CO-EVOLUTION OF DIVERSE ELEMENTS INTERACTING WITHIN A SOCIAL ECOSYSTEM

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Abstract

The aim of this paper is to discuss the evolution of diverse elements within a social ecosystem and its underlying feedback processes, with special emphasis on the notion of *co-evolution* of the principal elements – human and artefacts – participating in the ecosystem. It is based on a research project looking at the *co-evolution* of the business process and information systems (IS) development. The project is part of the SEBPC IT Legacy Systems Programme, funded by the EPSRC. The project tests the hypothesis that if co-evolution between the business process and IS development is enabled, then the problems associated with legacy systems will be reduced. The study went beyond the interaction between software and business evolution. It first looked at IT systems (i.e. at both hardware and software) and at the IS domain, which includes the individuals involved with the IT systems (i.e. both developers and users). Secondly, it looked at the multiple elements, which make up the complex environment (or social ecosystem) interacting with the two areas under study. Finally, the research identified some of the conditions that facilitated co-evolution between the business and IS development in two case studies. This paper will focus on the complex interactions between the multiple elements within a social ecosystem, which contribute to the creation of IT legacy systems; on some of the underlying feedback processes; and on the conditions that facilitate co-evolution.

Keywords: business process, co-evolution, complexity, connectivity, coupling, emergence, exploration of the space of possibilities, far-from-equilibrium, feedback, interaction, interdependence, IT legacy systems, self-organisation, social-ecosystem.

1. Theoretical Background[1]

The paper draws on the theories of complexity to support its arguments. These theories include work on complex adaptive systems [11, 13, 14, 15, 16, 18, 19, 37], dissipative structures [35, 37, 38], chaos theory [12], autopoiesis [23, 24, 25, 26], and increasing returns [2, 3]. The work of the LSE Complexity Programme has focused on complex *social* systems, and specifically on human systems and organisations. It does not map directly from any of the sciences, but uses the generic characteristics common to all complex systems as a starting point, and then considers what is relevant and appropriate to human systems [30, 31, 32].

In an organisational context, complexity provides an *explanatory framework* of inter-relationships: of how individuals and organisations interact, relate and evolve within a larger social ecosystem. Complexity also explains *why* interventions may have un-anticipated consequences. The intricate inter-relationships of elements within a complex system give rise to multiple chains of dependencies. Change happens in the context of this intricate intertwining at all scales. We become aware of change only when a different pattern becomes discernible. But before change at a macro level can be *seen*, it is taking place at many micro-levels simultaneously. Hence *micro-agent interaction and change leads to macro system evolution.*

This section will outline a few generic characteristics of complex systems and attempt to identify some of the feedback processes associated with them. Although work on a theory of complex systems in general, and of complex *social* systems in particular, is at an early stage of development, it might provide some understanding of

[1] The Theoretical Background was written by EMK who is responsible for opinions expressed.

the thinking behind the LSE research and give some theoretical weight to assertions made in the paper.

The characteristics that will be outlined, are the following: feedback, far-from-equilibrium, self-organisation, emergence, connectivity, interdependence, exploration of the space of possibilities and co-evolution. Two points need to be noted. One is that feedback and co-evolution are two of many characteristics and cannot be seen in isolation from the others. However, as an experiment, an attempt will be made to tease out some feedback processes in each of the characteristics. The other point is that feedback, connectivity, interdependence and emergence, are characteristics that have been articulated by systems theory, and therefore familiar to most of us. Complexity therefore builds on and enriches systems theory.

Feedback 'mechanisms' tend to fall into two types: "reinforcing (i.e. amplifying) and balancing. While the former is seen as a driver for change the latter operates whenever there is goal-seeking behaviour." [17]. Putting it another way, positive (reinforcing) feedback creates change and negative (balancing, moderating or dampening) feedback creates stability. Two points need to be made regarding the Kahen and Lehman quotation. First, feedback *'mechanisms'* are related to machine-type systems, as indicated by the language used (i.e. 'mechanism'). Since this paper is dealing primarily with human systems, the term feedback *process* will be used, in an attempt to avoid machine metaphors, and thus to distinguish human from other complex systems. Second, the term 'goal seeking' is taken to mean that the *actual* system behaviour is seeking to attain the condition of a *desired* system. It is however worth making the point that biological evolutionary processes are not 'goal seeking' in the sense that they are *directed*. Organisational evolution, on the other hand, is not a direct analogue of biological evolution, as cognition and learning do provide a strong element of direction. However, both biological and social evolution depend on emergence, self-organisation, exploration of the space of possibilities, and other processes whose outcome is not goal seeking or directed, in the sense that there is a *specific desired outcome*, which can be planned and whose behaviour can be *precisely* predicted.

Something odd happens in human systems. We wish to create change through interventions, for example through the restructuring of organisations, but are so afraid of entropy and dissolution, that we impose control 'mechanisms' which constrain self-organisation and emergence - i.e. we constrain emergent order by imposing 'designed' order. The imposition of performance measurement offers a counter-example. The effect of the intervention and its use of performance measurement as a control is the emergence, often completely unexpected, of procedures which negate the intended effect of the intervention, or produce other dysfunctional effects.

We try to design and control every aspect, relationship and method of working in an organisation, because of a deep fear of instability. Yet the work of Noble prize-winner Ilya Prigogine, on the thermodynamics of non-equilibrium systems, shows that new order can arise from disorder and that dissolution and entropy are not necessary conditions of change. *"In far from equilibrium (conditions) we may have transformation from disorder ... into order. New dynamic states of matter may originate, states that reflect the interaction of a given system with its surroundings."* [38, p. 12] In **far-from-equilibrium conditions**, non-linear relationships prevail, and the system becomes *"inordinately sensitive to external influences. Small inputs yield huge, startling effects"* [38, p. xvi] and the whole system may reorganise itself. Part of that process is the outcome of positive or reinforcing feedback. *"... in far-from-equilibrium conditions we find that very small perturbations or fluctuations can become amplified into gigantic, structure-breaking waves."* [38, p. xvii] Prigogine, has reinterpreted the Second Law of Thermodynamics. Dissolution into entropy is not a necessary condition – but *"under certain conditions, entropy itself becomes the progenitor of order."* To be more specific, *"... under non-equilibrium conditions, at least, entropy may produce, rather than degrade, order (and) organisation ... If this is so, then entropy, too, loses its either/or character. While certain systems run down, other systems simultaneously evolve and grow more coherent."* [38, p. xxi]

