The Dynamics of Innovation in Electronic Networks - a System Dynamics Perspective on IT Innovation Diffusion

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This paper analyses IT innovation diffusion within communities joined through electronic networks. Emphasis is laid on qualitative system dynamics, as a methodology of structure and behaviour, in order to understand successful IT innovation. The focal point of interest is the adoption-diffusion continuum, from prior use to post-adoptive behaviour, analysed and modelled by means of "adaptive structuration" based on "duality of structure". We draw upon the structurationist system dynamics approach (Reichel A. 2004) and extend it within the context of IT innovation in electronic networks. The aim is to begin the development of an integrative modelling base for IT innovation diffusion. "Cognitive model building", and "information processing", are secondary (supporting) epistemic levels, used to aid clarifying issues of collective sociality and group outcomes in innovation uptake. The endeavour undertaken ventures on a holistic route of thought, with the emphasis shift from pure subjectivism to "structuration", moving beyond "intention" toward a system dynamics analysis of IT innovation.

Keywords: IT innovation diffusion, adoption, modelling, structuration, system dynamics

0 Introduction

Successful innovation requires enthusiasm and commitment from all parties involved (SDS 2006). Information and Communication Technology (ICT) has not fulfilled its promise of total diffusion into society. Some individual innovations have been widely successful while others have succeeded only in narrow niches. The major problems fall into two basic classes: finding the right business model; and influencing user community attitude to innovations and the changes which accompany them to extend end-user uptake beyond what Rogers calls the "innovators" into the "early adopters" and "early majority" (Swatman and Swatman 2004).

This paper strives to understand the dynamics of IT innovation in electronic networks, by analysing group outcomes resulting from involvement of all relevant constituencies and stakeholders in making innovation work. The structurationist system dynamics approach (Reichel 2004) is drawn upon to begin the development of an integrative grounding for innovation diffusion modelling. The aim is to capture the whole diffusion system, reflecting on the "duality of structure", reproduced by cognitive routines, exchanged between innovation-adopting and innovation-propagating organisations. This study undertakes to theorize more richly than has heretofore been done on the *network* perspective of user-acceptance decision processing through the lens of group model building. The remainder of this paper reviews and builds on the current stage of research on innovation diffusion modelling (Section 1), IT pervasiveness and embeddedness (Section 2), DOI (Diffusion of Innovation) model building tools (Section 3), and outlines practical suggestions for utilising system dynamics to refine traditional modelling methods to achieve DOI success (Section 4).

1 Innovation diffusion modelling

Faced with a growing realization that a number of innovative IT products and practices have suffered from a lack of utilization, technologists are beginning to turn to innovation diffusion theory in an effort to find a systematic model of adoption and diffusion to serve as a starting point for their strategic planning. The closest any researcher has come to presenting a comprehensive theory of innovation diffusion is Everett M. Rogers with his book "Diffusion of Innovations" (1960). Four of the theories discussed by Rogers - Innovation Decision Process, Individual Innovativeness, Rate of Adoption, and Perceived Attributes theory, are among the most widely used theories of diffusion. These, and similar theories are classified according to (1) their view of the goal of technology diffusion (systemic change or product utilization), and according to (2) their philosophical view of technology diffusion (determinist or instrumentalist). Two axes of theory are formed: horizontally - macro- and micro-level, and vertically - instrumentalists and determinist. The systemic change, also called *macro-level* theories focus on the institution and systemic change initiatives, while the product utilization, also called *micro-level* theories focus on the individual adopters and a specific innovation or product rather than on large-scale change. For *instrumentalists* the process is evolutionary, and the causes of change are in human aspirations for change and improvement, with human control over the innovation being a key issue. *Determinists* regard technology as the primary cause of social change (Carr 2005).

Later researchers tended to view these classical theories as representing a somewhat two-dimensional approach to the issue and extended the approach via a network-based understanding of the innovation process (Callon & Latour's 1981, Bijker & Pinch's 1984), while redefining the social diffusion system as a network, in which communication patterns

are analysed as relational structures (Scott 2000, Wassermann & Faust 1994). Evolutionary diffusion theory (Nelson & Winter 1982; Metcalfe 1994, Dosi & Nelson 1994, Lambooy & Boschma 2001, Fagerberg 2003, based on Schumpeter 1949) extended the concept still further, with focusing upon open systems and areas of rapid change, differentiations, complexities and unexplained outcomes in technology diffusion (for an overview see Krueger & Swatman 2005). W. Brian Arthur (1999) developed a complexity economics outlook on technology adoption, with emphasis on the formation of structures rather than their given existence, while analysing network effects, increasing returns, path dependencies, and lock-in (Arthur 1989).

All these orthogonal tribes of theory have given rise to *subjectivist* or *objectivist* techniques of innovation diffusion modelling, with the first focusing on the individual human being and his motivation, and the second - avoiding reference to an individual predicate. An ultimate manifestation of the *subjectivist* modelling approach is the Unified Model of Acceptance and Use of Technology (Venkatesh et al. 2003), with its four core determinants of intention and usage (performance expectancy, effort expectancy, social influence, facilitating conditions), and four moderators of key relationships (gender, age, experience, voluntariness of use). The *objectivist* stream of modelling has produced frameworks, similar to Fichman´s (2000), with the emphasis laid on environmental factors of organizational and technological nature affecting the innovation diffusion context.

Innovation diffusion modelling, as triangulated in this paper, is neither subjectivist nor objectivist; it is above and beyond all structural. The analysis applies the structurationist system-dynamics method, suggested by Reichel (2004). The endeavour undertaken ventures on utilising this method to shift the emphasis from "intentionality" to "structuration", with the long-term goal being one of (re)routing innovation-diffusion research away from "intention" (as the coronation of all analytical efforts) toward an integrative systems approach. Epistemological grounding is built around the centrality of *internal mental models* as cognitive network schemes, thus focussing on the cognitive process (Reichel 2004) of collective "goupthink".

The existence of internal (system-wide) mental models lays ground for the emergence of cooperative structure as well as behaviour. Internal mental models, therefore, work as a "social glue" of any system (Albert and Silvermann 1984 in Reichel 2004), and are suggested in this paper as basic structural elements to analyse the joint mental states of collective "aboutness" or attitude toward innovation (- adoption/rejection) within user communities. Within this context, "collective sociality" (Ylikoski 2004) is understood to refer not only to phenomena of collective intentionality (e.g. joint intention and commitment, mutual belief, we-attitudes, collective acceptance and agreement, collective responsibility, and the like) but is also taken to cover collective action, social practices as well as social institutions and organizations.

1.1 Innovation diffusion stages

Shumarova and Swatman (2006) formulated a unified model of innovation diffusion stages *(*see *Figure 1*[1]*)*, extending a basic concept from Engel et al. (2001) (i.e., the Consumer Decision Process Model) with three innovation diffusion process models: Cooper and Zmud

[1] Figures are to be found at the very end of this paper.

