Tools for Complex Systems Research

Erik Verbeeck

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Abstract

Three tools for research in complex systems are presented. Hierarchy Theory explicitly separates the role of the observer and the observed object and looks for powerful viewpoints. Logical Level Analysis sorts out confusions between strategies and objectives in a system and identifies the origin of a malfunction. Econophysics has developed models for systems where a large number of agents interact and self-organised macroscopic behaviour is displayed.

Erik Verbeeck
Hoekskensstraat 82
9080 Lochristi (Belgium)
Phone : +32/22748327 and +32/93567264
e-mail : erik.verbeeck@fortisinvestments.com

Present position : Organisation Consultant at Fortis Investments (Belgium).
Disclaimer : the opinions expressed in this document are purely personal and do not imply Fortis Investments in any way.

Introduction : Why would we need extra tools?

Marketing deals with a subject that is familiar to all of us. Firms and relations with firms are part of everyday life. Every individual, even long before his marketing research career officially started, has many kinds of relations with firms such as being a customer, employee, shareholder, neighbour and so on. This close familiarity with the research subject induces a major risk, namely that terms and concepts are frequently used without an explicit definition. A request for a definition would even feel ridiculous because the object is so familiar. Moreover, a definition is rarely valid in all circumstances, but should be formulated for the research situation at hand. Once the researcher has chosen an appropriate definition, his audience will be able to understand exactly what it is about, instead of referring to their own implicit set of definitions.

In day-to-day life, there is sufficient tolerance for imprecise definitions. But when one is to enter the area of complex systems, where fine-grain details are connected to macroscopic behaviour, confusion and white noise in intra- and interresearcher communication should be reduced ex-ante by carefully defining the concepts and terms used. The tools presented below support this efficient approach.

1. Hierarchy theory

Hierarchy Theory stems from General Systems Theory and was first proposed in ecology and psychology (Ahl and Allen 1992). Both ecology and psychology are a point in case where the research objects tend to be familiar for the researcher. In ecology, for instance, the human size appears to be a determining factor in how observations are conducted (Allen and Hoekstra 1996). In this way, a tree is more readily perceived as an individual organism than is grass, which is always referred to as a population. A human meets trees on a one-by-one basis. Large trees, in a sense, even belong to our context : we cannot push them away but we have to walk around them, we can sit and gather under them, and they live longer than us to the extent that an old tree seemingly remains unchanged during a human lifetime. On the contrary, because the individual grass blade size is much smaller than a human being, grass is always perceived as an entire population and rarely addressed at the organism level.

Hierarchy Theory proposes a general research approach in which the researcher is explicitly aware of the contribution of both the observer and the observed when making measurement decisions. For instance, by fixing the scale of the observation, the observer determines the grain (smallest possible details) and extent (largest possible details) of the measurement, both for the structure (spatial characteristics) and dynamics (temporal characteristics). The measurement decisions define the entities and the relations between them that can be possibly observed. The structural and dynamical features of the observed entities are then used to organise them in hierarchical levels according to criteria the observer has chosen.

When the researcher is observing phenomena, he isolates entities from the context and brings them to the foreground by considering a set of characteristics.

The **boundaries** of an entity may be defined unambiguously, like the skin of our body, or may be more ambiguous, like in the case of a company where one could include or not, for example, outsourced activities.

An entity may be **homogeneous**, i.e. consisting of similar parts or not. If a certain part is removed, both the result and the removed part may or may not still belong to the same class as the original entity. As an example, a division can be removed from a company by a buy-out, and both the division (now acting as an independent company) and the remaining company both still belong to the class of companies. On the contrary, when a piece of a dog is removed, in some cases a living dog remains, but the removed piece is by no means a viable organism of its own.

An entity may be **continuously scaled**, i.e. all sizes are allowed within a given range, or some sizes may be forbidden. If, for example, middle sized entities do not occur, the researcher should verify if for his purpose the large and small entities can be put in the same class.

Also the distinction between internal and border-crossing **flows** can help the observer to isolate the entities from their context. Internal cycles in general are more frequent or faster than cross-border cycles. Other structural and dynamical characteristics can be considered as well.

The objective of this exercise is to verify that the observed phenomena are cristallized into relevant entities or entity classes based on sound and objective characteristics, and that the choice to split or group entities is not made on mere implicit, intuitive criteria.

The next step is to organise the selected entities by assigning them into upper and lower levels. Hierarchy Theory proposes general criteria to estimate if an entity tends to be in the upper level with respect to another entity.

Examples of organising criteria are :

Constraint : the upper level constrains the lower level and serves as its context.

Nestedness : the upper level consists of the lower level. A company consists of its divisions, which at its turn consist of their subdivisions. An example of non-nestedness is the situation of the CEO who is the upper level for the people who report to him, but he does not consist of them.

Flows : information, matter and energy flow relatively unlimited inside a level, but are more restricted when circulating between levels.

