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Chaos attractors as an alignment mechanism between projects and organizational strategy

Hasse, G. W[a] & Bekker, M.C[a,*]

[a]*Graduate School of Technology Management, University of Pretoria, South-Africa*

Abstract

Chaos attractors have been studied in detail in the biological and environmental sciences and used to explain phenomena such as the Butterfly effect. Limited research has been done to identify and understand the use of chaos attractors in projects to help with alignment of project activities towards the project objective throughout the entire project duration. This paper will explore the literature on the use of chaos attractors as alignment mechanism between projects and organizational strategy. A conceptual model and propositions are proposed that could form the basis for further research.

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Keywords: attractor; complex adaptive system; point attractor, limit cycle attractor, strange attractor, phase space

1. Introduction

A total of 61% of executives indicated in a recent study that their organizations struggle to close the gap between strategy formulation and its day-to-day implementation (Economist Intelligence Unit, 2013). According to this study, organizational strategies are either poorly implemented or not implemented at all. The economic cost of such poor implementation is estimated on average at US$109 million for every US$ billion spend on projects i.e. 11% (PMI, 2014). The rapid changing and turbulent business environment requires firms to adapt their strategies on a regular basis. Strategic responses in a turbulent environment could range from “intrapreneurship” when there is a low understanding to “strategic intent” when there is a higher understanding of the business and operational

* Corresponding author. Dr. Giel Bekker. Tel. +27 12 420 2822
E-mail address: Giel.Bekker@up.ac.za

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environment (Garrat, 2003: 48). The concept of alignment between projects and organizational strategy in an ever changing turbulent business environment is key to ensure their successful implementation and could mean the difference between survival or destruction of a business. Dimitrov (2000) suggested that the concept of a strange attractor that originates from chaos theory could be used to align the complex thoughts and feelings of employees with the purposes of an organization. Could chaos theory and the concept of attractors perhaps provide a mechanism for alignment between complex constructs?

Chaos theory describes the concepts of attractors and attractor basins (Lorenz, 1995) where the trajectories of dynamical systems tend to converge towards attractors even with different initial starting conditions. The primary research question for this paper is if the concept of chaotic attractors could be used to attract and align projects with organizational strategy as indicated graphically in Fig. 1. The "ball-in-basin" representation (McGee, 2011) as shown in Figure 1a shows the trajectory of the dynamical system (project) that is converging towards a point at the bottom of the basin (organizational strategy) using a point attractor. A different three-dimensional view of a complex landscape is provided by Kent & Stump as shown in Figure 1b where the ball (project) may follow a number of different valleys in time. A specific valley may represent the desired organizational strategy while the others may represent the non-desirable organizational strategies. In this case the trajectory of the dynamical system (project) is aligned or progresses in the direction of a specific valley (organizational strategy) using a desirable attractor.

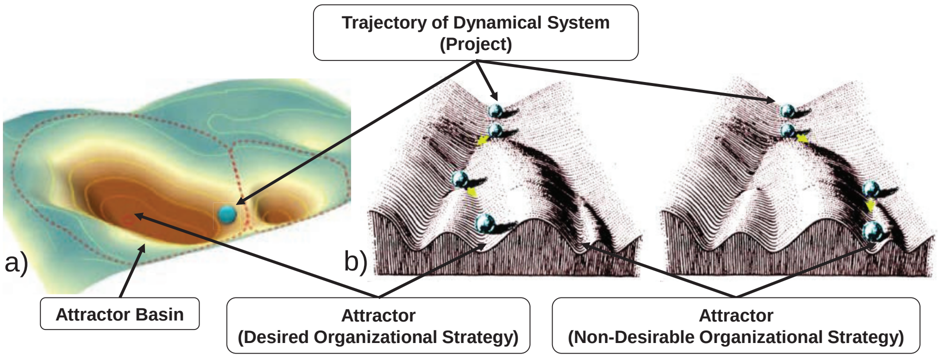

Fig. 1: a) The concept of an attractor and attractor basin (McGee, 2011) to attract a dynamical system. b) Complex landscape with different hills and valleys showing possible trajectories of a dynamical system (Kent & Stump, No date).

A number of interesting questions arise when viewing the landscapes in Fig. 1. Given a static landscape (stable organizational environment) how should a project be managed in order to allow for the possibility of attraction to the desired organizational strategy? If a project or program starts off towards the wrong attraction basin or valley, what needs to be done to change its trajectory towards the desired attractor? If the landscape is unstable (chaotic organizational environment) and the hills and valleys are also changing, how to steer the dynamical system towards a changing organizational strategy? Before these questions could be further explored, a better understanding is required of chaos, chaos theory and chaos attractors.

