A network perspective on sociotechnical transitions : the emergence of the electronic book

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Athina Piterou

Brunel Business School

Brunel University

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Abstract

The sociotechnical system of print-on-paper for the dissemination of textual information prevails despite widespread concerns about its sustainability. On the basis of sociotechnical transitions theory the print-on-paper system is perceived as a regime. Information technology is identified as one of the generic technologies that has the potential to address the unsustainability of the incumbent regime. Its potential effects are examined through the development of the electronic book, which is defined as those IT applications providing an alternative form of textual display to printed paper. Yet, such applications have remained marginal. According to sociotechnical transitions theory the electronic book can be seen as a niche in relation to the print-on-paper regime. An alternative conceptualisation of transitions as a process of network reconfiguration is suggested. On that basis, the electronic book is depicted as a number of emergent innovation networks. Social Network Analysis methods informed by network approaches to innovation theory are applied to visualise and discuss these emergent networks. In one of the representations, the electronic book is mapped as a sociotechnical network including organisations, users and technologies. It emerges that network formation often transgresses a distinct niche-regime divide. Patterns of network interaction are explored and assessed as to whether they represent a sociotechnical transition in progress. The analysis reveals different patterns of network formation which are indicative of prospective sociotechnical trajectories where different concepts of the electronic book are emphasised. It emerges that the discussion of sustainability and the emergence of the electronic book remain largely unlinked.

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List of abbreviations

BISG: Book Industry Study Group

DRM: Digital Rights Management

EPN: Environmental Paper Network

ICT: Information and Communication Technology

IDPF: International Digital Publishing Forum

MLP: Multi-level Perspective

NIST: National Institute of Standards and Technology

OEBPS: Open Electronic Book Publication Structure

SNA: Social Network Analysis

SNM: Strategic niche management

Acknowledgments

Author's declaration

I declare that this thesis is my own work and that it has not been previously included in a thesis or dissertation submitted to this University or to any other institution for any other qualifications

Introduction

Research objectives

Printing remains the prevailing technology for the dissemination of textual information despite widespread concerns on its environmental effects. The role of radical technologies in addressing the environmental effects of print has been identified (Steward et al., 2004). There are arguments that incremental innovation is not sufficient to address current sustainability challenges of increasing complexity (Hueseman, 2003). The pervasive nature of current environmental problems differs from earlier issues and reinforces their effects; in this context, the level of systems emerges as more adequate for the study of radical innovation with regard to sustainability goals as the effects of resource use are not isolated but embedded in wider systems of production and consumption (Geels et al., 2008). On these grounds printing technology is perceived as embedded in the sociotechnical system of the printed paper text. Sociotechnical systems include organisational actors, consumers and artefacts across the spectrum of the supply chain (Geels, 2004a). It is therefore the reproduction of the incumbent print-on-paper system that is detrimental to environmental sustainability concerns. Incremental technological innovation is not sufficient to achieve sustainability goals at the system level (Berkhout, 2002; Freeman, 1992&1996); instead what is required is major change in the way sociotechnical systems fulfil societal functions (Geels, 2002a).These major changes are termed sociotechnical transitions and they provide a framework to understand innovation at the systemic level.

Radical technologies are identified as a factor in addressing sustainability issues. Technological innovation as a pathway to sustainability has been discussed in the ecological modernisation approach (Mol and Spaargaren, 2000; Huber, 2000) and in Freeman's (1992) concept of a green technoeconomic paradigm that might be emerging as a result of the widespread diffusion of Information Technology. Along with biotechnology and nanotechnology, Information Technology is one of the generic technologies with the potential to contribute to sustainability goals in the print-on-paper regime (Steward et al., 2004).Considering the sustainability potential of the applications of these generic technologies, the initial aim of the research was to identify how the development of the electronic book could contribute to environmental sustainability goals such as dematerialisation in the print-on-paper regime. In this context, the electronic book is defined as those applications of Information Technology that provide an alternative to print as a medium of textual dissemination and particularly display. Among the wider set of electronic/digital technologies that interact with the print-on-paper regime emphasis is placed on those with the potential to substitute for paper use.

In order to address this research objective, concepts from innovation systems and sociotechnical transitions literature were used to develop a view of print-on-paper as a sociotechnical system. The Multi Level Perspective on transitions (Geels, 2002a; Geels and Schot, 2007) has been established as the prevalent framework for the study of sociotechnical transitions building on the analysis of historical case studies. The MLP expands upon earlier research regarding the role of niches as sources of radical innovation: niches are seen as

protected, incubation spaces for radical technologies which are initially isolated from the incumbent regime (Kemp et al., 1998; Kemp et al., 2001).However, the relation between the emergent electronic book technologies and the incumbent print-on-paper system is a case of innovation in progress where the structured approach of the MLP and the affiliated patterns of sociotechnical change(the transition pathways, see Geels and Schot, 2007) do not fit with observations on technology development and the interaction between involved actors. There is further discussion on the empirical limitations of the MLP (Genus and Coles, 2008; Elzen et al., 2008). Therefore, the role of the MLP in examining prospective sociotechnical transformation is questioned while the emphasis placed in the transitions literature on long-term systemic innovation is maintained. Hence, the theoretical question is how to perceive patterns of sociotechnical change in the form of prospective transitions. Kemp and Loorbach (2003) have phrased the questions on prospective transitions in terms of "the challenge (is) to bring about a transition from present functional systems towards more sustainable systems" (p.4) following a prescriptive orientation to future transitions. Instead, the thesis frames the research questions in terms of an emergent approach to potential transitions.

The alternative understanding of transitions developed in the thesis is based on relational approaches to agency and innovation which lead to the concept of network reconfiguration as a way to frame systemic sociotechnical transformation. Networks are not perceived in the form of collaborative arrangements but as structures of interaction between incumbent and emergent actors and relationships developing as a result of emergent technologies while simultaneously affecting the formation of these technologies.

A question relating to the initial research aim concerns the understanding of environmental sustainability on the print-on-paper regime, specifically regarding the role of dematerialisation as the major sustainability goal. It is questioned how different patterns of electronic book development could influence perspectives on sustainability.

Regarding radical change in sociotechnical systems, it is accepted that stability in the incumbent configuration has to be explained as well. According to the transitions literature, sociotechnical systems are identified by the societal function they fulfil; however, the concept of societal functions itself is not problematised. The resulting question is how societal functions can be seen as evolving along with the technologies and other arrangements that help reproduce them. With regard to the print-on-paper system it is questioned how its generic function of textual communication has evolved historically and how applications of digital technologies continue to reshape the understanding of textual communication. This question can be addressed by maintaining the conventional niche/regime distinction as it refers to historical developments.

Networks are used to discuss the interaction between emergent technologies and actors and the incumbent print-on-paper system. Instead of a distinct niche-regime divide the emergence of the electronic book is discussed as a process of network formation. Initially, one has to identify actors and technologies related to electronic books. In terms of the MLP, this question would be phrased as identifying the actors in the electronic book niche. Organisations, technologies and their linkages resulting from different data sources are

visualised and analysed applying Social Network Analysis (SNA). The following questions can be addressed through this analysis.

It has been argued that a balance between network diversity and homogeneity is required for innovation to emerge (Rogers, 1995; Callon, 1992). In addition Burt's (2004) argument on the role of structural holes suggests that lack of interaction allows for the emergence of new ideas as conformity is avoided. The question is how this is manifested in the electronic book networks and to what degree network heterogeneity affects innovation. In other words, it is questioned how interactions within the emergent networks and between the emergent networks and the incumbent regime enable the feasibility of electronic book innovation. In addition, it is identified how lack of interaction might delay or divert the innovation process. Network diversity regarding their composition is mostly considered as the principal area of the actors' activities which signifies the actors' knowledge base. Besides homogeneity and heterogeneity in terms of actor attributes the role of network cohesion in developing an effective network needs to be evaluated. The argument on structural holes (Burt, 2004) suggests that too low or too high cohesion is detrimental to innovation.

One of the main questions in transitions research is to identify patterns of sociotechnical change. Social network analysis is used to identify network substructures that are indicative of potential sociotechnical trajectories. These network substructures can lead to the identification of points where the interaction between incumbent and emergent actors is likely to be more fruitful. Therefore it can be assessed which electronic book technologies or business models are more likely to achieve viability. The characteristics of these substructures can also indicate to "reverse salients" (Hughes, 1983) which inhibit the further diffusion of innovation.

In the transitions literature there has also been a discussion on the role of actors pivotal to sociotechnical change (Elzen et al, 2008; van de Poel, 2000). According to the MLP radical innovation emerges from niche actors (Geels, 2002a) however this argument presupposes a strict dichotomy between incumbent and emergent activities. The hybrid character of actors that could be influential in transitions has been acknowledged (Elzen et al., 2008) along with the role of marginal outsiders in technological developments (van de Poel, 2000). With regard to the electronic book, the objective is to identify actors with the potential to affect the patterns of innovative activity and questions how they have achieved this position. Within SNA a number of techniques are available for this purpose. It is thus possible to focus on how these utilise their network position in order to influence the direction of innovation.

The sociotechnical transitions literature provides insights to the study of systemic, sustainable innovation. The electronic book case study thus provides a platform to question how prospective sociotechnical transitions can be discussed.

Thesis structure

The thesis structure is described below.

Chapter 1 discusses the relation between technological innovation and environmental sustainability. Having identified the role of generic technologies in sustainable innovation, the relation between digital technologies and the environment is considered in more detail. It is argued that the environmental implications of technology are best discussed at the system level. It is then possible to discuss long-term radical innovation at the system level. In addition, the environmental effects of the print-on-paper system are mentioned. The electronic book can thus be perceived as an expression of Information Technology in the print-on-paper system.

Theoretical perspectives on sociotechnical change are discussed in chapter 2, where the literature on systems innovation and sociotechnical transitions is reviewed. An alternative perspective is suggested for the study of prospective transitions. The societal function of sociotechnical systems is perceived in terms of practice. In addition, a relational approach to innovation is developed and contrasted with the Multi Level Perspective (MLP) on transitions, while it is maintained that the MLP can still be applied as a heuristic or retrospectively. The relational approach will provide the theoretical justification for the application of Social Network Analysis.

In chapter 3 the sociotechnical system of the printed paper text is described. Primarily the societal function and the defining attributes of the system artefacts are mentioned. In addition, an overview of historical developments in the system is provided. Finally, reference is made to the current configuration of the system and the current use of digital technologies within its context. The contribution of this chapter is to identify the difference between radical and incremental applications of Information Technology.

Chapter 4 addresses the methodological foundations of the research. Specifically, it is mentioned how Social Network Analysis (SNA) measures correspond to innovation concepts. The research design is described referring to the use of non-obtrusive methods of data collection for relational data and the techniques to be used in their visualisation and analysis. Three distinct datasets are used and the sources of data are identified. In addition the selection of SNA measures is justifies combining arguments from SNA and the innovation literature.

In Chapter 5 the emergent electronic book networks are visualised and analysed according to SNA measures. The results of this analysis are elaborated in chapter 6. Characteristics of network composition and structure are applied to address the research

questions. Network attributes, such as the degree of cohesion and heterogeneity are discussed in relation to their effects on innovation. Patterns of innovative activity indicative of potential sociotechnical trajectories are identified as a result of the network substructures.

Finally, chapter 7 considers the implications of the research findings on the sustainability of the print-on-paper system. Different perspectives on the electronic books can be assessed according to their sustainability potential. In addition patterns of sociotechnical change are identified and compared with the pathways and mechanisms mentioned in the transitions literature. Sociotechnical trajectories identified in chapter 6 can be evaluated to the degree that they indicate potential transition. The relation between incumbent and emergent actors and practices, standardisation and diversity, radical and incremental change structures this discussion. The multiple framings of the electronic book and sociotechnical transitions are mentioned, because they enable the understanding of different forms of change. Finally, the contribution of the thesis to the study of transitions as a form of network reconfiguration is reiterated while the implications for future research are considered.

1. Technological innovation and environmental implications

Sustainability in the print-on-paper system

This chapter introduces the background of the research referring to the relationship between technology, innovation and environmental sustainability. The relevance of the research topic is explained by situating it in the context of broader debates: the environmental effects of the print-on-paper system are related to the discussion of technology systems as the appropriate level to discuss sustainability while innovation related to the electronic book can be linked to the more specific discussion regarding digital technologies and the environment. Firstly, a general overview of the conflicting relationships between technology and the environment is provided. These relationships are somehow polarised between what could be termed as technoscientific myths: technology is either seen as a cause of environmental degradation or it is presented as a source of progress, regardless of how problematic the notion of progress itself is. The tension between these two approaches is acknowledged while it is discussed how technology could contribute to environmental goals and how different sustainability strategies incorporate technological factors.

A prevalent approach is that generic technologies, which have pervasive applications, could contribute to sustainability goals. The role of generic technologies has been identified in the ecological modernisation literature and in the concept of a green technoeconomic paradigm (Steward et al., 2004). Biotechnology, nanotechnology and Information Technology have been identified as having this potential (ibid.). The relationship between Information Technology and the environment is discussed at different levels and the diversity of their interaction is considered. Despite widespread claims on the relation of digital technologies and dematerialisation it emerges that the actual relations are more ambivalent. In addition, the interpretation of sustainability as dematerialisation is questioned in terms of its effects on defining sustainability strategies. Regarding the relation of digital technologies and the environment, a summary of the main approaches is provided and their methodologies and research focus are compared. Once the complexity of the interaction is taken into account, the system level is selected as most adequate for analysis.

Finally, the role of sustainability on the print-on-paper system is examined. The environmental effects of the print-on-paper lifecycle are discussed specifically with regard to book production. The conceptualisation of sustainability on the print-on-paper systememerges from recent research from industrial organisations. In that sense, the discussion shifts from general views on sustainability towards a specific context. This move flows from the assumption that the system level is more adequate for the discussion of environmental effects. Furthermore, the impact of print-on-paper is assessed in terms of future trends on consumption and the effects of printing are positioned in relation to the aggregate use of paper.

In addition, the discussion focuses more specifically on the research topic as the relation between technologies and the print-on-paper system is considered. The aim of the research is to examine how the development of the electronic book perceived as an

alternative form of textual display could contribute to sustainability goals by reconfiguring the print-on-paper system. However, it has been identified that paradoxically the diffusion of digital technologies has not led to a decrease in the total use of printing paper and that it may have had unintended effects in generating increased paper use in certain contexts.

The relation between technology and sustainability is one of the assumptions leading to the research questions. The theoretical frameworks for the discussion of innovative activity are introduced in Chapter 2 where sociotechnical transitions are discussed. Sociotechnical transitions are related to the sustainability discussion and to approaches on system innovation (Geels et al., 2008).

1.1. Technology, innovation and the environment

In this section the conceptualisation of environmental sustainability is discussed and the problematic aspects of the concept are acknowledged. The relation between technology and sustainability is summarised and specific strategies towards sustainability are mentioned, each of which has a different understanding on the role of technology. The role of technology in promoting sustainable innovation can be discussed where behavioural modification also appears as a factor affecting the development of sustainable patterns.

1.1.1. Technology and the environment: an ambiguous relationship

The relation between technological innovation and the environment is ambivalent. A summary of the relationships between technology and the environment was provided by Foray and Grûbler (1996). It appears that an interest in technology as a source of environmental solutions originated in the early 1970s contrary to the prevailing views at the time. At the time the emerging environmental movement regarded technology as a source of continuous degradation; technological growth was seen as intrinsically static and efforts to address environmental problems through regulation adopted this view on technology. The alternative view that started to emerge required a more complex understanding of the nature of technological change and the context where the diffusion of environmental technologies would occur.