(1990), Rogers (1995), and Swanson and Ramiller (2004) in order to provide a framework to serve as a point of departure for understanding ICT user decision processing within broad context. The unified model is structured based on the time-related user acceptance constructs: Prior Use, Use, Habit, and Post-Adoptive Behaviour (Jasperson 2005), and two mediating cognitive processes - External Search, and Internal Search (*Figure 1*).

Following External Search, and Prior Use[2], the stage of *ICT Use* contains the sub-stages of acceptance, retention (information perspective), and routinisation (management perspective) *(*see *Figure 1)*. Acceptance implies commitment to usage, and routinisation implies usage, exercised as a normal activity (based on Cooper and Zmud 1990). Both imply multiple exposures to the ICT artefact. The mental model of the ICT artefact is updated on each exposure. Thus the episodic information (gathered during Prior Use) is generalized, and stored in the subject's semantic memory. Retention implies formation of semantic knowledge, as a map that ties together the multiple exposure reflections in a meta-mental model of committed comprehension.

With any repetitive behaviour, reflective cognitive processing dissipates over time, leading to non-reflective, routinised behaviour, also called *Habit* (Jasperson 2005) (see *Figure 1*). Expectancy here relates to familiarity and routine, and the ICT artefact survives occlusion in space, and over time (based on Brinck 2003). Habituation as related to IT usage (Ng-Kruelle and Swatman 2003) is the psychological phenomenon of the individual continuing to either reject or accept an innovation - based on previous experience - without indulging in much pre-thought or structured decision making. Habituation contains the sub-stages of infusion (management perspective), and confirmation (user perspective) (see *Figure 1*). Infusion implies using the application in a comprehensive and integrated manner (Cooper and Zmud 1990), and confirmation implies decision reinforcement (Rogers 1995).

With the decision being repetitively reinforced, the brain desensitizes to the significance of the decision-making process. An individual's past use behaviour produces a tendency (e.g., post-adoptive intention) for the individual to act in a particular manner (i.e., applying a common set of ICT application features) given a particular context (i.e., a specific work task) - the so-called Post-Adoptive Behaviour (Jasperson 2005). Post-Adoptive Behaviour is the joint outcome of Prior-Use level of comprehension, and Usage-stage disconfirmation-driven adaptation.

1.2 The dynamics of innovation - information processing perspective

The interaction that occurs when human society converges with pervasive information technology is more than complex. Time and experience are revealing significant differences between engagement in the real world and engagement in the virtual world, particularly with regard to social and behavioural norms. Shifting boundaries for human interconnectedness are especially intricate in a technological environment that has optimized the free exchange of information regardless of physical proximity or individual characteristics (Berson 2003). Information processing, in a broader sense, requires both computation and a medium of computation - internal representations (Stufflebeam in Mandik -).

[2] For detailed elaboration on each stage, see Shumarova and Swatman (2006)

Prompted by a consideration that consciousness supervenes on cognitive processing, we present (in *Figure 2*) our interpretation on the Elaboration Likelihood Model (ELM) (Cacioppo and Petty 1979) adapted within innovation-diffusion context. Some of the core epistemological ELM categories are revisited and assigned diffusion-related meaning, as follows:

The ELM is based on the idea that persuasion is a primary source for attitude-formation. The model features two routes of persuasive influence: central and peripheral. The key variable in this process is involvement, the extent to which an individual is willing and able to "think" about the position advocated and its supporting materials. In *Figure 2* involvement is detailed through the two auxiliary equations: motivation to process (personal relevance, need for cognition, personal responsibility), and ability to process (distraction, repetition, prior knowledge, message comprehensibility etc.). These two auxiliaries affect positively the level of cognitive processing (i.e., when people are motivated and able to think about the content of the message, elaboration is high). Elaboration involves *cognitive processing* such as evaluation, recall, critical judgment, and inferential judgment - depicted in *Figure 2* in the "adoption decision processing" flow. When elaboration is high, the central persuasive route is likely to occur - resulting in favourable or unfavourable thoughts, followed by innovation adoption or rejection; conversely, the peripheral route is the likely result of low elaboration. In this case, neutral thoughts predominate, which leads to peripheral-route routine guided behaviour, habituation and desensitisation (*Figure 2*). Low motivation and ability to process may cause delays in decision processing.

Especially worthy of focused study, we believe, is *low* elaboration, exhibited during *post-evaluation* stages. We hypothesise that this type of low elaboration may be analysed through the lens of *disconfirmation* - a term borrowed from Expectation-Disconfirmation Theory (Oliver 1980), which describes the discrepancy between one's cognition and reality. Within IT usage context, disconfirmation implies discrepancy between users´ original expectations and observed performance of the ICT application. This logic is consistent with Helson's (1964) Adaptation Level Theory (ALT), which holds that later-stage cognitions can be viewed as an additive function of prior cognitions plus the deviation or discrepancy from those levels due to actual experience (Bhattacherjee and Premkumar 2004).

1.3 The dynamics of innovation - network perspective

As recognised by both social network theory - the study of how the social structure of relationships affects beliefs or behaviours - and system dynamics, causal pressures are inherent in social structure. Network analysis is a set of methods for detecting and measuring the magnitude of the pressures (Berkowitz 1988). *Habituation* (see *Figure 2*) related to IT usage is an interesting type of causal pressure, which deserves special scrutiny. Group habituation, as exhibited throughout social networks, may play the role of subjective norm within e-communities: pervasive informational cascades may prevail, falsely suggesting that a broad, substantive, and well-considered consensus exists (Shumarova and Swatman 2006). Swanson and Ramiller (2004) elaborated on the commonplace practice of innovating *mindlessly* with IT - as being entertained whenever organizations choose to be inattentive to the firm's own circumstances; by doing so, they let IT-usage routines lull them into complacency (e.g., group habituation) with some widely touted "best practice". The origins of IT-mindlessness are in attention deferral (i.e., low elaboration), which extends into adoption (bandwagon pressures). This is known as the "bandwagon" effect, also called "me too"

variety or ”join the crowd” effect (Swanson and Ramiller 2004). This effect originates in a self-reinforcing process (critical mass pressure), which yields a tendency for a community to become locked-in to widely adopted technology standards. Hence, a trend emerges for excess inertia to develop around an existing standard because of reluctance among users to leave a mature network and join an immature one (Farrell and Saloner, 1987 in Fichman 2000).

We may try to analyse the ”bandwagon” effect, as one example of group habituation, through the lens of *groupthink*. Groupthink is a kind of thinking in which maintaining group cohesiveness and solidarity is more important than considering the facts in a realistic manner (Aronson et al. 2003). Another way of looking at the bandwagon effect is from a structurationist perspective, namely from the angle of what Rogers (1986) called “the interpersonal linkages created by the sharing of information in the interpersonal communication *structure*”, that is, the network (Berkowitz 1988). Relevant here are the epistemological constructs of:

- *Reciprocal determinism* - the dynamic interaction of the person, the behaviour, and the environment in which the behaviour is performed (Bandura 1986);
- *Behavioural acquisition* that occurs by watching the actions and outcomes of others' behaviour during observational learning (Bandura 1986);
- *Reflexive intentionality* - consciousness arising in the interpretation of a meaning which is already there (Book in Mandik -);
- *Contagion* of “infectious” attitudes and behaviour, transmitted within networks, depending on factors such as frequency, multiplexity, strength, and asymmetry (Erickson 1988 in Burkhardt & Brass 1994);
- *Double contingency* - expectations we have about the behaviour of others being, at least in general, matched by the observed behaviour (Reichel 2004).

