

# Trans-disciplinarity and meta-structures to meta-model complexity of social systems

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## Abstract

*The concept of meta-modelling, i.e. the use of models of models, was introduced several years ago. Current research converges towards considering systems as complex when processes of self-organisation and emergence, i.e., acquisition of subsequent different properties over time, occur within them. We outline a series of approaches based on meta-modelling to deal with such dynamics to be considered as a typical example of a trans-disciplinary conceptual framework. Meta-modelling of the processes of acquisition of systemic properties may be considered typically trans-disciplinary, i.e., when dealing with systemic properties and their acquisition in non-disciplinary contexts. We present a number of cases as appropriate examples.*

*Keywords: complexity, emergence, meta-modelling, meta-structures.*

## Résumé

*Le concept de méta-modélisation, c'est-à-dire l'usage de modèles de modèles, a été introduit il y a des années. La recherche actuelle converge vers considérer systèmes comme complexes lors que des processus d'auto-organisation et émergence, à savoir, l'acquisition subséquente des propriétés différentes au fil du temps, se produisent en leur sein. Nous présentons une série d'approches basées sur la méta-modélisation pour faire face à une telle dynamique que doit être considéré comme un exemple typique d'un cadre transdisciplinaire conceptuel. Meta-modélisation des processus d'acquisition de propriétés systémiques peuvent être considérées comme typiquement trans-disciplinaire, c'est à dire, lorsqu'il s'agit de propriétés systémiques et de leur acquisition dans des contextes non-disciplinaires. Nous présentons un certain nombre de cas à titre d'exemples appropriés.*

*Mots-clés: complexité, émergence, méta-modélisation, méta-structures.*

## Introduction

The introduction of the concept of meta-modelling may be credit to Bandler and Grinder (1975) when introducing controversial concepts of Neuro-Linguistic Programming (NLP). The idea of placing the epistemological focus upon the meta-level to deal with social systems usually modelled as organisations was present in several contributions by John P. van Gigch (see, for instance, van Gigch, 1978; 1979; 1984; 1991; 2003) and I consider that this represents his major contribution to Systemics. It introduced the need to consider the meta-level of description in Systemics in periods when focus was placed on *organisational* views and due attention was only beginning to be paid to processes of self-organisation and emergence in establishing systems and the related suitable level of description adopted by the observer *generating*, rather than *detecting*, *coherence* as in constructivism. Several scholars explored, with particular reference to management, meta-methodologies (see, for instance, Jackson, 2000; Yolles, 1999).

Some contributions within this context, at different levels, include:

1. Dynamic Usage of Models (DYSAM), (Minati and Brahm, 2002; Minati and Pessa, 2006);
2. Use of *variation of ergodicity* to detect the occurrence of processes of emergence (Minati, 2002; Minati, 2008c; Minati and Pessa, 2006);
3. Introduction of the concept of *logical openness* as a conceptual extension of the classical thermodynamical one (Minati *et al.*, 1998);

4. *Multiple systems* as an extension of the concept of *virtual systems* based on resources effectively usable *as if* they really existed or *instead of* resources unavailable at that particular moment. For instance, a *virtual company* *really* exists only as a temporary way of using resources belonging to other companies. The concept of Multiple Systems was introduced as being related to systems established by the *same* elements interacting in *different* ways. *Collective Beings* are Multiple Systems established by *autonomous agents*, i.e., agents possessing cognitive systems, and thus being able to *decide* their belonging (Minati and Pessa, 2006);
5. The Meta-Structures project, considering coherent sequences of structures over time rather than the *same* structure assuming different parametrical values over time as a step towards a *General Theory of Emergence as Meta-Theory* (Minati 2008d; 2010; Minati and Licata, 2010);
6. In Architecture a project based on the meta-level of description is now in progress and relates to *Architecture as the Design of structures for inducing processes of emergence in Human Social Systems* (see Di Battista *et al.*, 2006; Minati and Collen, 2009). Within this context researchers have the opportunity to consider, in a completely new way, the profound and extensive interdisciplinary content of Architecture which turns out to be very suitable for modelling processes of emergence of behavioural properties acquired by inhabitant agents occurring within social systems by combining scientific modelling and architectural content.

Systemic research focuses more and more upon processes of *acquisition* of properties by systems through processes of emergence rather than on systems *possessing* properties.

There is a profound link between meta-levels of the levels of description adopted and the *trans-disciplinary* content of Systemics, i.e., the study of systemic properties *per se* and the relationships between them, as for emergent acquired properties.