The controversial relationship between growth and the environment is also explored in Newman and Dale (2008). Economic growth, facilitated by technological developments, leads to environmental degradation. On the other hand technological developments and the development of systems theory allow for a better understanding of human impacts on the environment and the resilience of ecological systems. Neither the issues of ecological resilience nor the capacity for innovation are well-understood at the moment. Strongly contrasting views exist on the boundaries of the carrying capacity of ecological systems. The pessimistic thesis is that the earth has a limited carrying capacity and that continued growth above these limits will lead to societal collapse. On the other hand, it is argued that because of human ability for innovation and specifically technological innovation growth can continue unaffected by ecological limits. These contrasting arguments are underpinned by different philosophies and metaphors.

The problems associated with exponential growth in a system of finite resources firstly concern lack of accurate information on the limits and carrying capacity of ecological systems. The knowledge of carrying capacity would facilitate decision making. The upper limits to growth cannot be calculated on the grounds of carrying capacity alone as these are also affected by innovative capacity and technological developments (Newman and Dale, 2008).

A more nuanced view of technologies with regard to the environment developed in the 1980s (Foray and Grûbler, 1996). The so-called "paradox of technological development" acknowledges that productivity increases resulting from technology have led to increased consumption. On the other hand the positive environmental influences of technology resulted from the following factors: technological substitution, discovery of natural resources and

decreased resource intensity of production processes. In addition, the perception of absolute limits to physical resources is doubted considering the view that the abundance of resources is socially constructed and not geologically pre-defined. The treatment of technology and natural resources as exogenous to economic growth is thus limiting.

Three overlapping themes emerge from Foray and Grûbler's (1996) review. Both technological and environmental knowledge are characterised by uncertainty. In addition, the tension between technological stability and change is mentioned where the environment itself is identified as a source of change. The notion of environmental pressures as a source of change resonates on what will be mentioned in chapter 2 as landscape pressures on sociotechnical regimes. Regarding policy it is recognised that it should incorporate long-term knowledge acquisition and combine long-term objectives with a focus on factors that affect technological diffusion. Sometimes the policy of promoting short-term end-of-pipe measures can prove counterproductive to the pursuit of long-term more ambitious objectives.

1.1.2. Conceptions of sustainability and strategies towards sustainable development

The terms sustainability and sustainable development are established as a popular way to frame environmental issues (Mulvihill and Milan, 2007).There are intrinsic problems with the term sustainability however is has prevailed in the environmental discourse. The criticism does not refer to the role of sustainability as such but rather to its use in discourses. The term is widely used although it is considered controversial and its usefulness has been doubted. When the term is generally defined it lacks meaning but as it is specified it becomes more controversial. Competing views contribute to the discussion but they can be confusing. The discourse on sustainability attempts to balance conflicting goals. In addition, there is contradiction between those who view sustainability as an ideal resulting in guiding principles and those that regard it as achievable. Furthermore, the term is somehow too abstract to be motivating although it has also been claimed that the term can be inspiring even if it lacks objectivity. It is suggested that it needs to be placed in relation to more specific contexts in order to become more compelling .There is also the question whether there are degrees of sustainability or whether it should be viewed in more absolute terms. The above limitations of the term are mentioned in Mulvihill and Milan (2007).

Despite these limitations, the benefits of the term derive from claims on being more holistic and reconciling unlike fragmented approaches to management and governance. In addition, the terms makes evident the trade-offs between environmental and economic issues indicating the improbability of win-win approaches at least in the short term. Also sustainability considers the concept of complexity as it becomes clear that the further it is pursued new problems arise (ibid.). In fact, the further sustainability is discussed the more controversial it becomes (Hajer, 1995 cited in ibid.)

Environmental sustainability has not been empirically defined and measured successfully so far although attempts to do so have contributed to the understanding of the complexity in ecosystems (Munasinghe and Shearer, 1995 cited in Huber, 2000). Furthermore limits to growth, the existence of which makes a compelling argument for sustainability, are constantly being redefined qualitatively while they are restricted or expanded. Without more precise definition the rules towards sustainable development remain inapplicable imperatives (Huber, 2000).

The meaning of sustainable development emerges from the United Nations Conference on the Environment and Development in Rio de Janeiro. The Rio process reflects the continuing interaction between the academic business and policy world and social movements that resulted in the formulation of policy documents in the conference. Although some points are controversial a general consensus has emerged on the following characteristic of sustainable development: further economic growth should be promoted at the same time as ecological sustainability and social equity. Thus the notion of sustainable development includes not only the relationship between economy and the natural environment but also the social question of resource distribution on a global scale. However the egalitarian aspect of sustainable development appears neglected (Huber, 2000).

The process of sustainable development is compared with the transition from a traditional to an industrial society labelled the great transformation by Karl Polanyi. The "great transformation" disentangled the emerging industrial system from the social and natural surroundings. Sustainable development can be perceived as attempting to reintegrate industrial activities within ecology and society. The rules resulting from the Rio process refer both to the ecological use of resources and to their distribution (Huber, 2000).

i. Sustainable development strategies

Two strategies for promoting sustainable development are initially identified: sufficiency and efficiency (ibid.). Sufficiency is the preferred approach by the organised ecology movement. It promotes self-limitation of material consumption, withdrawal from a free market economy and an equal distribution of scarce resources. Therefore, one could argue that the sufficiency approach is more consistent with behavioural modification measures as conducive to sustainability. The efficiency approach has been favoured by the business world: it focuses on improving the environmental performance of resources used in industrial production by improving the rate of utilisation for materials and energy so that economic growth and ecological adaptation can be achieved simultaneously. There are strong arguments behind both approaches. Huber (2000) suggests a new kind of transformational strategy labelled as consistency, which shares common ground with the industrial ecology approach. The notion behind industrial ecology is that the so-called industrial metabolism should be consistent with the nature's own metabolism. Hence, current industrial structures would require adaptation to an ecologically modernised industrial metabolism on the basis of major technological transformation unlike incremental change which is more geared towards increasing efficiency. Also, expectations towards environmental action have been oriented from government towards industrial and corporate actors with the potential for innovation.

The sustainable development strategy currently favoured by business is that of efficiency. The following description of the efficiency strategy derives from Huber (2000). Efficiency focuses on the process of input-output rationalisation. It refers to increased efficiency of energy and material use therefore to specific resource productivity, which will complement the productivity of labour and capital. In relation to sustainability the aim of increased efficiency is to achieve a relative or even absolute decrease in resource consumption and related environmental burdens. Measures towards increased efficiency include recycling and reuse, longer product duration and better operative technology. The efficiency strategy is more easily applicable and attractive in the dominant economic system to the degree that the business world tends to interpret sustainability as efficiency. Yet, even substantial increases in efficiency would not suffice. Efficiency is in a way limited by the same problems as sufficiency.

The aforementioned strategies can be identified in policy documents regarding sustainable development. Some additional observations on these strategies are made (Huber, 2000). Sufficiency refers both to population growth and to consumption patterns. The strategy of efficiency includes efficiency in both production and use, hence it refers to the product life cycle as a whole. The sufficiency approach somehow emerges from the fact that

the limits to the earth's carrying capacity are not known. According to the precautionary principle it thus makes sense to reduce demands on resources. In the past the term self-limitation was used instead of sufficiency. Sufficiency may be voluntary or not, however it entails reducing consumption. This approach and the related zero growth view have long been criticised as unrealistic and undesirable. Yet, the strategy of sufficiency has highlighted the finite nature of resources.

On the grounds that industry and business are responsible for pollution a number of environmental management strategies have been developed in industry. These are classified into three groups (Huber, 2000).

1. Environmental information

2. Environmental Organisation and personnel management

3. Environmental strategic and operational management

The importance of accurate environmental information and the role of technology in supplying it have been acknowledged (Foray and Grûbler, 1996; Berkout and Hertin, 2004)

Huber (2000) discusses these environmental measures as follows. Among the environmental management measures it has become common knowledge that end of pipe/downstream approaches have side effects when applied independently. Furthermore, the application of these measures indicates that even the sufficiency approach cannot afford to ignore its implications for technology. Although the industrial metabolism is foremost analysed in scientific and engineering terms it is also controlled by non-technical factors. The concepts considered in environmental management cannot be regulated by the government similarly to end of pipe measures. Therefore the emphasis is shifting from command and control approaches towards more subtle methods such as negotiation and the use of economic rather than bureaucratic instruments. Approaches geared towards the prevention end of environmental measures are more focused on the ecological consistency of the industrial metabolism rather than on dematerialisation.

Technology policy measures towards sustainability were traditionally divided in the areas of technology promotion and control referring to variety generation and the selection environment respectively. Policies in these two areas may have conflicting goals (Coombs, 1995, Coombs et al., 1987).Huber' s (2000) measures refer mostly to activities undertaken within the firm.

Among the three strategies described in Huber (2000) efficiency is positioned between sufficiency and consistency. It is clear that efficiency and sufficiency strategies can be combined in order to further reduce the strain on the environment. Although these strategies produce better results in combination, considering the effects of both population and production pressures an alternative approach transgressing sufficiency and efficiency needs to be developed. Consistency requires qualitative change by altering the basic structure of technology and products leading in permanent changes in the turnover of material flows. With regard to the environment consistency means that industrial material and energy flows are compatible with natural flows. Consistent material flows are those that are either totally independent from natural flows operating in a close technological systems or those that can

be integrated in the metabolic processes of a natural system so even when production/consumption volume is large it can be easily integrated into the environment. Practical examples of ecological consistency are difficult to predict because of the uncertain nature of technology: they include types of ecological farming and the use of energy systems with relatively cold energy processes such as fuel cells. Regarding future applications one could envisage certain uses of biotechnology replacing mechanical processes in the chemical industry. The consistency strategy is in agreement with the environmental management measures that oppose simply end of pipe downstream solutions.

Huber (2000) distinguishes the three strategies according to their perspective on technology. The efficiency version is said to focus on the use of existing technologies in order to use natural resources more economically. The consistency approach to sustainable development views innovation with regard to new technologies that would change the qualities of the industrial metabolism so that the goals of industrial ecology can be achieved. Industrial ecology (Ayres, 1996) is similar to consistency through it has been mostly geared towards replicating natural processes. On the other hand the consistency approach is more about guidance from rather than imitation of natural processes. As far as the limits to growth are concerned the consistency approach does not reject them but accepts that they should be identified through a process of innovation and developments that fully exploits technological capabilities instead of being set arbitrarily. This argument resonates with the point raised by Foray and Grûbler (1996) regarding the social construction of natural resource limits.

Consistency requires what has been termed as basic innovations by Schumpeter (1939) and what is currently referred to as system innovation (Huber, 2000). These extend beyond product or process innovation and require the co-operation between government, industry and research. These system innovations relate to the concept of creative destruction.

The factors of substitution and efficiency gains illustrate how technological change can contribute to sustainability goals. In the most optimistic position even if there are limitations in some resources, a substitute could always be available. Yet, ecological economists have argued that there are strict limits to substitution considering that natural goods are compliments not substitutes and that many have no known replacement. The arguments towards an ethereal economy begin with the discussion of efficiency. Efficiency gains could support growth without increasing demands on natural resources. The current state of the economy is far from an efficient use of resources; in particular the process of industrialisation has been inefficient. However, efficiency gains do not lead to decreased resource use. This occurs because consumers take advantage of these efficiency benefits in order to consume further. This phenomenon is called the Jevons paradox where increased efficiency results in increased use (Newman and Dale, 2008).

The three strategies of sufficiency, efficiency and consistency can be combined. According to Huber (2000) the contribution of sufficiency is that the limits posed by the natural environment should be respected while priority should be placed on achieving long-term consistency and applied efficiency strategies in the mid-term.

ii. Constructive technology assessment

The Constructive Technology Assessment (CTA) approach provides a more interactive account of the relation between technological innovation and environmental goals, whereas it addresses the dichotomy between technological and social determinism. CTA brings together insights from the economics of innovation and the sociology of technology. It emerges from technology assessment which has traditionally combined demand and control policies (Green et al., 1999). CTA is based on the following assumptions (Coombs, 1995): Technology does not develop according to a hidden internal logic neither is it the response to market mechanisms; there is a role for social actors to affect it. In addition, this opportunity for social action can result to consensus formation. Construction is regarded both as active construction and also as the more sociological meaning of interpretation (ibid.). Unlike typical technology assessment, CTA focuses on the internal dynamics of the technology through interaction with stakeholders rather than with the external effects of technologies (Schot, 1992).

The CTA model suggests three ways of strategic action (see Schot, 1992).

1. The development of alternatives variations

2. Modification of the selection environment

3. The development or use of the technological nexus

A quasi-evolutionary model of technological change is adopted.

iii. System approaches to sustainable innovation

In the following section the role of digital technologies and the environment is discussed. A review of the relevant methodologies will indicate that the system level rather than the level of individual product or the aggregate economy can be more fruitful to the study of these relations. At this point some of the system concepts relating to the environment are introduced.

First, the approach of socio-ecological systems is considered (Young et al., 2006). The approach of socio-ecological systems combines a more holistic conception than previously thought of in the context of either social or natural systems. They are also termed as coupled human-environment systems. Resilience and vulnerability studies have hence accepted both endogenous and exogenous factors in their understanding. Resilience, robustness and vulnerability are seen as intrinsic characteristics of socio-ecological systems. It is argued that human societies have partly exchanged environmental over societal complexity. In that sense the survival and resilience of socio-ecological systems have become more dependent on their social rather than biophysical dynamics. In addition, reflexivity and action in anticipation of change are characteristics of social systems (Young et al., 2006)

Socio-ecological systems are normally easily adapted to their environment. Under normal conditions they do not reach a state where radical change would be necessary. The necessary degree of resilience may be achieved through spontaneous or self-generating processes however as the systems become more complex it is less likely that resilience will emerge as a side-effect of actions taken for other motives. Vulnerability can then be a result

of changed environmental conditions and inability to adapt. Adapted systems can operate with varying levels of variability and remain dynamic (Young et al., 2006).

The increasing links between social and biophysical systems and globalisation have indicated that questions of adaptability and resilience should be addressed in coupled systems (ibid.)

The concept of socio-ecological systems has been correlated with the sociotechnical systems approach in innovation studies (Smith and Stirling, 2008).Although technology is a factor in socio-ecological systems it is sometimes overshadowed in that literature. Political questions raised in transition management regarding sociotechnical systems regarding who governs and how sustainability is prioritised are also relevant to socio-ecological systems research. However, the focus of transitions research on sociotechnical systems and socio-ecological systems research is different (ibid.).

In terms of policy a systems approach allows for a better integration between environmental and innovation policies (Geels et al., 2008). This is important considering the pervasive nature of current environmental problems that require policy approaches complementary to existing solutions. The environmental effect of a single product, process or practice should be placed within the wider system it is part of. Regarding efficiency, the substantial improvement required can only be achieved through systemic innovation (ibid.).Systems innovation in the form of transitions is discussed in chapter 2.