The practical implications of these constructs have been paid scant attention in the literature, and have rarely been visualised by DOI models. One of the best representations in this respect gives us the Conceptual Model for Visualising DOI (Ng-Kruelle et al. 2005) - an extended interpretation on Gallivan (2001). Unique in this framework is the feedback-loop structure (see *Figure 3*) between the three levels of infusion – (1) Consequences, (2) Secondary Adoption and Assimilation Processes, and (3) Primary Authority Adoption Determinants. This is consistent with the central assertion of system dynamics about the generality of feedback structures in social systems - that no real decision or policy can be made outside a feedback structure (Legasto 1980 in Reichel 2004), and opens the way toward discovering and describing DOI behavioural patterns (in system dynamics known as system archetypes).

If we aim at discovering DOI behavioural patterns over time, the characteristic of *dynamicity* (Ng-Kruelle et al. 2002) would clearly play an important role. Significant issues, as identified by Ng-Kruelle et al. (2002) include:

- Complexity of IT innovations that calls for necessary technical know-how for their successful adoption (Nambisan and Wang 2000);
- Suggestions that IT innovations do not form homogeneous categories but should be sub-classified before analysis (Swanson 1994);

- Many IT innovations are highly evolving innovations in that the underlying technologies are often "under continuous (re)development, social (re)construction, and IT itself tends to have high interpretive flexibility" (Orlikowski 1992);
- The evolving nature of an innovation implies that its adoption process is not a one-time decision (e.g. deploy or not to deploy), but is a "continuous process of living with the evolving innovation". Thus, it is necessary to formulate a view of adoption as a process rather than a one-time decision, and that living with an evolving innovation is in itself a learning process (Iivari and Janson 2001).

Ng-Kruelle et al. (2002) stressed that most researchers highlighted *dynamicity* indirectly, by associating it with factors such as "reversibility and susceptibility to successive modification" (Zaltman et al. 1973), or "flexibility" (Tornatzky and Klein 1982). Rogers himself (1995) has indicated that adopters do reinvent or modify the innovation during adoption, while Iivari and Janson (2001) focus on the evolving nature of a new technology. The lack of direct emphasis on this characteristic illustrates a weakness in the recognition of the *intrinsic dynamic* of the innovation itself, and therefore of the final adoption decision (Ng-Kruelle et al 2002).

2 IT pervasiveness versus IT embeddedness – types of networks and types of influence

The Social Informatics community has undertaken a number of studies of IT pervasiveness in society - and of the impact of that pervasiveness. In “Computerisation Movements”, Kling (1994) first stated that “pervasiveness of computerization is having quiet cumulative effects in American life (p.18)”. He contrasted these effects with the term “computer revolution” which he classified as a “shallow promotional claim” (p.18). In the context of the shift from traditional to informational capitalism, Kling looked at a variety of public discourses of technological pervasiveness, including the development of a pervasive consumer culture, and a pervasive command and control culture, the shift from provincialism to cosmopolitanism, and the development of a multi-centred functionally-differentiated spatial organization (Kling and Iacono 1994, Kling et al. 1995, Kling 1996). A technical perspective on IT pervasiveness gives us the definition of “pervasive IT innovation” (Lyytinen and Rose 2003), in that it “simultaneously and necessarily spans new services, and new types of development processes, thereby covering all of the IT innovation subcategories”, i.e. IT Base, System Development, and Services (Swanson 1994).

Despite the importance of the technical definitions, one aspect has to be stressed: the term IT pervasiveness is much misunderstood whenever it is being compared or equated to “pervasive computing” (PrC), with its commonly quoted (Stanford 2000) qualities of connectivity, interoperability, embeddedness, and unobtrusiveness. IT pervasiveness is before and above all a social phenomenon, related to how the structures of technological innovations penetrate societies, influencing them, and how the social structures of those societies in turn influence and modify innovations' original intent. It is a two-way process of transformative influence, with a constant feedback (Reichel 2004) between the explanans (i.e., innovation adopter) and explanandum (i.e., innovation adopted).

Cuff (2003) described the “reformulation of public and private life” (p.46) - one consequence of IT pervasiveness - as “the infusion of human knowledge into the material environment (and vice versa)” (p.49). The simultaneous existence of cyberspace and cyburg-space (i.e., embedded networks – see 2.1) creates a socio-spatial digital arena like none before. Its origins

are inherently modern: the modern world of contradiction, display, and where, as Marx famously put it "all that is solid melts into air, all that is holy is profaned". The results are paradoxical: greater connectivity coupled with increased isolation, intimacy paired with distance, privacy paired with publicity (Cuff 2003). Trying to innovate sustainably in such a complex environment is like pushing a rope to move it, if one ignores factors of embeddedness.

We consider *IT embeddedness* as a superior stage of "ordered chaos" to be strived in order to achieve competitive advantage. According to Uzzi (1997, p. 35) IT embeddedness is a logic of exchange that promotes: economies of time, integrative agreements, Pareto improvements in allocative efficiency, and complex adaptation. Shumarova and Swatman (2006) elaborated on IT embeddedness from two angles: mental embeddedness in the form of cyberspatial reputation capital, associated with the innovation (information processing view) and organisational embeddedness in the form of system assimilation (management view).

2.1 Embedded and captive networks

> To be an agent, one must be somewhere.
> Robert Sack[3]

Cuff (2003) endeavoured stimulating active discussion on *embedded networks*, as structures implying not only physical space but also "the metaphorical space of public discourse, social norms, interaction, and social sentiment". She made a strong distinction between *cyberspace* and embedded networks. Cyberspace is defined as having no physicality, no matter, and no Cartesian duality because there is only the mind, and communication is the only transaction. ("Ours is a world that is both everywhere and nowhere, but it is not where bodies live"[4]). If cyberspace is dematerialized space, embedded networks are enacted environment saturated with computing capability, where human agency is enhanced, for humans can know and act in more powerful ways. Embedded networks, in this context, functionally sidestep all the dystopian visions of disembodied, disengaged, socially remote cyberlife. Furthermore, they expedite the *restructuring* of everyday life because they permit what we considered "the context" to become a bona fide agent in the public arena (Cuff 2003).

We consider the discussion on embedded networks to be a fruitful start of rerouting scientific attention toward the more meaningful, from a system dynamics point of view, discussion on *captive networks*. Our argument rests on the literature on modular production networks. The latter stream of literature defines *captive production networks* as relying on lead firms to exert power akin to the managerial control in the vertically integrated firm to coordinate tiers of largely captive suppliers (Sturgeon 2000, Schonberger 1982, Dore 1986, Sayer 1986, Aoki 1987, Sako 1989, Womack et al. 1990). The lead firm sets the parameters under which others in the chain operate (Schmitz 2004).

