed part-time studies in work-study methods and subsequently graduated from the Institute of Work Study (UK) in 1974. An opportunity to further employ his ever growing work study know-how enabled him to take up an appointment as Operational Methods Manager for the Port of Singapore Authority (1975 to 1981), where he successfully deployed all aspects of work study and its applications.

In 1981 he joined Inbucon, a British consulting organization. By 1984, Chin had further qualified himself as an MTM Instructor through the UK MTM Association and subsequently, in 1988, established an on-going business relationship with the H.B. Maynard & Co to provide for MOST® Systems training throughout the Asia/Pacific region.

In 1992, he received the Value Engineering Award from the Society of Value Engineers and by 2001, qualified as a TRIZ Master. In the past few years, Chin Wong's main professional focus has been in the field of Lean Implementation where his knowledge of work study, standard work development and process cycle time and line workflow configuration design are brought together for one-piece flow line processes.

He is one of the few IEs today who has had the opportunity to work with/studied with industry's best known personnel in the field of work measurement: *Dr. Fred Evan (the Developer of MTM Core Data) and Alan D. Evan both of the UK MTM Association, Kjell B. Zandin (Developer of MOST®) and Edward H. Hartmann both of H.B. Maynard & Co., Jim Mercer (the Originator of General Sewing Data), Jim Hewart (the Developer of Top IX), Australia's own Chris Heyde (the Developer of MODAPTS) and Bejamin W. Niebel (Professor Emeritus of Industrial Engineering – Pennsylvania State University).*

An Introduction to the TRIZ Problem Solving Technique

W C Wong

Introduction

The success of organizations, in meeting today's rapidly changing world-wide demands and environment, necessitates the development of knowledge capital to drive and meet ever-changing performance requirements at an ever increasing (accelerating) rate. This has resulted in a great knowledge-gap disparity between information availability and the ability of today's resource-seeking enterprises to harvest potentially available solutions that may already exist in science but not yet in technology (i.e. a 'problem looking for a technological solution'), and in technology, but not yet recognized as such (i.e. a 'technological solution looking for a problem').

In the design world, the needs for time compression from idea conception in creative innovations and technological development must comply with today's fast-speed race to succeed. Organizations that are able to achieve this will accumulate knowledge capital for technological development. Further, in the real world, enterprises have to contend with sustaining their existing operational functions as well as simultaneously making numerous improvements.

While there exist many 'thinking tools' and equally numerous problem solving techniques, most of them are either too chaotic (like that of brain storming in one extreme) to rigid, step-wise general approaches that are not able to make a significant break-through in developing a creative innovative-thinking process that is required for the New Thinking Paradigm which models along the trend of technological development. The old ways of problem solving, starting from team building basics and the use of basic statistical tools, is no longer able to meet this trend in technological innovation. Their continued reliance can only help in maintaining basic conditions through costly trial and error approaches.

TRIZ

'TRIZ' is an inventive Russian – approach to problem-solving, which has increasingly emerged as a very powerful tool to make a significant contribution to closing the many gaps between discovery, science, technology and applications. TRIZ essentially organizes the thinking process to evolve creative solutions. As a problem solving tool, TRIZ organizes the thinking processes to systematically examine a problem (e.g. poor product design, process failure, system and organization dysfunctions) using a methodological approach to seek clever solutions that have been blocked by our own psychological inertia as well as the continued reliance on inadequate problem-solving thinking processes.

The TRIZ Technique

Genrich Altshuller, before his death in 1978, developed a set of design rules, models, algorithms and physical principles based on his study of hundreds of thousands of product patterns.

He had trained over 500 TRIZ masters to ensure the proper propagation of the TRIZ Techniques. Since then, many TRIZ specialists have been trained and the technique is now spreading rapidly.

Today, TRIZ is a powerful technique to start with in the 'Design for Six Sigma' approaches. It can guide the problem solver/system analyst or design analyst to quickly determine the basic interacting elements by the use of the Substance Field Model (SFM) which is modeled as shown in Figure 1.

F(Force/Field)

↙

Tool → Object ⇒ Physical Effect ⇒ Resulting Outcome

Figure 1

Understanding how to apply this SFM will aid the analyst to identify the force/field acting on the substance structure parameter/property of tool on the object's substance/property to generate a physical effect that produces the desired outcome.

There are also many other (76 in all) rules of design applications derived from thousands of product pattern studies. These 76 Design Application Standards are classified into 5 classes for ease of search and application as shown in Table 1.

Table 1

Category 1 Standards	– How To Construct and Deconstruct Substance Field Models
Category 2 Standards	– How To Conduct Technological Transition Into Complex Substance Field Models
Category 3 Standards	– How To Develop Super-System Models & Micro-level Models & Particle Level Models
Category 4 Standards	– How To Apply Measurement & Detection Models
Category 5 Standards	– How To Apply The Desired Physical Effects

In addition to SFM, Altshuller also invented the '40 Principles of Creative Ideas' matrix. This 40- Principles matrix provides a table of creative ideas to resolve design conflicts based on "WHAT IS (a) DESIRED Feature" and "What Deteriorate(s) As A Consequence". It only takes a few common product designs to illustrate the sound organization of the creative principles behind the so called 40-Principle Contradiction Table.

The most difficult part of the TRIZ Technique, however, is the stringent step-by-step ARIZ procedure (Algorithm of Inventive Problem Solving). While Altshuller developed the original ARIZ procedure, many TRIZ Masters have subsequently developed numerous other sets of equally or more powerful ARIZ procedures.

The purpose of ARIZ is designed to help the analyst go through the complex steps of TRIZ. In this way, the analyst will be guided to arrive at the Ideal Final Results and developed solution with X-Resource that would not create any other harm to a final solution.

For further information on the TRIZ/ARIZ tool and its applications, see aprcline@singnet.com.sg

Management Solutions to The Financial Crisis

Dr John Blakemore CEO Blakemore Consulting international Sydney

1.1 Free Enterprise

The Macquarie Dictionary describes Private Enterprise as:

> *"Business or commercial activities independent of state ownership or control."*

In 2009 we have entered a new, more volatile and uncertain business future. Numerous economists cannot agree on the correct course of action but one thing is certain, the lender is more powerful than the borrower. This will always be the case. Why therefore has the classical economist always claimed that trading in deficit does not matter as long as you can service the debt. I have never agreed with this but as a result I have been pilloried because "You are not an economist". Thank heavens I am not. Even Alan Greenspan has claimed before a Senate hearing in the USA that "mea culpa". What an admission.