Although the discussion focuses on the relation between technology and the environment behavioural modification viewed as sustainable consumption also contributes to environmental goals. A model developed by Spaargaren (2003) suggests that sustainable production and consumption should be complemented. However, sustainable consumption research usually reverts to micro-analysis of individual consumption patterns. It is argued that it should be analysed under the social practices model whereby instead of focusing on individual behaviour it is considered how groups of actors can reduce the impact of their everyday activities. This model analyses how the effects of consumption can be addressed in separate domains of social life regarding consumer as agents in specific systems of provision (ibid.) Therefore, systems thinking can also be supported from a consumption perspective provided that consumption is viewed as a set of social practices.

1.2. Information technologies and the environment: dematerialisation

The relationship between digital technologies and the societal goal of sustainability is ambivalent and not clarified. Information and communication technologies (ICTs) have mostly been analysed as general purpose technologies in terms of their impact on economy and society. A number of studies have been concerned with impacts on productivity and the consequences for economic growth. The effects on environmental sustainability emerged later as an issue of enquiry. On the other hand, sustainability also poses challenges for information society studies (Jokinen et al., 1998). One reason is that compared with other industries the effects of ICT seem fairly benign. Research has also been inhibited by lack of reliable data as the available studies tend to lag behind reality (Berkhout and Hertin, 2004).

In addition, the net effects of particular technologies as demonstrated by life cycle analysis studies are dependent on the circumstances of their application (ibid.) therefore one should be cautious to generalise.

A pronounced contrast exists regarding digital technologies and the environment. On the one hand ICT effects are seen as solely positive in the sense that "information" is regarded as immaterial and thus distinct from material and energy resources: in that sense it substitutes for material resources. The most optimistic evaluations considered that post-industrial societies would become liberated from material goods as economic value would become embedded in intangible information products. On the other hand the diffusion of ICT is regarded as an example of unsustainable consumption: the effects of computers and other hardware disposal in the waste stream are acknowledged and by taking into account the short lifecycle of the products it is argued that ICTs are an example of short-term consumer culture rather than evidence of dematerialisation (Berkhout and Hertin, 2004). One has to move beyond this clear dichotomy in order to reveal the complexity of relationships between digital technologies and sustainability.

Berkhout and Hertin (2004) distinguish among three types of effects in the role of ICTs and e-commerce:

1. Direct effects: the direct effects result from the production use and disposal of computers and related hardware. They are not dissimilar to the environmental effects related to other physical products. Their overall impact is negative. Regarding their manufacture ICTs are produced through global supply chains requiring the sourcing of some components with sensitive effects. Their use entails electricity usage which grows as a proportion of total electricity used. Finally, the disposal of hardware requires the handling of hazardous contaminants.

2. Indirect effects: These are represented as mostly positive. They include the contribution of ICTs in production processes with technologies such as Computer Assisted Design. In addition, a number of products and services are likely to become fully dematerialised through ICT applications. As a disadvantage, digital

products may become added into existing goods and services rather than replace them thus exacerbating environmental problems.

The indirect effects include issues such as the contribution of ICT in understanding environmental change, effects on resource productivity and dematerialisation as it can be examined in different sectors.

3. Structural and behavioural effects: The structural and behavioural effects of ICTs refer to more fundamental changes that pervade the economy. It is presented as a positive that ICTs facilitate a shift from an industrial to a service economy which will have lower energy and resource requirements at the point of use. In addition, behavioural changes towards "greener" patterns of consumption are likely to be supported by ICTs. On the other hand, any gains could be countered by the so-termed rebound effect where efficiency gains in some sectors result in growing demand in other therefore cancelling out any environmental benefits.

The dematerialisation or intensity of use hypothesis is based on the assumption that as economies grow, a point is reached where less intensive material use is achieved. ICT is meant to result in decoupling economic growth and environmental damage. However, although ICTs may lead in relative resource efficiency in absolute terms even post-industrial economies are still materialising (ibid.).

There are limitations in this classification in that is does not reflect how ICT contribute to the diffusion of knowledge and the development of solutions to environmental problems. Paradoxically ICTs have environmental impacts but they are also used as a tool to measure their own effects (ibid.; Foray and Grûbler, 1996).

A substantial part of the literature regarding digital technologies focuses on isolated case studies. This research has certain limitations in that it tends to overestimate potential environmental benefits. Mokhtarian (2002 cited in Berkhout and Hertin, 2004) argues this occurs because case studies tend to identify the substitution effects of new technologies while ignoring the more subtle complementarity effects that could generate demand for more products. In addition, case studies have to accept assumption about consumer choices and rates of technological diffusion, which are often unreliable in the case of rapidly changing technologies.

A number of challenges obstruct the study of these relationships in the long-term. There is still a lack of empirical evidence and there is difficulty in producing complex models of technological change in tandem with models of environmental change. In particular when referring to generic multiple purpose technologies it should be taken into account that they are also shaped by broader changes in their environment and the interdependence of the relationship inhibits the development of explanatory models (Berkhout and Hertin, 2004)

On account of these observations three directions for research are suggested (ibid.):

1. Macro-level qualitative studies which evaluate a range of alternative pathways regarding the long-term relationship between ICTs and sustainability.

2. Macro-level quantitative studies correlating ICT and environmental indices

3.   Meso-level analysis of sectoral developments and ICT effects looking at sustainability indicators in order to assess the effects

A recent review on the effects of e-business and ICT on the environment has identified that there are still two dominant research approaches: either micro-level case studies or macro-level statistical approaches (Yi and Thomas, 2007). The authors suggest that a more predictive and empirical models applied within sectors would be a more beneficial approach. Such an approach would be based on the use of indicators in order to promote the positive and counteract the negative effects.

The rate of diffusion of information technologies is a compelling reason for the study of their effects. Yi and Thomas (2007) identify that initially such effects are perceived as positive. Examples include the digitisation of products, dematerialisation of transport and the rationalisation of supply chains. The negative impacts however tend to be more prominent. The review refers to the main research articles, theses and projects on the topic and provides a categorisation of the methodologies used. The focus on methodologies contributes to understanding how the debates are framed at different levels.

One major methodology is the use of scenarios: scenarios are used mostly as tools of qualitative planning and communication rather than for predictive purposes. The Future Impact of ICT on Environmental Sustainability Project suggests that scenarios are appropriate for this area of research because they take into account the uncertainty inherent in such developments and allow for the exploration of multiple alternatives in policy making. Scenarios are used as methodology when examining the long-term pervasive impacts of ICT. In the case of micro-level research Life Cycle Assessment (LCA) is one of the preferred methodologies. LCA follow the input-output method in order to evaluate the environmental effects of goods and services throughout their life cycle. It has been applied in comparative studies between conventional processes and their digital alternatives. LCA is considered a reliable method in terms of its long history and the fact that it considers all impacts including energy and material use up to the disposal stage. Nonetheless, in the case of digital technologies the boundaries of the life cycle and all the involved factors are not easily established. The ecological footprint method has also been suggested as a sustainability indicator (ibid.).

Overall, research on the effects of ICT on the environment ranges from individual projects in research institutes to consortium level research, from the strictly defined to that including all digital technologies and electronic business applications and from the sub-sector to the general level. Generally, the research objectives refer to identifying the most obvious effects and make a qualitative evaluation of the impacts (Yi and Thomas, 2007).

The three-order effects of ICT are a common categorisation in the area and can serve as a platform for future research. The first order effects refer to the impact by the physical ICT infrastructure, second order effects refer to the application and continuing use of ICTs and third order effects refer to the implications over the medium to long term by the continuing use of ICT by increasing numbers of people. Most of the benefits reside in the

second order effects, while first order effects are mostly negative at the moment. Third order effects are more difficult to evaluate because of their complexity (Yi and Thomas, 2007).

One of the difficulties in research is identifying the adequate level where the environmental effects should be considered. New methods should be developed in order to address these questions. According to Yi and Thomas (2007) future topics of research should include.

1. A complete account of the e-business and ICT factors that have an impact on the environment

2. A choice of indicators needed to represent the aspects of the environment that are likely to be affected

3. Evaluate the impact of different ICT and e-business factors on different environmental aspects

The relationship between sustainability and information technology can also be evaluated by examining the interaction between information itself and sustainability at a more fundamental level. The link between the two will not be necessarily fruitful. Both sustainability and information are problematic terms in their own right (Mulvihill and Milan, 2007). One relation is that lack of knowledge inhibits the pursuit of sustainability. In addition, it is doubtful whether information intensive solutions are more sustainable or whether information simply adds complexity to environmental problems. Instead of using a single generic term as sustainability more specificity is required in the discourse. Information in the generic sense can make a contribution to behavioural modification through learning. It is suggested that because of the problems associated both with sustainability and with information focusing on their interaction is not likely to be fruitful, however information technology also allows for a more subtle use of information systems (ibid.)

The argument that economic growth can persist despite the finite nature of natural resources is the shift towards an economy where ideas dominate over material and physical inputs (Newman and Dale, 2008). It is argued that such an economy would follow different growth cycles dependent on the absorptive capacity of the population to absorb new ideas and innovate. Growth in what is termed an ethereal economy would follow a model of punctuated equilibrium where periods of stagnation would be interrupted by periods of exponential growth. Although that economic state is unlikely in the near future insights can be developed regarding the exploitation of ecological capital and the need to utilise information and enhance its diffusion. The limits of technological change relate mostly to the supporting social and organisational innovation required to enable the growth of new technologies. The social obstacles to innovation that will affect growth patterns in an ethereal economy are also evident in current developments of sustainable technologies. At a time when society has to innovate and adapt faster because of the time frame imposed by sustainability challenges the delay associated with the diffusion of new ideas should be curtailed.

The argument on dematerialisation is the most relevant regarding the shift to an ethereal economy. Efficiency gains allow for more economic activity to take place on the

same amount of natural resources. Dematerialisation is the next stage where information replaces materials and part of the economy can thus be decoupled from the ecological base altogether. In that case policies that promote innovation would contribute to growth and at the same time lower environmental impacts (Newman and Dale, 2008).

The role of generic technologies in addressing sustainability problems has been identified in the concept of green techno-economic paradigm put forward by Freeman (1992). Among a taxonomy of innovations it is acknowledged that changes in technology systems and changes in technoeconomic paradigm (or technological revolutions) are most relevant to the goals of environmental sustainability. A number of ways are identified that show how ICT can contribute to these goals. Firstly, it allows for better monitoring of industrial processes, secondly it facilitates products quality and inventory control. These effects are more associated with managerial change rather than characteristics of the technology itself. These philosophies are beneficial in that they move away from the wasteful characteristic of the mass production paradigm. Thirdly, ICT technologies are conducive to miniaturisation. This is demonstrated beyond the electronics industry. Despite these effects ICTs have not yet realised their full potential partly because the necessary political support was not available. The diffusion of ICTs has been achieved mostly through the market mechanism therefore its potential environmental contribution has been ignored. Overall, the development of the ICT technoeconomic paradigm refers to the development and interactions between the areas of computing and telecommunications. The benefits associated with the partial convergence between these areas are largely unrealised (ibid.).

Information society can however be perceived as a transient period rather than as a paradigm. Jokinen et al. (1998) regard it as a stage between modern industrial society and the so-called conscious technology society. At this stage there is interplay between technological developments, development in information society and sustainable development. The relation is dynamic so that sustainable development is a process rather than a goal.

Policies to stimulate the direction of this new technoeconomic paradigm should take into account that the respective time scale runs in decades and that each paradigm emerges within the context of the former one. The technologies are already proven prior to the emergence of the paradigm itself. Technologies associated with the fifth ICT paradigm being presently established need to be combined with supporting policies and institutions in order to give rise to a new environmental technoeconomic paradigm (Freeman, 1992).

1.3. The environmental implications of the print-on-paper system

Systems are identified as the adequate level to study environmental effects. Therefore, activities and actors involved in the production, distribution and use of printed-paper are conceived as the sociotechnical system of the printed paper text. The print-on-paper system accounts for part of the environmental implications that are attributed through paper use and production. According to the confederation of paper industries printing and writing paper account for 31% of total paper production (Steward et al., 2008).

i. Patterns of paper use

Regarding the environmental effects of books in particular it is identified that book production corresponds to a relatively small portion of total printing. The diagram below illustrates the classification of printed paper in categories.
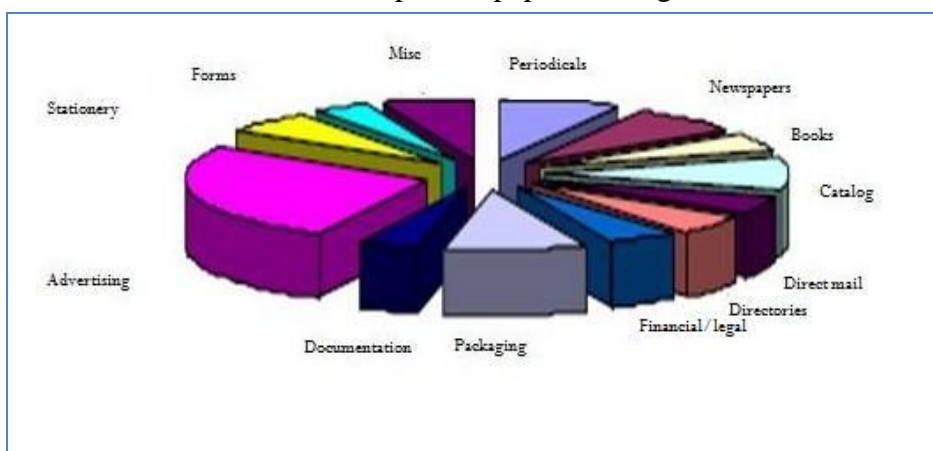
Figure 1.1: Categories of printed paper (EDSF, 2001a p.2)

The development of ICT and digital technologies has initially resulted in expectations towards a paperless world. The initial example of these ideas was the seminal article "As we may think" (Bush, 1945) which expressed a vision of electronic data storage device. However, the actual trends in paper consumption have shown that paper use for printing purposes has in fact increased. The use of print may decrease in relation to electronic media but it has increased in absolute terms (EDSF, 2001a).

