Enhancing Engineering Business through Benchmarking

Professor Chongqing University

Emeritus Professor The University of Adelaide

vernon.ireland@adelaide.edu.au

Yasmin Ooi-Sanches, Thales

Yasmin.OOISANCHES@thalesgroup.com.au

ABSTRACTI

The purpose of this paper is to explore a system for benchmarking a group of aspects which are relevant to complex projects, pursued both as systems engineering and construction projects, relevant to engineering business. It is the author's view that the practice of engineering has been much less affected by the Internet than conducting engineering business. A significant change has occurred in the area of management and business with the recognition of complex adaptive systems. It is not surprising to the authors that many engineers have difficulty recognising and understanding complex systems because this is an imprecise world, and very different to their normal practice of engineering. A survey and benchmarking service is being proposed. The purpose of the benchmarking service is also assist engineering practitioners to manage complex adaptive systems operating in their projects and to provide a basis for Engineers Australia to offer support in engineering business through recognising complex systems as part of engineering.. The fundamentals of complex adaptive systems, are emergence, self-organisation and dynamic systems. Integration of operational leadership, enabling leadership and adaptive leadership, are explored and tests proposed. Aspects of complexity, including structural, dynamic, socio-political, legal, financial and other aspects will be tested. Management aspects such as Beer's viable systems model, complex systems parameters such as mindfulness, preoccupation with failure and normalising deviance are also proposed for testing.

1. Introduction

The purpose of this paper is to outline a benchmarking system applicable to a group of systems engineering and construction projects, in order to assess the extent to which these projects recognise complex systems principles. An accompanying paper 'Managing complex systems and projects' (Ireland 2020) addresses a similar range of complexity elements, in greater detail.

There is a range of reasons for this approach, the primary one of which is extending knowledge in an important area. However Engineers Australia, the professional body for practising engineers, with its Royal Charter, has only 10-15% of practising engineers as financial members. Consequently the author is seeking evidence on the state of understanding of complex systems by engineers and other project practitioners, as this is considered a likely cause.

It is the author's view that while the practice of engineering has not changed dramatically since the introduction of the Internet, however engineering business has been severely affected, and as a consequence practising engineers need assistance in the leadership and management of their engineering business.

Recognition of complex systems, over the last 50 to 60 years, has revolutionised the understanding of management and business, the fundamental elements of complex systems are emergence, self-organisation and dynamic systems. These will be briefly discussed and their relevance to engineering business will be established.

For those who are tempted to think that complex systems is a fad or a fashion, there have been ten Nobel Prizes awarded for contributions to complex systems, the initial one being to Herbert Simon in 1972,

which was then followed by Nobel Prizes to Ilya Prigogine, Murray Gell-Mann, Charles Arrow, Daniel Kahneman and five other recipients.

Complexity science, or complex adaptive systems, is the 'study of the behaviour of large collections of … simple, interacting units, endowed with the potential to evolve with time' (Coveney, 2003, p. 1058). Some aspects of description are clear and direct, including the relationships between the system and its external environment, behaviours of elements of the system which produce system properties, such as birds flocking and fish schooling. Somewhat unpredictable emergence is relevant, such as new behaviours in society.

Sections 2-8 provide some justification for consideration of complex systems however Ireland (2020) provides much more justification. Section 9 provides a list of questions which will be bases of the benchmarking is tool. Section 10 provides a list of complex systems parameters which could be used as non-functional requirements in systems engineering projects.

2. Moving from classical science to complexity science in managing projects and enterprises

Tetenbaum lists six characteristics which the modern organization have to deal with (Tetenbaum 1998). These are:

a. **Technology**. spread of computer technology, electronic communications, multimedia and consumer electronics.
b. **Globalization**. Development of an interconnected world with global flows of information, money, people and goods.
c. Competition. An increase in global competition.
d. **Change**. Faster change than ever before, and the need to respond with agility.
e. **Speed**. An incredible increase in technological speed in product and process cycles.
f. **Complexity and paradox**. A result of all these changes and 'making more and more difficult demands on managers who are used to seeking certainties and 'either/or'-type solutions to issues'.