2. Literature review

2.1. Topology of attractors

Only three prominent attractor types will be explored in this paper namely the point attractor, limit cycle or periodic attractor and a specific chaotic attractor – the strange attractor. Although there are many other attractor types these three types sufficiently demonstrate the potential of using attractors for the alignment of constructs i.e. using attractors to potentially align projects with organizational strategy.

2.1.1. Point attractors

The concept of a point attractor could perhaps be best explained by examining the behavior of a pendulum with friction as shown in Figure 2a). Friction will dissipate the systems total energy and the pendulum bob will ultimately come to rest at the bottom center. This point is known as the point of attraction and therefore a point attractor. The behavior of the pendulum bob could be described by two variables that change continuously namely velocity (shown in Figure 2b) and position (not shown) as a function of time (Gleick, 2008). However, when these variables are transformed into the phase space domain (where time is absent) they may be plotted as indicated in Figure 2c) as a spiral that curls inward towards the point of attraction at position 0 and velocity 0. For different initial starting positions of the pendulum bob, different inwards curling trajectories will be traced as indicated in Figure 2d). However, all these different trajectories are moving towards and end up at the point attractor at position 0 and velocity 0.

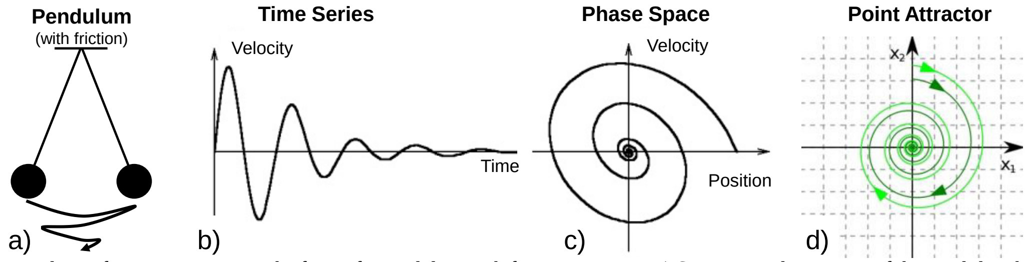

Fig. 2: The topology of a point attractor in the form of a pendulum with friction showing: a) Structure and trajectory of the pendulum bob, b) Time domain behavior of velocity, c) Trajectory of the pendulum bob in the phase space domain and d) The converging trajectories of a point attractor for different initial conditions.

2.1.2. Limited cycle or periodic attractors

The concept of the limit cycle or periodic attractors may also be explained by using a pendulum but this time without friction as shown in Figure 3a). The time series behavior of the pendulum bob will trace a sinusoidal graph with a phase difference between velocity and positions as a function of time (Figure 3b), only velocity is shown). The phase space plot for a certain level of energy of the pendulum is given in Figure 3)c for all possible values of

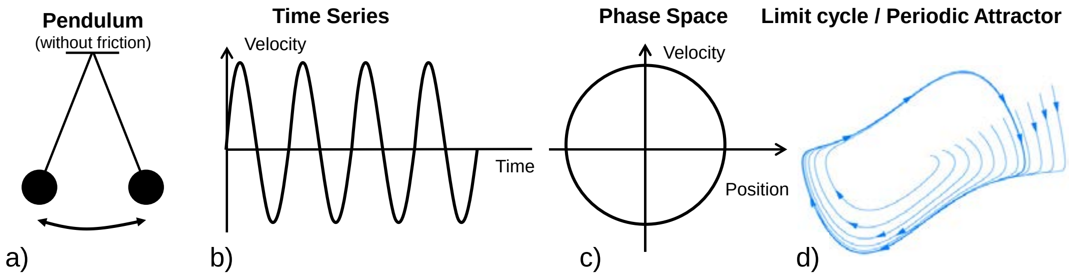

Fig. 3: The topology of a limit cycle / periodic attractor in the form of a pendulum without friction showing: a) Structure and trajectory of the pendulum bob, b) Time domain behavior of velocity, c) Trajectory of the pendulum bob in the phase space domain and d) The converging trajectories towards the same cycle attractor for different initial conditions.

velocity and position. Should the pendulum start at a higher initial position, it will trace another full circle but with a bigger diameter. In complex dynamical systems where such limited cycle attractors exist they serve as attractors for nearby system trajectories as shown in Figure 3d) (Wikipedia). Where attraction is towards a fixed point for a point attractor (Figure 2d), the attraction for a limit cycle or periodic attractor is towards an established and repeatable cycle (Figure 3d).