### 1. Complexity in social systems

As introduced in the literature (Guberman and Minati, 2007) we may distinguish between:

- artificial systems, i.e., *designed* by the observer. In this case structure of the system given by interactions amongst its elements are designed by the observer. Examples are electronic, mechanical systems and assembly lines; and
- natural systems, i.e., the observer constructivistically (Butts and Brown, 1989; von Glasersfeld, 1984) *models* a phenomenon as a system, by identifying its elements and their interactions. Examples are ecosystems and living beings modelled as systems.

In the former case a system is a designed, physical or organisational device. In the latter it is a model taken on when it is effective, in an objectivistic way, to consider a phenomenon as a system, *as if* the phenomenon was designed as a system.

In this latter case phenomena have been modelled as systems by considering the availability of a suitable organisation, i.e., a structured way of interaction by single and fixed rules. In this case organisation is expected to completely explain the establishment of a system and of its properties.

In this classic view systems are intended as entities *possessing* properties which their elements do not possess. In fact, a *necessary condition* for the establishment of systems and, consequently, of their retaining their properties, is that elements *continuously* interact. Their properties are not *acquired states* after undergoing processes of transformation, i.e., cooking food, mixing colours, and changing shape. The *maintaining* of systemic properties requires that elements continuously interact. Examples are given by electronic and mechanical devices acquiring and maintaining properties when powered on, i.e., elements are made to interact. The same occurs with biological systems, where life needs to be continuously supported. Examples of systemic properties, which component parts do not have, include: adaptive, allopoietic, anticipatory, autonomous, autopoietic, chaotic, deterministic, dissipative, equifinal, ergodic, far from equilibrium, goal-seeking, open-closed, oscillating, self-organized, symmetry breaking and so on. Examples of non-systemic properties, i.e., possessed by elements not considered as systems include: age, weight, geometric

measurements, numeric properties (e.g., odd-even, order, and results of computations), and speed or direction in classical physics.

In the literature one of the several meanings of complexity relates to:

- processes of establishing systems in a non-organised way, i.e., through processes of self-organisation and emergence;
- the occurring of processes *within* systems leading them to *acquire* new properties.

Examples of processes of *emergence of systems* are given by the establishment of collective behaviour acquiring properties such as ferromagnetism, superconductivity, superfluidity and social systems such as flocks, swarms, markets and industrial districts.

Examples of *emergence of systemic properties within systems* (i.e., acquisition of new properties) are given by cognitive abilities in natural and artificial systems, collective learning abilities in social systems such as flocks, swarms, markets, teams, firms and functionalities due to machine learning and in networks of computers (e.g., in Internet) or black out in electrical networks.

*The latter are examples of complex systems, i.e., systems able to continuously acquire new properties.*

### 1.1 Inter- and trans- disciplinarity to model complexity

Different approaches have been introduced in the literature when trying to model in a trans-disciplinary way, i.e., *in general*, complexity. *Multi-disciplinarity* consists of *using* multiple, specifically disciplinary knowledge to deal with multiple aspects of a problem (for instance, a project related to telecommunications needs the management of different cooperating disciplinary expertise: telecommunications, engineering, economics and law). Multi-disciplinarity relates to the *management* of different, specific disciplinary knowledge without affecting that knowledge itself.

#### 1.1.1 Inter-disciplinarity

*Inter-disciplinarity* takes place when problems and approaches of one discipline are used by another (for instance, when models of physics are used in economics and economic problems are represented as physical models, e.g., collective behaviour to represent markets). Contrary to Multi-disciplinarity, Inter-disciplinarity is not a *usage* of different disciplines, but a theoretical issue consisting of formulating a disciplinary problem by using the models of another discipline. Inter-disciplinarity also occurs in education when teaching one discipline by using another (for instance, teaching history while dealing with geography, mathematics with physics, and medicine with chemistry). Inter-disciplinarity deals with the study of the *same* systemic properties in *different* disciplines (e.g., openness, adaptability and chaos in physics, economics, biology and psychology). Inter-disciplinarity *is about* dealing with concepts, approaches, theoretical issues, and models suitable for usage within different disciplinary contexts. This is usually done by using mathematics as a *generalizing* language (for modelling), for instance, between:

physics and biology;	economics and sociology;
physics and economics;	anthropology and geography.