However many organisations are still dealing with a classical view of science rather than understanding complex systems. In this classical view leadership was seen as a series of positions with various degrees of delegated authority.

A number of organisations have failed to survive in an attempting to deal with this complex world, which has dramatically changed since the introduction of the Internet. While over 90% of members of SESA indicated in 2018, that their business was being affected by complexity, the author's view is that many organisations don't know how to manage this uncertainty, globalisation and management of change. Kodak, IBM, General Motors and a number of other large organizations, decided to downsize to make them more agile. Business process re-engineering was popular in the 1990s, however it was found that this was not enough to deal with complexity. Decentralisation was also seen as a possible way of dealing with complexity however this was found to be inadequate. Knowledge creating companies, networks and empowerment teams, lateral communications and many attempts to remove hierarchy, and virtual organisations, have emerged in this century.

Peter Senge's Learning Organisation concept was introduced late in last century (Senge 1990) as a public demonstration of the importance of complexity and how organisations can benefit by recognising complex systems.

However the construction and project industries have been shown to be conservative and somewhat resistant to change.

3. Dealing with a rapidly changing business environment

One of the first actions in recognition of complex systems was Ross Ashby's statement about requisite variety (Boisot & McKelvey 2011), which raises the question of how well organisations are dealing with a rapidly changing business environment. Dianne Decker and James Belohlav, back in 1997, recognise the relevant changes required by businesses (Decker & Belohlav 1997). The authors recognise that many businesses need to change.

4. Emergence

We are all aware of the rapidly changing business environment and emergence which stems from it, whether it is the behaviour of our partner or our teenage son or daughter. Ross Ashby introduced the concept of requisite variety, which means systems need internal systems to control the variety of the external system or environment. Requisite variety is the number of internal control systems matching the variety of external environment (Boisot & McKelvey 2011).

> Too many managers and writers on management are still influenced by old ways of thinking. These ways of thinking are essentially laboratory based and while very useful for the hard sciences and the creation of new technologies, they are extremely unhelpful for dealing with the real, very volatile world of people and organizations that exists 'outside the lab' (McMillan 2008:74).
>
> I would argue that if we are to learn to cope much better with our changing world then we need to radically change our thinking and our perceptions of change and the dynamics of change. Understanding and using concepts from complexity science – and the real world – will enable us to do that. In fact, it should enable managers to dramatically shift their thinking (McMillan 2008:75).

5. Emergence of self-organizing systems

Ireland & Gorod (2016) represented Lichtenstein's (2014) model of emergence as entrepreneurship as the five stages shown in figure 5 of their 2016 paper:

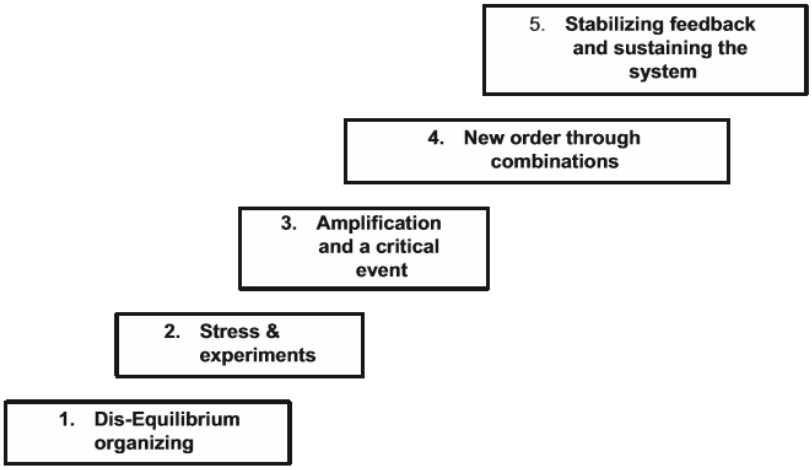

Figure 5: The authors' representation of the Lichtenstein (2014) regenerative emergence model.

