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Complexity and Business Networks: How can Complexity Theory inform Business Networks?

This paper is part of a ph.d. research project on Business Networks. During the past 20 years computer models and algorithms have provided us with an increased understanding of non-linear systems and components also known as complex phenomena or complexity. Based on this algorithmic view of complexity, different types and aspects of complexity are listed and described with special attention to their relevance for Business Networks. Although computer simulations of complexity phenomena can be highly seductive, the authors believe that analogies and parallels to business networks, that in their essence are based on human interactions should be made with a lot of caution. It is our intention to identify possible ways of using this understanding of complexity to illuminate and inform our understanding of the underlying processes of Business Networks. This is in contrast to much of the everyday references to complexity where it is used as a synonym for “too difficult” or “impossible” to describe or analyse any further. By making careful analogies and illustrations, we expect to present new angles from which to shed more and different light on what goes on between actors in business networks.

Traditionally the performance of an individual or that of an organisation has been described as a combined function of its capabilities and its motivation. Hedaa (1999) has brought forward an expanded model for describing the performance of an individual or of an organisation that also takes the contextual structure and the temporal aspect into account. The model describes Performance, P, as a function of four variables: C, for Capabilities, M, for Motivation, O, for Opportunity or opportunity structure and finally L for Luck or timing. The model can be described as a function, f :

$$P = f(C, M, O, L)$$

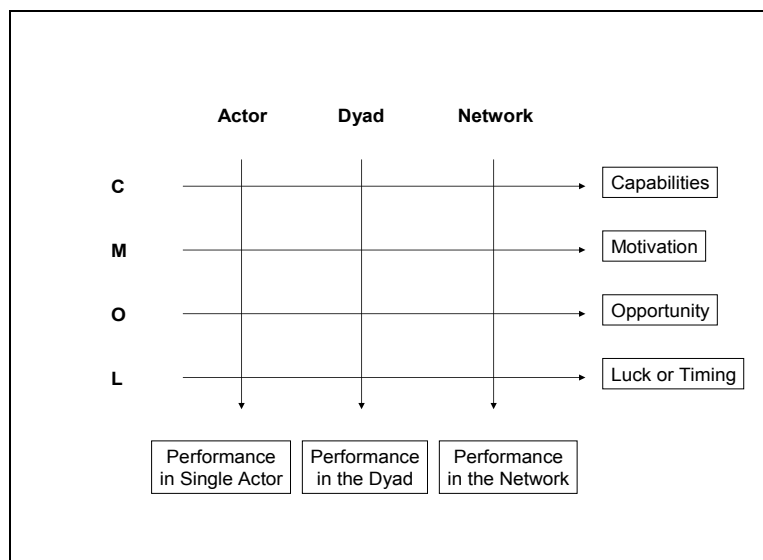
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The Capabilities are linked to the question of our abilities to perform. *Can* we perform? In the same way the Motivation can be viewed as a question of whether we *want* to perform. The Opportunity is then the question: are we *allowed* to perform or are we somehow constrained, legally, morally or otherwise? All of this will not materialise in any kind of performance or outcome unless the Timing is right as well (if we are lucky).

In reality though, performance is not a static concept and the variables in the formula are hardly independent variables. Motivation to do something is very likely linked to past Performance and to Capabilities as well. The better you have succeeded at something in the past the more motivated you will be in the future and vice versa. The more capable you feel the more motivated you are likely to feel as well. The same arguments can of course be made for the remaining variables of the formula.

Since the variables are dependent on each other as well as on past performance the function, f , is not a simple linear function. Motivation and Capabilities are likely influenced by our perceptions of other actor's Performance and certainly our Timing has everything to do with others. The degree of our luck can be seen as a function of our timing in relation to other actor's timing.

This paper will attempt to move the static function into the realm of the dynamics associated with adaptive systems and complexity theory. In order to do this we will start out by looking at just one single actor and this actor's performance dynamics and the interdependence of the variables. We will then move on to the dyadic relationship where two actors' performances are mutually dependent on one another. And finally we will move on to regarding multiple dyadic relationships and their linkage in other words the level of the network. The illustration below shows the structure of our treatise:



Definitions of CMOL

Let us begin by a short description the framework of the CMOL performance model. The formula describes the Performance of any actor be it an individual, a group, an organization or a nation. Performance is here taken to mean the execution of an action,

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something accomplished, an achievement, reaching a goal or creating results in general. It is assumed that the Performance is reached with the minimum use of resources and fulfilling the overall objectives to the fullest: that the Performance is efficient and effective.