The following diagram projects how the relation between print and electronic information is likely to develop. It should be taken into account that it refers to all types of information.
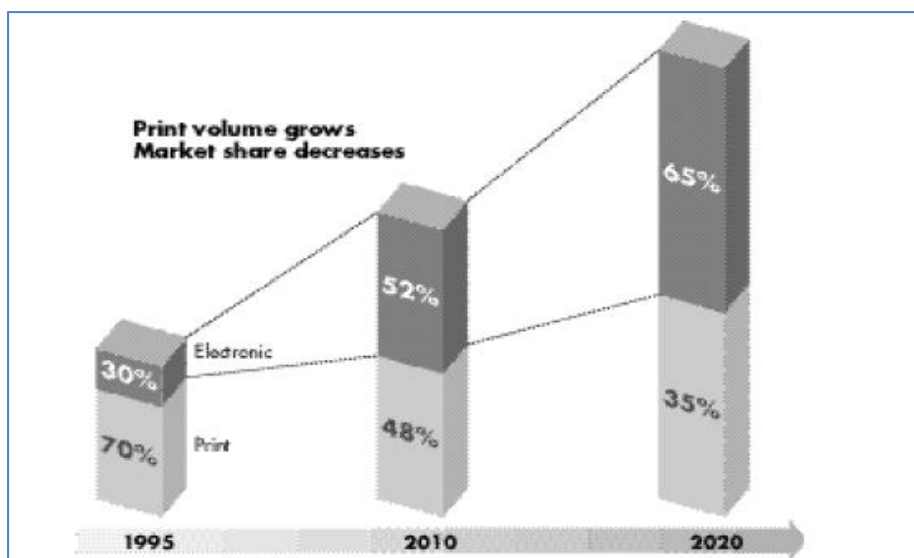
Figure 1.2: Print and electronic information (EDSF, 2001a p.9))

The graph below illustrates a projection on future paper consumption. On this account it appears that consumption peaks shortly before the middle of the century. Therefore, the environmental problems relating to print will be exacerbated unless there are efficiency benefits deriving from innovation in paper production.
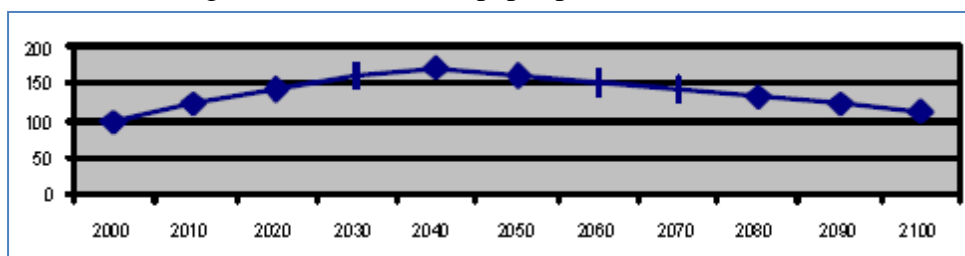
Figure 1.3: Projected paper consumption (EDSF, 2001a p.10)

So far IT has not contributed to the reduction in paper use. This argument has been documented in the case of printing and writing papers used in the workplace (Sellen and Harper, 2002). Instead, the diffusion of digital technologies has led to increased access to information which ironically is usually printed to be read in full. The diffusion of personal and office printers has contributed to that effect. The application of ICT has changed the model of document distribution as well as redefining the different categories of documents. In the traditional model, printing preceded distribution while in the current model printing follows distribution of digital material. In addition, printed documents themselves are more likely to result from a digital original (ibid.).

Therefore, it could be argued that digital technologies, which are expected to have a positive effect in the long-term, may actually reinforce environmental problems in the beginning. This is an example of the substitution versus generation effects of digital technologies. However, it can be argued in that case that the substitution effect has not yet taken place due to insufficient development of the technology.

Although books only comprise a small part of total paper use (Figure 1.1), the discourse on sustainability on print-on-paper tends to focus on them partly because of their symbolic role as a cultural artefact (personal communication).

ii. Perception of sustainability and the book industry

The environmental effects of the print-on-paper system are not only related to paper use through this is the main environmental strain. A recent report commissioned by the Book Industry Study Group and the Green Press Initiative illustrates findings on the environmental effects of print production relating these to climate change issues. The findings result from research in the US book industry however the methodologies used could be applied to the book industry in general. In addition, the report provides an understanding of environmental sustainability in relation to print-on-paper that identifies different factors relating to the climate impact and not solely on the quantitative issues of paper use. The surveyed population for the research included publishers, printers and manufacturers which represent a substantial representation of the industry's output (BISG, 2008).

The aim of this report is to help the industry participants assess their environmental impact and to identify points for improvement. A wide variety of environmental indicators is used which assesses energy use by all participants in the stages of the supply chain from sourcing to the disposal of paper. It results that the average carbon foot print of book through production, publishing and retail is a net 8.85 pounds. The majority of the climate impacts result from the loss of carbon storage capacity due to the wood fibre used and the energy demands for paper production. The model used in the research was based on the Carbon Footprint Measurement Methodology developed by the UK Carbon Trust. The table below shows what percentage of carbon emissions results from different processes in the book industry.

Segments of the Industry	Share of Carbon Emissions	Notes
Forest and Forest Harvest Impacts	62.7%	Harvest and transport of fiber to the mill constitute only 1.52%; the remainder, 61.22%, is removals of biomass from the forest. A portion of the latter is offset by storage in books, recycling of books, and energy recovery.
Paper Production, Printing Impacts	26.6%	Paper production at the mill constitutes 22.4%; the remainder, 4.16%, is printing and binding.
Landfill Releases (methane)	8.2%	Methane releases from landfilled books.
Distribution and Retail Impacts	12.7%	Distribution is for books to the market; retail is energy consumed in stores.
Publishers' Impacts	6.6%	Publishers' impacts are energy used in offices, internal paper consumption, and business travel.
Carbon Storage in Books and Energy Recovery	−16.8%	Books store a portion of the carbon from biomass in the products themselves; incinerating waste, although it has some of its own environmental risks, recovers some energy.

Table 1.1 : Book Industry Carbon Emissions (BISG (2008), p.2)

The indicators of environmental performance focus on the areas identified by the Environmental Paper Network (EPN, 2007). The following areas were identified

- Reducing paper consumption taking into account the return rates of books

- Increase the recycled content

- Responsible fibre sourcing

- Cleaner production processes: these involve the use of chemical in paper making, such as bleaching processes

Besides carbon emissions fibre sourcing was recognised in the BISG report as an issues regions where paper is sourced include areas of endangered or high conservation sources forests. Responsible paper sourcing in terms of avoiding area of ecological or cultural sensitivity is also recognised as a factor in the UK publishing industry and it demonstrates a tendency towards ethical responsibilities rather than solely environmental issues (personal communication).

According to the BISG survey the following trends are remarked in the book industry:

o A shift is observed towards the use of recycled fibre for books

o Environmental policies have been instituted by publishers and booksellers on a variety of issues

o The use of certified virgin fibre is increasing, as is industry support for certified fibre through environmental policies, with the Forest Stewardship Council (FSC) certification as the most preferred certification system.

o Research on readers has shown support towards the implementation of environmental policies

Suggestions towards step that should be taken by the industry include:

- Avoiding overproduction and increase the use of recyclable fibre

- Maximise the use of recycled and FSC certified or equivalent fibre in paper

- Moving to lower basis-weight papers where possible to reduce paper use.

- Adopting energy-saving measures and certified sustainable building plans, and purchasing renewable energy, especially in the retail sector

The challenges affecting the application of sustainable practices are similar to those generally inhibiting corporate social responsibility such as the externalisation of environmental costs, market constraints and an inability to have an accurate understanding of the issues.

The commissioning of the report had resulted from within the book industry itself. To a degree the industry's commitment is largely dependent on individual initiatives rather than the corporate strategy (personal communication).

Regarding the earlier expectation of paperlessness as a result of information Technology, these made no references to the sustainability discourse. Although the sustainability benefits of the electronic book are meant to be brought about by dematerialisation, the discussion on the environmental effects of the print-on-paper system appears to be more integrated throughout the life-cycle. However, the role of technological innovation in alleviating the effects of the print-on-paper system has not been discussed. It emerges that the discussion on digital technology and the discussion on sustainability goals with regard to the print-on-paper system remain largely unlinked.

2. Literature review

Sociotechnical transitions as processes of network reconfiguration

The sustainability challenges raised by the current printed-paper text regime have been identified. In addition, the relation between technological innovation and environmental sustainability has been widely documented (Freeman, 1992; Foray and Grûbler, 1996; Mol and Spaargaren, 2000). The aim of this chapter is to develop a theoretical background applicable to the study of prospective, systemic innovation with the potential to contribute to societal goals. In this case, societal goals are considered mostly under environmental concerns. The theoretical questions and the structure of the chapter are described below. It has been stressed that radical innovation at the systemic level is required to address environmental problems (Geels et al., 2008): in environmental studies the focus has shifted from the effects of individual products /processes to systemic effects. Nonetheless, the generation and adoption of radical innovation are relatively rare. Therefore, the underlying question in the study of technological change is twofold: first, one has to account for the relative stability in current production, distribution and consumption processes and subsequently to explain how radical innovation occurs (Green et al., 1999).

Firstly, a systemic approach to innovation is adopted and a number of technology system perspectives are discussed. The conceptualisation of technology consistent with a systemic approach is presented. The concept of sociotechnical systems and its origins in the innovation literature are discussed in more detail. Research in sociotechnical systems has illustrated the benefits of the approach in addressing goal-oriented innovation. The elements of the sociotechnical system and their interactions are described more specifically. Relations of the concept to other systemic approaches along with the methodological and empirical implications it raises are considered.

Secondly, stability and change in sociotechnical systems is analysed on the basis of insights from research of systems in transition. The multi-level perspective (MLP) is presented as it appears to have been established as the dominant paradigm in transitions research. Discussion of the MLP is integrated with the discussion of radical change in sociotechnical systems. The MLP provides the explanatory concepts to account for stability, incremental innovation and radical change. Within this framework particular mechanisms and patterns in transitions are discussed. The explanatory powers of the MLP are supplemented with recent work regarding its grounding on broader theoretic traditions. In addition, attempts towards the refinement of the MLP by both its critics and proponents are mentioned. Criticisms on the MLP, either methodological or conceptual are discussed.

Thirdly, a distinction is made between two strands in transitions research: the study of historical transitions and the associated forward-oriented areas of strategic niche management and transition management. This distinction helps to illustrate how historical studies of transitions can contribute to the analysis of transitions in progress and to identify the contradiction between retrospective and prospective forms of analysis in innovation studies. The time dimension in transitions also allows for the exploration of success/failure dynamics.

Finally, an alternative conceptualisation of transitions as the process of sociotechnical network reconfiguration is proposed. On the basis of the limitations of the MLP as a framework for the study of prospective transitions, the concept of societal functions is elaborated regarding its role in establishing system boundaries. This critique on societal functions culminates in the adoption of a practice-based conception of the regime. Following this argument it is evaluated which elements of the MLP could contribute to the understanding of transitions in progress. Then, it is argued that the process of transitions can be interpreted as the reconfiguration of sociotechnical networks. The causal mechanisms supporting the MLP are contrasted to network perspectives on agency and causality. The aim is to explain how a network approach can bring new insights in the study of prospective transitions. The methodological implications of this decision are then elaborated.

In addition, the MLP perspective on transitions is compared with the suggested network perspective and they are both perceived as representational devices which may have different benefits in the analysis of sociotechnical change.

2.1. Perspectives on innovation systems

Regarding the scope of innovation, the level of innovation systems is more adequate to explore sociotechnical change required to address sustainability challenges. Instead of addressing environmental implications at the level of individual products/technologies more complex environmental challenges require analysis at the systemic level (Geels et al., 2008). However, there are various approaches on innovation systems drawing both on the economics of innovation and the sociology of technology. Concise reviews of the main approaches are provided in Carlsson et al. (2002), Geels (2004b) and Miozzo and Walsh (2006). These approaches to technology/innovation systems are discussed and clarified. Then, the concept of sociotechnical systems is discussed in more detail regarding how it is applied in the transitions literature and the MLP. Issues raised in the discussion of innovations systems provide methodological insights relevant for an alternative understanding of sociotechnical change.

2.1.1. Conceptualisation of technology

Any discussion on technology should avoid sliding into technological determinism (Smith and Stirling, 2008). The definition of technology prevalent in the transitions literature focuses on technologies as configurations that work (Rip and Kemp, 1998). In order to work they have to be placed in a specific context, therefore the research focus is not on specific artefacts but on the surrounding processes, structures and actors that reproduce a sociotechnical practice (ibid.). Social processes affect the development and use of technology where technological artefacts themselves allow for the emergence of new social practices (Russell and Williams, 2002 cited in Smith and Stirling, 2008). In the sociotechnical systems perspective technological development emerges in complex adaptations between the social and material world (Smith and Stirling, 2008). New technologies cannot emerge in fully working order (Bijker, 1987) because heterogeneous elements have to be linked in a working configuration. It is therefore evident that more sustainable sociotechnical practices are at a disadvantage compared with already embedded technologies (Smith and Stirling, 2008)

From the perspective of actors involved in technological development (engineers, producers, users) technology is a concentric configuration (Rip and Kemp, 1998). They tend to view technology in a set of limited concentric circles and wider circles are taken as the given environment in which technology must function. The concentric view indicates that although wider social transformations are considered, the focus lies on the artefact and causal connections move outwards from it.

A functional configuration cannot be easily demarcated from the rest of society. Technologies work because they are embedded in organisations, routines and patterns of behaviour. The perception of technology as a configuration facilitates the understanding of large technical systems as well as technical artefacts (ibid.).

Although this definition of technology incorporates both technical and social elements it still implies that a distinction between these categories is feasible. This form of dualist separation between society and nature or society and technology is a characteristic of

most social science resulting from the modernity project of purification (Latour, 1993; Law, 2004).

2.1.2. Classification of innovation systems

The term innovation system is used to encompass a number of approaches. Regardless of their specific focus they all involve the generation, diffusion and use of technology. A system is composed of components, their interrelationships and their characteristics/attributes. Components are perceived as the operating parts of the systems. They can be individuals and organisations but also technical artefacts or institutions such as legislative artefacts. The system attributes refer to a set of capabilities upon which lies its ability to generate change and respond to changing environments (Carlsson et al., 2002).

A decisive criterion in distinguishing between systems of innovation approaches has to do with identifying the adequate scope and level of analysis. Innovation systems can thus be national, regional, sectoral or technological. Innovation systems can be identified on the basis of core technologies, products or end markets (Carlsson et al., 2002).The focus of the system can be the regional or geographical dimension where the boundaries are then geographically defined. Alternatively, the focus of the system could be a technology or sector. Besides their focus, systems are defined on the time dimension and categorised as static or dynamic (ibid.). Carlsson et al. (2002) define the level of analysis of innovation systems as relating to a technology perceived as a knowledge field, a product or an artefact or a set of related products that satisfy a particular function. With minor modifications to the criteria suggested by Carlsson et al. (2002) technology systems are divided into categories identified by geographical boundaries, by sector, by core technology and by user demand or societal need.

i. Space-based innovation systems

The focus of the system can be the regional or geographical dimension. Examples are the regional innovation systems and the national innovation systems approaches. The concept of local industrial systems (Saxenian, 1994) is also positioned within the regional systems of innovation perspective. In addition, there is empirical work on regional innovation clusters indicating towards an alternative form of capitalist organisation (Piore and Sabel,1984; Best, 1990).The contribution of these approaches has been that they identified how the role of location remain important in technological development.

ii. Technology-based systems

Innovation systems are also defined with a technological focus. The Large Technical Systems approach (LTS) focuses on how systems builders develop both a technological system and the societal structures required to accommodate it, as the study of electrification has shown (Hughes, 1983). LTS has derived with the sociology of technology tradition. The large technical systems approach thus presents a view of co-evolution where engineers, acting as "practicing sociologists", design both the artefacts and society.

In Carlsson (1995 and 1997 cited in Carlsson et al., 2002) the discussion on technological systems focuses on their dynamic nature and evolution over time. Moreover,

technological systems are defined on the basis of generic technologies with applications in several industries thus they are distinct from sectoral systems approaches (Carlsson et al., 2002).

The concept of technology systems illustrated in Freeman and Perez (1988) was meant to further the scope of innovation studies. Expanding the dichotomy between incremental and radical innovation, they identify two additional categories of technological change: change in technology systems and in techno-economic paradigms. Change of technology systems may coincide with the emergence of new industrial sectors but technology systems are not synonymous with sectors, instead they relate to a technological base.

iii. Sectoral systems of innovation

Approaches that define innovation systems on the basis of industries or sectors have also been identified in the literature. Porter (1990 cited in Carlsson et al., 2002) views economic activity as part of an industry and this leads him to emphasise the role of market competition while shadowing non-market interaction outside the industry. In that, sense his analysis has a static role. The approach of sectoral innovation systems (Malerba, 2002) also uses the sector to define the boundaries of the innovation system, however the analysis is more dynamic (Carlsson et al., 2002).