In human systems, far-from-equilibrium conditions operate when a system is perturbed away from its established norms, or away from its usual ways of working and relating. When it is thus disturbed (e.g. after restructuring or a merger) it may reach a 'bifurcation' point and either degrade into disorder, loss of morale, loss of productivity, etc, or create a new order and organisation - i.e. find new ways of working and relating – and thus create a new *coherence*. Positive or reinforcing feedback processes underlie such transformation. But there are other processes also at work, such as self-organisation, co-evolution and exploration of the space of possibilities. The two types of feedback mechanism are therefore not sufficient to describe all the feedback processes in complex systems, but they do provide a starting point and they do capture the constant movement between change and stability.

The LSE Complexity Programme, is working on the hypothesis that tight control mechanisms and inflexible organisational designs may be counterproductive and that

a different approach and way of thinking is required. Perturbation pushes organisations away from equilibrium and creates the conditions for change and for new order to emerge, in the form of new ways of working and relating. But if something new is truly capable of emerging then by definition it cannot be fully predicted and designed. A certain direction may be desirable and to achieve it the organisation may need to develop new behaviours. But these behaviours and structures cannot be dictated; they need to emerge and to be appropriate to the new conditions. For this to happen, the right enablers need to be in place, while inhibitors to the desired change and to learning, need to be identified, articulated and reduced or even removed. The set of enablers and inhibitors are referred to as the *'enabling conditions'*. These conditions include cultural, technical and organisational aspects that collectively make up an *'enabling infrastructure'*. This paper will outline some conditions, which facilitated co-evolution between the business process and information systems development.

One reason for interventions, which create far-from-equilibrium conditions, is that the current feedback processes are no longer working. These are usually negative or balancing feedback processes, which in the past were able to adjust or influence the behaviour of the organisation, and to produce the desired outcome. When efforts to improve or optimise behaviour, in order to improve performance and market position, continually fail and when small incremental changes are no longer effective, then organisations resort to major interventions in an effort to produce radical change. These however may also fail and the organisation seems to become locked in a constant cycle of restructuring. One reason for failure is over-reliance on 'adjustment mechanisms', which operate on negative feedback, and which have worked in the past. But in a turbulent environment, the fitness landscape of the entire ecosystem is changing and we cannot always extrapolate from past experience, as new patterns of behaviour and new structures do emerge, which may be the outcome of positive feedback processes. Recognising emergent new patterns and the multiple feedback processes that create them, may become a valuable skill in providing organisations with future sustainability and competitive advantage. This however assumes double loop learning, in the sense that one needs to reflect and to step outside existing assumptions [1]. Seeing new connections or perspectives or emergent patterns requires a change of assumptions. Yet there is reluctance to allow learning as a reinforcing process, within the scope of existing assumptions.

Another reason for failure, after major restructuring, is lack of understanding of organisations as complex social systems. If organisations are seen and thought of as machines which can be 'fine tuned' through 'adjustment mechanisms'; which can be 'designed', controlled and planned in fine detail; then the approaches and tools and methods used will be those relevant to mechanistic entities. Many traditional management approaches often block or constrain the processes that enable a new order or a new coherence to emerge. They constrain self-organisation and emergent behaviour. They also restrict exploration of the space of possibilities by dictating narrow boundaries of accepted behaviour.

Self-organisation in the context of the study is taken to mean the coming together of a group of individuals to perform a particular task. They are not directed by anyone outside the group. This is not the same as 'self-management', as no manager, outside the group, dictates that those individuals should belong to that group, what they should do or how it should be done. It is the group members themselves who choose to come together, who decide what they will do and how it will be done. A feature of these groups is that they are informal and often they are temporary. Enabling self-organisation, can often be a source of innovation. In the Building Society case study a group of experts known as the 'gurus' emerged as an informal resource, called upon by their peers for advice, since they had long experience with the IT systems, which newer members of staff lacked. Companies such as Xerox [4] and Sencorp [39, 40] have benefited by acknowledging and enabling self–organisation. In Sencorp in Cincinnati, there are spaces with removable whiteboards, available to anyone, to encourage thinking together.

In large complex organisations, every aspect of working and relating cannot be designed and controlled. Self-organisation allows for experimentation, for the exploration of alternatives. Some experiments will fail but others will prosper. The latter will do so because they are 'appropriate' to the new environment or social ecosystem and because they are able to successfully co-evolve with their related systems (other groups, departments, functions, organisations) within that social ecosystem. The feedback processes here are multiple, and borrowing from Lehman's VIIIth Law [22], they are "multi-loop, multi-level feedback systems" and they link the micro and macro processes. For example, individual self-organised groups will have their own feedback loops but they will also have cross-group feedback which propagates itself and creates new *emergent* behaviours at a macro, organisational level, which are greater than the sum of individual actions/contributions, and are not predictable.

Emergent properties or qualities or behaviours are by their very nature unpredictable. They are not the sum of the parts, and a reductionist analysis of individual parts would not yield prediction of macro-level emergence. It is

the non-linear, non-determined *connections between* the parts that create new emergent properties. [5, 15, 16] Emergent structures and patterns provide coherence and link the micro to the macro. We do not fully understand the nature and process of emergence, of the link between the micro and macro, but this paper suggests that it is a form of 'communication' based on multi-loop, multi-level feedback processes. In molecular biology for example, the *"basic mechanism (which) explains the transmission and exploitation of genetic information is itself a feedback loop, a "non-linear" mechanism"*. [38, p. 154] Furthermore, the recurrent feedback processes between the micro and macro influence and change both. As Prigogine and Stengers describe it *"One of the most important problems in evolutionary theory is the eventual feedback between macroscopic structures and microscopic events: macroscopic structures emerging from microscopic events would in turn lead to a modification of the microscopic mechanisms."* [38, p. 191] This dynamic process of change is important - neither the microscopic events nor the macroscopic emergent structures or patterns remain static. They change and evolve and in so doing influence each other through feedback processes.