Capabilities or competencies

This can also be seen as the question of: “Do we *know how* to do this?” Capabilities has to do with the actor’s attributes (like physical or mental powers) required for Performance. These attributes are often represented by *talent*, i.e. the aptitude or disposition of the actor, a natural endowment of the actor, and *skills*, i.e. the actor’s acquired power to accomplish something competently.

Motivation

Is the question of: “Do we *want* to do this?” Motivation is the actor’s *needs* or *desires* that causes action. It can take the form of *stimulus*, i.e. it feels good to do this, the form of *incentives or rewards*, i.e. if I do this I will get a reward. Finally motivation can be regarded as *intrinsic* or *extrinsic* depending on whether the motivational force originate within the actor or has its origin outside the actor in the form of externally provided incentives or rewards.

Opportunity

The question of: “Are we allowed (by our *context*) to do this?” Here the question is not so much one of law or morality but one of whether we are in a contextual structure that allows us to carry out some given action. One can in fact talk about an *opportunity structure* which we define as the network that the focal actor is embedded in with all of its resources. Or opportunity can be seen as social capital which is a concept that lately has gained considerable attention (Burt2000; Coleman1990; Leenders and Gabbay1990).

Luck

Is linked to the question of timing: “Is this the *right moment* for this?” Often we see that business people prefer to talk of timing rather than luck because this conveys a flavour of being in control rather than basing oneself on luck. However it is interesting here to note the old quote that has been attributed to many successful sports people: “The more I practice the luckier I seem to become”. This clearly indicates that luck is something that can be aimed for and that one’s luck can be influenced by appropriate preceding actions.

Luck is closely linked to the concept of the opportune moment or *Kairos* in Greek (Hedaa and Törnroos2001).

Performance: dependent or independent variable?

Performance, it would seem, is then the dependent variable. However, it is not that simple. We all know that past performance influences a least our motivation. As human beings we tend to be more motivated if we have performed in a certain way. In some cases the link will be positive in other cases it can be negative: If we have previously performed well in some way this can have a positive effect on our motivation to try it again. On the other hand, poor performance can also be seen as a gap between what we *can* do and what we would *like* to do. Here the motivation is our lack of past performance together with a desire to do better in the future.

Performance also has an influence on our capabilities. Past performance to the degree that we learn from it will enhance our capabilities to achieve at a later point in time. Again we

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see that the relationship is not always positive or negative: poor performance can lead to new insights that enhance our capabilities, sometimes much more than positive or successful performance would have done. This is in fact learning.

Depending on whether we want to explain Performance by the four variables C, M, O and L or if we are more concerned with the CMOL implications of Performance, we might choose to write the model differently:

$$P \Rightarrow C, M, O, L$$

to indicate that Performance *causes* CMOL, or:

$$C, M, O, L \Rightarrow P$$

to indicate that CMOL *causes* Performance. With our interest in the dynamic characteristics of CMOL in mind, we find that it is useful to use another representation of the model, that more clearly illustrate the dependent/independent dichotomy:

$$P \Leftrightarrow C, M, O, L$$

In addition to the model's causal direction it is interesting to consider its explanatory as well as its descriptive features. In the original format the function $f(C,M,O,L)$ will allow the model to indicate e.g. what Performance to expect. But if we want to go in the opposite direction and use the model to describe the requirements for the CMOL variables based on some observed (or intended) Performance, we will need to consider the inverse function f^{-1} :

$$C,M,O,L = f^{-1}(P)$$

If the function was linear, this would not be a problem, however, when the function is not linear, we cannot be sure that this inverse function even exists. In mathematical terms this would require that the function f is bijective, (both surjective and injective). And since this is very unlikely we will need many observations of P and corresponding CMOLs if we are to be able to triangulate with any degree of confidence.

Causal direction and inverse function

If we combine the question of causal direction and the question of what function we are interested in f or f^{-1} , we can construct a 2-by-2 matrix of the model. Each of the quadrants of the matrix will then illustrate a combination of causal direction and explanatory or descriptive aspect of the model. We will not go further with this at the moment, but the idea is illustrated in Figure 1.