Malerba (2002) defines sectoral systems of innovation and production as "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of these products" (p.250). They have their own knowledge base, technologies, inputs and demand. The involved agents are individuals and organisations and the nature of their interactions is varied: it can be co-operative, competitive or hierarchical. These interactions are shaped by institutions and a sectoral system evolves as it is transformed through the co-evolution of these various elements. The foundations of a sectoral system are identified as: knowledge base and learning processes, basic technologies, inputs and demand, type and structure of interactions among organisations, institutions and processes of variety generation and selection (Ibid). The boundaries of the sector appear to be set by the end uses of its products. In certain sectors, such as chemicals, the end uses of the product are quite varied. Also, some sectors produce intermediate products to be used as input in other industries and they do not strictly correspond to a user's need. Yet, there is support to the claim that firms in different sectors follow different patterns of innovation: Pavitt (1984) suggested taxonomy of industrial sectors according to characteristics such as the size of innovating firms and sources of innovation.

iv. Demand- based approaches

Finally, technological systems can be defined on the basis of the demand side. The notion of competence blocs developed by Eliasson and Eliasson (1997 cited in Carlsson et al., 2002) refers to the total infrastructure required to generate, select, identify and diffuse innovative ideas in a cluster of firms that correspond to a particular need or demand. The

concept has been exemplified referring to the Swedish competence bloc for healthcare. In the notion of competence blocs the user side is explicitly brought in the foreground. This bears relevance to the concept of sociotechnical systems that is discussed in the following section.

2.1.3. Sociotechnical systems as units of analysis

As sociotechnical systems broaden the focus to consider the user side of the system, the development of technical knowledge does not overshadow the diffusion and use of technology and its effect on social transformations. The user side is not limited to mentioning the selection environment. Because the aim of a sociotechnical system is the fulfilment of societal function more emphasis is placed on functionality and use (Geels, 2004a; Geels and Kemp, 2007).

Socio-technical systems explain how socio-technical configurations become established as a result of the linkages between their elements. These linkages are re-produced through the activities of groups of actors. The activities of these groups are aligned and coordinated (Geels, 2002a).Sociotechnical systems are loosely defined as the linkages between elements necessary to fulfil societal functions. Within each system there are sub-functions of production, distribution and diffusion. Because the elements of a system are used to perform these functions they are characterised as resources (Geels, 2004a).

A sociotechnical system usually comprises the following elements: artefacts, infrastructure, markets and user practices, production system and industry structure, maintenance and distribution networks, regulation and policy, finance rules and the cultural meaning of technology (Geels, 2002a and 2005a). These elements can be classified in separate spheres of production and application domain. On the production side one has elements and resources that are inputs to the production of artefacts: natural resources and material parts, tools and machines, capital, technological and scientific knowledge as well as knowledge transfer mechanisms, and labour. Regarding the application domains and user practices the relative elements include cultural meaning, facilities for repair and maintenance and complementary artefacts that could be linked in a technical system. Among the production and application domain the function of distribution is performed: it includes markets, distribution networks and infrastructure. Other intermediary elements such as quality standards and product property rights laws bridge supply and demand by providing trust (Geels, 2004a).The actors that reproduce the system are also divided into the production side or the selection environment. The production side includes research and educational organisations, engineers and skilled personnel, design firms and technical consultancies, finance organisations and suppliers of material resources. The user side includes the final users, societal groups such as NGOs, the media and finally repair shops that provide maintenance. Public authorities at regional and national level provide have linkages on both spheres. Consumer markets and distribution networks mediate between producer firms and consumers (ibid.)
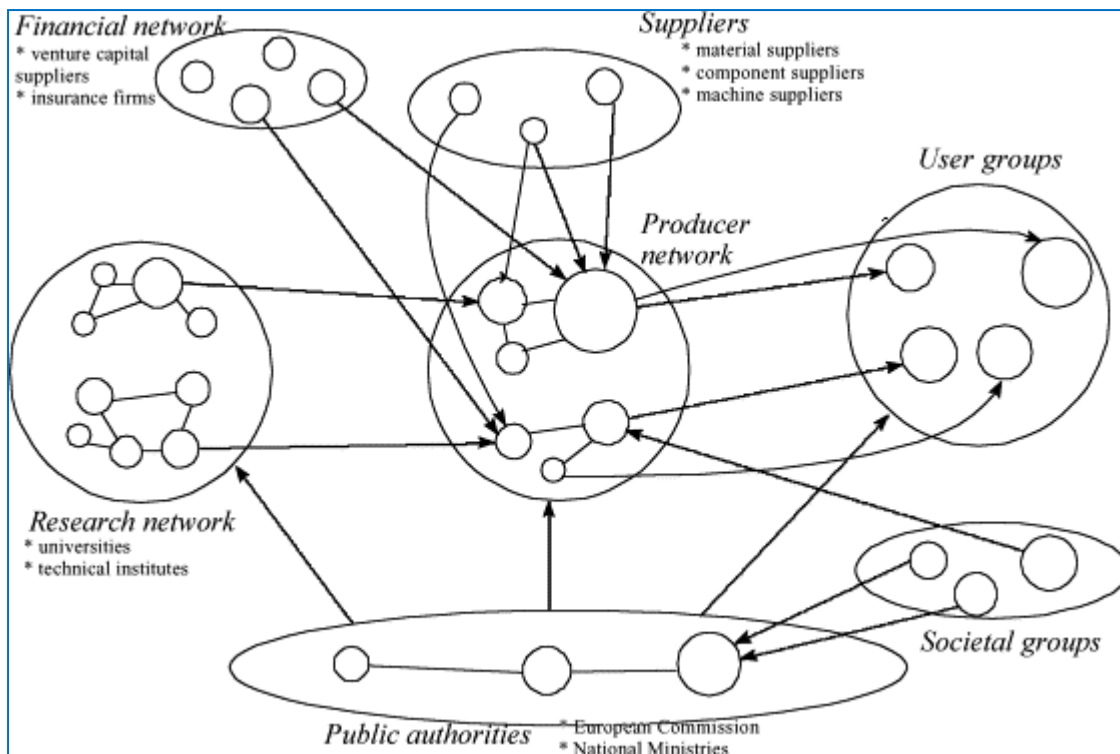
Figure 2.1: The network of actors in a sociotechnical regime (Geels, 2002a p.1260)

The linkages in a socio-technical system stabilise because actors' activities are aligned and co-ordinated (Geels, 2002a). Because heterogeneous elements are brought together within a definition of a system, it is considered useful to draw an analytical distinction among sociotechnical systems, rules and institutions, and the network of actors involved in maintaining and changing the system. Sociotechnical aspects refer to resources (inputs) and material resources. Rules and institutions guide actors' perception and activities. Institutions should not be confused with non-market organisations, which is why the term rules can be used alternatively (Geels, 2004a).

Actors, systems and rules are seen as three interconnected dimensions. There are interactions between these three elements that work in two directions. Sociotechnical systems do not perform their functions in autonomy but result from human action. Actors are organised in groups and social groups are usually allocated specific roles with regard to resources and sub-functions within systems. Social groups have developed this specialisation overtime. In contemporary society production and use activities have been separated in different cluster. Social groups have relative autonomy and distinctive characteristics. There is co-ordination within groups because they share similar perceptions and practices. At a second level there is co-ordination between different groups as they are interdependent (Geels, 2004a).
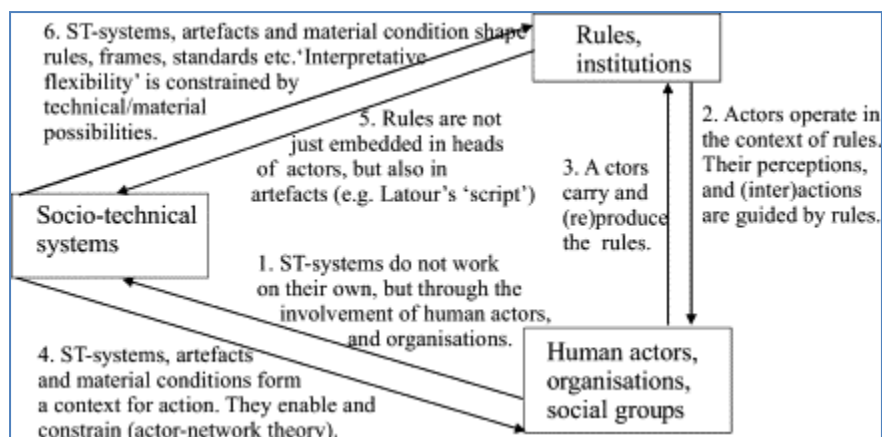
Figure 2.2: Actors, rules and systems (Geels, 2004a p.903)

Overall, there are six types of interactions involving systems, actors and institution/rules (ibid.). Between sociotechnical systems and actors there are the following interactions. Through their activities actors maintain and reproduce a socio-technical system. On the other hand, the material characteristics and systems enable and constrain human behaviour. This is similar to the ANT notion of the script (Akrich, 1992). The relationship between regimes and systems is similar to the one between artefacts and scripts (Rip and Kemp, 1998)

In this perspective non-human entities have the ability to direct human action. Socio-technical systems structure human action. Humans are surrounded by artefacts to the degree that it is mentioned that they live in a technotope. Technology forms the material culture of society (Rip and Kemp, 1998).Between actors and rules it is noted that rules guide the perception and interaction of actors. This position counteracts the idea that individual actors, such as system builders, can control the evolution of technology. Yet rules are reproduced through actors' activities. This way human agency is controlled by an external culture. Besides, rules are also embedded into artefacts and processes. This is consistent with the definition of the technological regime by Rip and Kemp (1998): "a regime is a rule set or grammar embedded in a complex of engineering practices, production process technologies, product characteristic skills and procedures, ways of handling relevant artefacts and persons and ways of defining problems"(p.2). These elements are embedded in institutions and infrastructures. The script is a type of rule inserted in an artefact that allows it to affect human relations as well as relations between humans and things. However there is a relative stability in technology because of its material nature and the past investment in established technology (sunk costs). Also, objective properties of materials and natural laws limit the possibility to shape technology by rules (Geels, 2004a).

Institutions (rules) co-ordinate and structure activities. There are three main dimensions: regulative, normative and cognitive. Regulative rules are formal, such as government regulation. They include rewards and sanctions. Normative rules are developed through socialisation and can take the form of values and norms. Cognitive rules relate to the understanding of reality and the processing of information to create meaning. These types of rules are mainly emphasised in evolutionary economics considering the notion of technological regimes (Nelson and Winter, 1977) and paradigms (Dosi, 1982). Rules are

grouped into systems that can be collectively shared. A rule regime is a social rule system that is supported by a social network through sanctions and control. Hence, a regime is a semi-coherent set of linked rules. These rules are aligned because it is difficult to change one rule without disturbing the others. One can distinguish between different regimes because actors within social groups share their distinctive set of rules. In that sense there are different regimes that result from linking groups of actors to rules. One can identify the following: technological, user and market regime, sociocultural, policy and science regimes. A socio-technical regime incorporates other regimes not in their entirety but only with regard to rules that are aligned to other regimes. This way, individual regimes maintain some autonomy. Each regime has an its own dynamics but there are interactions in their evolution processes, for instance, co-evolution between technology and market forces or co-evolution of different technologies (Geels,2004b).

The interaction between regimes and actors relates to the agency-structure debate. An approach to the dilemma is that although actors interact within a structure set by the regime, they nonetheless have the ability to alter that structure. Structure at the same time constrains and enables activities (ibid.).The relation between agency and structure as perceived in the transitions literature and the MLP is provided in section 2.2.1.

It can be argued that the concept of sociotechnical system is animated in its alternative conceptualisation as a regime that co-ordinates a network of actors. At this point it is described how the MLP begins with sociotechnical systems as the level of analysis in order to account for stability and change.

2.2. The multi-level perspective on sociotechnical transitions

The sociotechnical systems approach accounts for transitions through the interaction between three levels: niche, regime and landscape.

Socio-technical regimes can explain the stability of socio-technical configurations. This stability is of a dynamic kind; change still occurs but it is incremental. In this sense the regimes act as the selection environment does in evolutionary theory. Regimes give rise to technological trajectories (Geels, 2002a and 2005a). The regimes constitute the meso-level of the multi-level perspective. They can explain stability in the following ways. Regimes guide user perceptions and actions. Rules create expectations for the future and thus influence current action. For instance cognitive rules about consumer preferences lead to the introduction of similar products. Furthermore, actors are interdependent and a level of trust exists among them in the form of organisational capital. Firms may have interests in the continuation of the current socio-technical system. Because of these interests incumbent firms are likely to obstruct radical innovation. Finally, the material nature of sociotechnical systems hinders change. Complementarities between technologies perpetuate the same technical patterns because there is a need for compatibility (Geels, 2004a).

The above characteristics are sources of path dependence and lead to the emergence of trajectories. There are trajectories regarding all types of regimes. These trajectories co-evolve but their dynamics may result in conflict which indicates uncertainty and differences of opinion. Tensions may lead to the weakening of the linkages (Geels, 2002a). The fluctuations that occur in regimes are usually co-coordinated through their interdependence. If these fluctuations result in mismatches among the several rule systems, the sociotechnical regime weakens and there is increased possibility for actors to make their own interpretation. It can be argued that tensions result in change in the rules of the game but certain actors have the initiative in changing the rules (Geels, 2004a). This process is gradual but in time new regimes may replace the former ones. In this climate it is easier for a radical innovation to emerge.

It is supported that radical innovations are usually generated in niches. Niches constitute the micro level that provides the ground for variation and radical innovation. Niches are not perceived as market segments but rather as insulated spaces where radical innovation can be nurtured without being directly exposed to competition (Rip and Kemp, 1998). This protective space is possible because the selection environment operates differently from the one in the regime. In addition, niches supply space for learning processes and for the building of networks that are required in order to support the innovation (Geels, 2002a). It is considered that innovating firms have to access complementary assets so that an invention can be commercialised (Teece, 1986). Participation in networks facilitates access to these assets such as access to distribution. In the strategic niche management approach, providing isolation of radical innovations is useful because the potential of new technologies is uncertain and it would be unlikely that they could survive in market conditions (Kemp et al., 1998; Kemp et al., 2001). Yet, there should be caution about policy measures that try to support niches as it is difficult to identify technologies that have the potential to become

successful (Rip and Kemp,1998) and support for specific technologies could be unfair as it might decrease variety(Coombs,1995).

The niche includes the same components as a regime (actors, resources and rules). The only difference lies on scale and stability. Networks of actors are still small, the rules are still unclear and not as restrictive, and the artefacts of the sociotechnical configuration are still incomplete. Therefore, the different trajectories within the niche are divergent and actors have to try and build supporting networks and establish rules (Geels and Schot, 2007).

Sociotechnical landscapes form the macro level. It refers to factors in the wider environment that cannot be shaped at the will of actors. It includes factors such as cultural change, demographic trends, macro-economic and political change and pervasive technologies that are identified as key inputs in the economic system. The term landscape indicates that this level forms the background of human actions (ibid.).