In a review of power and IT impacts, Jasperson et al. (2002) posit that "IT can moderate the relationship between external power (power that derives from social *structures* outside the immediate context of formal authority) and the internal exercise of power" (p. 417). Melville et al. (2004) build on this concept in the context of the reinforcement politics argument

[3] In Cuff (2003).
[4] From *A Declaration of the Independence of Cyberspace,* John Perry Barlow, who first applied sci-writer William Gibson's term *cyberspace* to the digital social space enabled by the Internet. See http://www.eff.org/;barlow/Declaration-Final.html.

(Kraemer and Dutton 1979), and hypothesise that "the power of lead firms in captive networks is likely to lead to their orchestration of benefits resulting from the system to be skewed to their own interests" (p. 308). According to Jasperson et al. (2002, p. 427), "the creation and introduction of IT can be seen as a process that involves interested parties intentionally using their power to affect the nature of the systems that are put in place". IT may not only reinforce but strengthen power differentials (Melville et al. 2004). In a study of IT-based inter-organisational relationships, Clemons and Row (1993) found that retailers resist new IT and processes due to their expectation of lower bargaining power and less sharing of economic benefits. Thus, we are witnessing a process of some parties intentionally using their power to affect the nature of the systems, and other parties trying to resist the exercised pressure by rejecting innovation efforts.

We hypothesise that resisting lead-firm power pressures is difficult within pervasive IT networks because of:

- *Pervasive message distribution* - the boundless re-re-distribution of behavioural messages, enabled by efficiently linked flows of information, stimulating infectious cross-talk of shared pre-understanding among network members;
- *Behavioural acquisition* (Bandura 1986) that occurs by watching the actions and outcomes of others' behaviour, i.e., pushing adopters into complacency with some widely touted "best practice"; this is accompanied by speedier judgments, a quicker pace of activity, mimetic responses, and a tendency to favour impulsive adoption behaviour;
- *"Winner take all"* e-business dynamics (Frank and Cook 1995, Shapiro and Varian 1998), where the stakes for successful innovation have become high indeed;
- The importance of gaining critical mass, positing of distinctive *"all or nothing"* (Fichman 2000) diffusion pattern, where following the lead firm may be deemed as a measure of e-conomic survival;
- *Pervasive accumulation of experience* (Shumarova and Swatman 2005) - the individual consciously or unconsciously being influenced by the massive exposure to bandwagon pressures, reinforced by motivational cross-contamination (Ng-Kruelle and Swatman 2002) resulting from innovation use by the individual acting in different societal roles.

W. Brian Arthur (1989) explored a model where agents choose between technologies competing for adoption and where each technology improves as it gains in adoption. The analysis showed that the economy, over time, can become locked-in by "random" historical events to a technological path that is not necessarily efficient. When two or more increasing-return technologies "compete" for a "market" of potential adopters, insignificant events may by chance give one of them an initial advantage in adoptions. This technology may then improve more than the others, so it may appeal to a wider proportion of potential adopters. It may therefore become further adopted and further improved. Thus it may happen that a technology that by chance gains an early lead in adoption may eventually "corner the market" of potential adopters, with the other technologies becoming locked out. We believe that this "lock-in" tendency, described by Arthur from a complexity economics point of view, is another proof of the significance of captive networks within IT adoption context.

The system dynamics (constructivist) equivalent of *captive networks* are "closed systems", defined as being aware of their own performance and influenced by their past behaviour (Radzicki 1997). Modern e-networks thus are influenced by their past behaviour ("winner take all" scenarios, "best practices" etc.), and produce self-reinforcing streams of excess

inertia. The behavioural equivalents of captive networks are "reflexive intentional systems", defined as systems, which are not only subject to intentional interpretation by an observer, but able to interpret themselves (Book in Mandik -).

Against this background we may, then, theorise *pervasive IT captive networks* as: (1) context-embedded, where human agency is enhanced, for humans actors can know and act in more powerful ways; (2) capable of self-interpretation, thus producing self-reinforcing streams of excess inertia; (3) moderating the relationship between external and internal (to the organisation) exercise of power (4) thus reinforcing inter- and intra-organisational *power relations*.

2.2 Transformative influence, adaptation and routinisation

IT innovation diffusion has long been classified as a process of adopting a lifestyle rather than a technology perspective (Carroll et al. 2002). Lifestyle, in its turn, is a means to the development of transformative influence. Some researchers have tried to explain the dynamics of IT transformative influence with *fashion*: management-related institutions (consulting firms, business "gurus") have an interest in creating fashion consciousness to increase demand for their innovative ideas and related services (Fichman 2000). A vision's fashionableness (Swanson and Ramiller 2004, p. 571) is defined as "relatively transitory collective belief", disseminated by the discourse of knowledge entrepreneurs, that an IT innovation is at the forefront of rational management progress. Lee and Collar (2002) theorised *IT fashion lifecycles* as having ascent periods, shortening at a rate faster than that for management fashions. They explained this with the fact that IT fashions depend more heavily - compared to management fashions - on exogenous (i.e., context-related) factors.

We believe that IT fashionableness, as amplified by hyperbole, is being overestimated by innovation diffusion research. IT pervasiveness is much more than just "fashionableness". Consider, for example, the dot.com hype, or any of the numerous fashion bubbles created around "killer-applications" (like Artificial Intelligence, Groupware, Ontological Engineering, Data Mining etc). Rogers himself (1995) noted that the Fax was invented in 1843, its popularity, however, had to wait for a network structure with reasonable speed (it took eight minutes to transmit a single page in 1960s), a universal standard among the manufacturers, lower cost (it cost $8000 in 1965), and enough other users to make it worthwhile.

We therefore believe that the popular question of "why technically inefficient innovations diffuse while technically efficient innovations get rejected" - the phenomena that the traditional, rational, theory of innovation diffusion fails to explain adequately[5] (Lee and Collar 2002) - should not be interpreted based on constructs related to *IT fashion*, but with constructs related to *IT pervasiveness*. We deem three types of process characteristics as differentiating "fashionable" from "pervasive" IT innovation, namely *adaptation*, *routinisation*, and *infusion*.

We consider *adaptation* as generic to a successful and enduring innovation. Abernathy and Clark (1985) defined "architectural innovation" as a continuum of creative acts of *adapting* and applying latent technologies to previously unarticulated user needs.

[5] Arthur (1989) elaborated on the circumstances under which the economy might become locked–in by "historical events" to the monopoly of an inferior technology, while the superior technology may remain "locked-out" of the market.

Reichel (2004) regarded "reflexive control" as better suited (i.e., than adaptation) candidate for a causal mechanism controlling and driving social change. He argued that through the individual´s reflexivity, action is rationalised and control over systems is exerted. Thus, he outlined a "stylised" setup of subsequent reflexive control steps:

- *Practical knowledge* realised in interactive social practices;
- *Reflexive monitoring:* periodical control of action to establish (enforce) internal and external conformity;
- *Rationalisation of action:* production of codifiable hypotheses with respect to inferences about social action (discoursive knowledge);
- *Repeated application* of rationalised interpretative patterns;
- "*Sedimentation*" and/or "codification" of discoursive knowledge in social routines (Reichel 2004).