Figure 1 illustrates how this applies to divisions inside a firm. As an example of the relative intensity of internal/external flows between entities : one purchase order that crosses the boundary of the purchasing department outbound to the supplier firm is the result of numerous internal information flows like planning, inventory management and approval cycles. The purchase order results in one delivery at the warehouse. After crossing the border with the warehouse, it initiates a number of activities and flows to process the received goods. Likewise, in the vertical direction, a purchase order is exchanged between the firms more frequently than a contract. The contract comprises a longer time horizon, a larger amount of money, a larger scope, more pages of information, but less fine details than a purchase order. Moreover, the contract is likely to constrain the terms and conditions of the purchase order. All these characteristics converge to link the contract to a higher level than the purchase order.

As also shown in Figure 1, the operational teams have coordination meetings on a daily basis, while the executive committee is meeting only once a month. This is an illustration of upper level entities exhibiting low frequency behaviour while lower level entities tend to show high frequency behaviour.

The dyadic boundary drawn in figure 1 should not be misinterpreted or reified. It is not an exclusive or Euclidean boundary. Each firm usually engages in several dyads, for each of which a similar boundary could be drawn simultaneously. The fact that the focal firm belongs to the dyad doesn't exclude it is part of other dyads. So the focal firm isn't "in" the boundary.

In conclusion, Hierarchy Theory challenges the researcher's familiar view of the world and invites to reflect upon his domain and to select a powerful way of looking at the complex phenomena observed.

2. Logical Level Analysis

The concept of Logical Levels originated from psychology (Diltz 1983) and can be applied to complex entities, such as a person, a relation between persons, a family, a project, a team, a firm, a business sector, … . It is a useful tool to sort out observations into levels and to identify at what level the origin of a problem or phenomenon is situated. In terms of Hierarchy Theory, Logical Levels are a specific set of criteria to separate levels and to put them in a hierarchical model.

The logical levels are listed in table 1. The causality between logical levels is two way : the upper level controls the lower level and sets it into motion, the lower level limits the upper level to what is feasible at that moment.

A logical level analysis starts with the selection of a system, such as a person or an organisation. Each logical level of the system is explored, starting at the bottom level of environment and going "upstairs" until the level of mission. At each level an inventory of elements is made. When all levels have been reviewed and described, malfunctions within or between levels appear more clearly to the observer.

The correct definition of the system under review is crucial. When a company wants to improve efficiency (a goal), it could opt for a new ERP system (a strategy/capacity to reach the goal). For the ERP project team, the new ERP system will be a goal to be reached and the team will follow its project methodology (strategies/capacities) to reach that goal. So the same "item" can belong to different levels depending on how the system is defined.

Solutions can be divided into two types : first-order solutions act on the level where the problem resides. They work in cases where "more of the same" is useful. A second-order solution acts on the level above the problematic level and is sometimes called "reframing" or "out-of-the-box". For example, when a system seems to have conflicting goals, a priority setting could be considered. If this doesn't help, a more powerful solution would be a modification at the level of roles and identities, which in turn redirects the goals and beliefs level.

3. Econophysics

Econophysics is a discipline resulting of the application of models from statistical physics to other domains, mainly financial markets, but also linguistics, DNA, networks, traffic, … . Statistical physics typically investigates how large numbers of similar units interact to display macroscopic behaviour. Examples are turbulence (liquid or gas molecules) and avalanches (sand particles). The standard approach of econophysics is to analyse empirical data and try to detect the statistical properties. Then, simulation models with the same statistical properties are built to verify if the same macroscopic behaviour is reproduced. This created new understandings in the above mentioned domains (Stanley 2000).

The concept of networks is frequently studied in IMP literature. Econophysics investigated networks such as the World Wide Web, food chains, co-authorship in scientific publications, power supply networks etc. Real-world networks display other characteristics than pure random graphs : shortest paths are surprisingly small and clustering occurs to a high degree. Econophysics provides a methodology and a vocabulary to analyse the topology of a network and to infer characteristics such as robustness to failure and attack, the evolution of the network over time, the spreading of epidemics (Strogatz 2001; Albert and Barabasi 2002).

Predictably, business networks will display a different topology depending on sector, country, lifecycle phase (both at the company, the sector and the network level), role in the market (leader, follower, …), the economic cycle etc.

4. Conclusion

This paper mentions three tools that can be used in complex systems research.
Both Hierarchy Theory and Logical Level Analysis are research skills rather than pure techniques. Once they are mastered, they become attitudes that improve the "common sense quotient" of the researcher. Both skills should be applied actively early in the research set-up and then kept running in the background. Econophysics is more of a technical discipline. It is used at a later stage in the research project, when data have been collected and must be processed and interpreted.