Soaring debt and greed has caused the massive global slowdown. Our children will pay a heavy price. The Chinese with ling term strategies, our now buying assets at fire sale prices. The long term strategy of the Japanese is unravelling because Japanese politicians failed to respond quickly with good fiscal policy to rebuild the infrastructure of Japan the problems of this have been accentuated by a rapidly ageing population. The Japanese economy is based on export, and despite little natural wealth in raw materials and energy in particular, clever global companies like Panasonic, Toyota and Honda have thrived. Why?

Australia is indeed a lucky country. However we have not capitalised on our natural strengths.

At the beginning of the last century, the country with the highest standard of living in the world was Australia, but this is the case no longer. Trading in surplus has been replaced by trading in deficit.

Australia has its foundations steeped deeply in proud traditions of individual achievement. While in the early 1900's Australia's standard of living was second to none, in 2009, we have been passed by many countries which are not fortunate enough to have our prodigious natural wealth, wealth in uranium, coal, iron ore, bauxite and an outstanding pastoral productivity of wool and wheat.

In fact, during the period 1885 to 1900 Australia had the largest GDP per capita in the world. In 1950 Australia was third, but in 1980 we were 21st. By the year 2020 what will we be? Whether GDP per head is the right measure is a moot point, as I for one, realise its limitations. In fact in 2008, Prof Alan Hughes from the University of Cambridge, stated in Sydney in a forum on innovation, that from his study of the Australian Bureau of Statistics data, the element of our productivity showing the most growth was **warehousing.** I put to him that warehousing does not add what I would describe as a productivity gain, instead it ties up capital, slows down the supply chain, adds to unnecessary work which adds no value to the product, increases the risk of damage and ties up real estate. He was not impressed, but my view has not changed. It is clear that new thinking is required. As Albert Einstein said, "We cannot solve the problems of the present using the methods that created them in the first place". Who am I to argue with this?

For too long Australia balanced its overseas trade by exporting primary products such as wheat and wool, and mining basic commodities like coal, iron ore and bauxite. Australia did not traditionally concentrate on adding a lot of value to these products. As a result in 1989, Australia was the largest debtor nation after Brazil and Mexico. In 2009 Australia's total private net debt is equal to 65% of GDP and the current account remains in deficit (our CAD) and is oscillating between 4% and 6% of GDP. Put simply:

Australia is not exporting and producing enough value added goods.

The root causes of this are many and varied. A major cause is then short term management focus which continues to saturate US business school training, lack of capital since we are a young country and trade in deficit, and the high and outdated personal income tax system. Another is the poor savings ratio and the focus on investing in real estate rather than in innovation and wealth creating activities. These cultural characteristics will become increasingly important in the future as Australia deals with global warming and her increasingly fragile environment. It seems it is too easy to dig it up and ship it out.

Despite a world situation where demand exceeded supply after the Second World War, the Australian manufacturing industry required protective tariffs to compete. Now, her manufacturing industry and the associated infrastructure is still weaker by world standards than all but third world countries, whilst the productivity per head of high technology products is only slightly better than Greece, Turkey and Iceland.

Thirty years ago, 27% of the workforce was employed in manufacturing. The number of people employed in manufacturing has declined greatly since then to approximately 9%. This constitutes a loss of 400,000 direct jobs and possibly 2,000,000 jobs in total. Whilst this is parallel to world trends in all developing countries, it nevertheless needs to be addressed. How did this happen? Should it be a worry to policy makers? Does Australia need to take action? What should be done? These are some of the questions addressed in this book.

When protective tariffs were gradually removed, manufacturing industries are exposed to global competition and many could compete with imported products. Hence they contracted and many plants disappeared. With the signing of the free trade agreement with the USA and other countries, many of our smaller manufacturers will be exposed again. In addition cheap imports from China continue to take their toll. In addition, it has been reported that many products such as furniture from China over the last few years has been sold here for prices less that the cost of raw materials to an Australian manufacturer. This could be dumping or a direct result of the Chinese using their RMB to inflate the US dollar to accelerate trade.

The United States of America suffered from a similar decline in wealth per capita relative to many other developed countries well before the financial meltdown first precipitated by the sub-prime mortgage scandal and later the Bernie Madoff type ponzi scams. Greed is not good. Whether invoking massive Keynesian money injections into the economy fixes the problem remains to be seen. Recent figures indicate high debt levels, and an increase in the US debt of $6,000 per second. In the period 1885 to 1900 the USA was 4th place in standard of living as measured by GDP per head and then by 1950 she had moved to the top spot which she held for at least 20 years to 1970. By 1980, the US A had slipped to 17th place.

Japan in 1980 was 22nd just behind Australia, but in the mid 80's Japan passed Australia and was in the top 3 (only headed by rich oil nations like Brunei or Kuwait). As demand dries up in the financial meltdown, Japan which relies heavily on exports has a massive problem. Interest rates there have been very low and near zero for a long period of time and this combined with a very strong currency will make their home grown products very expensive. Japan has always had a problem, mountainous country, large population, little raw materials, no energy. She imports the lot. Despite this her intellectual capability has led to such manufacturing icons as Honda, Toyota, Panasonic and Canon, truly innovative clever companies who continue to lead in quality, cost delivery and innovation.

The spectacular collapse of Australian manufacturing, lucky enough to have a virgin isolated wonderland at it's door step was balanced by an equally spectacular rise by Japan. What can we learn from this? Let us however be clear, the world economic downturn will affect Japan greatly since she relies heavily on export and her markets are drying up quickly. However, she has survived so far on the strength of her innovation, mental capability and value added manufacturing. Where to from here? Well no one really knows but I do know that if I buy a Honda or a Panasonic product it will be good value and high quality and innovative. We can all learn from this. We must invest in wealth creating revenue streams in areas of high technology and value added manufacturing where we have a natural advantage and prioritise our efforts and not try to be all things to all men.

That is what this book is about.

Numerous studies of the blooming Japan (2-10), fittingly the land of the rising sun, have been made in an effort to understand how, a nation without the natural wealth of raw materials and devastated by war, could rise like a phoenix from the ashes of a nuclear holocaust and cast its shadow over all world trade. Japan has remained in a dominant position despite internal political and financial control woes, and a poor infrastructure, and now faces another crisis with the global financial meltdown.