The Lichtenstein model shown in figure 5 could be more readily seen as a change management process rather than a spontaneous event. Activity 3 emphasises the positive reinforcement which provides energy to the change process.

6. Self-organisation of people in an enterprise

We are aware of self-organisation through birds flocking and fish schooling, however . Trewavas (2014), in considering evidence of SE of ants, bees and plants, notes that this group provides evidence of over twenty illustrations of SE, motoring the key elements in the environment, which affect their outcomes.

They can identify what needs to change in their system when the external environment changes. However Trewavas (2014:79) sees self-organisation as a more fundamental characteristic in his statement:

Richard Knowles (2007), spend time working for Sencorp in the USA creating a self-organisation system within the company and was then engaged to create a similar system in multiple companies on behalf of an industry association. The model he used is shown in his Fig 2.

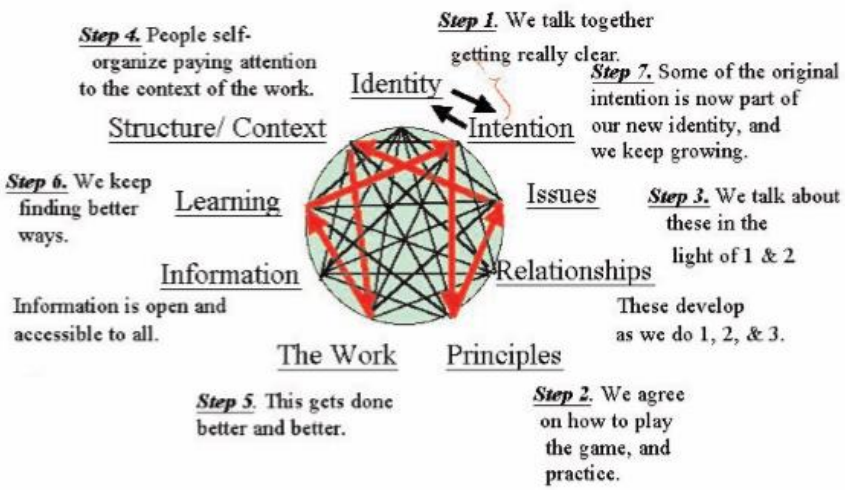

Figure 4 The living pattern and process of how the work gets done

The separate functions can be shown in Knowles' Fig 5.

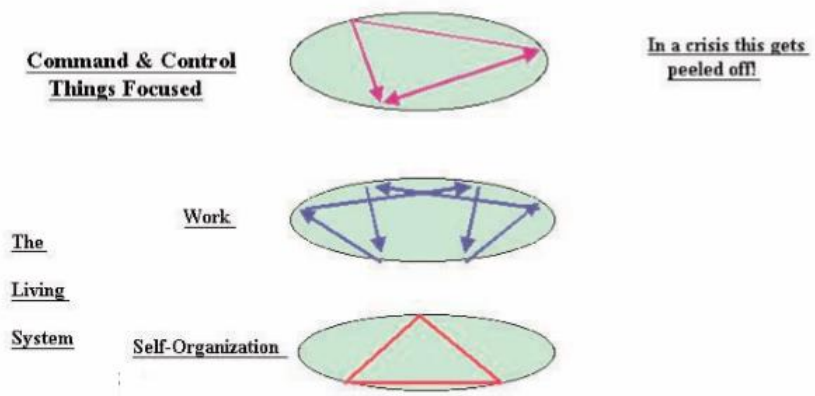

Figure 5 Simultaneous processes

7. *Dynamic systems*

Given the need for organisations to recognise the importance of adjusting to a rapidly changing business environment, and by adopting Ashby's requisite variety, it is inevitable that there will be dynamic business systems with changing values of key systems. Furthermore, part of this is also recognising that a rapidly changing world produces emergence with new concepts and elements occurring. Furthermore, Smith & Stacey (1997:91) point out those organisations must sit on the edge of chaos in order for them to be flexible enough to adapt to the rapidly changing business environment.