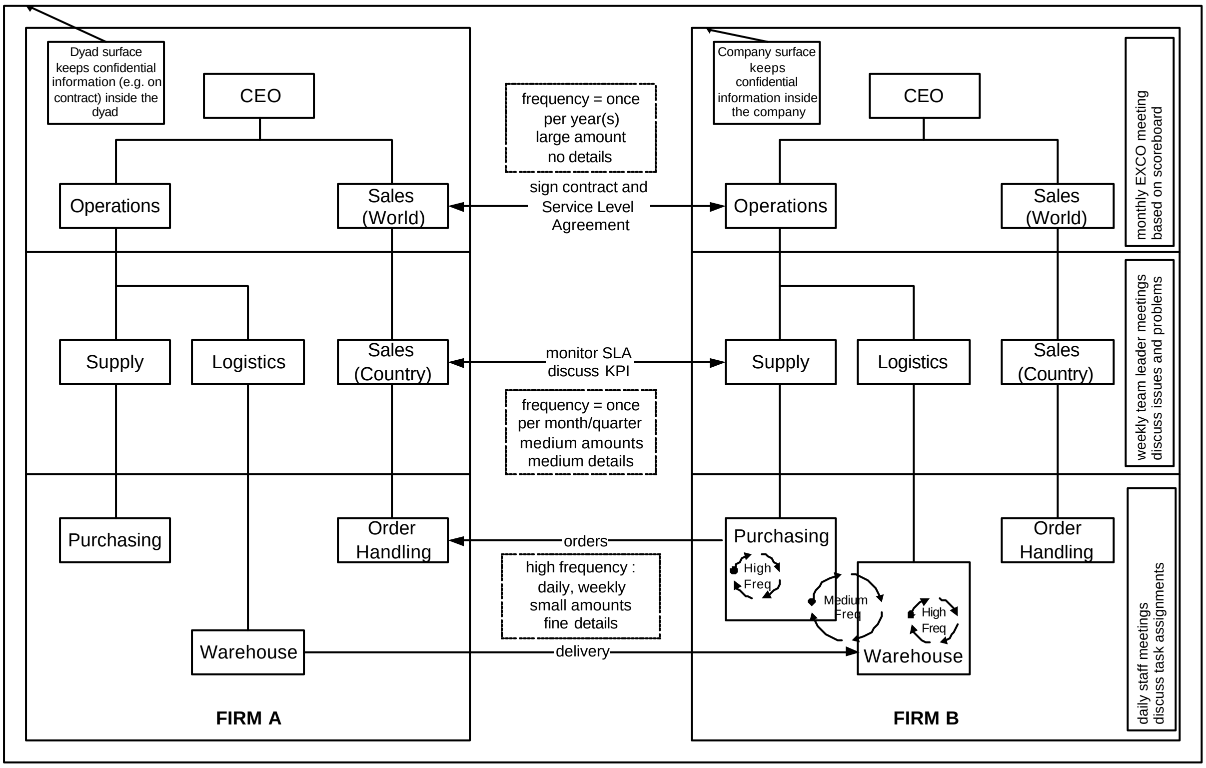
5. Suggestions for further research

In the IMP Group, conceptual reflections are made on markets, industries, change, adaptation, ethics/values, … . Hierarchy Theory and Logical Level Analysis are well suited to support such conceptual discussions and to keep track of multi-level arguments. Case studies could also benefit from an early screening of the context and elements under review.
The econophysical network framework and vocabulary, on the other hand, may inspire new network approaches in the IMP domain.

In addition to the conceptual work, a structured empirical effort could lead to the construction of an Atlas of the Networks of the Economy. Where a geographical atlas shows the same maps in different versions, with details on geography, geology, climate, infrastructure, agriculture, industry, politics, … , the Network Atlas would show the economy or the networks under different points of view. Candidate points of view are sectors or industries, financial networks, supply chains, life cycles, regions, … . Case studies could be requested to present conclusions in a format that makes them compatible to the Atlas. The advantages would be the availability of a huge amount of empirical data to test and verify theoretical work, and also an overview of the terrae incognitae in order to guide and prioritize future research. Finally, theoretical and empirical findings can be reconciled to identify “healthy” networks and to define the actions to be taken in case of problematic networks.

6. Figures

6.1. Figure 1 : relative frequencies in internal/external and high/low level cycles.



6.2. Table 1 : Logical Levels (start reading from below)

Logical Level	**Example for a firm**
Mission	**To what end** is the firm playing this role? On what mission are its role(s) and identity based?
Role, identity	**Who** is that firm, pursuing those goals starting from such beliefs? What role does it play, what identity does it attribute to itself?
Goals, beliefs	**Why** is a firm choosing that particular process or routine? What goals does it hope to achieve in doing so? On what beliefs is the choice of that strategy based?
Strategies, capabilities	**How** do firms make this behaviour happen? Which internal processes are running to deliver the observed behaviour? Which strategies, which routines are followed?
Behaviour	**What** do firms do when they interact? What behaviour can be observed?
Context	**Where** is the firm operating and in what context? Who and what does it meet in its environment?

7. References

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