Connectivity also creates **interdependence** between the related elements. Propagation through amplified feedback in complex intricately inter-connected and inter-dependent systems is a possible explanation for the familiar major unanticipated consequences in IT systems, following some relatively minor alteration in the software.

The exploration of alternatives mentioned above is another characteristic of complex systems. Kauffman's work on co-evolving fitness landscapes, shows that there is no single universally optimum solution. There are only local optima in a constantly deforming fitness landscape [18, 19, 20]. It is therefore necessary for systems to constantly **explore their space-of-possibilities**. If an ecosystem is seen as a landscape made up of hills and valleys which is constantly changing, then an entity (fittest) or a solution (optimum) which is at the top of a hill at any one time, may find itself in a valley if the landscape (or the environment or ecosystem) changes. If that is the only solution available then that entity will be unfit and unable to climb a new hill. If however, it had been exploring its space of possibilities and had developed other locally optimum solutions, then it has a better chance of survival. Pharmaceutical companies employ this principle in their R&D as a matter of course. Not all compounds will succeed, in fact only a very small proportion makes it to the market, but without an intensive search strategy no pharmaceutical company could survive. This example may appear extreme, but its application is constantly in evidence. Another example, at a totally different level, is an organisation, which allowed its employees to 'play' with their computer applications [7]. What Claudio Ciborra has called 'bricolage' [7], was in fact parallel exploration and self-organisation in action. The effect was a unique system and applications which could not be copied and which were totally tailored and appropriate to the needs of the organisation and provided a significant competitive advantage.

Co-evolution, in the context of the research project, is taken to mean that *the evolution of one domain is partially dependent on the evolution of the other* [8, 18, 19, 21, 27, 28, 36], *or that one domain changes in the context of the other.* The notion of co-evolution places the emphasis on the *evolution of interactions* and on *reciprocal evolution* [9]. In human systems, co-evolution in the sense of the *evolution of interactions* places emphasis on the relationship between the co-evolving entities.

Co-evolution takes place within an ecosystem. An ecosystem in biology means that "each kind of organism has, as parts of its environment, other organisms of the same kind and of different kinds". [18, p. 242] In the organisational context of this paper, a social ecosystem means all related businesses, within the same and other industries, which have an influence upon and are influenced by the organisation under study. The social ecosystem also includes the cultural, geographic and economic milieu, which includes government and other exogenous institutional actors. One way of thinking about co-evolution within an ecosystem is in terms of related fitness landscapes. Adaptation by one entity alters the fitness as well as the fitness landscape of related entities (the term *entity* is used as a generic term which can apply at different scales to individuals, teams, organisations, industries, economies, etc).

Co-evolution needs to be distinguished from evolution. In biological evolving complex systems selection acts only on the system as a whole, as the components do not replicate. While in co-evolving complex systems, the components of the system do replicate, *"and so selection may act on the level of the parts of the system as well as on the system as a whole."* [18, p. 237] Furthermore, there is a fundamental difference between adaptive evolution and co-evolution. In both cases, the attractors of the 'adaptive' process are local optima, which are single points. In a co-evolutionary process, the adaptive landscape of one actor heaves and deforms as the other actors make their own adaptive moves. [18, p. 238] But co-evolving behaviour is not *"limited to attaining point attractors which are local optima, nor is it clear that co-evolving systems must be optimizing anything whatsoever."* [ibid.]

In other words **co-evolution, which can only take place within an ecosystem, affects both individuals and systems.** This principle also applies to human systems and it may be assumed that feedback processes are operational at different levels, scales or domains (it is difficult to find the precise term, which differentiates the different entities without importing notions of hierarchy - all three terms will therefore be used interchangeably, without implying any hierarchical distinctions). But these feedback processes are inter-related with the different characteristics of complex co-evolving systems and cannot be as simple as positive or negative. They operate at the level of the individual agent or actor, at the level of the group, the organisation, the industry, the economy, etc. Each entity is a micro-agent whose actions create emergent properties at the next macro level or structure. For example the actions of individuals interrelating, create emergent properties at group or organisational level. Some behaviours at micro level include the act of self organisation. They also include exploration of different actions, different possibilities.

Co-evolution is therefore taking place at all scales and can be thought of as *endogenous co-evolution* when it applies to individuals and groups *within* the organisation and as *exogenous co-evolution* when the organisation is interacting with the *broader ecosystem.* This however is a simplification - as the endogenous and exogenous processes are necessarily interlinked and the boundaries between the organisation and its 'environment' are not clear cut and stable. Furthermore the notion of 'ecosystem' applies both within the organisation and to the broader environment which *includes* the organisation under study. Hence the notion of a complex co-evolving ecosystem is one of intricate and multiple intertwined interactions and relationships. It isn't just a nested hierarchy of 'levels' but also of multi-directional influences and links, both direct and many-removed. Connectivity and interdependence propagates the effects of actions, decisions and behaviours throughout the ecosystem, but that propagation or influence is not uniform as it depends on the degree of connectedness. The distinction however is useful in some types of analysis and may help clarify some feedback processes at a first level of analysis. For example, the distinction made by Kahen & Lehman [17] between endogenous and exogenous feedback refers to the software domain, that is to internal feedback caused during software development and to external feedback due to environment and software releases. This clarifies and distinguishes different types of feedback related to software development, but this useful distinction can also be used at many scales and domain interactions.