Sitting on the edge of chaos is recognising the rapidly changing business environment, actively engaging with this and being willing to take risks in the engineering business to the front of the wave of change rather than attempting to catch up'.

Smith & Stacey (1997) address the issue of dynamism being produced by organisations which have a reasonably open system and thus let self-organisation occur as part of the adjustment process. This then produces the issue of whether the whole organisation should take up a self-organisation in the same way, or whether there can be both a formal system, with formal values for these parameters, and a self-organised system, with a set of values which differ from the formal system. While this can be difficult to cope with, it also allows a more nuanced approach recognising and encouraging self-organisation. They comment:

> 'The science of complexity yields the insight that creative systems develop through a process of self-organization out of which the future governance of the system emerges'. … New patterns of behaviour emerge without prior shared intention when a system is pushed far from equilibrium to the edge of chaos'. (Smith & Stacey 1997:91)

Many engineers have a major problem in understanding the business world because it is fundamentally different to engineering. Richard Pascale (1999) comments that ***stable equilibrium means death*** to business. He quotes Steve Miller who, as CEO, transformed the Royal Dutch Shell from a wholesale business to a retail business, because he recognised that Royal Dutch Shell was not in sync with the needs of their customers or their competitors. A major amount of energy was injected into the business system by visits from the corporate team to every single business unit (47,000), can benefit from operating retail environment, selling food and services to all their customers, rather than just petrol. As CEO he spent more than 50% of his time over a year managing this transition.

8. Complex project management

Richard Heaslip (2014), after interviewing large numbers of practising project managers, concerning how they manage their projects, found that there was a conflict between the project manager's team in their planning activities and the corporate governance team. In the end, he concluded that there were three important functions, operational or administrative management of the project, the enabling leadership which needs to be provided to staff and the adaptive role which needs to be provided by the enterprise. The separation of administrative or operational leadership, from enabling leadership, was introduced by Uhl-Bien et al (2007), in a fundamental paper addressing inappropriate leadership approaches and behaviour.

These functions are illustrated in Heaslip's Fig 9.1.

The author has examined a group of engineering failures, including the failure of the Titanic in 1912, the two prominent NASA spacecraft failures of Challenger in 1986 and Columbia in 2003, the Fukushima Daiichi nuclear disaster in 2011 and the BP Deepwater oil spill in the Mexican Gulf in 2010. All indicated that a number of complex systems parameters were not observed including:

- Believing your own marketing with regards to the failure of the Titanic (*the ship is unsinkable*);
- Normalisation of deviance on the two NASA missions.
- Preoccupation with failure on the BP Deepwater oil well.
- Arrogance or lack of humility, the Fukushima Daiichi nuclear disaster (Omoto, 2013).

One of the most useful approaches to adaptive leadership comes from double loop learning Argyris (2002), who notes that learning occurs when a monitor is corrected for inaccurate behaviour without changing the underlying structure of the monitor (for example a thermostat), however double loop learning occurs when the underlying structure and values of the systems are corrected.