In 2000 Japan controlled 20% of world trade from a country of 2.5% of the world's population living on an island, 80% of which is mountainous and without great natural resources other than its people. Many of its largest companies continued to outstrip the west in profitability and growth and have market capitalisations greater than the majority of the countries in the world. (e.g. Toyota). At the same time Toyota and Honda have demolished the US auto industry in the American's own market. The highly paid American CEO's from GM, Ford, and Chrysler, blame the financial crisis. This is far from the truth. Even in 1990 MIT recognized the current and future problems for the US auto industry in "The Machine that Changed the World" (14), but the companies ignore advice and have now suffered the consequences. Despite this the CEO's are still paid massive salaries for failure.

Set in a world context, overall performance of manufacturing in Australia has the following elements which are all contributing to the difficulties.

- Lack of a prioritised strategic plan
- A management philosophy which is short term focussed
- Small domestic population
- Little or no understanding of how to use innovation of process
- Inability to commercialise it's own IP
- Management decisions made overseas and not in the Natuional interest
- Low return on investment
- Continuing high cost of production due to a high labour rate compared with Asian neighbours
- Low expenditure on research and development.
- An inordinate degree of protection for Australian industry through ad hoc schemes propping up industries without a natural competitive advantage
- Soaring charges for distribution
- The difficulty in the past, of moving goods in and out of Australian ports
- Poor transport infrastructure, numerous bottlenecks
- Application of outmoded technology

- A failure of Australian universities to produce graduates interested in manufacturing
- A workforce that is not flexible enough
- Too long a chain of decision making in industrial corporations
- A tax system which makes investment in manufacturing less attractive than for example real estate

The spectacular success of Japan since World War II in manufacturing high quality goods cheaply has recently prompted numerous studies on how this has been achieved.

A common thread is emerging which binds Japanese industry to a strong position in the world marketplace.

Keys to Japanese success are:

- Application of the scientific method and logical deduction. This is used extensively to solve production marketing problems, and general business problems. This in turn has led to a control system emphasising process and new ways of measuring the financial performance of manufacturing enterprises
- Management by consensus where possible
- Rapid application of new technology – innovation
- A continuous desire to improve incrementally (called Kaizen (11)
- Emphasis on:
    - Teamwork
    - Continuous value adding
    - Lean Manufacturing (Continuous Flow)
    - Process Innovation
    - Training and Education
    - Elimination of variation (Six Sigma)
    - Quality of product and process

The above are five points that can be summarised in terms of the words Creative Innovation using the principles of Lean manufacturing (continuous flow).

Amazing advances have been made by the Japanese in increasing quality and productivity since the second world war. Toyota, after establishing it's first plant in the USA in n1970, now dominates the US market and in the financial year 2003 to 2004 made a net profit of $US11.4Bn, enough to buy GM and Ford combined, but why would they? In 2009 she is the largest car manufacturer in the world.

The Japanese have proved that by increasing quality and rapid process innovation, you can increase productivity – a concept that was anathema to Australian management and technologists not so long ago.

Aajime Karatsu, Managing Director of Matsushita Communication, long ago has stated that as the quality increases the cost of production decreases. He has also stated that strict inspection is 'not to be proud of'. Also he claims that the number of breakdowns decreases as the process is improved, the operation rate increases and the cost is further reduced.

On the other side of the Pacific, results of recent analyses in the USA have yielded the facts that:

1. In excess of 75% of productivity problems can be traced to the system and management. (Dr Deming claims 85% of the problems are due to the system)
2. Less than 20% of productivity problems can traced directly to the workers or machines. (Dr Deming claims 15%.) Management must commit itself to production methods and quality standards
3. The control of quality must start at the top of the management hierarchy to be successful, but a successful quality system involves everyone
4. Adequate control of quality and productivity can lead to a reduction in operating costs of between 20% and 50%
5. Reasonable people will probably accept a quality system based upon majority and or consensus. Such a system makes Japanese workers more reliable, conscientious, diligent and smarter
6. The West must improve its productivity or its trading position will grow worse

There is ample evidence to suggest that the popularly held belief that the cultural, religious and class regimentation of the Japanese is more suited to high productivity, is untrue. In particular, the outstanding success of the Sony Corporation in San Diego using American workers, and the unchallenged supremacy of Honda and Toyota in the American's own backyard using Japanese methods is living proof that the Western world can do it. In addition, a 100% success rate for process Innovation programs based upon Lean manufacturing run by the author in Australia further confirms this (15).

1.2 Management – Western Style

Management must totally understand that the consumer is the most important part of the production line. Japanese management stand behind their products' performance and are continually looking forward to design and develop new products – unlike Western management. Using Lean thinking, Honda had reduced its development time for a new car from clean sheet of paper to world launch in under 36 months. (Honda). This is almost half the time of German Manufacturers. This is believed to be a result of the SPED process (16).

A successful product development plan involves an accurate analysis of the marketplace and a scientific approach and a quantification of the buying decision with continuous customer feedback. Too often we are myopic. We most often in our western culture look at short-term gain which can have a long term penalty. We too often judge on the size of the next annual dividend. This should not be considered to be as important as the continuation of the business in ten years' time.

Management in Australia must therefore learn to:

1. Plan ahead more effectively
2. Cope with technical change more successfully
3. Understand the philosophy that Australian industry can no longer live with the present levels of productivity, performance, quality, and low level of innovation and lack of research and development.

1.3 Problems to be Overcome

To introduce a new approach into Australian companies there are a number of potential problems that must be confronted. These are:

1. A decision based on the financial accounts alone. These systems are always after the event and late, and can measure a profit based on inventory increase. What about the manufacturing process? The marketplace should drive the process through manufacturing.
2. Inadequate planning and poor understanding of cycle time and its importance
3. Failure of management to get involved on the shop floor and understand quality and innovation
4. Failure to analyse productivity data and use the scientific method to isolate reasons and eliminate causes of problems
5. A tendency to always blame the worker on the job when most often the process is at fault and this is management's responsibility
6. The removal of lines in demarcation (necessary to improve efficiency) – the need for restructuring the workforce and using multi-skills
7. Poor communication between management and worker
8. Inadequate skills and training at all levels
9. Lack of industrial engineering an scientific expertise

1.4 Japanese Management

Japanese managers do not make hurried decisions as Australian managers do. They are painstaking in their demands for a cause and effect scientific analysis and hence require many technical details before they make a decision and a project gets approved. Once the decision is made however, everyone concerned is convinced it is correct and are committed to it.