2.1.3. Chaos attractors – the strange attractor

The concept of a strange attractor could perhaps be best explained by a model of a real world example in which the trajectory of a snow ski board is mapped along a down-hill ski slope with moguls for different initial positions and velocities when starting along the top horizontal line of the ski slope as indicated in Figure 4 (Lorenz, 1995). The computer model of the real world ski slope (Figure 4a) is simplified by including only three forces (gravity, friction and reaction of the slope on the board) and excluding the effect of the human skier, the effect of lift-off and aerodynamic forces in order to have a set of solvable partial differential equations (Figure 4b). The trajectories of seven snow ski boards as a function of time with identical starting velocities spaced 100mm apart at the top of the ski slope that is approximately 18m wide is shown in Figure 4c. The motions of the boards are clearly chaotic and definitely sensitively dependent on small changes in initial conditions – this is chaos theory in action! After 10m downslope from the starting line the original 0.6m spread of the boards have has more than doubled and after 25m the spread in the boards has increased more than tenfold. To visualize the strange attractor for this dynamical system, a collection of 5000 points each with different initial positions across the top of the slope and with different initial velocities are chosen (refer to Figure 4d). These points are plotted in the phase space diagram for velocity against position as shown in Figure 4(d1) and are a random collection of equal spaced points. Now release these 5000 boards and let them develop their trajectories downhill. The phase space diagram is plotted in Figure 4(d2) after just 5m downhill for velocity against position of all 5000 boards. The attractor becomes visible as an elliptical shape with two thin arms extending from it. The empty spaces as shown in Figure 4(d2) are states which cannot occur except as transient conditions. The phase space diagrams when the 5000 boards have descended 10m downhill is shown in Figure 4(d3) and when descended 15m shown in Figure 4(d4). It is clear that the shape of the strange attractor is developed when comparing the images as shown in (d2) – (d4). The invisible set towards which these 5000 points will be ultimately be attracted for an infinitely long ski-slope, will form the cross section of the strange attractor.

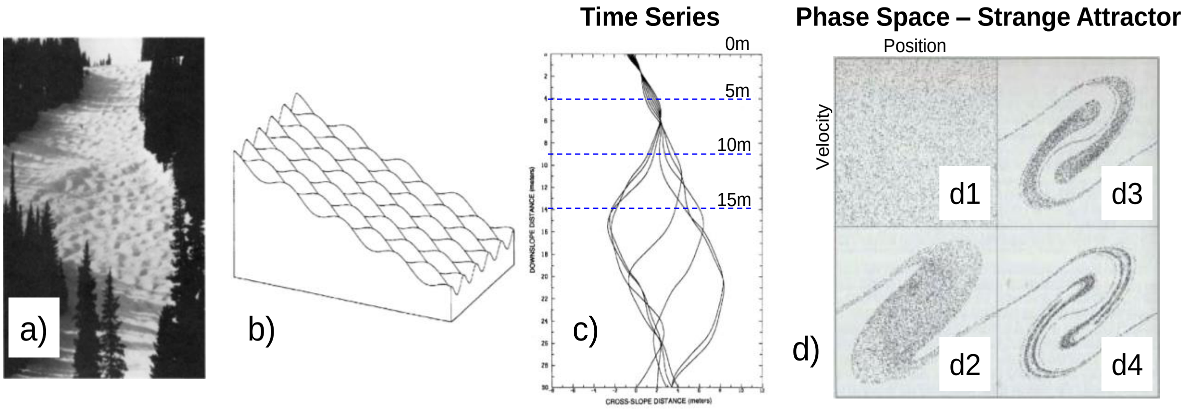

Fig. 4: Lorenz (1995:27, 29, 40 & 44) model and demonstration of strange attractors. a) Moguls on a real world ski slope. b) Model of the ski slope. c) Paths of 7 sleds, starting with identical velocities from points spaced at 10cm intervals at the top. d) Development of the strange attractor using five thousand sleds that starts at different positions and speeds at the top (d1) and the position and speeds of the sleds after they have travelled (d2) at distance of 5m, (d3) a distance of 10m and (d4) a distance of 15m down the slope.