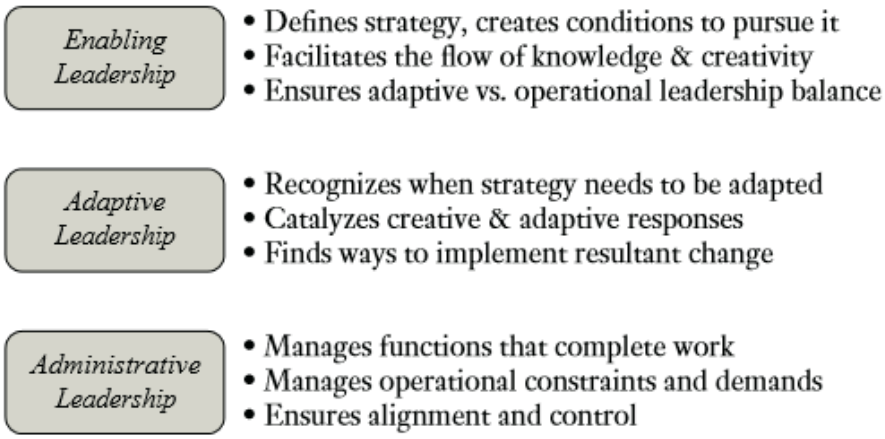

Figure 9.1 Key foci of enabling, adaptive, and administrative leadership.

Argyris notes that part of double loop learning is:

- Noticing inconsistencies.
- Asking other staff members for advice on how to address problems.
- Being aware of the workplace culture.
- Seeking advice from other staff members concerning their view of your failings.
- Not blaming others for your failings.
- Taking responsibility for your actions.
- Being aware of organisational politics.
- Both individual and group reflections on relevant issues.
- In-group discussions, including listening, rather than waiting for the answers you want to hear.
- Engaged new staff with different beliefs to your own.
- Avoiding being an action oriented leader, with inadequate pre-discussion and thought.
- Ensuring effective communications between the various power centres of the organisation, such as project manager, governance committees and the corporate group.
- Attempting to deal with groups who are unaware that they are unaware of a range of issues for effective adaptation.
- Ensuring that self-reinforcing and self-supporting, counter adaptive views, are reduced or eliminated (for example 'dumbing down' - the authors addition).

9. Additional aspects explored

A group of further complex adaptive system parameters are explored in an accompanying paper all (Ireland 2020). These include Beer's viable systems model, double loop learning, scenario planning, Soft System Methodology, the role of fractals, examination of megaprojects, Soft System Methodology and complex systems parameters as possible non-functional requirements on systems engineering projects.

10. Supporting engineering enterprise business

In order to encourage change and development of engineering businesses the author is establishing a benchmarking service based on the group of complex systems parameters. The following items will be benchmarked:

Table 1 Questionnaire items

Complex systems parameters	Assessment of engineering projects	Can this parameter be used as a requirement for a systems engineering project?
General		
1. Which college of Engineers Australia does your organisation most associate with: a. Biomedical b. Chemical c. Civil d. Electrical e. Environmental f. Information, telecommunications & Electronics engineering. g. Leadership & Management h. Mechanical		
2. Are you satisfied with what Engineers Australia offers you. On a 10 point scale, where 10 is very satisfied, what score would you give Engineers Australia?		
3. Which do you feel has been more affected by the internet: a. Engineering b. Engineering business		
4. Is your organisation dealing with globalisation adequately?		
5. Is your organisation coping with the flow global ideas?		
6. Is your organisation coping with global competition adequately?		
7. Is your organisation coping with the rate of change of products and processes adequately?		
8. Do you believe that engineering business has changed much more than engineering design in your career/ • No • Yes		
9. As globalisation providing opportunities for your business?		
10. Does globalisation create problems your business?		
11. Do you primarily work on: • Construction projects? • Systems engineering projects?		
12. Have aspects emerged on previous projects which were unexpected and unplanned for?		
13. Do you find that issues which arise on projects, such as late arrival of a design, can have multiple implications which combine, such as effect on suppliers, increased risk, time delays and cost increases?		