Therefore, they all work to a common goal.

Additionally, Japanese people set themselves exceptionally high standards probably a direct result of the culture associated with the Samurai. This has led to a process that the west calls six sigma (after Motorola). The samurai warrior's sword is never sharp enough. This adds to motivation. Consequently, the worker more closely achieves peak performance. Japanese management is efficient and integrated. The emphasis is on majority decision-making.

Japanese plants did not always produce high quality products. The change was begun by the USA in 1946 when General MacArthur found the quality of Japanese products was very poor. Traditional quality control was introduced, new statistical quality control followed and a quality revolution resulted. This then led to American researchers saying that Japanese factories looked "Lean" meaning that there was little or no inventory in the plant since processes were integrated and created little or no waste and operated with little inventory.

The Fathers of this revolution were:

- Dr Walter Shewhart
- Dr W.Edwards Deming
- Dr J.M. Juran

These three were all basically ignored in their own country (USA) but their work was revered in Japan.

Australia needs to listen to and practice this new Lean philosophy.

Let's look at the differences in the behaviour, the way Japan uses people, technology, the way they work and the organisation they employ. and how the Japanese improve their processes, quality and productivity, the way the workforce is educated and the way they organise themselves. Let's not concentrate on some traditional view that we must go to Western Europe to solve these sorts of problems.

My numerous trips to Japan and working in and studying Japanese companies like Panasonic, Honda, Toyota, Canon and later Kawai, have moulded this book and its ideas and the 300 plus clients I have worked with in Australia and overseas have helped formulate my thesis and adjust the ideas to Western conditions and the western culture.

This cooperation is based upon and directed towards the achievement of a national objective of full employment.

I would think the national objective should be much more than simply full employment, but nevertheless, I think the message here is quite plain. We must identify our strategic direction and all work together as a team if we are going to be successful in achieving a growth rate which is to be comparable with countries like Japan, South Korea and Taiwan. We must identify our natural competitive advantages and capitalise on them.

In addition to what we can learn from Japan, there are four innovative components of an industrial policy approach which have been valuable in Western Europe to adding growth to an economy.

Firstly, there is an increasing emphasis placed on policies which strengthen links between small and large businesses to enhance import substitution which was done by encouraging domestic supply of intermediate goods to larger exporting firms. Secondly, industry and trade programmes had a strong regional focus which emphasis both efficient restructuring and the maintenance of a geographic and industrially diversified economy, and thirdly, R. & D. is viewed as absolutely crucial to the restructuring process. Again, the approach of foreign investment is balanced, and specific policies are directed towards ensuring the maximum benefit to the domestic economy which accrues from both incoming and outgoing investment.

Australia's performance in Industrial R. & D. has been poor, mainly because of a poor commercialisation record and a concentration on basic research rather than the applied element of this activity and the dislocation between Universities, CRC's and industry.

Australia should develop a national economic and social objective which must be set and supported by all major parties, government, unions, business, educational institutions, and community groups. It should be highly visible, actively embraced and it should be promoted by everyone.

Surely this is the same recommendation or recipe for the success of any company. It must know where it wants to go, how it should get there, and when it wants to be there. There are other ways of saying the same thing. The company must have a strategic direction, it must have a plan, a broad outline of where it wants to go. One of the basic problems with the Australian way of life is that we all have 'got it too easy'. Hence, we can say that one element of our total problem is the lack of a national objective. Why do we lack such a direction? The answer is management, in each management area, political, social and industrial. Australia's management needs to improve. Politically we need to understand that even innovation as viewed by the Cutler report (13), must set priorities in areas of competitive advantage, not try to be all things to all men.

1.6 Political Management

Let us jot down a few major points about Australian political management over the last fifty years.

- Current account deficit- now high as a result of policies pursued from 1946-1980
- Industrial relations climate – poor by Japanese standards but improving
- Heavily over-protected industries – protection being removed
- Little long term planning
- No reasonable integrated science policy
- Science and technology very low on the agenda
- No clear and visible definition of long term goals
- Too many unions and fragmented professional societies
- Penalty rates that are far too high
- Low on ideals, high on pragmatism
- Planning that doesn't appear to look beyond the next election
- No recognition of sustainable and strategic advantages for winning (SAW) over other nations
- No well defined national economic goals. If they are defined they are not visible or well understood by business and the community.
- Easily swayed by pressure groups without strong consideration of the overall national benefit

1.7 Social Management

Let's now list some of the special characteristics of our social management program:

- Welfare payments up to 30% of the total budget (non decreasing)
- Youth unemployment extremely high (greater than 15% in some age groups, but decreasing)
- Educational expectations created by a secondary schooling system not commensurate with the workplace
- An aging workforce
- Tremendous loss of experience by demanding that many healthy people retire at an arbitrary age of 60 or 65
- Science, mathematics and engineering regarded as low priority by the community

1.8 Industrial Management

A list of some of the characteristics of the industrial management climate in Australia currently is useful. The significant characteristics of these over the last forty years are as follows:

- In general terms the management is one of confrontation rather than cooperation
- Poor leadership and strength, lack of understanding of industrial relations
- Lack of understanding in industrial research and its necessity
- Graduate schools for management geared in the American tradition which is now inappropriate. After all just look at the mess manufacturing and industry is in the USA.
- Management using financial indices, not manufacturing indices of performance. A lack of planning, particularly in the smaller and medium size industries.
- Little or no use of preventative maintenance. Concentration on breakdown maintenance only.

So set in this context, Australia has a long way to go, but change we must. The first stage in the process of solving the problem is quality and productivity improvement. The next stage is for management to look beyond the current financial reflect the real time performance.

Improved management practices based on simple process innovation as it relates to all aspects of the business but in the first instance as it relates to our manufacturing industry. Such a focus must be market driven, logical, scientific and capitalise on our identified and defined strategic advantages for winning (SAW) i.e. what are we best at and where do we have natural advantages.

The Industrial Engineer – Technical Specialist and Team Member or "Why doesn't everybody love me"?