We consider the outlined sequence of reflexive control steps as applicable and holding much promise in analysing phenomena like "routinization", and "habituation" within DOI context.

Reichel (2004) posited routines as the dominating mode of social activities. Routines provide actors with self-awareness. Continuity of social practices implies reflexivity. Through reflexivity, routines are consolidated. Against this background we may define IT innovation *infusion* as a peak of "ontological security" reached, based on routinisation of use behaviour. Fichman (2000 p.7) defined infusion as "the extent to which an innovation's features are used in a complete and sophisticated way". Infusion, in this context, never comes in a neutral context for neutral effect, but alters human subjectivity while inviting high levels of human-actor complicity.

3 DOI model building – theoretical tools

Traditional DOI modelling is predominantly based on "individual intention", with "intention to use IT" being theorised as the main (fundamental) predictor of "actual use of IT" (see Venkatesh et al. 2003), and understanding "intention" seen as the coronation of all analytical efforts. The Theory of Reasoned Action (Ajzen and Fishbein 1975), the Theory of Planned Behaviour (Ajzen 1991) and similar theories are mostly referred to in this respect. We believe that "actual use of IT" is rarely deliberately "planned", and therefore any modelling attempts that describe one-way routes of planned action are too simplistic. We consider system dynamics to be a much more relevant theoretical device, because of the *holistic, systemic,* and *dynamic* nature of the analysis it is capable of.

Fichman (2000) posited Adaptive Structuration Theory (AST) (Desanctis and Poole 1994) as a useful tool providing a view on the *systematic* features that influence the processes by which technologies are adopted and used, thus allowing researchers to develop richer models of the interplay between these features, the structures of adopting organizations, and the processes of technology appropriation. AST is based on Anthony Giddens' (1997) structuration theory, and studies the interaction of groups and organizations with information technology based on the following core assumptions:

- Groups and organizations using information technology for their work dynamically create perceptions about the role and utility of the technology, and how it can be applied to their

activities. These perceptions influence the way how technology is used and hence mediate its impact on group outcomes;

- AST examines the change process from two vantage points: (a) the types of structures that are provided by the advanced technologies and (b) the structures that actually emerge in human action as people interact with these technologies (Desanctis and Poole 1994);

- AST adopts the core concept of Structuration Theory (Giddens 1997) that systems and structures exist in a dual relationship with each other, such that they tend to produce and reproduce each other in an ongoing cycle. This is referred to as the "structuration process".

We consider AST to be highly relevant in aiding innovation diffusion modelling from a structuration perspective because doing so: (a) helps understand the relative balance in the deterministic influences and wilful choices that reveal groups' attitudes toward innovation; (b) makes clearer than other perspectives the dynamic character of "groupthink"; and (c) suggests possibilities for how innovations may be able to exercise more influence than they are otherwise thought capable of.

Reichel (2004) introduced a structurationist approach to system dynamics modelling, with the emphasis shift "from simulation to elicitation and thus the cognitive process itself" (p.19). He proposed the application of system dynamics (SD) for theory building in the social sciences, while drawing on the Theory of Structuration for ontological clarification of SD core concepts. The author re-defined "duality of structure" as "the constitution of social reality on a cognitive level" (p.32), and saw great potential for aiding theory building in the application of its core constructs, namely:

- *Interpretative rules* (constitute meaning, thus enabling communication);
- *Normative rules* (sanction behaviour and legitimise goals);
- *Allocative resources* (are control over physical capital);
- *Authoritative resources* (are control over people, organisations, and the organising process itself);
- *Signification* (denotes symbolic ordering and coding - "constitution of communication");
- *Legitimisation* (denotes regulative ordering - "constitution of norms");
- *Dominance* (denotes political/economic ordering - "constitution of power") (Reichel 2004).

Against this background, we hypothesise that the structures of technological innovations penetrating societies (*technological structure*), and the social structures of those societies (in turn influencing and modifying innovations' *use behaviour*), demonstrate a two-way reproduction circuit of transformative influence, with a constant feedback between the explanans (i.e., propagating institutions, performing IT propagating initiatives) and explanandum (i.e., adopting institutions) (see Figure 4). Feedback between technological structure and use behaviour is exercised on the three ontological levels: (1) signification - communication, (2) legitimacy - sanction, (3) dominance - power. Routine-guided action is stimulated through generalisation of use behaviour, and, reciprocally, routines are laid down in structure, which is reproduced through use behaviour by executing reflexive control. As soon as technology usage routines stabilise, they become structural entities; they are structure and guide use behaviour. Repetitive innovation use builds and transforms social routines, thus

guaranteeing system reproduction. Routine building is enhanced by system modalities. We operationalise some of the DOI modalities as follows:

- *Interpretative rules*: in the form of media intervention, promotion, and the resulting elicitation (user side), and the formed image and reputation of the innovation;

- *Normative rules:* subjective norms, critical mass pressures, captive network pressures, groupthink etc.

- *Authoritative facilities*: technology standardisation, managerial intervention, IT disciplinary action (in the form of increased immediacy of threats from failing to meet commitments etc.);

- *Allocative facilities*: technology sponsorship, subsidies etc. (see *Figure 4*) [6].

4 Innovating successfully with IT - moving beyond intention toward a system view of user acceptance

Adelman (in Radzicki 1997) predicted that "in the endless tug of war between diminishing returns and increasing knowledge, technology wins out". Purely technical innovations, however, often fail in the market because of user behaviour or institutional barriers (Majer 2002). In order to understand IT innovation success better, let us look at the following four types of technology usage: technologies can be used *faithfully*, in keeping with the intentions of designers, or *ironically* (DeSanctis and Poole 1994); technologies can be used *richly*, in ways that expand the capacities of the medium, or they can be used *thinly* (Carlson and Zmud 1999).

We hypothesise that technologies are used thinly or ironically in the case of *low cognitive elaboration* (see 1.2. - *Figure 2*). Our initial hypothesis is provoked by the following popular discussions: (a) Strassmann (1990, p.1) spoke about the need for "motivation through disaster" in the face of the growing feelings of weariness and mass abstinence (Franck 1999) within e-communities: a mixture of dissatisfaction and lack of motivation to contribute, because of absent material stimuli, i.e., devaluation of money on the Web; (b) a popular topic of discussion has been the "attention crisis" (Goldhaber 1997), characterised by attention becoming the scarcest resource in the value chain across e-markets. The origins of IT-mindlessness (see 1.3) may also be sought in attention deferral (Swanson and Ramiller 2004).

While elaborating on issues of personal privacy and the changed public and private spheres in the networked society, Johnson (in Stone 2003) suggests that the public has so far been willing to accept new pervasive devices or applications without question because of a too enthusiastic faith in the present commercial systems.