14. Do you delegate planning and management to junior staff?		
15. Do you find that many aspects of a project have changing values due to aspects which emerge?		
16. Assessing requisite variety (Boisot & McKelvey 2011).	It is requisite variety of the project dealt with?	**?**
17. Recognising complex versus complicated (Kurtz& Snowden 2007).	Does the project recognise the difference between complex and complicated?	**?**
18. Recognition of dynamic systems (Kaisler & Madey 2008).	Does the project recognise dynamic systems?	**?**
19. Recognising self-organisation (Knowles 2007).	Does the project support self-organisation?	**?**
20. Recognising emergence (Lichtenstein 2014).	Does the project recognise emergence?	**?**
21. Creating governance through Beer's viable systems model (Hoverstadt 2008).	Does the project recognise implement Beer's Viable Systems model of major group being structures in a similar way, with coordination of these, and integration and governance?	**?**
22. Developing Mindfulness (Weick & Sutcliffe 2016).	Does the project recognise mindfulness?	**?**
23. Preoccupation with failure (Weick & Sutcliffe 2016),	Does the project recognise preoccupation with failure?	**?**
24. Avoiding normalising deviance (Weick & Sutcliffe 2016).	Does the project normalise deviance?	**?**
25. Avoiding arrogance or practising humility (Omoto 2013);	Does the project practise humility and avoid arrogance?	**?**
26. Use of stage-gate: risk versus proposed benefits (Cooper 1986).	Do projects use a stage gate process of commitment by balancing risk and reward at stages of development pre-commitment?	**?**
27. Incremental Commitment via a Spiral Model (Boehm et al 2014).	Does the project use Incremental Commitment via a Spiral Model at stages of development pre-commitment?	**?**
28. Recognising we don't we don't know what we don't know (Taleb 2007).	Does the project recognise we don't we don't know what we don't know?	**?**

29. Responding to uncertainty when planning (De Meyer et al 2006).	Does the project recognise uncertainty in planning?	**?**
30. Use of 'V' model to verify and validate (Forsberg & Mooz 1999).	Does the project use the 'V' model to verify and validate?	**?**
31. Recognition of complexity in the supply chain (Spiegler et al (2001).	Does the project recognise complexity in the supply chain?	**?**
32. Cascading risk (Helbing 2013).	Does the project recognise cascading risk?	**?**
33. Systemic risk (Helbing 2013).	Does the project recognise systemic risk?	**?**
34. Root cause analysis (iSix Sigma).	Does the project recognise use root-cause analysis	**?**
35. Self-organised criticality (Bak, Tang & Wiesenfeld 1988).	Does the project recognise self-organised criticality?	**?**
36. Use of fractals (Hoverstadt 2008).	Does the project recognise fractals as an organising process?	**?**
37. Complex Responsive Process of Relating (Stacey 2001 & 2012).	Does the project recognise the importance of planners and organisers making an effort to build relationships with the project deliverers?	**?**
38. System dynamics to understand and integrate feedbacks (Sterman 2000).	Does the project recognise systems dynamics to understand and integrate feedbacks?	**?**
39. Soft System Methodology (Checkland & Holwell 1998).	Has the enterprises used the soft system methodology to clarify what the real project is?	**?**
Double loop learning		
40. Noticing inconsistencies.	Does the project recognise inconsistencies?	**?**
41. Asking other staff members for advice on how to address problems.	Do project team members ask advice of others on how to address problems?	**?**
42. Being aware of the workplace culture.	Are project team members aware of the workplace culture?	**?**
43. Seeking advice from other staff members concerning their view of your failings.	Do project team members seek advice from other staff on their failings?	**?**