AGL (Lex) Clark

Maynard's Industrial Engineering Handbook (5th Edition 2001) asks the question "What is your idea of the role of the Industrial Engineer. If you think of plant layout, work measurement, time and motion study, production and inventory control, you may need to think again".

Towards the end of the 20th Century and into the 21st Century, IEs have increasingly moved from being management sponsored technical specialists working largely in the disciplines indicated above to playing a much broader role as members of organisational change and improvement teams. While able to utilise their specialist technical skills when required, the IEs broader discipline and experience in such areas as systems analysis, statistics, incentives and simulation can also enable them to take on roles such as team leader or facilitator.

Organisation teams today are also increasingly multi-discipline whose membership can include participants from supervision, shop floor workers, quality specialists, sales, distribution and design. At times, even customers and other key stake holders may be included.

As a result of their training and operating experience, IEs may often have carried out projects with many, if not all, of these participant groups. They may therefore have a broader understanding of the sometime different cultural and operational requirements of the personnel involved from management, workers and other technical specialists.

The questions can then arise as to where and when do the organisational and ethical responsibilities of the IE lie:

- Are they there as representatives of management to ensure only that **management's** requirements are fully met?
- Are they there as professional IEs to ensure that the interests of **all participants** are protected and, where possible, met?
- Do they have a wider social responsibility when participating in the management of change which has both short term and long term implications for the organisation, participants and perhaps society in general?

As Technical Specialists, IEs have commonly seen their responsibilities principally aligned with the requirements of Management. They have worked for more than a century on developing and implementing productivity improvement systems such as work measurement, production and quality control, incentives and workplace participation. Often implemented under social conditions that appeared appropriate at the time, huge increases have been made in productivity and quality utilising techniques which today are often questioned and sometimes condemned for what may be seen to be anti-social reasons.

The arguments might sometimes be seen to be similar to those questioning the use of some military weapons systems (e.g. anti-personnel mines, gas, white phosphorous). While undoubtedly effective as weapons of war under certain conditions, it is their indiscriminate utilisation at other times which has resulted in an "all or nothing" approach to discussions on their use and future applications.

It might seem to be stretching the analogy a bit far to compare the discussions on some military weapons with some organisation and product improvement systems utilised by Industrial Engineers. However, without these discussions there is often the danger of "throwing the baby out with the bathwater" resulting in the subsequent deep distress of the parents (to use another analogy).

Scientific Management and Work Measurement

Scientific Management as described and discussed by Frederick Winslow Taylor is still widely available in the publications 'Shop Management', 'The Principles of Scientific Management' and the 'Testimony Before the Special House Committee' published in the United States from 1903 to 1912. Taylor's ideas developed from his own personal experience and experiments on the shop floor in iron and steel production.

Under the 'old system' of management, Taylor recognised that:

- There was a 'great unevenness or lack of uniformity shown… which together constitute what is called management'.
- There is a 'lack of apparent relationship between good shop management and the payment of dividends'.

Taylor discussed conditions when there were dull times and management may get men to work extra hard for ordinary wages (to use his words). On the other hand, when there is a scarcity of labour, men will exact higher wages than average which they become used to and become dissatisfied when the inevitable downturn results in lost jobs and/or lower wages.

Taylor's new management technique was said to be based on two simple concepts:

- A new division of labour between the management and worker, with management carrying out all production development and planning, while the workers would work at an easier (simpler) and more efficient rate.
- The development and planning of more efficient ways of work by management would be based on detailed experiment for every unit of production and every manufacturing operation.

Even then, the concept of the Taylor System as it was called was seen to be very controversial:

- The Workers were concerned at losing their trade skills and control of their work.
- The Management was concerned at the costs of developing and implementing this seemingly complex managerial system utilising increased numbers of non-productive (and presumably expensive) workers (staff).
- The Unions were concerned (as were the Workers and their families) with the apparent potential for a major loss of worker jobs together with their trade skills and control of their work.

Over the intervening 100 years or so until today, mass production and other systems utilising Taylor's (and others) techniques have produced a vast and relatively efficient output of world goods, together with the associated jobs and infrastructure that go with them.

Today, the same concerns of the Workers and the Unions are voiced. For example an article in the Financial Review (10 March 1999 when the economy was showing signs of future problems) noted "Frederick Winslow Taylor has a lot to answer for. The man who destroyed the working life of countless millions by stripping their jobs of autonomy and skill is now blamed for the failure of modern firms to adapt to the needs of the knowledge economy".

Taylor was also well aware of the concern of Workers for their jobs if they increased their individual productivity. As he stated in his testimony to the Special House Committee, if the Worker 'were to double his output, and if the rest of the men were to double their output tomorrow…. he can see no other outcome except that one-half of the workmen engaged with him would be thrown out of work'. Taylor worked hard to illustrate that historically, greatly increased output (such as achieved during the Industrial Revolution) had created increased markets due to greatly reduced costs and the ability to meet these increased market demands. This in turn created very large numbers of jobs.

As part of his new management system, Taylor advocated the setting of experimentally based Work Standards through the use of accurate Methods Study and Work Measurement. This also helped to meet concerns (and to help prevent go-slow practices) of the Workers, as well as fostering the inter-dependency and hopefully trust between Management and the Workers. He also experimented with differential piece-rate systems which might be seen to provide a fair days pay for a fair days work.

Today, in many organisations, accurate Work Standards have often been replaced or 'benchmarked' by so-called 'best practice' targets from other organisations or even other in-house workers. The disappearance of these Work Standards may also take with them the understanding and use of Allowances for contingencies such as fatigue and difficult working conditions. The final result can be an open-ended (ie. no upper limit) output requirement placed on the workforce along with limited or no concern for their associated working conditions.

An interesting summary of some modern Management practices today was illustrated in a somewhat cynical Canberra Times article by Geoff Davies (6 June 1999). Behind the 'productivity' and 'labour-market flexibility' euphemisms is a logic that (at the time) employers and Government are pursuing. Fire a fair fraction of your employees and expect the rest to pick up the work – after all, they could be next. Outsource or restructure so you don't have to pay employees benefits. Use contract and casual labour so they carry the business risks while you reap the profits. If the shareholders are still not happy, the managers can move their production 'offshore'.