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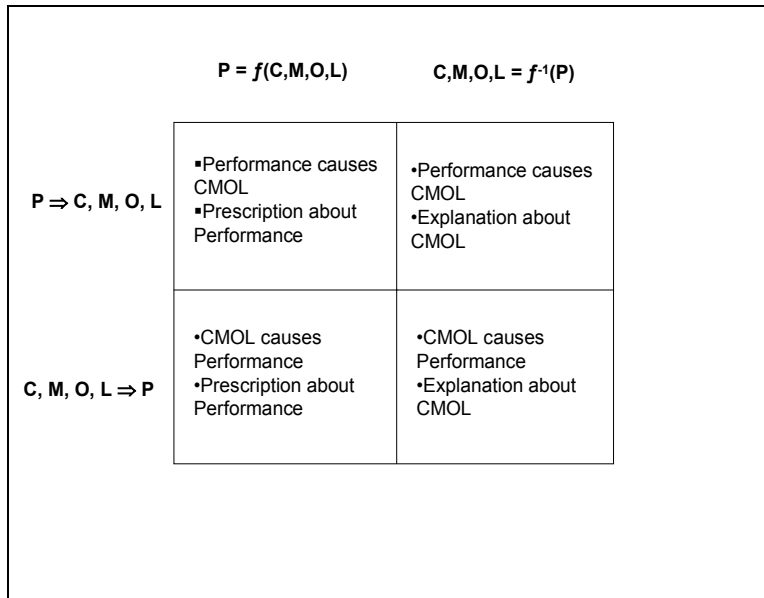


Figure 1: The expanded Performance model

Performance in the single actor

One way to introduce dynamics into a formula is to consider the parameters change over time. If for example we denote the present time T then we can express the parameters at a later time $T+1$ as a function of the present state of the variables even if we do not know the function i.e. how for example Capabilities, C_T , at a given point in time influence the Capabilities in the future, C_x or indeed how it influences the other future parameters, M_x , O_x , and L_x . As we have expressed the Performance, P as a function of the other four parameters we can assume that the influence which present Performance, P_T will have on future performance, P_{T+1} , will be contained in the four parameters C_T , M_T , O_T , and L_T . Based on the way we have defined Performance as a function of four parameters or variables it is easy to regard P a dependent variable, as we discussed above, and C , M , O , and L as the independent variables. However in the following we find that it is more useful to consider Performance an *emergent* property influencing or causing effects (through the C , M , O , and L variables) on the future value or state of those variables. Thus, over time, the variables actually depend on one another in a non-linear fashion much in line with how we would describe this in everyday terms and logic.

This approach is actually one of the classical ways in which complexity has been studied. One of the best known descriptions is probably that of Kauffman in his book “At Home in the Universe” (1995). Here he devotes chapter 4 to the description of Boolean networks and n,k -modeling that has inspired this section.

Using binary representations

To simplify things, we will limit ourselves to binary representations of the four parameters. Although this might seem like grossly underestimating the complicated nature of the phenomena we are investigating, this is actually not an unreasonable simplification since we are looking for the dynamics of the formula or model, not the actual values and states a

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given context or situation will give rise to. In the first step we are simply interested in finding out how the variables influence one another and how Performance emerges.

Using Boolean algebra

A Boolean function with 4 input variables constitutes 16 different inputs and since the output is also binary and can take on a value of either 0 or 1, the total number of functions that are possible is 2^{16} or 65.536 different functions.

C	M	O	L	P
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

If we consider each of the variables at time $T+1$ as a Boolean function of the other three at time T , we can write down a decision table for each one of them. This will illustrate the dependence between the four factors: how is e.g. Motivation at $T+1$ influenced by C, O, and L at time T ? Again there are a number of possible Boolean functions (2^8 or 256) to choose from, however in this case we start with just a single set of decision tables. Each of the decision tables are listed below with an argumentation for choosing this particular Boolean function. One way of seeing this is to view each of the variables as a light bulb. Each light bulb is then turned on or off according to the state of the other three light bulbs. For simplicity's sake we have decided not to include the effects of the four variables at time T directly onto themselves at time $T+1$. With sufficiently small time intervals we find this to be a reasonable simplification and the indirect effects (via the other variables) will still be possible from T to $T+n$ (where $n>1$).