2.1.4. Multiple attractors, attractors in combination and change in attractors

Systems can have multiple attractors without being chaotic (Lorenz, 1995) which means that the both the pendulum (a periodic and non-chaotic system) as well as the flapping flag in the wind (non-periodic and chaotic system) could have one or more attractors. This also implies that ordered systems can have attractors. Similarly to the appearance of the four individual project complexity types that may appear either individually or simultaneously in a project (Remington & Pollack, 2007), it is also possible for attractor types to appear in combination. Spiral attractors combines the features of a fixed point attractor with that of a limit cycle to produce a system that is attracted in a spiral manner towards a set point (Butner et al, 2015). Eoyang & Olson (2001) suggested three strategies to change from one strange attractor towards another in human-based systems. They also propose that these strategies could be implemented simultaneously. The three strategies include: a) disruption of an existing attractor, b) creation of a new attractor and attraction towards a new vision and c) creation of a hybrid attractor where some of the behaviors of the previous system are combined with the desired behaviors of the new system. However, these descriptions of the characteristics of attractors remain on a conceptual level and in order to derive value from attractors as alignment mechanisms, reals world applications of attractors needs to be explored and their generalities be investigated and understood for potential practical application.

3. Conceptual model

In order to derive a conceptual model for attractors as alignment mechanism between projects and organizational strategy, it is required to first define the key variables and attributes of chaos attractors. This is done by translating the characteristics of attractors from the metaphorical or general environment as found in the relevant literature to the project and organizational strategy environment. These variables are then combined into a conceptual model and propositions formulated for further research.

3.1. Key variables in a construct for attractors in projects and programs

References to attractors in the literate and their potential or suggested application to align projects with organizational strategy are shown in Table 1.

Table 1: Characteristics of attractors as found in literature, and potential application to align projects and organizational strategy.

No.	Attractor Characteristics and References	Interpretation	Potential application of attractor in projects as alignment mechanism
a	"British weather, for example, is recognizably the British weather, and not that of the Arctic or of Texas" (Cicmil et al, 2009:24)	The expected behavior of a specific type of nonlinear dynamical system will follow certain patterns.	(a1) Different types of projects will have different attractors each describing the typical expected behavior for each type of project.
b	"Although the potential for chaos resides in every system, chaos, when it emerges, frequently stays within the bounds of its attractor(s)" (Cicmil et al, 2009:69)	When a nonlinear dynamical system state changes to include chaotic behavior, this behavior is bounded by the range/shape of the attractor even for different initial conditions.	(b1) Chaotic behavior in projects will remain within the bounds of its attractor(s).
c	"Stability is achieved at the level of patterned behavior influencing and simultaneously being influenced by the patterns at a higher level of interaction and governance (the boundary of strange attractor)" (Cicmil et al, 2009:69)	Behavior at lower levels in nonlinear dynamical systems is influenced and governed by attractor patterns at a higher level.	(c1) Lower level project activities are influenced and attracted towards higher level interactions and governance.
d	"Complex systems can follow a number of qualitatively different attractors, depending upon initial conditions and external perturbations" (Cicmil et al, 2009:69) "Complex Adaptive Systems, including the weather, tend to maintain generally bounded behavior, sometimes called an "attractor," regardless of small changes in initial conditions. (Begun et al, 2002:6)	People in nonlinear dynamical systems exert choice to follow a specific attractor among a number of qualitatively different attractors. Their choice is influenced by initial conditions and external perturbations.	(d1) People in projects exhibit choice among attractors. (d2) Projects have multiple attractors. (d3) Initial conditions and external perturbations may shift the choice (of people) in projects which attractor to follow.