Propagation of influence through the ecosystem, as mentioned above, depends on the *degree* of connectivity and interdependence. "Real (biological) ecosystems are not totally connected. Typically each species interacts with a subset of the total number of other species, hence the system has some extended web structure." [18, p. 255] In human ecosystems the same is true. There are networks of relationships with different degrees of connectedness. *Degree of connectedness* means strength of coupling and the dependencies known as *epistatic interactions* - i.e. the fitness contribution made by one individual will depend upon related individuals. This is a contextual measure of dependency, of direct or indirect influence that each entity has on those it is related to or is coupled with. Each individual belongs to many groups and different contexts and his/her contribution in each context depends partly on the other individuals within that group and the way they relate with the individual in question. Degree of connectedness, dependency or epistatic interaction may determine the strength of feedback. *Feedback in this context is taken to mean influence, which changes potential action and behaviour*. Feedback in human systems cannot be a single measure. Humans do have a choice. They are also more or less susceptible to the influence of others. Feedback therefore cannot be a straightforward input - process - output procedure with predictable and determined outputs. Actions and behaviours vary with different individuals, as well as with time and context. Co-evolution may be dependent on reciprocal influence between entities. An interesting and important question is therefore *how does degree of connectedness influence co-evolution?* This becomes particularly relevant when considering enabling conditions for co-evolution. Another related question is *how does the structure of the ecosystem affect co-evolution?* Kauffman makes the bold statement that "We have found evidence ... that the structure of an ecosystem governs co-evolution." [18, p. 279] But this confident statement is based on simulations of an abstract model. It is however intuitively convincing and the LSE Complexity Programme is examining the evidence that the same is true of social ecosystems. The relevance of these questions to this paper is that *feedback processes have a bearing on both degree of connectedness (at all scales) and ecosystem structure, and hence on co-evolution.*

2. The Research Project

The research project is investigating the co-evolution of the business process and information systems (IS) development and the hypothesis being tested is that *if co-evolution between the business process and IS*

development is enabled, then the problems associated with legacy systems will be reduced. Although, most other projects within the EPSRC IT Legacy Systems Programme are studying either the technical or the business aspects of legacy, the LSE project is focusing on the *relationship between* the business and IS domains, and the hypothesis being tested is based on the assumption that the degree, intensity and density of *interaction* between the two entities affect the rate of co-evolution between the two domains. Since the agents in human systems are individuals, emphasis was placed on the relationships *between individuals*, as well as between individuals and artefacts such as IT systems. This emphasis was in contra-distinction to the approaches, which centre the focus of interest on changes *in* entities or objects such as the evolution or flexibility of software.

Although the main focus of the study was the interaction between business evolution and IS development, it became necessary to extend the research to a more complex set of interactions, which encompassed the organisational, market and technological environments. Since co-evolution is defined as the *reciprocal interactions among agents at all levels of analysis* [28], the study needed to examine relationships at both the ***micro*** and the ***macro*** levels of interaction. At the ***micro*** level, it looked at interactions between individuals (e.g. software engineers, IT developers, users, business project managers and strategists) and between individuals and artefacts (IT systems). At the ***macro*** level, it examined the interaction between the business and IS domains (as whole entities) as well as between the organisation and its environment. That is, it looked at both the endogenous and exogenous ecosystems and their interaction. This provided the context and a deeper understanding of the interrelationships and interactions under study, between the IS and the business domains.

This paper proposes that *legacy arises from a multiplicity of intricately inter-related and inter-dependent socio-technical factors, which influence and change each other, through multiple, but inadequate, feedback processes*. These interactions take place between the changing IT systems and the evolving organisation within business, market and technological environments which are themselves changing. As these elements interact, they *co-create their co-evolving social ecosystem*.

The relationship between these elements is important and is dependent on different feedback processes. *Feedback* in the context of the study is taken to mean *influence, which changes potential action and behaviour*. In human systems feedback is associated with different types of communication, with the assigning and imparting of meaning and understanding. These in turn are influenced by *epistatic interaction*, *dependency* and *degree of connectedness*, and vary between different individuals, as well as with time and context. As outlined in the Theoretical Background, feedback in complex social systems is based on multi-loop, multi-level processes, at many inter-related micro and macro levels. Emergence operates at the micro-macro interactions, but self-organisation, far-from-equilibrium conditions, and exploration of the space of possibilities are also operating at cross-entity interactions within a co-evolving social ecosystem. Reinforcing and balancing feedback mechanisms introduce change and stability respectively, and may operate sequentially or in parallel. The feedback loops, which take place at both micro-agent and macro-structure levels, vary in their intensity and influence. They may be imagined as *a plethora of interacting and interconnected micro-feedback-processes whose connectivity and inter-action creates emergent macro-feedback-processes and structures.*

An example of such a process is communication with, and understanding of, the other domain. The study focused on two primary and interrelated domains: that of the IS professionals and of the business IT-users and strategists. Legacy in the study is taken to mean lack of support for the current business and its future development (e.g. the IT systems may not be able to support the introduction of a new product). For legacy problems to be reduced, the IS professionals need to understand the business process, its language, values, direction and future development, if they are going to provide information systems which support the business. On the other hand, the business users and strategists need to understand the technical potential as well as the limits of the IT systems. Since the individuals who are attracted to the IS and business domains are psychologically and culturally different [29], this kind of interaction and mutual understanding is neither simple nor easy, and it certainly does not happen as a matter of course. A study carried out by Mitleton-Kelly in 85 organisations, between 1988 and 1992, interviewing over 300 business and IS strategists, indicated that communication which leads to a deep understanding of the other domain was very rare. When it did occur it depended on specific individuals taking the initiative. The general interaction between the business and IS domains, however, was limited to occasional formal exchanges when necessary. There was little regular informal interaction and the professionals in each area of operation felt uncomfortable with the other.

Many attempts have been made in the past two decades to enable communication between the business and IS domains, including the introduction of the 'hybrid' manager, able to understand both areas of operation, but

success has been limited. The current study has identified two cases, one in an international bank and another in a UK-based building society, which have enabled communication between the IS and business domains. Some of the conditions underlying the feedback processes and enabling a deeper and richer degree of interaction to take place have been identified. A direct outcome of this interaction has been IT systems which meet the requirements of the business. Furthermore, in the process of providing the new IT systems that needed to interface with the existing systems, many of the problems associated with the core legacy systems were also reduced.

One finding of the research project has been that legacy is not a function of age. Legacy systems are not necessarily old IT systems. *New* systems may quickly become 'legacy systems' in the sense that they do not meet the full requirements of the users and are unable to fully support business evolution. This is often the outcome of a lack of understanding and communication between the two domains, or lack of adequate and appropriate feedback, which leads to separate evolutionary paths and to a divergence of interests and hence to differing future directions. In such cases there has been a low rate of co-evolution between the business and information systems domains.