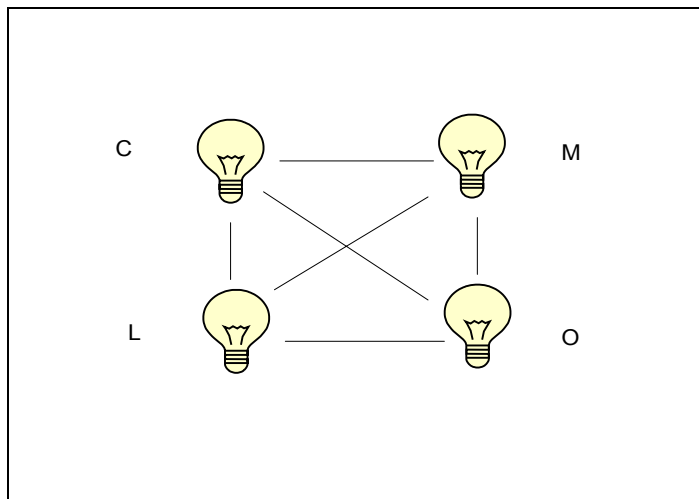


Figure 2: CMOL as light bulbs turning each other on and off

In the following tables we have chosen one particular Boolean function to illustrate our point. The individual tables express what we expect will be the outcome in $T+1$ if we increase (binary 1) or leave unchanged (binary 0) the other three parameters. The function shown represents the outcomes we judged to be likely in the given situations. They are, however, not based on anything but commonsense and our subjective opinions. As such

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the function can only be regarded as an example of this approach and it is only indicative of the behaviour of such a system.

Capabilities			
M_T	O_T	L_T	C_{T+1}
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

Motivation			
C_T	O_T	L_T	M_{T+1}
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

Opportunities			
C_T	M_T	L_T	O_{T+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

Luck			
C_T	M_T	O_T	L_{T+1}
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

A state transition diagram showing the result of the simulation is shown in Figure 3. We see that the system will go to 4 possible attractors: two single-point attractors and two cyclic attractors. To the degree that our function initially chosen can be said to represent the real world we can infer that if we start in a position without any CMOL (state 0) we will never get out of that situation. The same is true for state 15 which represent “all on” for CMOL. This tendency to stick in either “all on” or “all off” situations is not unlike our experience from daily life:

we tend to stay in such states for longer periods of time until something from the outside triggers a change.

If we consider the two cyclic attractors we see that although they look very similar they can be interpreted very differently. The first cyclic attractor starts in state 1 (that is only Luck/Timing is on), moves to state 14 (Motivation and Opportunity is now on), to state 12 (Capability and Motivation is on), and the back to state 1. This looks very much like a positive or virtuous circle.

The other cyclic attractor starts in state 14 (all on but Luck which is off), moves to state 9 (Motivation and Luck is off), on to state 7 (Capabilities is off), and then back to state 14. With this interpretation we would call this a negative or vicious circle.

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the research in this area is done using computer simulations programs. However the use of computer programs and their intriguing behaviour makes it, perhaps, too easy to draw parallels and analogies to human behaviour. Such parallels may be problematic or directly misleading.

Stacey (2000; 2001) argues that the way we use analogies between complex adaptive systems and human activities is a key issue. If we simply assume that a person corresponds to an algorithm or a computer program, which can interact with other computer programs, we will have difficulties in dealing with human issues like free will, and rationality. We may add intuition. Stacey's definition of a complex adaptive system is (Stacey2000 p.276):

“A complex adaptive system consists of a large number of agents, each of which behaves according to some set of rules. These rules require the agent to adjust their behaviour to that of the other agents. In other words, agents interact with, and adapt to, each other.”

Here there is no overall blueprint to determine what the system is supposed to do. Rather agents interact locally according to their own intentions, understanding, and principles.

On the difficulties in drawing parallels, or analogies, between computer simulations of complex adaptive systems and real organisations, Stacey says (2000 p.281)

“The question becomes one of how to interpret, in organisational terms, the logic of iterative, nonlinear interaction between replicating algorithms and their self-organising and emergent properties. Even more fundamental is the question of whether it even makes sense to try to do this”

He goes on to explore the question of how insights from chaos theory and complexity theory can be translated to human and organisational behaviours and the difficulties of drawing analogies. Can a human being be taken as the analogue of a software simulated agent or algorithm in a computer, he asks.

What Stacey ultimately suggests is that the analogies be made between digital agents or computer programs and *narrative themes*. This approach will defocus the individual but still keep it in the picture. The theme or the story now becomes the focal actor and the dynamics are seen in relation hereto. The narrative approach allows us to view the real complexity of the phenomena. The dynamics are not collapsed in time and space but are still there in all the details of the narrative. As all human interaction at some level can be seen as exchange of chosen interrelated stories, this step seems quite appropriate.