Inter-disciplinarity occurs when considering, in different disciplines, systemic properties, such as how a system can be:

Adaptive	bifurcating	equifinal	Oscillating
Anticipatory	chaotic	ergodic	self-organized
Allopoietic	complex	far from equilibrium	symmetry breaking.
Autonomous	deterministic	goal-seeking	
Autopoietic	dissipative	Open-closed	

Examples of issues in interdisciplinary research are:

1. 'How models used in physics may be used in the social sciences',

2. 'How models describing processes of biological aggregation may be used to model socio-economic processes',
3. 'When Game Theory is sufficient to model decision-making processes and when the cognitivist view must be adopted'.

The approach usually consists of using the same models but change the meaning of variables, for instance in econophysics. Generic rather than general usage of inter-disciplinarity occurs when using, for instance, metaphors and analogies instead of models. In this case conclusions reached have limited values of robustness and reliability.

### 1.1.2 Trans-disciplinarity

The term Trans-disciplinarity is widely used, but with no clear, unequivocal or generally accepted definition. Jean Piaget probably first used the term on the occasion of the workshop "L'interdisciplinarité - Problèmes d'enseignement et de recherche dans les universités", Nice (France), September 7-12, 1970. There are different international institutions devoted to research on this subject mostly focusing upon *humanistic interpretations*.

For the purpose of this paper, we will use this term in a very precise way. We consider Trans-disciplinarity to arise when systemic properties are studied *per se*, i.e., considered in general as properties of models and representations without any reference to specific disciplinary cases. Trans-disciplinarity also studies the relations between systemic properties, e.g., models of dissipation, equilibrium, openness, adaptability and chaos, and their relationships (Fig. 1).

Examples of issues in trans-disciplinary research are:

- 'Is it possible to formulate a theory about the *relationship* between systemic properties?'
- 'How can processes of emergence in systems be induced, maintained and varied?'
- 'How, *in general*, can systemic properties be induced or regulated?'
- 'Is it possible to identify a *general way* to measure systemic properties?'
- 'Using mathematics for modelling is a way to represent systemic properties. Are there other *equivalent* ways of representing the same systemic properties?'

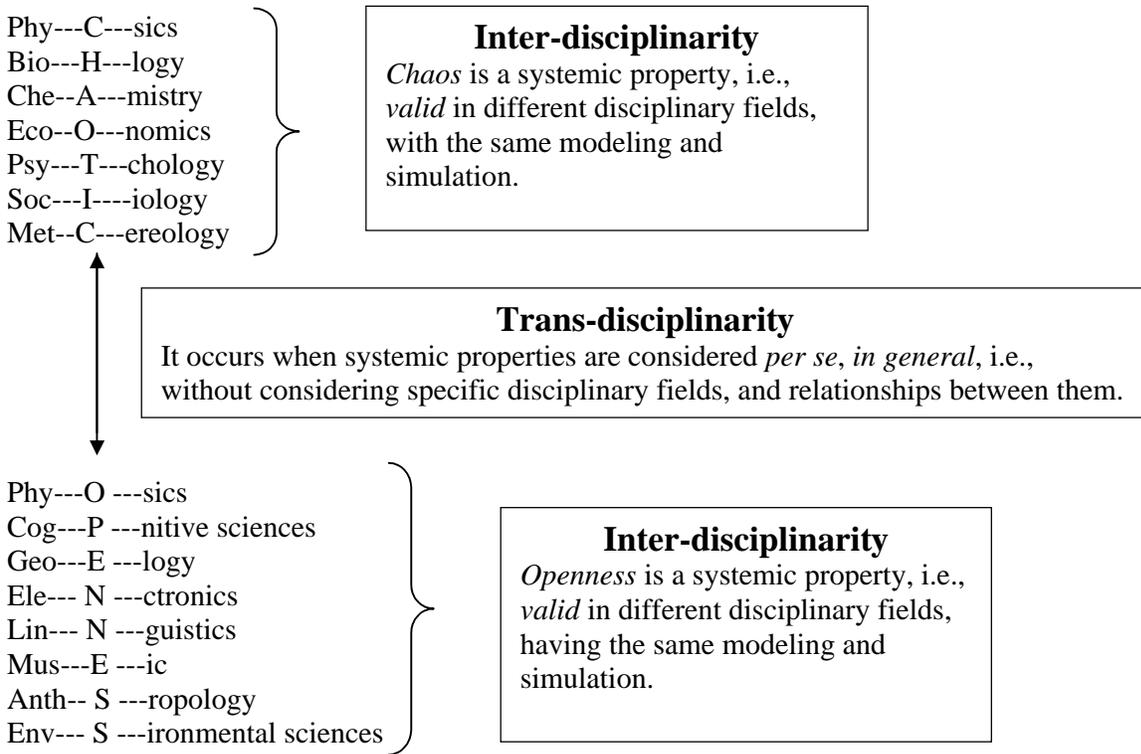


Figure 1: A schematic example of inter- and trans-disciplinarity: the study of properties of chaos and openness and their relationships.