> "Right now people are not afraid of it because it is not being built by the government. It's being built by the market and by commercial interests."
> Debotah Johnson[7]

The *institutional* perspective - analysing the role of institutions in the process of DOI - deserves special scrutiny for two reasons: (1) full institutionalization (Fichman 2000) is considered to be the highest level of technology assimilation within societal structures; (2) institutionalization is part of the *advanced* technology assimilation stages (from adaptation to

[6] The framework presented in *Figure 4* is readily extensible to include other context-specific modalities.
[7] In Stone (2003)

infusion), which are especially worthy of focused study within the context of trying to develop richer models of intra-organizational innovation. For us, *institutionalisation* of IT innovation is the "richest" level of infusion, with the structure of the information system being applied as (infra)structure of society. Reichel (2004, p.13) defined "institutions" as the most enduring and regular social practices. "Enduring" as it is, however, institutionalisation *in its legal form* is no guarantee for system reproduction and reflexive (self-) control.

Against this background, we argue that the concentration of DOI research on "individual intention" (even within organisational/institutional context), theorised as the main, often single predictor of "actual use of IT", is a major obstruction, hindering the progress toward careful analysis on IT innovation diffusion. We therefore suggest that pure subjectivism be learned from, but avoided in DOI modelling to enable a holistic and systemic view on larger issues of societal capability and group outcomes in innovation uptake.

While sharing the position advocated by Book (in Mandik -) that semantic (representational) intentionality is more fundamental than pragmatic (behavioural) intentionality, we suggest that *internal mental models* as cognitive network schemes (McKellar 1957, Albert and Silvermann 1984) be adopted from system theory as central epistemic elements in DOI modelling. When mental models are picked as a central theme, they often come in close relation to learning and are described as rationalised images of knowledge, which are subject to permanent learning processes (Krieg 1971, p.81 in Reichel 2004). The latter will allow for non-exclusion of the aspect of *dynamicity* of IT innovation (see 1.3), as living with an evolving innovation is in itself a learning process.

4.1 On IT innovation success

Successful IT innovation can only be achieved by appropriate DOI modelling to serve as a starting point of the interested parties´ strategic planning. Khan and Al-Ansari (-) suggested that successful innovation is a dynamic process that sustains itself. Dearing (2002) stated that successful innovation involves risk but it also requires *structure*.

Let us go back to 1.2 (*Figure 2*): Here innovation adoption/rejection corresponds to central route *cognitive structure change* (see ELM - Cacioppo & Petty 1979), where - opposite to peripheral route shift - attitude is relatively enduring, resistant and predictive of behaviour (Cacioppo and Petty 1979). We believe that the *predictive* nature of central-route cognitive structure change implies diffusion success in that it carries potential for system reproduction and reflexive (self-) control.

We thus hypothesise *central route cognitive structure change* as a necessary condition for achieving IT innovation diffusion success. One important note must be made here - DOI can, in our view, draw on the ELM (Cacioppo and Petty 1979) at the early modelling stages, but for the advanced modelling stages, we see a bigger potential in benefiting from system dynamics. Here we suggest the application of feedback-loops, applied to visualise "duality of structure" reproduction circuits (Giddens, p.79, 245 et seq.) in the process of diffusion.

As theoretical background for this proposition we provide the following (readily extensible) list of general-level necessary conditions for IT innovation to be successful:

(1) In order to be successful in the long run, the system of IT innovation must be capable of self-reproduction;

(2) The system's reproduction circuits must be reflexive (i.e. self-controlling), as opposed to homeostatic (see Giddens 1997);

(3) The influence exercised by Propagating Initiatives over Adopting Institutions (see *Figure 4*) must be capable of causing "central route cognitive structure change" (see *Figure 2*) within the user community, as a necessary condition for enduring, resistant and *predictive* of behaviour attitude;

(4) In order to be successful, the system of IT innovation must function based on reproduction loops, responsible for sustaining as well as changing (a) the types of structures that are provided by the advanced technologies and (b) the structures that actually emerge in human action as people interact with these technologies;

(5) In order to achieve system diffusion success, the question of what is the optimal combination of transition anxiety (brightness of transformation caused) and leveraging on existing content in order to retrieve the maximum profit, has to be answered from a system dynamics perspective, namely: it is better to structure a system to withstand uncertain external shocks (Radzicki 1997) than to try to predict those external shocks;

(6) IT innovation success should be understood as *pervasiveness* transformed into *organic embeddedness*, where adaptive structuration is exercised to counter/modify internal system feedback by external policy intervention;

(7) The last, but not least, necessary condition for IT innovation success is the presence of dynamic capability (Lyytinen et al. 2002, Eisenhardt & Martin 2000) - enabling organisations to relentlessly integrate, reconfigure, gain and release resources that create and respond to swift and dramatic changes in the system.

5 Conclusion and future work

Intervention in complex systems can frequently yield short-term successes but long-term failure, or the reverse. This study has unearthed a rich source of research questions that lead to a better understanding of DOI modelling, as a means towards paving the way of successful innovation diffusion. We thus hope to have sparked the interest of other academic research in examining the potential of system dynamics for the analysis on diffusion of IT innovations. We intend that the issues and propositions, identified above, stimulate the development of a broad research agenda, with the long-term objective being to connect system dynamics and user acceptance modelling more fundamentally. In future research we plan to further develop understanding of user acceptance of pervasive IT, with emphasis on adaptive structuration, rather than "intention", while considering larger issues of societal capability and group outcomes, related to IT innovation uptake.