The paper is therefore based on the following assumptions: that (a) co-evolution happens *within* a social ecosystem, and is the outcome of multiple interactions and feedback processes; (b) feedback depends on the degree of connectedness and epistatic interactions; (c) feedback is taken to mean influence, which changes potential action and behaviour; (c) co-evolution does not happen as a matter of course, but needs to be enabled. Since organisational and cultural factors may constrain the co-evolution of interaction between individuals in different domains, these inhibitors need to be recognised and conditions which enable co-evolution be encouraged. Both the study and the paper focus on the relationship between *individuals* and between individuals and artefacts, not on the characteristics of the software.

2.1 The Legacy Problem & The Empirical Study

The legacy problem is usually associated with old and large systems, written in assembly or an early version of a third generation language. They have been developed 20-30 years ago without anticipating that they would still be running decades later. The architectures and technology used to build the systems were relatively inflexible, and they had not been designed to accommodate such a magnitude of change over an extended period of time. The software systems have been changed extensively, but in an incremental and ad hoc manner. This provided the required improvement in functionality in the short term, but at the cost of increased complexity in terms of connectivity and dependence, and with relatively poor system understanding. Moreover, they are associated with high maintenance costs and they have become very difficult and expensive to change to further support the business objectives. When the balance between the technical and business dimension is lost, legacy can be seen as a *gap* between the business needs and the technical capabilities.

The empirical research was carried out in two organisations, one international bank and an UK building society, with the aim to investigate the issues of legacy and to build a rich picture of the problem. Data was collected through semi-structured interviews with individuals at various positions within the organisations (business users, systems developers, business and IT strategists). Part of the methodology was to identify and study a *natural experiment*, in the sense that a group of individuals developed a different way of working and relating, which was different from the established working practice, and which could not be supported by the dominant culture of the organisation. Natural experiments exemplify the principles of self-organisation, exploration of the space of possibilities, emergence and far-from-equilibrium. It was found that the dominant culture of the bank supported one kind of *order*, that is a particular way of relating and working which had inadvertedly contributed to a legacy problem. A different way needed to be found and the UK office *self-organised* itself and created a new order. Although certain individuals took particular actions, no one was deliberately *orchestrating* the process. Certain conditions were introduced which encouraged and supported a different type of interaction and enabled the individual agents to co-evolve in a reciprocal co-evolutionary context. In other words, certain individuals in the bank's UK office, initiated the conditions which helped to create a new enabling infrastructure, which in turn allowed a new organisational form to emerge through the interaction of a group of *agents* from both the IS and the business domains. One of the outcomes of this natural experiment or *exploration of the space of possibilities*, was an increase in fitness in terms of the amelioration of the legacy problem.

In both case studies, the organisations admitted to a significant legacy problem. Legacy systems were perceived as those *systems that no longer support the current business objectives or are inhibiting future developments* (for example, the creation of new financial products). The systems were typically large, the cost of maintaining them was very high and they constrained the business from responding fast enough to desired changes in the business domain. Legacy systems were not sufficiently flexible to allow significant modifications.

However, the applications supported by the legacy systems were vital to the business.

The two empirical studies have shown that legacy is not merely a technical but a socio-technical issue and it emerges from the intricate interrelationships of diverse elements related to business, market, organisational and technological aspects that are part of the social ecosystem within which the organisations operate. *Multi-loop, multi-level feedback processes create a range of influences on differentially coupled elements, which give rise to the legacy problem.* The following section describes the interactive elements that were identified as contributing to the emergence of legacy.

2.2 The Social ecosystem

We propose that *legacy is the outcome of restricted co-evolution and inadequate feedback* between the changing business process and information systems development. The two domains are evolving along two separate evolutionary paths with minimal co-evolution.

The two domains exist within multiple environments, i.e. within business, market and technological environments, which are themselves changing. As these elements interact, they co-create their co-evolving social ecosystem. However, *weak coupling* between some of the elements, lowers the *rate of co-evolution*, and creates legacy systems, which do not support the changing business process. If the rate of co-evolution can be increased through conditions that facilitate interactions, then the legacy problem space may be reduced.

The *boundary* of each element is not fixed, but is flexible and changes according to the relationship with other elements. For example, when suppliers become 'partners' or when end-users participate in the design of a new IT system and become part of the design team, the boundaries of identity and relationship change.

It should be noted that the research does not interpret change as adaptation *to* a changing environment. Working with the principles of co-evolution, there is no hard boundary around the 'system' and the 'environment', which is made up of a number of inter-related elements, that include the system under study, and influence each other. The emphasis therefore changes from a simple relationship between the system and its environment to a complex relationship between multiple interacting elements within a social ecosystem, co-evolving *with* each other. This notion makes an important distinction between *adaptation to* and *co-evolution with.* [32] It isn't a matter of a system always *adapting to* changes in its environment, but of all the related elements, including the system under study, *co-evolving with* the social ecosystem, made up of all those related elements. Feedback is therefore seen as those processes that influence change in decisions, actions and behaviours between the multiple differentially coupled elements. In one sense the *feedback loop* becomes a *multi-dimensional spiral* as each change in one element may trigger a change in a related element, which in turn may trigger other changes in its coupled elements. Just to complicate matters, this is not a linear causal process in the sense that change A *causes* change B. Many changes e.g. A,D,G,M, etc may *together* contribute to change B. *The reciprocal influences or feedback processes are neither uniform nor universal. They depend on the degree of connectedness, on epistatic interactions and on time and context.*

Drawing from both case studies, the factors identified are summarised in three general categories as business, organisation and technology. It should be noted that the distinction between the three is primarily conceptual, in the sense that it offers a framework for understanding the interdependence and interrelationships between them. It is also relevant for recognising and creating the complex socio-technical conditions, which enable co-evolution between the business and IS domains.