### 1.1.3 Modelling complexity

Models introduced in the literature are based, for instance, on theories of phase transitions, bifurcations, and dissipative structures. In this case models assume the *homogeneous hypothesis*, i.e., when elements of systems are assumed to be *indistinguishable*. This is, for instance, the case for processes of self-organisation occurring in physics and chemistry, as in *Rayleigh-Benard Convection Cells* (Koschmieder, 1993) and the *Belousov-Zhabotinsky* reaction (Belousov, 1959; Zhabotinsky, 1964). When elements interact according to very simple rules, they may be considered as particles. This is, for example, the case for eco-systems and markets modelled by using agents interacting through a few, simple rules.

In this case the usage of *variation of ergodicity* has been introduced to detect the occurrence of processes of emergence as changes in structure (Boschetti *et al.*, 2005; Minati, 2002a; Minati and Pessa, 2006). Several definitions and models of ergodicity have been introduced primarily in physics and then in economics, geomorphology and in the study of population dynamics (Minati and Pessa, 2006). We just recall the general concept as in population dynamics, relating to the probability that in a system any state will recur, especially having zero probability that any state will never recur, for example, “If x% of the population is in a particular state at any moment in time, one can assume that *each* individual (or a suitable subclass) in the population spends x% of time in that state.” (Minati and Pessa, 2006).

Another approach is based on *heterogeneous assumption*, i.e., when elements of systems are assumed to be different, distinguishable. In this case each element interacts in a different way, i.e., they *not only react*. This is the typical case of autonomous agents *processing* interactions, performed by the cognitive system and computed *each* time. In this case elements may be not suitably modelled as particles, but as agents *deciding* their behaviour. This is the typical case of social and biological systems. This latter case has often been reduced, for simplicity, to the former by standardising rules of interaction. Examples of social systems of this kind are crowds, flocks, swarms, markets and properties acquired by organisational systems such as those related to reliability, safety and effectiveness or occurring in industrial districts.

There is a huge amount of literature regarding approaches for modelling and managing *organisational* social systems. There, cases such as corporations are considered to owe their complexity first of all to their *changing* and the multidimensional aspects to be considered, e.g., cultural, organisational, and psychological (Flood and Carson, 1988; Midgley, 2000; Stacey, 2007; Yolles, 1999, pp. 64-65).

Moreover, in this paper we will focus on social systems not suitably modelled as organisations and not even suitably modelled by considering them as reducible to particulate systems.

## 2. Modelling complexity in social systems

“In turn, *the fundamental problem* of the METASYSTEM is to select one design for the SYSTEM from a set of alternative designs. In other words, SYSTEM design is one of the outputs of the METASYSTEM. A *meta-inquiry* (at the meta-level) is an inquiry into the possible designs of the SYSTEM or, *meta-inquiry* consists of an investigation (at the meta-level) about SYSTEM organisation (at the “object” level).” (van Gigch, 2003, p. 5; see also van Gigch, 1978).

We have introduced *five* major concepts useful in the modelling of complexity in social systems and based on meta-modelling. They relate to social systems established by collective behaviours not suitably modelled by organisation nor by reducing elements to particles. They are Multiple Systems when same elements establish different systems over time and even simultaneously, Collective Beings established by collective behaviour of elements possessing the *same* cognitive system, Logical Openness when interacting agents change their cognitive models over time, Dynamic Usage of Models (DYSAM) when the purpose is not to find the *best* model, but to coherently use different, non-equivalent models, and Meta-Structures to identify and use meta-structural properties to manage general collective behaviours.

## 2.1 Multiple Systems

A MS is a set of systems established by the same elements interacting in different ways, i.e., having multiple simultaneous or dynamical roles (Minati, 2006a; Minati and Pessa, 2006). The role of single systems in a MS must be not confused with that of *subsystems* related to different *functions* within the same system. Within the conceptual framework of MS concurrent/cooperative effects of different interactions affecting the same elements perturb the effects of single interactions. Moreover, the action of concurrent interactions may be neither simultaneous nor regular. The same interacting components may establish different systems through organization or emergence and at different times (i.e., simultaneously or dynamically).