Taylor may or may not have supported these examples of workplace incentives and cost reduction. He certainly would have understood the short-term logic behind them as he struggled to convince Management, Workers and Shareholders 100 years ago that trusting each other and working together was in all their long-term interests. Times may have changed, but people are basically the same.

Scientific Management and the Quality Movement

Before the widespread introduction of the modern Quality Management systems, Productivity increases were commonly seen to be closely associated with Quality decreases. If you increased the output per worker, it was often assumed that a corresponding reduction in the quality of his output could be expected. As a result, more inspectors might be required to help detect and correct these faulty products. In fact, the Quality Movement was able to prove that, correctly managed, almost the reverse could be achieved ie. increased productivity with increased quality.

Another genuine concern of many managers and organisational improvement specialists has been that the use of IE techniques such as Work Measurement and setting of Work Standards by IE specialists can inhibit changes for improvement. Once Work Methods and Work Standards are set, together with associated piece-rate or bonus pay schemes, the incentive to simply increase productivity may be seen as undermining these Standards and requiring a continuation of often difficult and sometimes controversial working condition and pay agreements.

The Quality Movement also has some of these concerns. Total Quality Management quoted from Taylor as he attempted to lead organisations from the chaos of craft-based technology towards the 'Industrial Utopia' of scientifically managed mass production; "The inspector is responsible for the quality of work, and both the workmen and speed bosses (foremen) must see that their work is finished to suite them….The full result will not have been realised until almost all of the machines are run by men who are of smaller calibre, and therefore cheaper than those required under the old (craft based) system".

Dr Deming in his publication 'Out of the Crisis' listed his 14 Points for the Transformation of Western Management, largely based on his experiences with the post World War 2 Japanese management systems (which were themselves based on United States management systems). In his 14 Points, 11a "Eliminate numerical quotas for the work force" discussed the role of individual worker work standards which he noted were based on times set for the 'average worker'. Half the work force were therefore above this average and half were below. Those above the average tended to hold back their work rate to the standard, while those below could not make the average.

Dr Deming in Point 11b also proposed to "Eliminate numerical goals for people in management" (eg. Improve productivity by 3 percent next year, or decrease costs of warranty by 10 percent next year). He believed that, with a 'stable' (controlled) organisation you did not need to set numerical goals, and with an unstable organisation there was no point in setting goals as there was no way of knowing what the system could produce. The apparently arbitrary setting of 10 percent productivity improvement or cost reduction goals by some managements today would presumably not have been supported by Deming, even though he would have understood the short term imperatives of top managements which otherwise have little control over components of their organisations.

Industrial Engineers working in teams with Quality Management personnel may therefore find themselves sometimes appearing to be at cross purposes. However, an understanding of where the differences lie and how they have been developed can often resolve the issues. Industrial Engineers themselves have often been at the forefront in the introduction of many Quality Management systems as they recognise their validity in today's organisations.

Industrial Engineers and Behavioural Scientists

As a final example, mention might also be made of the many contributions that the Behavioural Sciences have made to the understanding and improvement of modern management practices. As also indicated above with other techniques, managements and others have utilised some of these practices for purposes that might not have been originally intended and which their practitioners might not agree.

Industrial Engineers have long been aware of, and utilised the effects on a workforce of, what has become known as the Hawthorne Effect. This was originally developed from research between 1924-1927 carried out by American Psychologist Elton Mayo at the Hawthorne Works of the General Electric Company in Chicago. In a series of shopfloor experiments on improving productivity by modifying the working environment, Mayo more or less accidently found (or appeared to find) that actually engaging the individual workers in the improvement process itself motivated them, together with their co-workers, to increase productivity and quality to a greater degree than simply improving their working environment.

From this early work, a great amount of further experiment and development by others has produced the modern management emphasis on increased Worker Participation. IE's have found this to be of great benefit to their work on the shopfloor, and has often changed the role of the IE from a Technical Specialist to that of a Team Member and Facilitator as the modern more educated Worker learns to understand and apply the IE techniques themselves.

However, sometimes to the dismay of some IEs, Managers have often interpret these findings to mean:

- It can be cheaper to motivate the workforce to work harder than it is to pay them for their extra output.
- Management can utilise these worker participation systems to shift responsibility and difficult decision making (eg. who should be made redundant and how many) on to the Workers themselves.

Summary

This article is intended to illustrate that the profession of Industrial Engineering today can be as interesting and stimulating as it has always been for the last 100 years or so.

It also hopefully illustrates that the needs and aspirations of people have not changed much over these years, and the Industrial Engineer can participate in a far wider range of organisation improvement activities than perhaps they have in the past, both as Technical Specialists and Team Members.

However, while the IE may have a wide understanding of the systems and techniques available from disciplines such as Industrial Engineering, Quality Management and the Behavioural Sciences, they should also recognise that some of their own techniques (and at times even their own disciplines) are regarded with deep suspicion by others with lesser understanding.

With this recognition and understanding, the Industrial Engineer can further enhance their roles, and increase their opportunities, as they work both as Technical Specialists and Team Members.

ALG Clark

First principles of performance measurement and the utility-productivity performance equation

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Abstract

This paper relies on a simple definition of performance measurement, that being 'degree of goal attainment'. The paper subsequently develops a unique formulation of performance measurement $P_{P=\mu,\eta} = \mu_g \eta_a$ based on two fundamental concepts of goal-utility of input resource and actual-productivity of process. The formulation is independent of type of goal being sought and includes all goals of a maximising, minimising or targeted-goal nature.

Keywords

Performance measurement, Performance measurement definition, Maximising goal, Minimising goal, Targeted goal, Utility of input resource, Productivity of process, (Utility-Productivity) Performance equation.

Introduction

Neely (2005), in his introduction to "Defining Performance Measurement: A Growing Debate" states that… "The reality is we will never resolve the question of how performance measurement is to be defined." This, being such a definitive statement within itself, is extraordinary. Confusion between what performance measurement is and the context in which it is to be performed is apparent.

Performance Measurement

All performance measurements P_p simply involve some form of assessment of actual performance-parameter value p_a against a set goal value p_g (for a minimising goal), p_G (for a maximising goal) or $p_{t\pm\delta}$ (for a targeted goal). When actual performance parameter value p_a betters set goal values – be they maximising, minimising or targeted goal values, by convention 'superior' performance $P_p \geq 100\%$ is deemed to have occurred. Alternatively, when actual performance parameter value equals expected goal value, 'paid-for' performance $P_p = 100\%$ occurs; and when actual performance is poorer than expected, 'poor' performance $P_p < 100\%$ is then said to have occurred.