These levels form a nested hierarchy because they are embedded. As we progress along these levels there is increased structuration of activities. Niches often address issues that result from problems in the existing regimes (Geels, 2005a).
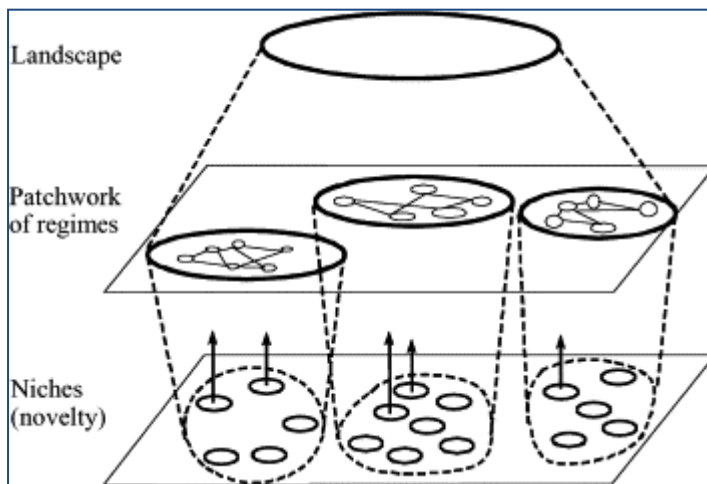
Figure 2.3 :A nested hierarchy of levels (Geels, 2002a p.1261)

Technological transitions occur when innovations break from the niche to the regime level. It has been claimed that transitions evolve in four stages: pre-development, take –off, acceleration and stabilisation (Rotmans et al., 2001). Geels (2005a) describes these stages as follows. Initially, radical innovation occurs in niches in the context of influences by the dominant regime and the landscape. In the second stage, the novelty is used in applications within the niche and a dedicated community of engineers and practitioners is developed to support it. This second phase results in a technological trajectory, the expression of user preferences and a dominant design. In the third phase, the new technology is widely diffused and starts competing with the incumbent regime. There are internal reasons for this breakthrough such as actors' interest and scale economies. Yet, it is influenced by the situation at the regime level. Problems at the regime level provide a "window of opportunity" for radical innovations (Geels, 2004a). A remark in this approach is that a dominant design for the new technology emerges before its breakthrough in the regime level. Still, it is possible that different prototypes of the product concept can compete with the existing

regime as well as with one another. However, certain coherence must exist within the niche so that it can be competitive.
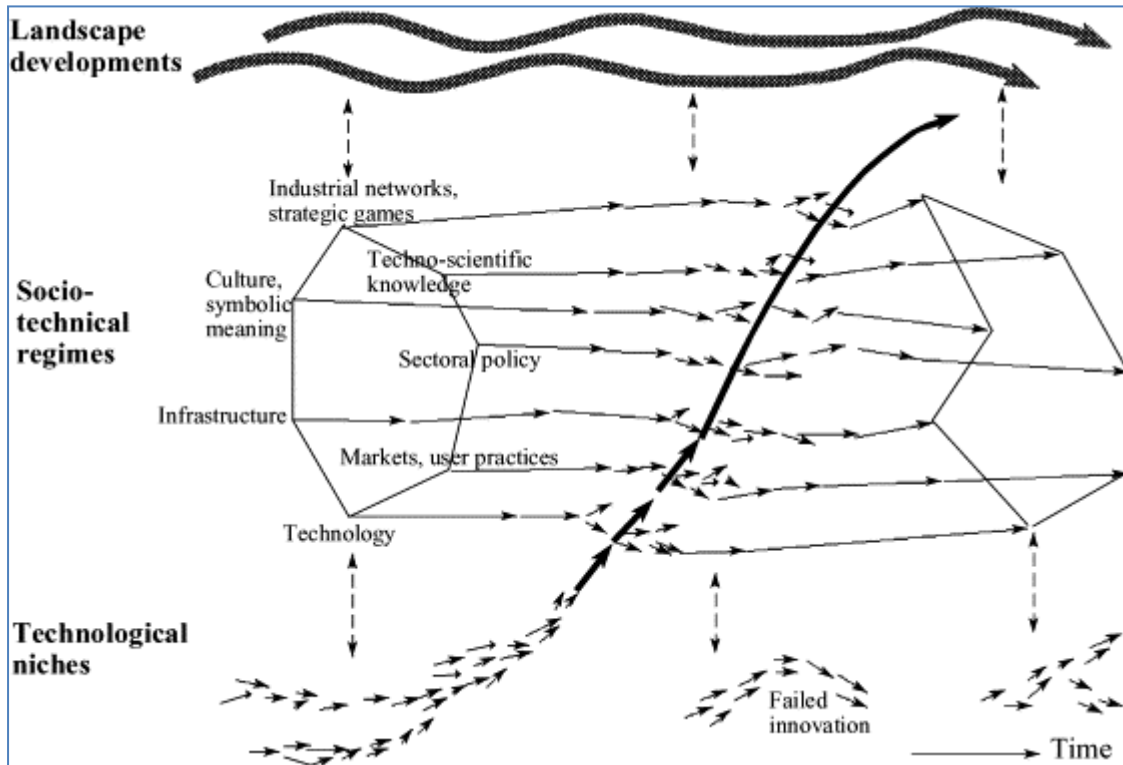
Figure 2.4: Dynamic interactions in the MLP (Geels, 2002a p.1263)

2.2.1. Ontology, agency and structure in the MLP

In innovation theory, the sociotechnical transitions and particularly the MLP framework appear to initially sidestep ontological questions (and there have been attempts to rectify this (Geels and Schot, 2007).As a result, attempts have been made to clarify the ontological foundations of the MLP and describe how it can provide explanations of technological change and what kind of explanations these are meant to be. Recently, an exposition has been provided on the ontological foundations of the MLP, which helps clarify what kind of questions the MLP can address. The MLP has been accused as being overtly functionalistic with its emphasis on rules and institutions; however structuration theory has been applied to explain how space for actors' agency is made available (Geels and Schot, 2007). Drawing on Mahoney (2004) seven foundational social paradigms are identified distinguished by their perception of causality; the causal agent and primary causal mechanisms are discussed (in Geels and Schot, 2008).

According to Geels and Schot (2008) the ontological foundations of the MLP combine evolution theory, specifically the quasi-evolutionary version that encompasses social and cognitive dimensions and structuration theory that fits more with interpretive ontology. Structure in the MLP is understood as regimes. In both evolution and structuration theory, the idea of universal routines and rules is present. In the MLP, structure is seen as a guide not as a determinant. In structuration theory, different local interpretations of a rule are possible, so there is potential for agency. Quasi-evolutionary theory also adds an interpretive dimension to economic theories. Quasi-evolutionary theory contributes to the long-term process analysis of transitions (global model) while structuration focuses more on the local model. An attempt to combine evolution and structuration as foundational paradigms can be observed more generally in the social sciences. The MLP is positioned as a process theory and this has implications for the generalisation of results. Limitations of the structuration approach can be identified but it is a useful way of reinserting agency into rather functionalist explanations.

Limitations of the MLP are acknowledged so that certain criticisms can be bypassed. By explaining what type of theory the MLP is greater focus can be expected from future work.

Broadly two types of explanations are applied in social science. Either cause and effect relations are identified or processes are explained by identifying patterns and mechanisms. In the study of historical processes one either aims to find causes or to construct a narrative and find typical patterns (Abbot, 2001 quoted in Geels and Schot, 2008). These types of explanations correspond to variance theory and process theory. Variance theory examines the effect of independent on dependent variables with an aim in explaining their variation. Process theories look at events rather than variables. Outcomes result from a temporal sequence of events, their timing and conjectures. The result is the identification of patterns. In order to explain an outcome the trace of events has to be followed (Geels and Schot, 2008).

The MLP is positioned as a process theory. It is ontologically based on a combination of evolutionary and structuration theory, both of which focus on developments over time. Transitions are relatively rare long-term processes. Hence, variance theories are of limited

applicability in transitions research because one cannot abstract variables from a relatively small number of cases and analyse their relations statistically. In addition the MLP is a process theory because the timing of interactions is important in differentiating the pathways and explanations are layers while variance theories support immediate causality (ibid).

Identifying the MLP as a process theory has implications on the generality of results. Unlike variance theories the generalisation of explanations does not depend on their applicability in a large number of cases across diverse settings. Rather it depends on their ability to include a different range of patterns without altering its essential character (Poole et al., 2000 cited in Geels and Schot, 2008). In the case of the MLP it is remarked that the different pathways include the same fundamental understanding of change as interaction between the three levels on the basis of evolution and structuration.

In that sense the MLP is a typological theory because patterns and mechanisms are grouped into categories(the pathways).Typological theories adopt a form of classification but acknowledge that the entities classified are too complex to be reduced to variables(ibid.).

Process theories are also described as narrative explanations. However narratives have to make explicit use of theory to avoid reducing them to mere story-telling (ibid). It has been argued that social science should amount to more than mere story-telling (Amsterdamska, 1990). However there is an alternative argument that a good description does not require an explanation (Latour, 2005).

An additional point is raised that has implications of the management of prospective transitions. Causality in the MLP is probabilistic: the MLP provides general patterns of transitions but the specific events in each case depend on local sequences. The probability of transitions is raised in certain context, but the actors may not exploit the opportunities.

2.2.2. Patterns in sociotechnical transitions: linking tactics

Specific mechanisms have been identified relating to the interaction between the MLP levels. There are different processes through which a transition can occur. They may lead in complete substitution of the former sociotechnical configurations, although the resulting sociotechnical system can share common characteristics with the previous one. It is suggested that change occurs through processes of niche cumulation. Niches may come into existence through changes in the landscape development. Because the landscape is less influenced by actors' actions this type of change is less predictable. Niche cumulation occurs as new technologies are gradually introduced to new application domains or market segments (Geels, 2002a).

Linkages between multiple technologies can help explain this gradual advancement of niches. A useful pattern is technological add-on and hybridisation (Geels, 2002a). In the initial stages a niche can be introduced in the current regime in a symbiotic relationship. The new technology is considered as complementary (Geels, 2005a). This mechanism is helpful if the new technology cannot be self-sufficient. Other technological interactions are interlocking and sequential accumulation. Interlocking overcomes obstacles that a technology faces in the current context by linking it with a more compatible technology. In the sequential accumulation pattern a technology breaks into the regime first and the regime is opened up in a way that favours another technology in the future although the first technology may later be rejected. Finally, technologies borrow elements from others partly to make up for their inherent limitations (Geels, 2005a). In the same manner, regimes borrow characteristics from previous regimes (Van den Ende and Kemp, 1998).

In that sense there are similarities between new and established technologies. The fit and stretch pattern explains how radical technologies originally adopt similar form and function to the established technology and are presented as a substitute. They develop into new domains and change their external characteristics as they become more established (Geels, 2005a). In practice, new technologies have both substitution and generation effects regarding demand (Berkhout and Hertin, 2004; Geels and Smit, 2000). Besides transition patterns based on technology there are also patterns concerning firms, user activities and policies. Firm–related patterns explore the reaction of incumbent companies to radical innovation, maturity and decline of existing markets and competition. User-related patterns refer to expectations about technology (enthusiasm or fear) and the links of a technology with broader cultural trend. Policy patterns relate to the support government provides to industries (Geels, 2005a).

Sociotechnical change in the MLP may be accounted for through the interaction of three levels, but the landscape is mostly seen as forces "out-there" that exercise pressure on the regime. In practice the two focal levels on the MLP are the sociotechnical regime and technological niches. Specific mechanisms on the linkages between niche and regime have been presented in historical case studies. Such mechanisms include the aforementioned interlocking, technological add-on and hybridisation (Geels, 2002a). However, these refer mostly to interactions between emergent and established technologies. Overall, the interaction between niches and regimes are not sufficiently understood (Elzen et al., 2008).

Smith (2007) proposes that we need a 'theory of linking'. Citing Loeber (2003), Elzen et al. (2008) apply the concept of anchorage in order to account for these interactions.

According to the MLP radical innovation occurs as a result of the interaction between three levels. Because of the timeframe the descriptions of past transitions have to abstract from the more detailed, complex dynamics of change (Smith, 2007); this is how a typology of transitions pathways is created. There have been attempts to articulate a theory of linking. It has been emphasised that the interaction between niche and regime should be seen as reciprocal rather than as a one-way process from niche to regime: niche innovations are not simply adopted in the regime but sociotechnical practices are translated as they move between niche and regime. Therefore, it is not sufficient to identify opportunities for niche-regime interaction but one needs to understand how the connecting processes bring about developments at both niches and regimes (ibid.)

The concept of anchorage provides a more detailed analytical framework of the dynamics between niche and regime and equally importantly it allows for a less hierarchical understanding of the MLP. Boundaries between levels can be identified for analytical purposes but from the agents' point of view it is not always clear at which level they operate. Hence, a new representation of the MLP is proposed which incorporates the following assumptions (Elzen et al., 2008).

- o Niches and regimes overlap to some degree

- o Landscape pressures are exercised on the niche as well as on the regime

- o Niches and regimes are not hierarchically ordered.

- o The overall multi-level concept is maintained as a heuristic.

Although Smith (2007) and Elzen et al. (2008) do not support a clear distinction between the niche and the regime, they accept the overall multi-level perspective and make suggestions on the elaboration of interaction processes. Considering the blurred boundaries between niches and regimes the multi-level processes in system innovation is described in the following diagram.
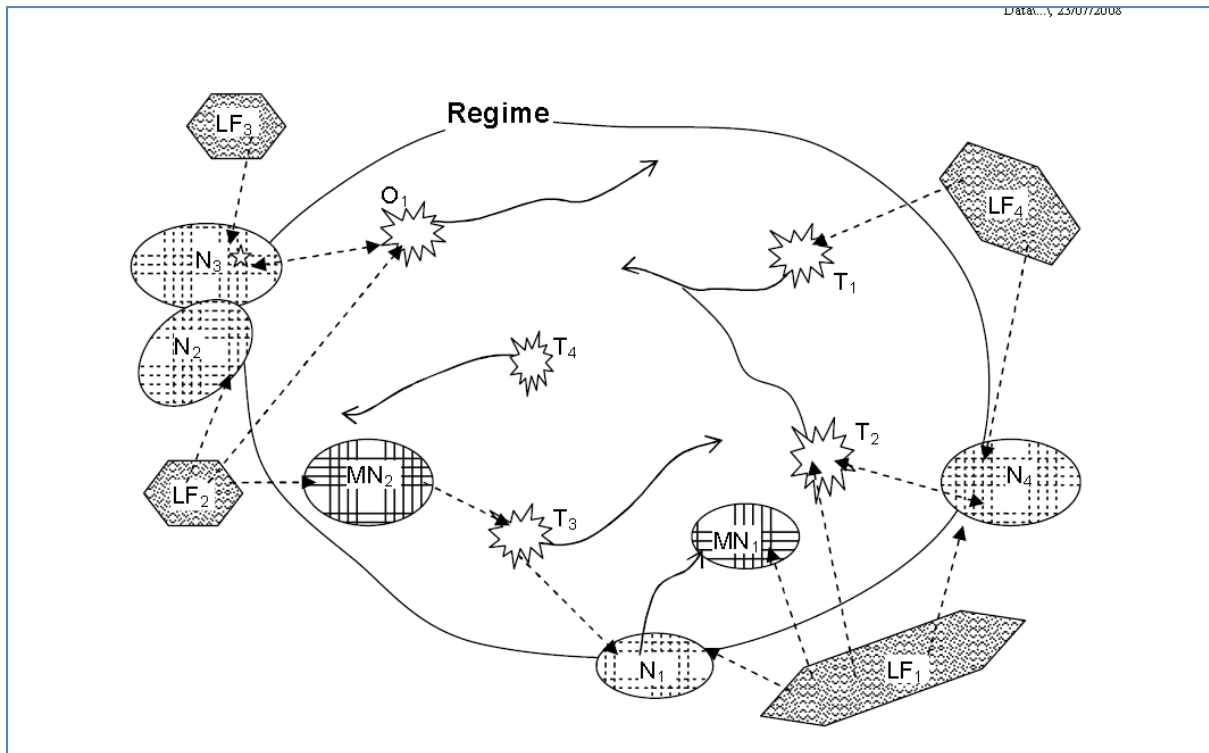
Figure 2.5: Multi-level processes in system innovation (Elzen et al., 2008, p.7)

(LF: landscape factor, N: niche, MN: market niche, T: tension, O: opportunities)

It is interesting to observe that the representation resembles a flat area with the regime at the centre and niches and landscape pressures around it instead of the visual representation of the MLP found in Geels (2002a&2004a) and Geels and Schot (2007). In that description linking takes place in the overlap between niche and regime whereas market niches are already included in the regime.