Examples of MSs in *systems engineering* include networked interacting computer systems performing cooperative tasks, as well as the Internet, and electricity networks (an unfortunate emergent property is the black-out) where different systems play different roles in continuously new, emerging usages (e.g., market of telephone traffic).

## 2.2 Collective Beings

CBs are particular MSs established by agents possessing a (natural or artificial) cognitive system. In CBs the multiple belonging is *active*, i.e., *decided* by the component autonomous agents (Minati and Pessa, 2006). In the process of emergence of CBs agents interact by simultaneously or dynamically using, in the model constructivistically designed by the observer, *different* cognitive models.

Examples are *Human Social Systems* where (a) agents may *simultaneously* belong to different systems (e.g., behave as components of families, workplaces, traffic systems, as buyers, of a mobile telephone network). *Simultaneously* is not only related to time, but also to agent behaviour, considering their simultaneous belonging, and their roles in other systems; and (b) agents may *dynamically* give rise to different systems, such as temporary communities (e.g., audience, queues, passengers on a bus), at different times and without considering multiple belonging.

Modelling social systems has been based on considering families, corporations, cities, hospitals, schools, and so on, as *subsystems*. We postulate the effectiveness of also considering them as CBs. The management of the multiple systems of a CB by considering them as *subsystems* is a source of serious *managerial* problems. Moreover, subsystems are *functional*, i.e., *specialised components* in an organised system. Managerial problems occur when failing to consider that in the case of MSs and CBs which are considered as subsystems are dynamically established by the *same* elements. Management of properties acquired by MSs and CBs should focus on multiple roles and related processes of acquisition. The various multiple roles taken on by a subsystem within a system must be not confused with the multiple roles assumed by autonomous agents when making emergent a new system.

## 2.3 Logical Openness

The concept of *logical openness*, as opposed to *thermodynamic openness* has been introduced in the literature of systemics (Minati *et al.*, 1998; Minati and Pessa, 2006; Licata, 2008). While thermodynamic openness relates to the ability of systems to have permeable boundaries, the concept of logical openness relates to the constructivist role of the observer generating *n-levels* of modelling by assuming *n* different levels of description, representing one level through another, modelling a strategy to *move* amongst them, and considering simultaneously more than one level as in the Dynamic Usage of Models (DYSAM). Examples of logical openness in Systemics relates to the multiple processes of acquisition of properties in complex systems and particularly for MSs and CBs. The conceptual framework is the constructivistic one when systems are modelled as such by the observer (see Section 1).

With reference to the concept of systemic complexity, i.e., the occurrence of the acquisition of new properties within a system through processes of emergence or multiple dynamic roles of components, as for MSs and CBs, we recall that the number *n* of levels of modelling assumed by the observer may be assumed as a *measurement of the complexity* of a system (Licata, 2008).

## 2.4 Dynamic Usage of Models (DYSAM)

The DYSAM approach (Minati, 2009; Minati and Brahm, 2002; Minati and Pessa, 2006) was introduced to deal with the dynamical emergent properties of complex systems, i.e., when one single dynamic model is not sufficient. Dynamic models model dynamical properties of a specific phenomenon, while DYSAM models change over time, i.e., the dynamic acquisition of different, emergent properties and properties of MSs and CBs as well.

DYSAM is conceptually based on approaches already considered in the literature and not based on the simplistic assumption of the existence of a unique, optimum solution. Examples are the well-known Bayesian method, Pierce's abduction, Machine Learning, Ensemble Learning and Evolutionary Game Theory. DYSAM is a dynamic, adaptive strategy of meta-modelling, i.e., modelling dynamic usage of models within different contexts.

DYSAM is based on a repertoire of different possible models and a strategy for selecting, on the basis of general and momentary goals set by the observer, interactions between the adopted models. Examples include multiple corporate modelling and multiple roles with reference to markets, structure and goals (Minati, 2007); processes of balancing and compensation in damaged systems, i.e., the disabled (Minati and Ricciuti, 2002); learning the *coherent* use of the five sensory modalities in the evolutionary age for children when the purpose is not to choose the best one, but to use all of them together; usage of one kind of modelling to influence another as for consent manipulation (Minati 2004; 2006b).

An implementation of DYSAM based on Neural Networks has been introduced by Minati and Pessa (2006).