e	"The patterns of strange attractors are fractal - the same structures appear at various levels of scale, but they are not predictable" (Eoyang & Olson, 2001:2)	The same patterns/structure of the attractor(s) will appear at various levels in nonlinear dynamical systems.	(e1) The same patterns/structure of the attractor(s) will appear at various levels in all projects.
f	"If the desire is to change the attractor, then one must deconstruct the current and investigate ways to establish new attractors to shape new patterns of behavior" (Eoyang & Olson, 2001:2)	Attractors in nonlinear dynamical systems cannot be changed, they need to be deconstructed and re-constructed.	(f1) Project attractors cannot be changed, they need to be deconstructed and re-constructed.
g	"As the energy in the system increases, we note a progression from simple to periodic to chaotic attractors. The energy increase may be from external flow, internal flow, from increasing feedback or from resonance." (Herbert, p. 2)	As the energy in nonlinear dynamical systems increases (internally or externally), there is a progression from simple to chaotic attractors.	(g1) Increase in project energy (internally or externally) drives the transformation of attractors from simple to periodic to chaotic.
h	"Attractors are phenomena that arise when small stimuli and probes (whether from leaders or others) resonate with people. As attractors gain momentum, they provide structure and coherence" (Snowden & Boone, 2007:6)	Stimuli that are created by leaders and that resonate with followers has the potential to become an attractor. Attractors that grow in strength have the potential to create order from chaos for a nonlinear dynamical system.	(h1) People that resonate with the objectives and management style of a project choose to follow that specific attractor. (h2) Project attractors have the potential to create order from chaos.
i	"The 'dynamical' part of Nonlinear Dynamical Systems refers to the way that systems modeled by these nonlinear equations exhibit a kind of evolution or development through a series of different phases, the behavior of each constrained by its "reigning" attractor(s)" (Goldstein, 2008:11)	Nonlinear dynamical systems develop through different phases of which the system behavior in each phase is determined by the dominant attractor(s).	(i1) Each phase of a project will have a unique attractor or attractor sets and will be dominated by specific attractors.
j	"The system is expected to contain multiple alternative attractors, giving several different possible behaviors for the same system" (Antoniadis, 2012:79)	A nonlinear dynamical system is expected to have multiple and different attractors. The system behavior for each attractor is different.	(j1) The behavior of a project is the result of choice of people to follow a specific attractor and not other available attractors.

3.2. Model for using attractors to align projects and organizational strategy

Referring to Table 1 a conceptual model can be constructed as shown in Figure 5 for the independent variables as project type (a1), project phase (i1), system energy level (g1) and choice (d1, h1 & j1) that influences the nature and shape of the chaos attractor (dependent variable). Initial conditions and external perturbations (d3) are intervening variables on the choice of attractor to follow.

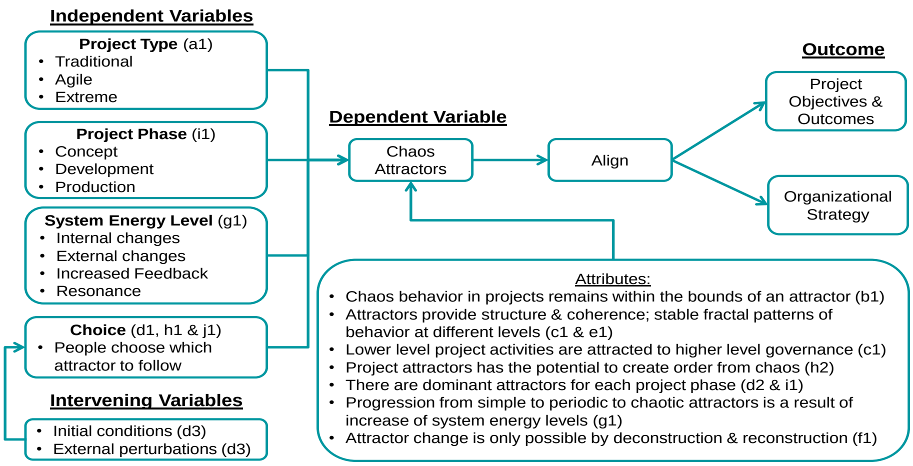

Fig. 5: Conceptual model for using chaos attractors as a mechanism to align projects with organizational strategy.

The chaos attractor has attributes pertains to the appearance of chaos (b1), stable patterns of behavior at different levels (c1 & e1), lower level activities are attracted to higher level governance (c1), creation of order from chaos (h2), dominant attractors for each project phase (d2 & i1), the progression of attractors based on the system energy level (g1) and the construction and deconstruction of attractors (f1). The model shows that chaos attractors could then be used as alignment mechanism between project objectives & outcomes with organization strategy.

3.2.1. Propositions

The conceptual model as shown in Figure 6 allows for the formulation of the following testable propositions:

<u>Proposition1</u>

The type of project (traditional, agile & extreme according Wysocki (2010)) determines the nature and shape of chaos attractors.

<u>Proposition 2</u>

The project phase (concept, development & production according to INCOSE (2011)) determine the nature and shape of chaos attractors.

<u>Proposition 3</u>

The system energy level (due to internal & external changes, feedback and resonance) determines the nature and shape of chaos attractors.

<u>Proposition 4</u>

The choice of people determines which attractor is followed in a project. This choice is influenced by initial conditions and external perturbations.