Maximising, Minimising and Targeted-Goal Performance Measurement

For maximising goals, therefore, the form of performance measurement must be of form $P_P = \frac{p_a}{p_G}$. For minimising goals, however, the form of the performance measure must invert to the form $P_P = \frac{p_g}{p_a}$ if the above 'superior', 'paid-for', 'poor' performance convention is to hold.

For targeted goals, the form of the performance measure is dependant on where the actual value of the performance parameter p_a lies in relation to the targeted range $p_{t\pm\delta}$. If the actual value of the performance parameter p_a lies above the upper limit of $p_{t\pm\delta}$ then action must be taken to encourage the performance parameter *p* to travel in a minimising goal direction. The appropriate form of the performance measure is thus the minimising form $P_P = \frac{p_{g=t+\delta}}{p_a}$. If, however, the parameter p_a lies below the lower limit of $p_{t-\delta}$ then action must be taken to encourage the performance parameter *p* to travel in a maximising goal direction. The appropriate form of the performance measure, in this instance, is the maximising form $P_P = \frac{p_a}{p_{G=t-\delta}}$.

The utility-productivity performance equation

When the above performance measurement basics are applied to a productive system[1] which (by implication) uses input resource set {*i*} to generate an output resource set {*o*}, a measure of the productivity-performance of the system is normally given by the maximising-goal form of performance measurement, viz $P_P = \frac{p_a}{p_G}$. This is appropriate since productivity is a performance parameter normally maximised when the set of output resources {*o*} is a set of desired products and services[2]. Thus, where the performance parameter p is the productivity measure $\eta = \frac{\{o\}}{\{i\}}$, the productivity-performance of a productive system is given by $P_{P=\eta} = \frac{p_a}{p_G} = \frac{\eta_a}{\eta_G}$ or $P_{P=\eta} = \frac{p_a}{p_G} = \frac{\eta_a}{\eta_G} = \mu_g \eta_a$ where μ_g is defined as the minimum goal utility of the set of input resources $\{i\}$ and η_a is the actual productivity of the process used to convert the input resource set $\{i\}$ into the desired output resource set $\{o\}$ [3].

Alternatively, if the performance parameter of interest is switched to the utility of the input resource set $\{i\}$, then $p = \mu = \frac{\{i\}}{\{o\}}$ and a measure of the utility-performance of the system is given by the minimising goal form of performance measurement viz $P_P = \frac{p_g}{p_a}$. This is appropriate since utility is a performance parameter which is normally minimised when the set of output resources $\{o\}$ is again a set of desired products and services. Thus, where the performance parameter p is the utility measure $p = \mu = \frac{\{i\}}{\{o\}}$, the utility-performance of a productive system is given by $P_{P=\mu} = \frac{p_g}{p_a} = \frac{\mu_g}{\mu_a}$ or $P_{P=\mu} = \frac{p_g}{p_a} = \frac{\mu_g}{\mu_a} = \mu_g \eta_a$.

Interpretation of the utility-productivity performance equation

In both goal cases, productivity-performance and the utility-performance of a productive system, result in the same 'utility-productivity' performance equation of general form $P_{P=\mu,\eta} = \mu_g \eta_a$. That is, the equation suggests that the maximising of the desirable productivity of a productive system's processes is equivalent to the minimising of the utility of the input resources used both by the productive system itself (the 'house' resources) and those used within the productive system itself (the 'variable' input resources).

The utility of input resources is interpreted (in the simplest case) to mean the amount of each category of input resource (labour, material, etc.) required to generate a unit of output resource. This is readily setable as a minimising goal either as a simple extrapolation of existing learning curve loci or as 'stretch-goals' located well below past performance-parameter learning curve trends. Thus, the aim (goal) is to always to minimise the amount of each category of input resource required to generate a unit of good output resource. The productivity of the productive system, on the other hand, is interpreted to be that of the processes themselves used to convert the input resources into outputs. The actual productivity of process is a measure of the amount of output resource generated per unit of input resource. Thus, the aim (goal) is to always maximise this.

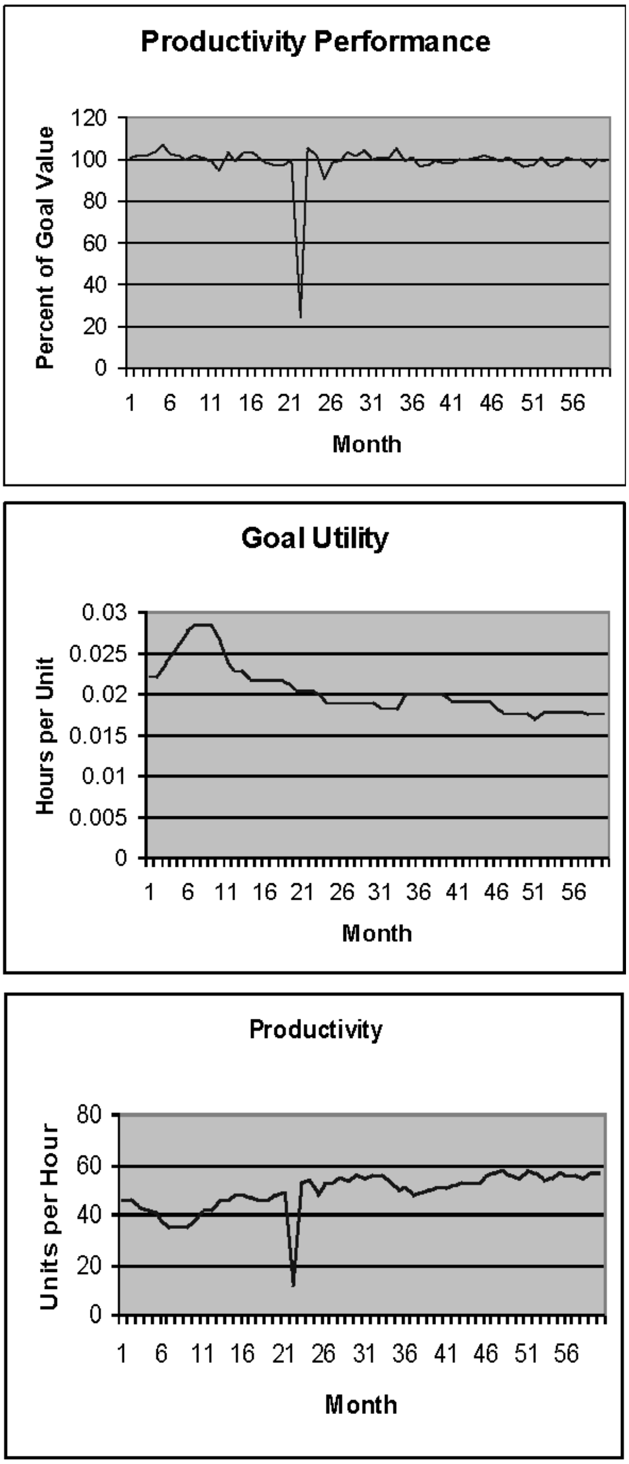
Measuring the utility-productivity performance of a productive system