## 2.5 Meta-structures

A further theoretical approach to model processes of emergence, such as flocks, swarms and markets (Minati, 2008d; 2010) within a constructivistic approach is under investigation (also see the entry in Web Resources), being based on considering collective behaviours given by coherent sequences of different structures ruling interactions between composing elements rather than by the *same* structure. Such coherence is considered represented and modelled by the mathematical properties of sets of values taken by some suitable *mesoscopic variables*, e.g., number of elements having the maximum, minimum or same distance; the same speed, the same altitude and the same topological position *at a given point in time* rather than variables related to single agents.

Mesoscopic variables are constructivistically decided by the observer in a kind of *Gestaltic continuity* (Minati and Licata 2010). For example mesoscopic variables used to model coherence of a flock of birds will relate to their speed, direction, distance and altitude rather than their age, weight, colour and sex. Other global variables are macroscopic such as volume, surface and density. Mathematical properties, e.g., statistical and periodicity, of sets of values assumed by such variables are intended as meta-structural properties and are proposed to model process of emergence of collective behaviours. See also a related approach introduced in (Pessa, 2011).

## 3. Management of complexity

Multiple dynamic modelling, i.e., DYSAM or meta-modelling corresponds to multiple interactions and multiple roles adopted by elements. This meta-modelling enables one to manage multiple systems by acting upon elements and interactions establishing a system whilst belonging to another one. Moreover, the management of complexity is no longer *only* related, for instance, to planning, controlling and setting suitable rules, but to general conditions for the system such as influencing cognitive models, language, availability and speed of information, suitable pre-processing interfaces used by components, and multiple modelling by the observer. They do not relate to the model of a system and related possible optimisations, but to multiple modelling of the systems established by same components, assumed to interact in different ways. Examples of applications are available (Bouchard, 2008; Minati, 2007) and mentioned in the Section 3.1.

Related concepts include flexibility, resilience and virtuality.

## 3.1 Cases

### 3.1.1 Growth and development

While growth may be considered as a process of a quantitative increase, different models of developments are possible, such as: harmonic processes of increases in different processes of growth; sequences of different versions of the same processes of growth through optimisation; sequences of different processes of growth through innovation and, finally, emergence of new processes. Within this framework the concept of *sustainability* seems more suitable for logically closed systems, i.e., where processes of emergence, or transformation are not possible like growth processes. (Minati and Pessa, 2006).

### 3.1.2 Ethics

Ethics can be considered as *social software* used by elements of a system to adopt transformative or multiple behaviours (Minati, 2002b). Within this framework the concept of effectiveness of any given ethics relates to properties acquired by the social system.

### 3.1.3 Architecture

Architecture may be considered as the disciplinary design of suitable structural conditions to induce processes of emergence, to *influence the emergence of collective behaviour* within social systems such as a cities, crowd in normal and emergency situations, traffic, structures of homes inducing life styles, hospitals and schools inducing ways of thinking (e.g., health to be *repaired*, knowledge *divided* into disciplines), populations of buildings acquire properties which a single building does not have, e.g., ecological, safety, harmony (Di Battista 2006; 2008; Minati, 2008b; Minati and Collen, 2009).

### 3.1.4 Health

The concept of health in medicine, considered from a dynamical modelling point of view, no longer refers *only* to the ability to *resume* a biological state assumed as health, but to the management of the available resources by using new cognitive models, i.e., with aging and disabilities (Minati, and Ricciuti, 2002) to *continuously establish coherence as health*.

## Conclusions

In this paper we have mentioned some approaches introduced in the systemic literature to deal with, i.e., to model and manage, complexity using meta-modelling. As shown in the cases considered, meta-modelling is particularly suitable for processes of emergence and related dynamical and hierarchical acquisition of new properties when a single model is, in principle, insufficient to model the complexity of such subsequent, multiple properties. In this case focus is no longer only on the *dynamics of systems*, but rather on the dynamics of usage of models constructivistically adopted as suitable by the observer and of subsequent coherent structures as in meta-structures. We have presented some specific approaches such as considering Multiple Systems, Collective Beings, Logical Openness, Dynamic Usage of Models (DYSAM) and meta-structures suitable for modelling social systems within the framework of such trans-disciplinarity. We conclude by mentioning specific cases such as the modelling of Growth and Development, Ethics, Architecture, and Health. We also consider how the concept of sustainability is more suitable for *non-complex systems*, i.e., systems unable to acquire new properties, while the concept is currently misused as in ecological and so-called green technologies.

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## Web Resources

<http://www.meta-structures.org/> retrieved on May 17, 2011