<u>Proposition 5</u>

The attributes of chaos attractors are that:

- Chaos behavior in projects remains within the bounds of an attractor
- Attractors provide structure & coherence; stable fractal patterns of behavior at different levels
- Lower level project activities are attracted to higher level governance
- Project attractors has the potential to create order from chaos
- There are dominant attractors for each project phase
- Progression from simple to periodic to chaotic attractors is a result of increase of system energy levels

Attractor change is only possible by deconstruction & reconstruction.

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3.2.3. Considerations

The conceptual model and the propositions pose further potential research questions regarding attractors in projects. For instance, are there simultaneously multiple attractors present in any complex-chaotic project space? And if so, are there dominant attractors and submissive attractors i.e. primary and secondary type of attractors? Are attractors appearing, growing, subsiding and becoming dormant with a "life-cycle" character? The limited literature survey done for this paper warrant a deeper investigation into the character and attributes of attractors as they appear in various field of science to inform the generation of a more comprehensive conceptual model.

4. Conclusions

This paper investigated the possibility of using chaos attractors as a mechanism to align project and organizational strategy in order to improve the realization of the intended project benefits to the organization. The trajectory of nonlinear dynamical systems (such as projects) is made possible by the phase space method and system behavior may be attracted to a point, a limit cycle or a chaos or strange attractor. References in literature for various scientific fields were used to list the behavior of attractors and to construct a conceptual model with testable propositions. The literature survey that was done is limited by coverage and depth and therefore needs to be complemented by further work in order to build a more comprehensive conceptual model and related testable propositions. Once an updated conceptual model is formulated, a suitable research strategy should be developed and implemented.

References

Ackoff, R. L. & Emery, F. E. 2008. *On Purposeful Ssytems – An Interdisciplinary Analysis of Individual and Social Behaviour as a System of Purposeful Events*. New Jersy: Transaction Publishers.

Psychological Methods, vol 20, no. 1, pp. 1-25.

Cicmil, S., Cooke-Davies, T., Crawford, L. & Richardson, K. 2009. *Exploring the Complexity of Projects: Implications of complexity Theory for Project Management Practice*. Pennsylvania: Project Management Institute Inc.

Dimitrov, V. 2000. Swarm-like Dynamics and their Use in Organization and Management. *Complex Systems*, vol. 12, pp. 413–421.
Economist Intelligence Unit. 2013. Why good strategies fail – lessons for the C-suite. London : Economist Intelligence Unit.
Eoyang, G. & Olson, E. E. 2001. AI: Path to a New Attractor. Appreciative Enquiry Commons. Available at: https://appreciativeinquiry.case.edu/research/bibPapersDetail.cfm?coid=760 [Accessed on 23 May 2015].
Garrat, B. 2003. *Developing strategic thought – A collection of the best thinking of business strategy*. London: Profile books.
Goldstein, J. 2008. Introduction Complexity Science Applied to Innovation – Theory meets Praxis. *The Innovation Journal*: The Public Sector Innovation Journal, vol. 13, no. 3,), article 1, p. 1 – 16
Herbert, G. Progressions. Canberra, Australia. Available at: http://www.progressions.info/9chap.pdf [Accessed on 24 May 2015]
INCOSE. 2011. *Systems Engineering Handbook - A Guide For System Life Cycle Processes And Activities*. Version 3.2.2. San Diego: INCOSE.
Kent,R. G & Stump, T. Lexicon of Terms. Available from: http://www.psych.utah.edu/~jb4731/systems/Lexicon.html. [Accessed on 10 May 2015].
Lorenz, E. N. 1995. *The Essence of Chaos*. Seattle: University of Washington Press.
McGee, T. 2011. Adaptable systems – When do you need to design for change? Eco Interface. Available from: http://www.ecointerface.com/?p=157. [Accessed on 29 April 2015].
PMI. 2013. Pulse of the Profession. In-Depth Report: The impact of PMOs on strategy implementation. Philadelphia: PMI.
PMI. 2014. Pulse of the Profession. The High Cost of Low Performance. Philadelphia: PMI.
Snowden, D. J. & Boone, M. E. 2007. A Leader's Framework for Decision Making. *Harvard Business Review*, November 2007, p. 1 - 9.
Wikipedia. Attractor. Avilable from: https://en.wikipedia.org/wiki/Attractor [Accessed on 20 May 2015].
Wysocki, R. K. 2010. *Adaptive Project Framework – Managing Complexity in the Face of Uncertainty*. Boston: Addison-Wesley.