The term anchorage is used to describe such forms of linking. Anchorage is similar to concepts such as institutional or societal embedding which are used in strategic niche management. Somewhat ambiguously, it is used to express that a link has some durability but also that is vulnerable and may not lead to sustainable change (Elzen et al., 2008).

Applying the concept of anchorage to describe niche regime dynamics Elzen et al., (2008) follow Geels's (2004a) description of a regime as comprised by sociotechnical systems actors and rules. Drawing on these dimensions three forms of anchorage are identified: technological anchorage, network anchorage and institutional anchorage. In practice, these may be difficult to disentangle (Elzen et al., 2008).

Technological anchorage occurs when technical artefacts or practices developed in niches become more defined and possibly linked to form a new configuration. Network anchorage indicates that a technology becomes accepted by a broader group of actors. This could mean that other actors use, produce or develop it. Network anchorage can describe closer involvement of regime actors into niche technologies, a strengthening of coalitions in support of the innovation, increased interaction among network actors and potentially a formalisation of the network. Institutional anchorage is related to the rule dimension of the sociotechnical regime. The institutional anchorage of a technology indicates change in formal and informal rules that guide behaviour and action (ibid.).According to Geels (2004a) a

regime is governed by cognitive, normative and formal regulative rules. Elzen et al., (2008) draw on Scott (1995 cited in ibid.) to categorise institutions as cognitive or interpretative, normative/regulative and economic rules. The translation concept as applied by Smith (2007) can be used to refer to types of institutional anchorage: for example, translations can be seen as a change in the cognitive rules applied to a situation (Elzen et al., 2008).

It is remarked that technological anchorage refers to interaction between technologies. This form of anchorage is interpreted as illustrating that technologies have agency and their own patterns of interaction which can be analytically separated from human and organisational interaction. Network anchorage refers to links between technologies and social actors. It should be noted that acceptance of a technology is not limited to adoption as would occur in the diffusion model, but it can also entail a modification of the technology by the involved actors. Hence, network anchorage includes patterns where the differentiation between innovation and adoption is blurred. Institutional anchorage to a degree follows the description of regimes according to the MLP though a change in rules is also seen through the perspective of niche/regime translation.

The application of anchorage forms demonstrates the difficulty in distinguishing between radical and incremental innovation; this has implications for the support of systems innovation (Elzen et al., 2008).Forms of anchorage provide opportunities for subsequent dynamics. The following patterns have been identified (ibid).

- Translation: an incremental innovation can be translated into a more radical idea with the addition of a new concept.
- An opportunity that can appear after a former anchorage in the guise of a new market.
- Internalisation: pressures by outsiders that affect niche developments are internalised into the regime
- The alignment between different forms of anchorage improves durability.

Introducing the concept of anchorage in transitions is part of the attempt to provide more detailed representations of niche-regime interactions. The benefits of the concept are that it emphasises that links must have durability and that developments at niche and regime level are often simultaneous. In addition, as anchorage activity is located in the intersection between niche and regime (or between regimes) the hybrid character of pivotal actors is identified (Elzen et al., 2008). In the sociotechnical transitions and more generally the innovation literature there tends to be an argument that radical change originates from outsiders (e.g. Tushman and Anderson, 1986; van de Poel, 2000). Such outsiders are seen as external or marginal to the regime and they do not share the same approaches to technical development (van de Poel, 2000). However, the actors that have proved more influential in anchorage processes do not meet these criteria. Instead interaction between actors in different regimes is observed in a so-called "hybrid forum" (Elzen et al., 2008).

There are a limited number of studies regarding interaction between regimes (e.g. Raven and Verbong, 2007) but interaction between regimes should be recognised as an additional dynamic alongside niche-regime interaction. The following patterns of interaction between regimes are identified. Competition occurs when the regime in questions fulfil a

similar function. In the case of symbiosis both regimes gain advantages through co-operation. Integration occurs when different regimes or parts of them are combined. The opposite process can also occur when a regime is divided due to different developments in its components. Finally spillover occurs when rules from one regime are adopted into others.

Smith (2007) and Elzen et al. (2008) emphasise the need for a theory of linking particularly between niche and regime but overall they accept the principles of the MLP. To a degree the MLP has become a point of reference in the study of transitions. Below attempts at refining the MLP are described and an alternative conceptualisation is proposed.

2.2.3. Pathways in transitions

It was described how the MLP accounts for stability and change in sociotechnical systems. The mechanisms of actions in the MLP have been analysed as the interplay between agency enacted by actors and structure articulated in rules. Sociotechnical change in the MLP is conceived as the interaction between levels. Particular mechanisms of interaction involving actors, systems, artefacts and rules are described. On the basis of particular patterns of interaction a number of transition pathways are identified and then organised into a typology. This typology emerges from research of systems in transitions. The typology of pathways contributes to further refinement of the MLP along with the explanations on the role of agency and simultaneously counters the critique on niche-driven bias and the emphasis on substitution (Geels and Schot, 2007).

Two criteria are combined to identify transition pathways (ibid).The first criterion refers to the timing of interaction between levels. Although earlier research focused on the alignment of simultaneous developments between levels, it is now remarked that the timing of interaction can result in different outcomes. The timing of landscape pressure on the regime in relation to the developmental state of niche innovation is of particular importance. Landscape pressures have different effects depending on the existence of fully developed niche innovations. The ambiguity in defining a fully-developed innovation is acknowledged and proxy criteria from the literature on niche development and diffusion are drawn upon in order to identify them. Generally, landscape pressures are seen as initiating change and creating windows of opportunity for potential transitions. Niche innovations that are not fully developed cannot take advantage of this opportunity.

The second criterion concerns the nature of this interaction. Niche innovation and landscape developments may have reinforcing developments with the regime or disruptive relationships characterised by pressure and competition. In the case of landscape developments, reinforcing developments have stabilising effects on the regime and do not provide an impetus for transitions. The disruptive landscape developments render the regime vulnerable to change. Niches have a competitive relationship with the regime when they are meant to substitute for it. Niche innovations have a symbiotic relation when they can be incorporated as competence enhancing add-ons in the existing regime.

Combinations of these criteria result in the following transitions pathways. An alternative route to transitions includes the shifting between pathways at different stages.

The initial proposition refers to the stability of the existing sociotechnical configuration labelled as the reproduction pathway. The regime reproduces itself in a state of dynamic stability. Landscape developments are reinforcing (or absent?) hence radical niche innovations that may be present cannot achieve a breakthrough. Stable regimes still experience incremental innovation, which can increase performance over time.

The transformation path is characterised by moderate landscape pressure at a time when niche innovations are not adequately developed. Hence, regime actors respond by modifying the direction of development paths and innovation activities. In the transformation pathway old regimes grow into new ones through cumulative adjustments and reorientation. Niche innovations exist but it is symbiotic to regime developments and does not alter the

basic configuration. A case study account of the transformation pathway is provided in Geels (2006a). The role of regime outsider in affecting the transition draws on van de Poel's (2000) categorisation of outsiders. It is also clarified why niche developments in the case study are best described as symbiotic and competence expanding to the regime although a degree of substitution can be observed.

The de-alignment and re-alignment pathway is observed when landscape developments are divergent, large and sudden. Then regime actors lose trust and the regime is eroded, hence de-alignment occurs. This weakening of the regime leads to gaps that can be covered by niche innovations. Interestingly, these innovations may be developed by outsiders or diversifying incumbents in the regime. When niche innovations are not sufficiently developed there is not an available substitute for the regime. Hence multiple niches co-exist and compete for attention and resources, until one niche innovation is established as the dominant design. An example of this pathway is provided in Geels (2005b) referring to the transition from the horse-drawn carriage to the automobile. It is observed that some niche innovations that failed to become dominant were nonetheless important in further destabilising the regime and preparing the infrastructure for the automobile. Hence, one could remark that niche developments can be seen as reinforcing instead competitive.

The technological substitution pathway precedes the other in terms of theoretical development as it was initially elaborated in Geels (2002a). The criticisms regarding emphasis placed on substation pathways and additional empirical work has resulted in the development of additional pathways. According to this pathway radical innovations have been developed in niches while the regime is stable, facing only minor problems that can be addressed with incremental innovation. At this stage little attention is paid to niche developments. Without the development of landscape pressures the regime would follow the reproduction pathway. Landscape pressure is exercised in the form of avalanche, disruptive change leading to significant regime change and generating windows of opportunity for the already developed niche innovation. Unlike the de-alignment and the re-alignment pathway niche innovation have already developed their own internal dynamics. This linking between niches and regimes usually takes the form of niche-accumulation (Geels, 2002a). The interaction between niche and regime is competitive. Regime actors attempt to defend the incumbent practices which may lead to improvements in existing technologies (described as the sailing ship effect). This pathway appears to have a technology-push character, because co-evolution processes follow technological substitution. In addition, the substitution of technologies is accompanied with the fall of incumbent firms as has emerged in technology management studies (Tushman and Anderson, 1986).

In the reconfiguration pathway niche innovations which are symbiotic to the regime are adopted as an add-on or a component replacement. They are included in the regime to solve local problem mostly on economic grounds and they leave the underlying regime rules unchanged. If the basic regime structure remained unmodified, there would be cases of the transformation pathway. But as incumbent actors may further explore the possibilities of new combinations involving the niche innovation, it is possible to observe major regime change over time. The transformation and reconfiguration pathways are distinguished because the

reconfiguration path includes more substantial changes in the regime infrastructure. In addition the reconfiguration path appears more punctuated as change occurs in subsequent steps. The initial add-ons or component replacements act as a pre-requisite for the subsequent niches to link-up to the regime. An example of transition through-stepwise reconfiguration is analysed in Geels (2006b). It is observed that the reconfiguration pathways is of more relevance to sociotechnical systems that include a multitude of technologies rather than to those organised around a core technology (Geels, 2006b, Geels and Schot, 2007).

Finally, when landscape pressures take the form of "disruptive change" a sequence of transition pathways can be observed. In the most usual pattern these transitions begin with transformation, develop into reconfiguration and finally leading to substitution or de-alignment and re-alignment. In this case there has to be a distinction between a sequence of transitions each developing according to one of the pathways and a single transition combining different pathways. This leads to the question raised by Genus and Coles (2008) regarding the definition of a transition timeframe.

A more limited typology of these change processes is provided in Geels and Kemp (2007).Three type of change processes are suggested: reproduction, transformation and transitions. Reproduction refers to incremental change within exiting trajectories, transformation refers to change in the direction of trajectories due to the rules guiding innovative action and the term transitions is limited only to refer to a discontinuous shift towards a new trajectory and a new system.

An alternative typology of transitions is suggested by Berkhout et al. (2004). The criteria applied are the intentionality of transitions and the location of the resources required for change. If the transition is achieved through internal resources it is described as endogenous renewal if the process is planned. If it is emergent the process is described as reorientation of trajectories. When external resources are motivated and co-ordination is low the transition is labelled emergent transformation. Finally, purposive transitions are the outcome of organised action and are achieved with external assets. It is remarked that the sources of change either in the form of pressures on the regimes or as the locus of innovative activity are considered in all patterns.

Transition research has also considered patterns of interactions involving more than one regime (Geels, 2007; Verbong and Raven, 2007). In earlier work Van den Ende and Kemp (1999) have described how a new regime may come into existence through the interaction between incumbent regimes. In these cases it has to be defined which regime is to be selected as the unit of analysis and how the regimes are related.

Critique on the transitions pathways has related both to empirical and conceptual foundational issues. A number of contested points regarding the MLP are raised below.

2.2.4. Methodological and conceptual issues in the MLP

The MLP has been used as an explanatory framework with regard both to past transitions and to transition management (Genus and Coles, 2008). A basic question regards whether the existing body of research on the basis of the MLP has been conducted systematically in order to allow for the development of effective accounts on the dynamics and governance of transitions. Issues concerning the operationalisation of MLP and the organisation of data used in transition studies have not been adequately resolved. In addition further elaboration is needed with regard to the identification of transition pathways (Genus and Coles, 2008).

The criticisms raised by Genus and Coles (2008) can be distinguished between empirical/methodological critique on the existing application of the MLP and more fundamental/conceptual ones. Regarding methodology, it is observed that important issues are left to the choice of the analyst. One problem inherent in existing research is that the regimes and the associated levels are not defined satisfactorily. This point has also been raised by Smith et al. (2005). It has been partly addressed by distinguishing between the empirical definition of the levels regarding how broad the scope of the regime should be and the theoretical definition (Geels and Schot, 2007).

In addition, the identification of a start and end point on transitions is also the analyst's choice. It appears that transitions are identified retrospectively and that the start point of transitions may signify technological developments or points of adoption (Genus and Coles, 2008). To that degree the different case studies are not easily comparable.

Furthermore, there is difficulty in interpreting whether observe radical, systemic change that could be labelled as transition is observed rather than continuous system renewal, taking into consideration that radical innovation is more effective when it can fit into the existing regime. The same data can be interpreted to support the concept of ongoing renewal or radical transition depending on the time frame chosen or the setting of regime boundaries (Genus and Coles, 2008).

There are considerations regarding the data collection concerning the study of historical transitions because there is a tendency to rely on secondary data rather than conduct direct research in the primary sources (Genus and Coles, 2008).More importantly the available data are subject to different interpretations as has been conceded by transition analysts. There is a need for a more detailed exposition on how data interpretation leads to the identification of pathways.

2.3. On the examination of transitions in progress

2.3.1. Retrospective and prospective dimensions in transitions

The literature indicates that the main theoretical development on the structure of the MLP and the identification of transition pathways have resulted from research in past transitions. However, two main strands can be identified in transitions research: the study of systems in transitions and transition management. These correspond respectively to the main questions in transitions research: how to develop a better understanding of long-term technological change and how to generate tools for the analysis of technological change that could inform the governance of technological change in practice (Genus and Coles, 2008).