44. Not blaming others for your failings.	Do project team members blame others for their failings?	**?**
45. Taking responsibility for your actions.	Do project team members take responsibility for their actions?	**?**
46. Being aware of organisational politics.	Are project team members aware of organisational politics?	**?**
47. Both individual and group reflections on relevant issues.	Are there both individual and group reflections on relevant project issues	**?**
48. In-group discussions, including listening, rather than waiting for the answers you want to hear.	Are project team members willing to listen to others when contrary views are being stated?	**?**
49. Engaged new staff with different beliefs to your own.	Are project team leaders willing to engage staff with different views of their own?	**?**
50. Avoiding being an action oriented leader, with inadequate pre-discussion and thought.	Do project team leaders primarily exhibited an action-based approach rather than a discussion first and then action?	**?**
51. Ensuring effective communications between the various power centres of the organisation, such as project manager, governance committees and the corporate group.	Does effective communication occur between the various power centres of the organisation such as the project manager, governance committees and the corporate group?	**?**
52. Attempting to deal with groups who are unaware that they are unaware of a range of issues for effective adaptation.	This deal with appropriate adaptation?	**?**
53. Ensuring that self-reinforcing and self-supporting, counter adaptive views, are reduced or eliminated (for example 'dumbing down' - the authors addition).	Do the project leaders attempt to dumb-down issues?	**?**
Adaptation at the edge of chaos) – Benne (2005)		
54. Does your organisation use "what if" scenarios for analyzing the potential disrupting events and their potential consequences?		**?**
55. Does your organisation scan the business environment for discontinuities?		**?**
56. Does your organisation focus on possible discontinuities in processes and interfaces?		**?**
57. Does your organisation focus on the capacity for learning and adaptation, as opposed to the fit between structure and environment		**?**

11. Use of complex system parameters as mon-functional requirements in systems engineering projects

A group of complex systems parameters are proposed in column 3 of Table 1 for consideration as a possible non-functional requirement for a systems engineering project.

12. Assessment of measures

Benchmarking measures will be assessed by a six-point scale of:

a. Zero or a small amount = 1
b. A little = 2
c. A reasonable amount but less than half = 3.
d. More than half = 4.
e. A substantial amount = 5.
f. Approaching 100% or 100% = 6.

13. Correlations with business success

Information on an appropriate measure of business success will initially be sought, examples of which are:

a. Increase in revenue in the last year of 0-2.5%.\
b. Increase in revenue in the last year of 2.5% - 5%.
c. Increase in revenue in the last year of 5-7.5%.
d. Increase in revenue in the last year of 7.5-10%%.
e. Increase in revenue in the last year of greater than 10%%.
f. Decrease in revenue in the last year of 0-2.5%.\
g. Decrease in revenue in the last year of 2.5% - 5%.
h. Decrease in revenue in the last year of 5-7.5%.
i. Decrease in revenue in the last year of 7.5-10%%.
j. Decrease in revenue in the last year of greater than 10%%.
k. Decrease in revenue in the last year of 0-2.5%.\
l. Increase in profit in the last year of 2.5% - 5%.
m. Increase in profit in the last year of 5-7.5%.
n. Increase in profit in the last year of 7.5-10%%.
o. Increase in profit in the last year of greater than 10%%.
p. Decrease in profit in the last year of 0-2.5%.\
q. Decrease in profit in the last year of 2.5% - 5%.
r. Decrease in profit in the last year of 5-7.5%.
s. Decrease in profit in the last year of 7.5-10%%.
t. Decrease in profit in the last year of greater than 10%%.

Please indicate which of the above measures is most applicable to your engineering business (both revenue and profit if possible.

14. Analysis of results

The results of the benchmarking service will be analysed statistically, provided there are enough participants, and correlations reported between questionnaire items and measures of success, indicated in section 12. This will assist engineering businesses to identify important areas of focus on for their development

15. Arrangements to facilitate the benchmarking group

The author is willing to both offer the benchmarking service, to a group of engineering businesses, including members of SESA, and a group of construction management businesses, analyse the results and report back to the engineering businesses, free of charge for one cycle of results. After that discussions will need to occur on whether the service was valuable or not and what is an appropriate payment for service.

16. Conclusions

The objective of the benchmarking service is to improve the performance of engineering businesses, in order to assist engineers to cope with the rapidly changing business environment. To reiterate, it is the view of the author that the practice of engineering has not changed dramatically, however this is being assessed in the proposed survey.

References

Argyris, C., (2002), Double loop learning: Teaching and Research, Academy of Management Learning and Education, Vol 1, No 2, 206-218.

Arthur, B. (1996), Increasing Returns and Path Dependence in the Economy, University of Michigan Press.