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Figures

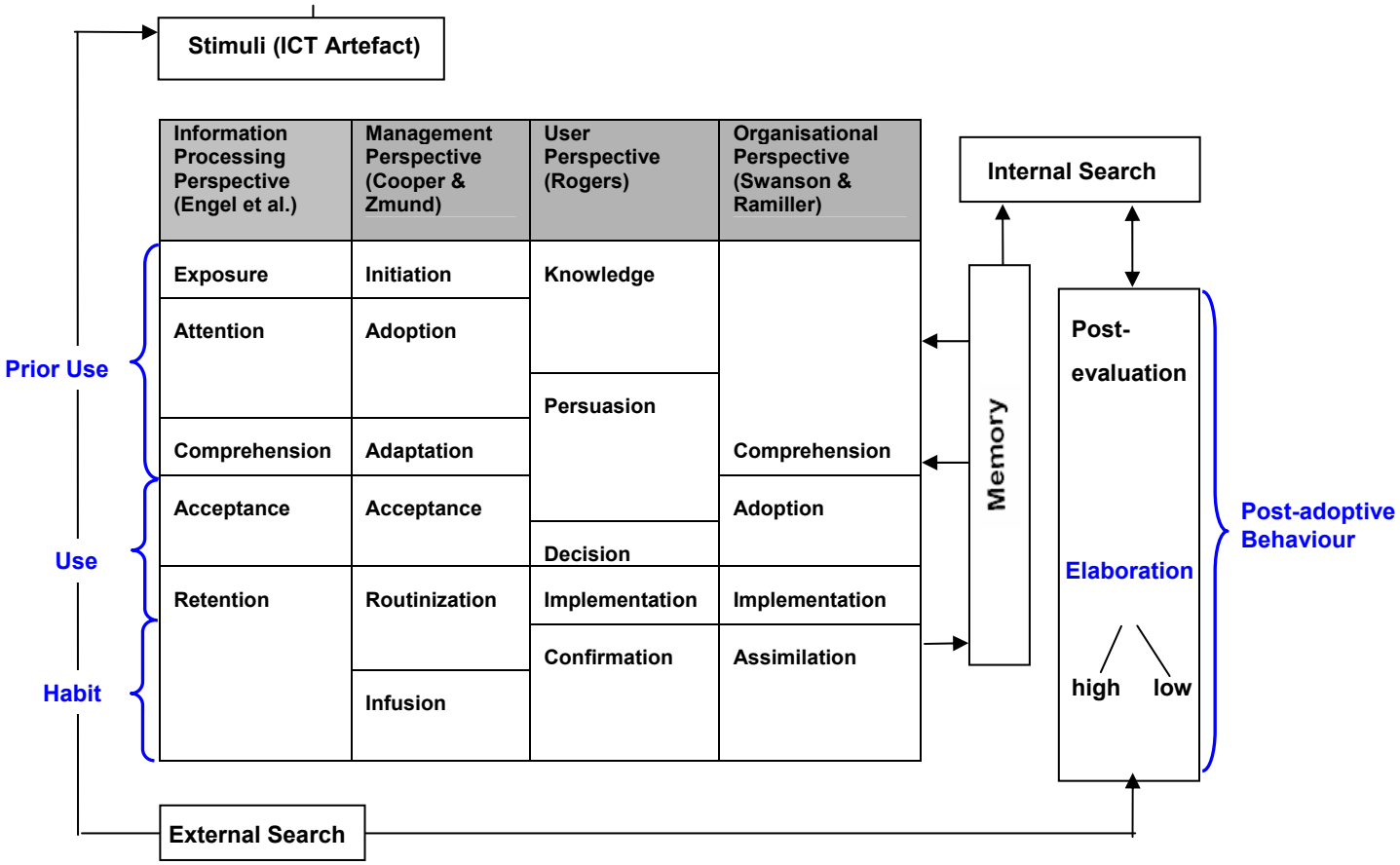

Figure 1. Information Diffusion - Information Processing Perspective (Shumarova and Swatman 2006)

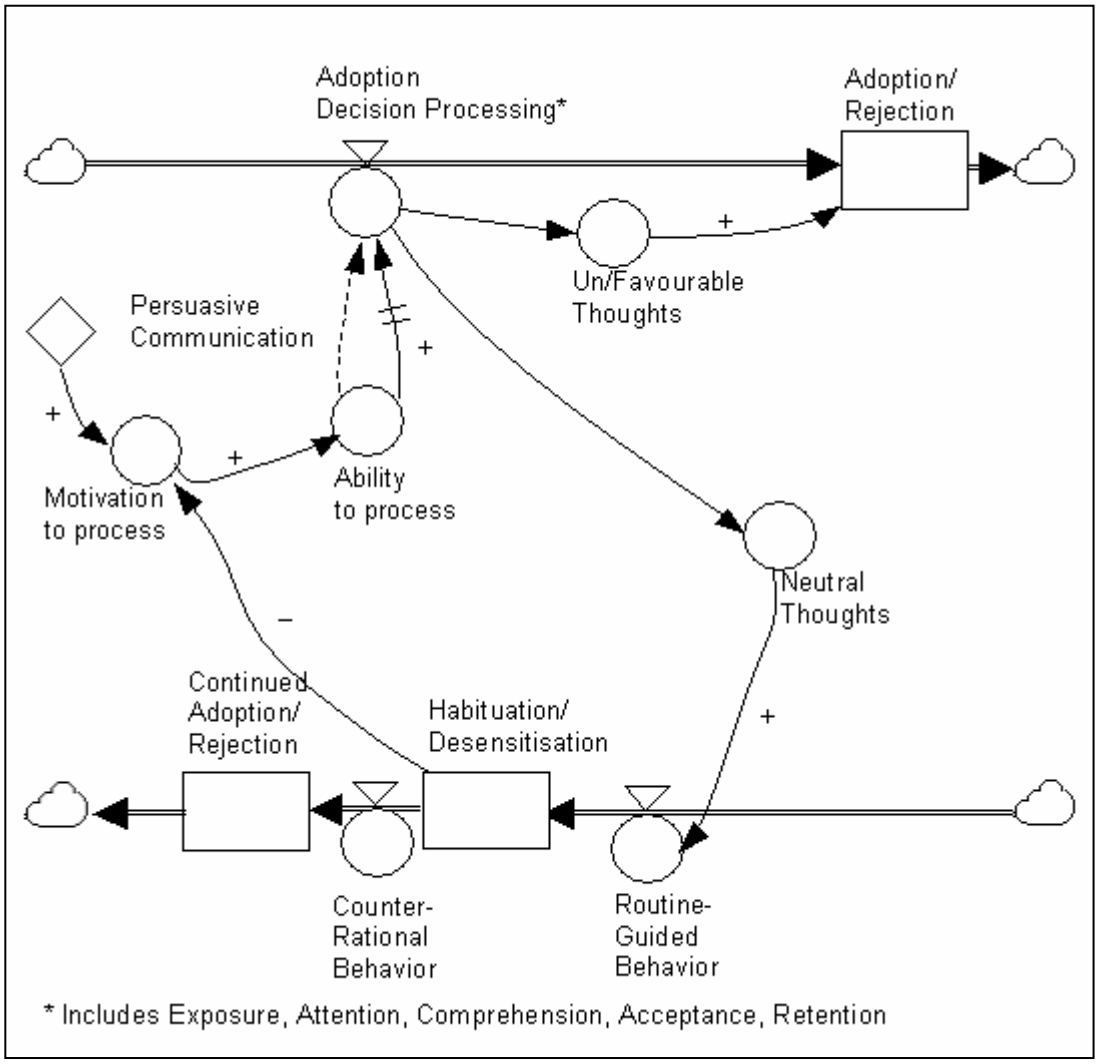

Figure 2. Innovation Adoption Decision Processing
Authors´ Interpretation on Cacioppo and Petty (1979)