2.2.1 Business and market

In the bank, *changes in business processes,* products and services have an *impact* on the bank's *technological infrastructure.* For example, new business development in other geographical areas and changing business objectives may require the development of a new system or enhancements of the existing systems. Other examples include intensifying **competition** and the need to offer **new products** to respond to market forces. Offering new products demands changes in the existing systems to accommodate new functionality or the development of a new system that will interface with the existing ones. Further, **changing customer expectations** that demand sophisticated service, will affect the way information is provided by the current software infrastructure. This results in the need for building new interfaces to support the information. Furthermore, the economic climate and the market exert financial pressures that affect the allocation of funds to build or rebuild an application. As a consequence new applications are often built on old technology or incremental functionality is added onto the existing system, which in turn contribute to the problem of legacy. Another way of looking at this aspect is that co-evolution needs to take place at all levels: from the macro level between the organisation and its social ecosystem (which includes all related businesses, customers, competitors and suppliers as well as the economic and cultural environment) to various micro levels within the organisation. Furthermore, changes at the macro level

affect the various inter-related micro levels within the organisation, such as the IT systems.

In the building society, *changes in the strategic focus* of the organisation (whether for example, the priority lies with insurance products sold directly or through intermediaries or through cross-selling), have important *implications* for the *technological infrastructure*. The *lifecycle of some insurance products* (like pensions) also contributes to the legacy problem as they are very long (around 25-30 years). Even if a product is withdrawn from the market the IT application that supports it cannot be "*switched off*" for a number of years, until all existing policies have reached the end of their life. This partly explains the existence of many interconnected systems, of different technological characteristics and ages of systems that run in parallel.

Changes in legislation have an impact on the business in terms of the products sold and the systems that support these products have to be adjusted to accommodate the new regulations. These adjustments might range from simple code changes to the system itself, changes to other systems that are interfacing with the original system, the development of a new system that will interface with other older systems or all of the previous. The influence of exogenous institutional factors, like legislation, are part of the feedback process which impact decisions, IT systems and ways of working and also contribute to the legacy problem.

2.2.2 Organisation and management

Some of the legacy issues are closely linked to the human and organisational context, such as the delivery of applications. Short cuts and compromises are made to the systems' capabilities and frequently only a part of the original specification is delivered. This results in incremental system enhancements and eventually to complex and problematic applications. Some more specific problems are: (1) The **communication gap** between the developer and user communities further impedes the development process due to the different views and use of different languages. As a consequence of this poor appreciation of each other's domain, developers do not deliver according to users' expectations. (2) The **lack of skills** to maintain the legacy systems is another consideration. It is difficult and expensive to recruit people who have knowledge of the old systems since current training is focused on the current rather that the older technologies. Furthermore, resistance to change might prevent some people from moving away from old technology. Consequently, some new applications do not benefit from the state-of-the-art technologies and the legacy problem is perpetuated. (3) The age of employees as well as exposure to new technology can contribute to an individual's attitude towards any kind of change, but the attitude of the organisation is also important. The lack of supporting change through **training** and **education** is very important. (4) Personal **career agendas** are sometimes in conflict with business. Younger employees are keen to use the latest technological tools. More time and resources are committed to the development of new systems whereas old systems are ignored. *"Obsession with the new technology"* and personal choices in moving on with one's career have priority over the considerations of the business. (5) **Management discontinuity** seems to exacerbate the problem. The managers responsible for new initiatives do not as a rule stay in their job long enough to complete a project and to make any real impact and as a result projects are never completed.

2.2.3 Technology

Some issues: (i) Rapid technological change and the need to keep up with current technology exert a constant pressure on management, which must be offset against the cost of the investment. (ii) The existing technological infrastructure, in combination with the increasing obsolescence of technology fails to meet emerging expectations and to keep up with new business requirements. (iii) Alignment and interfacing between existing and new technology (in terms of new platforms, new hardware, new software and processes) introduce multifarious problems contributing to institutional friction.

2.2.4 Interactions between the various elements

In the bank case study, a high degree of interconnectivity and interdependence between the b*usiness*, *market*, *organisational* and *technical* elements created a complex social ecosystem which influenced and impacted the business process and the IT systems. The co-evolutionary processes included the following interactions, which have been simplified for ease of illustration: changes in the business and the market necessitated changes in products. This in turn meant adjustments to the existing applications. After many repetitions of this process, positive feedback created applications with cumulatively incremental enhancements, which exacerbated the legacy problem. Yet each enhancement worked in the short term and created a balance between the business need and its IT support – i.e. there was short term balancing feedback. In the longer term, however, each short-term adjustment added to the legacy problem. The legacy systems in turn constrained the business from offering new products. This was *a continuous reinforcing process, interspersed with*

occasional balancing processes. In other words there were multiple feedback processes 'embedded' within each other. *Co-evolution took place in the sense that each domain* (i.e. IT systems and business process*) changed in the context of the other, and in turn influenced that other.* Coupled interactions and feedback processes, therefore, contributed to the creation of a problem space associated with legacy systems, which constrained the way business could evolve. Yet each attempt to aid business evolution reinforced the legacy problem.

Following are some examples of how interacting elements created the legacy systems problem space in the bank case study. (For a more detailed account of this study, please see [32]).

a. One element arises from increasing interconnectivity and interdependence among the **system components and the applications**. The institution services *"very high value global corporate clients"*. The basis of that service is that it will provide those customers with the technology infrastructure to support their business. This means that the bank will often customise or engineer solutions into its systems, and change their coded components. Over time a layered system infrastructure is created, which is tailored to service many different customers. The interconnectivity and interdependence become so intricately intertwined that a point is reached when *"to undo that complexity is almost insurmountable without going back to the business perspective and understanding where those customers are going and whether they are willing to accept a change in the way that we're working with them which allows us to undo some of the legacy and therefore some of the complexity."* (Bank interviewee) An important point to note is the emphasis placed on the **relationship** between the business and the IT developers, based on a reciprocal understanding of business direction (related to the future needs of customers) and IT constraints. This kind of relationship, leading to an understanding of each other's domain, helps create the conditions that enable co-evolution.

b. Another element contributing to the operational complexity of the socio-technical system has been that **organisational restructuring** (a social aspect) **has changed the systems' architecture** (a technical aspect). The main European system is on two hardware bases. Eleven European countries, with smaller branches, using HP hardware, are serviced from the USA. While the larger branches, with IBM systems are now run from the UK. Originally the IBM system was implemented in seven different countries and it started in the late 70s, early 80s, as a branch or country-centric system, referred to as *"a bank in a box"* and it run all the local bank's operations. Since then, the bank has gone through several phases of restructuring. The first set of changes in the mid-80s was to regionalise the infrastructure, that is the hardware and the software were brought into central service centres and the branches were run remotely. The branch users run their terminals connected over leased lines into a centre, which has been moved several times and is now based in the UK. This involved two phases: moving the technology and then the branch back-office processing.