This brings us to the question of what stories or narrative aspects to look for when we are interested in CMOL. Now instead of looking at CMOL as four almost embodied qualities or parameters living their lives interacting with other CMOLs, we focus on the stories being exchanged. The CMOL are now relegated to the roles of participating elements or factors in the story, and they can be viewed as thematic influences.

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Let us briefly indicate how the four elements can be identified in the themes and how we can trace their effects. One observation to start with is that themes can be *directly* or *indirectly* about some element. When themes deal directly with an element, we will say that this element is the topic of the theme. The aspects or qualities of the element are described within the theme. When themes are set in a context of the element, the qualities and aspects of the element can only be inferred from the theme.

If the theme is “what is it that makes this actor so skilful?”, then the theme deals directly with the actor’s capabilities. In “this is how we won the new customer” –theme, the theme may describe certain key success factors, but only through a closer analysis of these factors are we able to infer something about the CMOL elements of the organisation. This distinction is close to what Stacey (2000 p.381) calls conscious-unconscious themes. He also argues that themes can be of a formal or in-formal, legitimate or shadow type. We can illustrate this by two overlapping triangles (please see Figure 4 which we have developed from an illustration by Stacey (2000 p.382)). It is important to note that the formal-conscious-legitimate themes do not interact in isolation from the others. On the contrary, legitimate themes will be followed by shadow themes that may or may not come out into the open. Such shadow themes can only be seen a’posteriori or we can see more indirect indications of their presence.

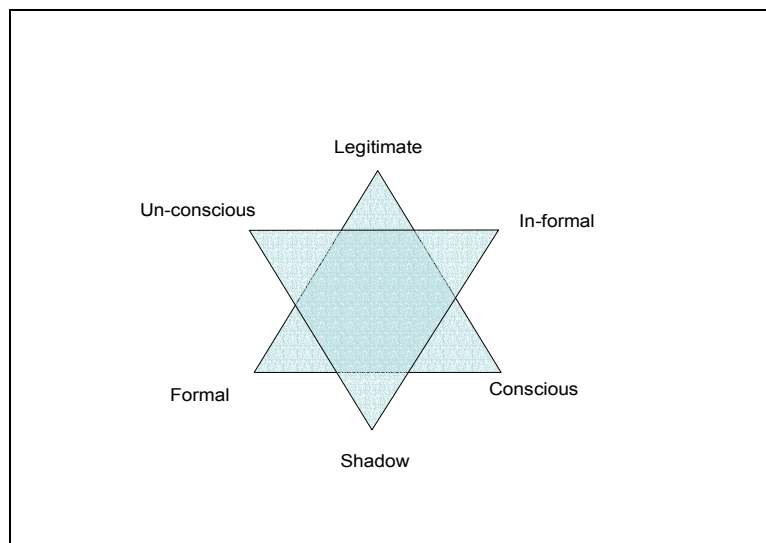


Figure 4: Different types of themes

Performance in the network

Analysing performance *of* a network as such is not possible as it would require the network to have boundaries (Gadde and Håkansson2001). One of the characteristics of networks is that they are in principle without boundaries. However there is nothing to stop us from investigating performance *in* a network.

Using the narrative theme approach that we use to investigate CMOL or Performance in the dyadic relation we hope will also prove to be a fruitful avenue when it comes to understanding performance in the network. We also believe that it could be used to gain a

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new perspective on individual performance. As we showed the more mechanistic n,k-modeling could prove very difficult to apply in this context. Also our main interest is the performance in the network.

Clearly the step from dyadic perspective to network perspective brings in a range of new issues. From the network research we know that for instance embedded-ness must be considered. Embedded-ness means that what goes on in one dyadic relation is dependent upon developments and events in other relations in the network. Each relationship is embedded in a network of other relationships.

Focal themes, we can then see, must be considered in a context of other themes all connected in a network of themes. Thus it will be natural to use the term Theme-Network in the same way that Actor-Network, Activity-Network and Resource-Network (Håkansson and Johanson1992) and to some degree Event-Network (Hedaa and Törnroos1997) have been employed to focus and describe specific qualities or aspects of a network.

Mapping out how the individual themes interact in the network, we believe, will provide a new insight into the performance in networks.

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