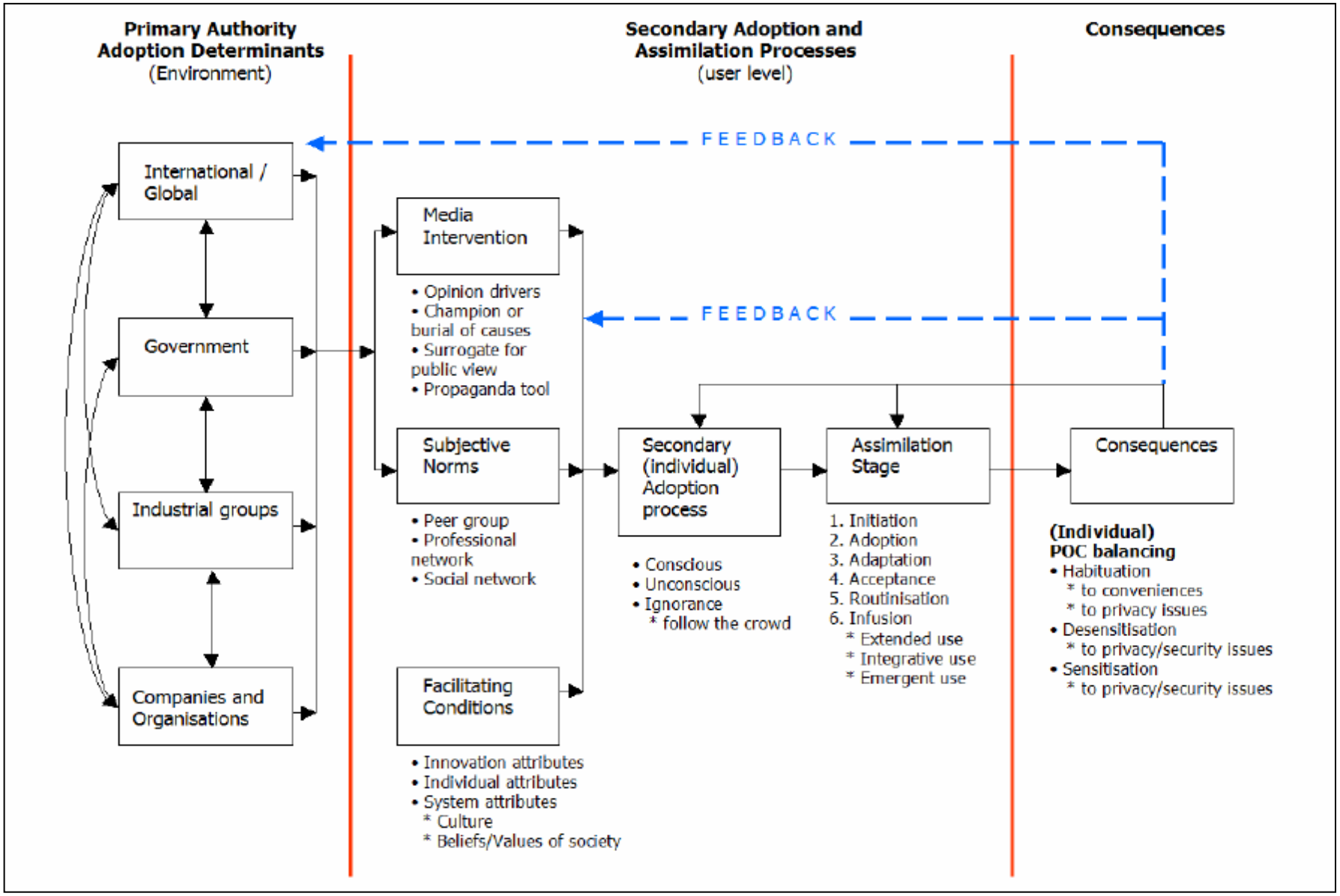

Figure 3. Social Adoption Innovation System: an Alternative Conceptual Model for Visualasing DOI Ng-Kruelle G. et al. (2005) - Interpretation on Gallivan (2001)

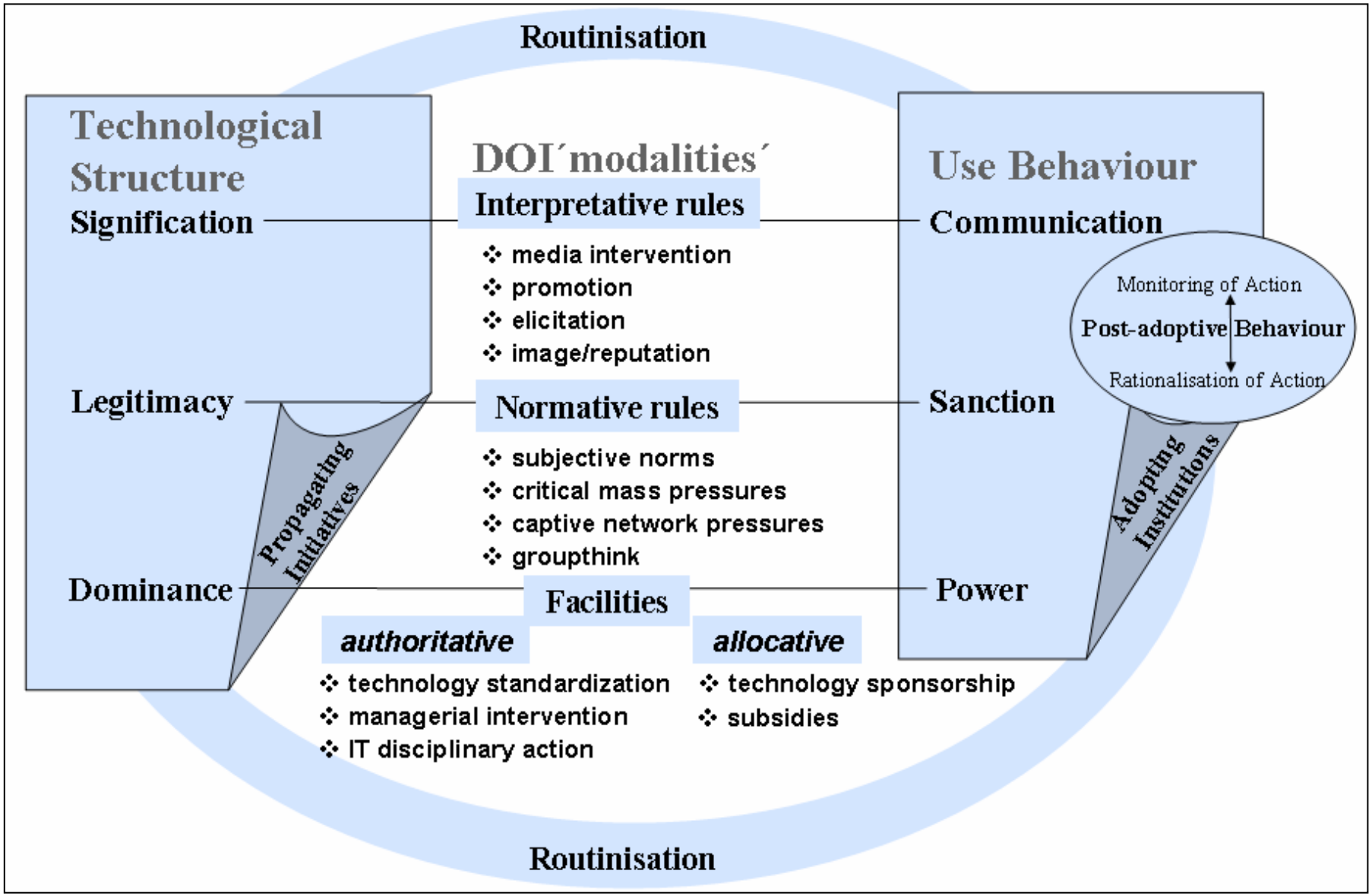

Figure 4. DOI Duality of Structure
Authors´ Interpretation on Reichel (2004)