c. **The identification of ownership of common components** and of the need for upgrading was much more difficult as multiple owners had to be identified and to be persuaded of the benefits, before they would sign off. The technical problems impacted the organisational issue of ownership and the geographically dispersed organisational structure added to the problem. The multi-ownership issue did not arise with systems that were managed and owned locally in a single country. This example shows how the intricate interrelationship and feedback processes through influence and impact, between technological and organisational factors, creates the complex problem space of legacy: a technical problem impacted an organisational issue while organisational changes exacerbated the technical concerns.

d. Another component is that the bank has made a conscious effort to try and isolate elements of the legacy 'bank in a box' system and to **create stand-alone components**, which still communicate with it. They are Windows NT based front-end servers. But they haven't yet succeeded in replacing the full set of legacy software. The part replacements use current technology. In an effort to update the system with new technology (instead of incremental adjustment) it has created new complex interfaces with the old systems.

e. Another element contributing to the complexity of legacy is that the maintenance and further development of the IT systems have been centralised within the UK group, which now controls 16 systems on both HP and IBM platforms. Thus, as resources for the maintenance and support are held centrally, there is now **no local knowledge** of the branch technology of the system. Hence an organisational issue (centralisation and cost reduction) affected the technology infrastructure, which in turn affected the knowledge base. This may have consequences on the future maintenance of the local systems and on local business.

The above examples illustrated the complex interactions of diverse geographic, business, organisational and technical elements, within a co-evolving social ecosystem.

2.3 The Socio-Technical Enabling Infrastructure

2.3.1 The bank case study

Despite the above and other problems, the bank project was completed successfully. One of the main drivers was the exogenous pressure of legal and regulatory requirements, which needed to be implemented before the bank was ready to handle the common European currency. However, although the exogenous pressure was a necessary condition, it was not sufficient for success. Many other conditions needed to be created internally and this section describes some of them, which contributed to a local *socio-technical enabling infrastructure.*

The project introduced new technologies, and because of its high profile was also able to import an international team of technical experts. But what facilitated the technical success were certain social conditions initiated by the Project Manager in charge of the project. One of the most important aspects was the facilitation of a closer working relationship between the business and information systems professionals. They were:

- New procedures introducing regular monthly meetings, which enabled *good networking* and *trust*, as well as a *common language* leading to mutual *understanding*.
- *Autonomy*: the project manager was left alone to introduce the new procedures.
- A *senior manager supported* the changes, but did not interfere with the process.
- *Stability*: sufficient *continuity* to see the project through, in an environment where constant change of personnel is a given.
- An *interpreter* mediated the dialogue between the domains. This ensured understanding on both sides but also protected the technologists from constant minor changes in requirements.

The monthly meetings, supported by weekly information updates, enabled the three environments of technology, business and operations to talk together regularly and in a way that was going against established ways of working. In time, the various stakeholders involved in the projects began to identify **cross-dependencies in terms of the business project relationships,** which led to new insights, and new ways of working. Once the conditions were provided the individuals involved were able to self-organise, to make the necessary decisions and take the appropriate actions. This illustrates micro-agent interaction, which is neither managed nor controlled from the top. Once the inhibitors were removed and the enablers put in place, new behaviours and ways of working emerged. The monthly sessions improved communication between the different domains by improving understanding, but they also allowed for the **emergence of new ways of working**, and in the process helped the business become fitter or more competitive.

Another important element was the **articulation of business requirements** as an iterative process with regular face-to-face meetings. These meetings were at a senior management level with (a) a vice president who owned the product, was responsible for the P&L and determined the business requirements; (b) a senior and experienced business project manager who was a seasoned banker, with a good knowledge of the bank, and (c) a senior technology project manager who defined the IS platform(s) and the technical development of the project. This constant dialogue created a willingness to **communicate** and a level of **trust** which were essential enablers of co-evolution. These social processes can also be seen as *feedback enabling or facilitating processes.* For example, trust facilitates better communication, which in turn enables the building of IT systems that facilitate the evolution of the business.

What was achieved took a particular individual, supported by his senior manager, to create the conditions that enabled dialogue, understanding and a good articulation of requirements. He created the initial conditions, to improve the relationship between the domains, but he could not foresee how the process would work or whether it would work. As it happened, it did work and substantial *network rapport* was established between the domains based on **trust**, **a common language** and **mutual understanding**. They worked well together, because the conditions were right and they were prepared to *self organise* and work in a different way. The new relationships were not designed or even intended. They happened spontaneously in the sense that they were enabled but not stipulated.

The achievement however, could be a one-off. Unless the new procedures and ways of working become **embedded** in the culture of the organisation, they are likely to dissipate over time. Once the initiator is no longer in place, the danger of dissipation or reversion to the dominant mode of working will assert itself. In this case there has been some embedding and some continuity, but the process is fragile. A new set of organisational changes could destroy it. Part of the embedding is the networking rapport that has been established. But the network rapport is implicit and informal, and is therefore under threat if there are too many and too frequent changes and the Bank's culture is one of constant change in management positions. *"Every two years someone else is in the post so that there is that lack of continuity."* If

the rate and degree of change is too great then the network will become invalid.

2.3.2 The building society case study

The emphasis in the bank study was on the interaction of multiple socio-technical elements at micro and macro levels of interaction. It also used the example of a natural experiment to illustrate how some enabling conditions helped create a new way of working and relating. The emphasis in the building society case study will be on some complexity principles, which create an enabling infrastructure.

a. *"Gurus" as emergent phenomena; operating far-from-equilibrium and exploration of the space of possibilities.*The part functionality and shortcomings of the legacy systems, the continuous changes and enhancements, and the difficulty involved in the process due to lack of proper documentation gave rise to the so-called "**system experts**" or "**gurus**". These people have invaluable system knowledge and expertise and have either a business or a technology background. The "experts" from the business side, act as interpreters between the business users and the IT developers by helping in the translation of business requirements into technical language. This helps to overcome the communication problem between the business users and the IS developers. While the technical gurus have a deep knowledge of the undocumented legacy system and are able to help the new developers navigate its intricacies.