The utility/productivity performance equation is generic in form and can be applied to any productive system situation. This includes productive systems both human and non-human, singular or collective – such as operating within groups. Examples of the latter include singular stand-alone supply chains or supply chains operating collectively within complex supply networks. To measure the utility-productivity performance of a productive system, using the utility-productivity performance equation, is a relatively straight forward exercise. The utility-productivity performance equation $P_{P=\mu,\eta} = \mu_g \eta_a$ suggests that a minimising goal value μ_g be set for the utility of each category of input resource employed and that actions be taken (eg: new input resource selections, re-design of processes, etc.) and that followup measurement of the resulting actual productivity of process η_a be made. Simple multiplication of the goal utility value of a category of input resource and the subsequent corresponding actual (partial) productivity of process value automatically generates the required performance measure for that category of input resource. Thus, partial productivity performance of labour, materials, etc can be made. Total, or overall, performance measures can then be obtained, but these are necessarily restricted to overall return on investment type financial productivity measures. An illustration of the basic use of the utility-productivity performance equation in measuring productivity performance is illustated through the following case study summary.

Case study

A case study application of an initial form of the utility/productivity performance equation was first described by Kennedy (1988) and further elaborated on in research papers (Kennedy, 1993, 1999). The reported case study situation involved using a resource-accounting type methodology to (primarily) measure the impact of major process technological change on the productivity performance of a major Melbourne-based automobile manufacturer. To measure the full productivity impact of the major process technological change, the case study covered a 5 year (60 month) period in which the major technological change (robotics) occurred approximately mid-way through in month 23.

The category of input resource chosen for the study was total labour hours. The utility of this category of input resource was then the total number of labour hours planned per unit of product to be produced (hours per unit).



Productivity Performance = Goal Utility of input resource x Productivity of Process

Figure 1: Productivity Performance of an Automobile Manufacturer over a 60 month period

The Goal Utility plot of Figure 1 shows the series of goals progressively set throughout this 60 month period.

Surprisely, the first six months of data within the Goal Utility plot of Figure 1 shows a planned *increase* in the total planned labour hours per unit produced. This is explained by the fact (as evidenced in a major-events calendar) that then industrial relations required excess labour to be carried through a severe industry downturn in the first 6 months of the study period. However, following this initial six months, industry demand picked up and plant management then aggressively set out to *reduce* the total labour hour requirement per unit produced. This was to be achieved through a series of industrial-engineered-based waste reduction efforts throughout the entire plant to be capped-off with the introduction of a major process technological change beginning month 23.

The actual-Productivity plot of Figure 1 (measured in actual units produced per labour hour) shows steady increases in labour productivity from month 6 up till month 23. The resulting Productivity Performance was nominal during this period at approximately 100 ± 5 % (This suggests that the reported series[4] of 13 waste reduction/line re-balance exercises undertaken during this period were successful or 'paid-for' exercises). Month 23, however, marks a severe downturn in actual-productivity achieved. The planned 'turn-key' introduction and operation of robotics was obviously not seemless and productivity performance plummeted to a very poor performance level of 20% productivity-goal attainment. That is, actual productivity results show that poor productivity performance resulted when the actual productivity time series data decoupled from set labour input resource utility goal points. The productivity curve of Figure 1 (and formal cross-correlation analysis) also shows that the effect of the decoupling lasted a full 3 months before another series of 8-off (major-event calandar evidenced) plant-wide waste reduction/line rebalancing actions further increased plant productivity against continued planned reduced utility goal points, resulting in again nominal paid-for productivity performance for the period months 26 to 60.

The above case study suggests that the singular 'introduction-of-robotics' project was not as well project-managed as were the series of 13 and then 8 waste reduction/line re-balance exercises. This is not surprising as the waste reduction/line re-balances were an on-going series of plant activities undertaken by a team of well experienced and knowledgable industrial engineers getting well down their experience curve whereas the introduction of robotics was a relatively complex, one-off exercise undertaken by a separate team of production engineers and outside consultants.

Finally, Figure 1 also demonstrates the application of the utility/productivity performance equation in graphical form. To simply measure the effectiveness of any further technological change (either amongst the input resource factors, in the process factors, or in the output factors), the effect on utilty/productivity performance is readily determinable from simple utility of input goal setting and subsequent measurement of productivity of process.

Conclusion

A simple definition of performance measurement as 'degree of goal attainment' has informed the development of a goal-based Utility (of input resource) - actual-Productivity (of process) performance equation, of general form $P_{P=\mu,\eta} = \mu_g \eta_a$. This equation is generic as it is applicable to any work (productive system) situation. In particular, since all instances of performance measurement involve the setting of goal values (maximising, minimising or targeted) and the assessment of the success of subsequent efforts made in order to achieve such goals, the utility/productivity performance equation should prove to be a valuable tool in the ongoing effort to better understand all instances of "performance"and its subsequent measurement.

Footnotes

1. *Defined as any entity that does work.*
2. *This is not so if the outputs are undesired (eg. Pollutants, poor quality produsts and services, etc.). In this case, productivity is to be minimised.*
3. *The notation* $\frac{1}{\eta_G} = \mu_g$ *has been used to indicate that the reciprocal of a maximising productivity goal value is a minimising utility goal value.*
4. *As evidenced in the Case Study's major events calandar.*

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