Benne, B., (2005), Managing AEC Project Organizations at the Edge of Chaos: An Analysis of AEC Projects' Adaptive Capacity from a Living Systems Perspective, PhD in Architecture, UCLA Berkley.

Bible, M. J. & S. Bivins (2018), Project Interface Management - Reducing Risk on Major Projects, J. Ross Publishing, Plantation, Fl.

Boisot, M, & B, McKelvey, (2011), Connectivity, Extremes, and Adaptation: A Power-Law Perspective of Organizational Effectiveness, Journal of Management Inquiry 20(2) 119 –133.

Chiles, T & A. D. Meyer (2001), Managing the Emergence of Clusters: An Increasing Returns Approach to Strategic Change, EMERGENCE, 3(3), 58–89.

Coveney, P. (2003). Self-organization and complexity: A new age for theory, computation and experiment. Paper presented at the Nobel symposium on self-organization. Stockholm: Karolinska Institutet.

Decker, D., & J., A. Belohlav, (1997), Managing Transitions, Quality Progress, April, 93-97.

Heaslip, R. (2014), Managing Complex Projects and Programs : How to Improve Leadership of Complex Initiatives Using a Third-Generation Approach, Hoboken, John Wiley & Sons.

Ireland, V. and A. Gorod, (2016) Contribution of Complex Systems to Entrepreneurship, Editorial, Entrep Research Journal 6(1), 1-41.

Ireland, V. (2020) Managing complex systems and projects, SETE 2020, Brisbane 11-12 May .

Knowles, R., (2007) Self-Organizing Leadership: A Way of Seeing What Is Happening in Organizations and a Pathway to Coherence, EMERGENCE, 3(4), 112–27

McMillan, E., (2008), Complexity, Management and the Dynamics of Change Challenges for practice, London, Routledge.

Majchrzak, A., D. Logan, R. McCurdy and M. Kirchmer (2006) Four Keys to Managing Emergence, MIT Sloan Management Review, Winter, Vol 47, No 2,

Nooteboom, U. (2004), Interface Management Improves On-Time, On-Budget Delivery of Megaprojects, Management, Aug.

Omoto, A (2013) The accident at TEPCO's Fukushima-Daiichi Nuclear Power Station: What went wrong and what lessons are universal? Nuclear Instruments and Methods in Physics Research A731 p3–7

Pascale, R. (1999), Surfing the Edge of Chaos Sloan Management Review. Spring

Region-Sebest, M. (2013), The new small business leader - skills for managing today's turbulent business environment, PhD, Capella University.

Senge, P. (1990), The Fifth Discipline – Art and Practice of the Learning Organisation : Random House Business Books

Smith, M. Y. and R. Stacey (1997), Governance and cooperative networks: An adaptive systems perspective, Technological Forecasting & Social Change, Vol.54(1), pp.79-94

Stacey, R.D. (1996) Strategic Management and Organisational Dynamics, London: Pitman. Stacey, R. (2001), Complex responsive processes in organisations: Learning and Knowledge creation, London, Routledge.

Stacey, R. (2012), Tools and Techniques of Leadership and Management: Meeting the Challenge of Complexity, London, Routledge,

Tetenbaum, T.J. (1998) 'Shifting Paradigms: From Newton to Chaos', Organizational Dynamics, 26(A): 21–32.

Trewavas, A. (2014), in A. Trewavas, Plant Behaviour and Intelligence, Oxford University Press.

Uhl-Bien, M., R. Marion and B. McKelvey (2007) Complexity Leadership Theory: Shifting leadership from the industrial age to the knowledge era, The Leadership Quarterly 18, 298–318

Van de Ven, A (1993), The all development and infrastructure for entrepreneurship, Journal of Business Venturing 8,21 l-230.

Weshah, N.. W. E. Ghandour, G. Jergeas & L. C. Falls, (2013). Factor Analysis of the interface management (IM) problems for construction projects in Alberta, Can. J. of Civ. Eng, 40, 848-860.

Weick