The "gurus" *emerged* out of necessity. Lack of skills, lack of system knowledge, and lack of documentation, exacerbated when IT professionals moved, retired or left the company, acted as a constraint to business evolution. Constraints are not always a bad thing, as they can force both the individual and the organisation to find a different way of working to overcome the constraint. A trivial but illustrative analogy is a boulder in the middle of a stream of water. It cannot be moved, but the water can flow around it, perhaps cutting new channels in the process. The organisation therefore had to find a different way of operating. One way of looking at the process is that constraints may push the organisation *far-from-equilibrium*, in the sense that they push it away from the standard way of working, from the norm. The gurus are not the norm, there is no career path or job description for them and no one could have predicted their emergence. When pushed far-from-the-norm individuals and organisations are forced to explore alternatives. This exploration may be deliberate or it could be implicit and emergent. However, exploration needs to be enabled and emergent properties need to be recognised and not inhibited. In this case the gurus enable a different way of working, and help to overcome certain constraints which could have a deleterious effect on the development of the business.

b. Self-organised informal networks, epistatic interactions and connectedness. A particular multi-disciplinary project on legacy systems, brought together various experts. They found that they worked well together and could help each other. This was a new departure in established ways of working. Once that project was completed the team was disbanded, but the *informal network* it created, has since been often resurrected, on a self-organised basis. Whenever there is a project related to IT legacy systems, people in the network call each other and try to work on the project together, on an informal basis. Because of their previous experience of working together, they know each other's expertise and can call on those with the necessary knowledge. No manager external to the group dictates or directs these interactions. The individuals within the self-organised group initiate them. This is self-organisation in a micro-scale where individuals take the initiative to talk to others. With improved communication, results were always good. The enablers here were knowledge of available skills and expertise gained through the initial project. But subsequently, flexibility in allowing self-organised groups to work together helped. However, to create a robust enabling infrastructure, it would be necessary to acknowledge the value of such interactions and actively encourage them. Both the self-organised groups and the gurus are also illustrations of *epistatic* interaction. The contribution of each individual depended on those other individuals he/she worked with, and was enhanced in particular contexts. The quality of contribution or epistatic interaction also depended on degree of coupling and connectedness. Networks or webs are not constantly connected (Kauffman 93, 95). Their robustness lies on their ability to re-establish dormant connections, when necessary.

c. Legacy as positive feedback and pattern repetition. The way management views the legacy systems, and continuation of the same processes reinforces the legacy systems. The business, organisation and technology processes interact with each other on established and repeated patterns to produce more legacy.

Even when the organisation has explored its space of possibilities and introduced new technology, established thinking, ways of working and relating can counteract and reduce the expected advantages. The building society implemented a component approach to systems development to enable new insurance products to be designed and marketed within a short period of time. It was expected that the new approach would solve many problems and enable new products to be marketed within a couple of weeks instead of the usual 8 weeks, by allowing those responsible for product marketing to bypass the problems associated with legacy. The marketing people

could use components to develop a new application to support new insurance products that could be designed and marketed quickly. This would enable the organisation to co-evolve quickly with its marketplace. However, despite all the expectations, the mind sets, technology procedures and ways of working which originally helped create the old legacy systems, are being repeated. The repetitions of patterns of behaviour, as reinforcing feedback processes, recreate the legacy problem space.

3. Summary and Conclusion

The paper reported on work-in-progress. The specific research project and its two case studies, have not been completed; while the theoretical work on complex social systems is still under development.

One of the assumptions made was that evolution needs to be distinguished from co-evolution and that co-evolution of diverse elements, can only take place within a social ecosystem. Co-evolution is operational at different levels, scales or domains and it therefore affects both individuals and systems. Similarly feedback processes operate at the level of the individual agent or actor, at the level of the group, the organisation, the industry and the economy. Co-evolution is therefore taking place at all scales and can be thought of as *endogenous co-evolution* when it applies to individuals and groups *within* the organisation and as *exogenous co-evolution* when the organisation is interacting with its *broader ecosystem.* Feedback, in the context of the paper, is taken to mean influence, which changes potential action and behaviour.

Another assumption was that there are networks of relationships with different degrees of connectedness. The notion of degree of coupling and of *epistatic interactions* were introduced. Feedback processes have a bearing on both degree of connectedness (at all scales) and ecosystem structure, and hence on co-evolution.

The paper proposed that legacy arises from a multiplicity of intricately inter-related and inter-dependent socio-technical factors which influence and change each other, through multiple, but inadequate feedback processes. Feedback in complex social systems is based on multi-loop, multi-level processes, at many inter-related micro and macro levels. Emergence operates at the micro-macro interactions, but self-organisation, far-from-equilibrium conditions, and exploration of the space of possibilities are also operating at cross-entity interactions within a co-evolving social ecosystem. Reinforcing and balancing feedback mechanisms introduce change and stability respectively, and may operate sequentially or in parallel. The feedback loops, which take place at both micro-agent and macro-structure levels, vary in their intensity and influence. They may be imagined as *a plethora of interacting and interconnected micro-feedback-processes whose connectivity and inter-action creates emergent macro-feedback-processes and structures*

Reference was made to two case studies in a bank and a building society. Both cases emphasised the importance of communication, trust and understanding as essential feedback processes facilitating co-evolution between the business and IS domains. The bank case, was used to illustrate the interaction of diverse elements and their feedback processes, in terms of influence, within their social ecosystem. The elements chosen were the organisational, market and technological environments and their influence on business evolution and IS development. The case also showed the relationship between micro-agent interaction and macro level relationships, within a social ecosystem. Finally some of the conditions that enabled co-evolution were identified, both between the business and IS domains, and between the organisational, market and technological environments. The building society case study was used to illustrate some complexity principles and their contribution to the creation of an enabling infrastructure. Both cases show that co-evolution takes place between diverse elements within a social ecosystem.

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