Interest in transitions is largely explained because they can provide a framework for the analysis of prospective sociotechnical change. In addition, research in prospective transitions under the label of strategic niche management (SNM) has predated the study of systems in transitions with a focus on historical examples. Two related fields are dedicated to the study of prospective transitions: strategic niche management and transition management (sometimes used as an umbrella term). Transition management appears to have replaced SNM as used in the literature. A short explanation on the principles of strategic niche management and transition management is given below.

It is observed that the concept of niches as illustrated in SNM has persisted without serious modifications in the MLP.

Transition management is about the deliberate steering of technologies, practices and social arrangements in a more sustainable direction. It is meant to be interpreted as reflexive mode of governance and it is promoted as a "model of co-evolutionary management of transformative change in societal systems" where management is about adaptation and influence rather than command and control methods (Rotmans and Kemp, 2007, p. 1006).

Advocates of transition management at times adopt models of agency and intervention that are not shared by researchers on the systems literature on which they draw upon. There are also, disagreements within the field. However, transition management researchers advocate the deployment of a variety of methods and argue for the engagement of diverse actors and knowledges (Shove and Walker, 2007).

A contribution of strategic niche management and transition management is that they have explicitly incorporated sustainability considerations in the study of transitions and have argued that the promotion of sustainable technologies requires particular governance methods. There is however, a difference between the analysis of systems in transitions and models of transition management. The literature of systems in transition analyses systems dynamics through retrospective analyses; there is no explicit assumption that explanations of change could provide insights applicable to future transitions (ibid.). Therefore, there are difficulties in reconciling theoretical developments regarding systems in transition and transition management models. Transition management has a strong normative component while as it was mentioned research on past transitions is not meant to be prescriptive.

The two strands of transitions research have different aims: research of systems in transitions aims to identify patterns of technological change while transitions management

research is oriented towards the development of appropriate governance methods. Although, the focus is on the case of a potential transition in the making, the research does not have a normative orientation. Instead, the aim is to describe the current state of innovative activity in the area and how this might indicate to sociotechnical trajectories with different implications on sustainability. Hence, a model of sociotechnical change has to be constructed that will be applicable for the study of prospective, potential transitions. Below the difficulties of identifying transitions in progress are identified when a normative approach is not followed.

With regard to its ontological foundations the MLP has been identified as a typological process theory. In order to develop this typology MLP related research focuses on the dynamics of individual case studies. However, this approach has been applied with regard to historical case studies, applying the method of "constructive social history" (Geels, 2004a). There has not been a forward-oriented approach to transitions without a normative, prescriptive orientation. However, the research aim is to develop an understanding of prospective sociotechnical transitions. Because transition studies tended to focus in the past, the notion of a prospective transition or a transition in progress is paradoxical because transitions are usually identified after their completion by the analyst. Therefore, when prospective transitions are examined one should somehow assess what level of sociotechnical change in the system would amount to a transition. Yet, the existing body of research on sociotechnical transitions inevitably influences expectations on the appropriate usage of the term.

It has been acknowledged that the study of "innovation in the making" requires a different methodological approach from the study of historical innovation (Akrich et al., 2002). Retrospectively one can fairly easily identify the factors that led to the success or failure of an innovation, success or failure being measured by degree of adoption. Yet, it occurs that that factors used to explain success or failure retrospectively were not suggested as explanatory factors when the innovation was in progress. One should attempt to reconstruct the actors' narratives without resorting to knowledge unavailable at the time innovation decisions were made. In order to avoid retrospective explanations, the methodology has to take into account the actors' own experiences. Past innovation can be studied as innovation in the making if it is examined through the perspective of the actors at the time. In the case of a potential prospective transition, when the end result of innovative activity is unclear, the STS methodological precept to follow the actors (Law, 1991a) becomes more pronounced as retrospective explanations are not available. In addition, the dichotomy between success and failure is avoided because in historical studies there may be a latent tendency to treat "successful" and "failed" innovation differently however, when the end result is open one has to remain symmetrical towards success and failure (according to the principle of symmetry (Bloor, 1976). In that sense the study of transitions in progress is less structured than the study of historical transitions or transition management because in these cases there is a descriptive or normative setting of boundaries.

2.3.2. Units of analysis: the boundaries of a sociotechnical regime

Contrary to most innovation system approaches the boundaries of the sociotechnical regime are defined in relation to the societal function it fulfils. Actors and activities involved

in the system/regime all somehow contribute to the fulfilment of its end function. Sub-functions can be identified in the spheres of supply and demand. By analysing the concept of societal function a more detailed understanding of system boundaries can be achieved.

The notion of societal functions comes at the core of the sociotechnical systems approach. Sociotechnical transitions are defined as major technological transformations in the way basic societal functions, such as housing and transportation, are fulfilled (Geels, 2002a). Technologies are viewed as configurations that work in the sense that they help achieve a societal function(Rip and Kemp,1998;Geels,2002a); however, technology achieves these functions only in association with human agency and social structures (ibid).The term configuration signifies the alignments of technical and non-technical elements; by restricting technology to configurations that works it is implied that a function is fulfilled(Geels,2002a).A social function results as the outcome of a sociotechnical configuration that successfully bring together heterogeneous elements.

The importance of functions is consistent with the conceptualisation of technology as transformer, which regards mainly production technology. Technology transforms inputs into outputs. Its shape and form is derived from the fulfilment of a function (Rip and Kemp, 1998) In practice it is not easy to distinguish configurations that work from the rest of society, as technologies can be effective only because they are embedded in society. Artefacts and skills are integrated in routines, behavioural patterns and organisations (ibid.).

Although societal functions are presented as the aim of a sociotechnical system it is not clearly explained what exactly constitutes a societal functions, the impression can be created that the main function of a system is always visible. For instance, Geels (2002a, 2004a) mentions functions such as housing and transportation but the elements of these functions or their significance and social impacts are not elaborated. It could be possible to rank functions according to their social contribution if there are limited resources for their satisfaction. Although a function such as transport can be viewed from different perspectives such as personal or mass transport the functions described are not usually deconstructed according to their context. If a function is too broadly defined, it can lose its ability to act as a guidepost for the sociotechnical system.

In addition, when using the term fulfilment oneshould consider what it practically means to successfully fulfil a function and what criteria can be used to decide whether a sociotechnical system does that efficiently. As the notion of functions is meant to be user-focused, it is argued that it depends on the users to decide whether a function is delivered efficiently and give feedback to the producers but such a process would be subjective. Furthermore, the bargaining power of end-users differs across sociotechnical systems; if this is the case a system can survive without providing the function efficiently, particularly if there is little competition. Within the broader selection environment (market and non-market institutions) expectations about a function may differ. As Carlsson et al. (2002) have indicated there is a lack of appropriate methods to evaluate system performance.

Regarding sociotechnical systems as they relate to environmental sustainability the question of evaluating how functions are fulfilled becomes more pronounced. From the perspective of users a function may be fulfilled in a satisfactory way, but the users do not

always bear the negative implications involved in the achievement of the function in question. Although conflict within regimes is discussed in the transitions literature, the notion of functions appears unproblematic. However, it should be taken into account that there is no perfectly designed technology that can be standardized for all potential users (Star, 1991). Any resulting configuration is meant to serve some groups better, hence the concept of function relates to the perception of "winners" and "losers" in transitions.

Furthermore a sociotechnical configuration is not limited to serving the needs implied by its official function. Products are not only means to fulfil needs or achieve goals but also act as means of communication within cultures (Rip and Kemp,1998).In that sense, alternative terminology is sought that does not bear the teleological connotations implied in societal functions.

Functions in innovation systems can be described at three levels: generic, intermediary and end use functions (Wettering cited in Geels, 2002b).The term societal function signifies the end use functions that provide a service to satisfy needs or wants of the end consumer. Generic and intermediary functions include the supply of services and materials required to deliver the end use function. Practically, they regard the process of consumption within production, which has been partly overshadowed by end use consumption (Green and Morton, 2000 cited in Harvey et al., 2001).

In the sociotechnical transitions literature, there is not a clear description of what constitutes a societal function. In statistics analysis by function is used to supplement analysis by production and analysis by industry to provide a more complete view of economic activity. Certain non-invoiced activities are not available to sectoral analysis. Analysis by function is undertaken using the classification of individual consumption by purpose to understand household expenditure and the classification of functions of government to dissect government expenses (Eurostat).

There is a differentiation between functions that refer to business activities, for instance production, sales and administration and to functions that group together all activities related to the satisfaction of a given need. The former represent ancillary activities that are undertaken within firms in order to facilitate other activities. Functions that relate to a given need can cover various industrial sectors. Functions include invoiced and non-invoiced economic activity (Eurostat). As can be induced from Geels (2004a), by considering societal functions the focus of analysis broadens from individuals sectors to systems that are defined as the linkages between elements necessary to fulfil functions.

Regarding the central role of functions, Beck et al. (2003) argue that modern societies are based on the principle of functional differentiation. Society is divided in subsystems and the differentiation of societal functions through specialization is mean to provide an alignment between means and ends.

The attempt is to provide alternative perspectives on societal functions that do not bear the same teleological connotations. It is observed that societal functions refer to the satisfaction of a given societal need. Needs in the current societal configuration are satisfied through the process of consumption. Needs should be demarcated from demand which is expressed in a market setting. Instead of abstractly referring to consumption, one can identify

a set of societal practices according to which society is organized. Hence, one can replace the concept of societal function by the concept of societal practice by elaborating on the concepts of need and demand.

Besides deconstructing the concept of societal functions, there is also the issue that the regime boundaries are retrospectively defined by the analysts rather than the actors of a system in transition.

2.3.3. Practice-based view of regimes

The societal function of a system is best represented through the introduction of societal practices. The societal function refers to the end results of the regime. However, an additional set of practices takes places in different dimensions of sociotechnical regimes. In the MLP the three levels conceptualized as a nested hierarchy, however there are arguments for and alternative conceptualisation of the regime as a set of practices. Rules are rather abstract; what it takes to follow a rule is not contained within the rule itself (Wittgenstein cited in Lynch, 1993 and Schatzki, 1991). This is where the concept of practice comes forward.

The notion practice should not be trivialised and confused with everyday human activities. Practices are routinised types of human behaviour consisting of interconnected elements: forms of bodily and mental activity, things and their usage and a particular type of knowledge understanding and emotions. Practices represent patterns that can be filled by single actions reproducing the practice. In addition individual agents act as carriers of the practice. Practice (praxis) in the singular refers to the whole of human action and is different from individual practices (Reckwitz, 2002).

Practice theories belong to the field of cultural theories that seek to explain action and social order through symbolic and cognitive structures. These theories reject the former purpose-oriented and norm-oriented theories of human action. The approaches differ on the location of the social. For purpose-oriented social theory the social derives from subjective interests. In norm-oriented models, the social is situated in the consensus of norms and roles. Except for practice theories, other cultural theories are mentalism, textualism and intersubjectivism. For mentalism the social resides in the human mind. Textualism emphasizes signs, discourse and "texts". For intersubjectivism the social is based on interactions. In practice theories a practice is social as it is a type of behaviour and knowing that occurs in different locales and is undertaken by bodies/minds (ibid).

Although theories of social practice have not been formalised and despite the differences among them, they share a common perspective on the body, mind, things, knowledge, discourse, structure and agency that differentiates them from other cultural theories. Practices are routinised bodily and mental activities. They include particular ways of knowing and feeling that are culturally specific and carried out by agents. In that sense wants and emotions do not belong to individuals but to practices. Things are also part of practices (ibid).For instance, as most practices incorporate consumption products are put to use as the practice is carried out.

The networks developed within niches and regimes can be perceived as communities of practice (Brown and Duguid, 1991). The concept of communities of practice indicates the close link between learning innovation and work as opposed to more abstract approaches to learning.

Regarding issues of agency and structure practice theories tend to be influenced by structuralism. The social world is primarily populated by practices rather than individual agents. Agents are carriers of practices, neither autonomous nor completely subjected to norms (Reckwitz, 2002).

2.3.4. A relational perspective of agency

There has been increasing recognition in the importance of social interaction through networks in the innovation process. In the area of innovation studies it can be argued that the interest in a network approach has emerged as a result of the tension between two views: innovations result as isolated instances of individual genius and entrepreneurship or, more plausibly, they result within a larger community of actors and are embedded in a broader pattern of development of technoeconomic systems (Green et al., 1999). "The "heroic inventor" is, if not interred, at least firmly placed within some sort of wider context" (Ibid. p.777). When relative importance is placed on the community aspects of innovation rather than on the technoeconomic factors, then it can be argued that a network approach is taken.

According to network theories of agency each entity can be seen as an arrangement of heterogeneous elements that ordering processes keep as one. Only part of these arrangements is under the agent's control. Hence, a person is an effect a fragile association of elements. Because agency is a result of ordering it is a matter of degree rather than something to be granted (Law, 1994). Symbolic interactionism is a process sociology that claims that agents (or selves) are constituted in social relations. Simultaneously, agents reconstitute those that they encounter through social relations in a process similar to negotiation. Symbolic interactionism thus avoids the agency-structure dualism and does not resort to the greater social structure. Actor-network theory is similar to symbolic interactionism in that it is also sociology of process, with an additional commitment to emphasising the underlying material character of the social. Agents are treated as relational effect, a finding shared with structuralism and post-structuralism. Actor-network theory draws on post-structuralism in that it decentres the subject. Agents are effects of ordering attempts but not unified effects; hence agency is a fragile and temporary achievement. However, it is a more process oriented approach than post-structuralism; therefore it is nearer to a contingent sociology (Law, 1994).

A relational interpretation of agency is put forward by Callon (1998a) in the study of markets. In order for markets to exist agents have to become calculative. The question raised is how agents can become calculative when they lack adequate information and there are no institutional guidelines that make them share expectation to manage an unknowable future. Most explanations in the question of calculative agencies begin by presupposing the existence of autonomous and isolated agents and provide them with the social relations necessary to co-ordinate their actions with those of other agents; therefore agents open up to their environment. Instead, the notion of the agents' dependence on their environment should be taken as the starting point. Beneath the contracts among agents there is a primitive reality without which co-ordination would not be possible. The notion of a social network or more broadly that of embeddedness provides the basis that makes co-ordination possible. Agents can calculate their actions even in an environment of uncertainty because they are already embedded in a web of relations; "they do not have to open up to the world because they already contain the world" (ibid., p.8). Agents exist as actor-worlds. Therefore, the structure-agency division is avoided because the network is not a context that frames the actors. Actor and network are two sides of the same reality. Analysis begins either by examining a network

though agents characterised by the shape of their relationships or by focusing on the network as a whole in which case the association of the agencies is used to describe it (Callon, 1998a).

The above mentioned interpretation of agency draws on Granovetter's (1985) concept of embeddedness. His perspective has often been misinterpreted and this has obstructed the understanding of its originality (Callon, 1998a). Firstly, he abandons the concepts of homo economicus and homo sociologicus. Despite their differences both approaches assume the existence of individual agents; they share the assumption of individual agents closed in themselves. In states of radical uncertainty this hypothesis cannot provide a solution to the problem of co-ordination. The concept of a network provides a feasible solution, however Granovetter does not refer to a network that links agencies already out there but to a network that reconfigures their ontologies. Agents do not have a fixed identity as their interests and objective are transformed along with the form and dynamics of their relation. Hence, actors, become calculative as a result of their connections (Callon, 1998a).Granovetter's solution is similar to the actor-network explanation of the relation between actor and network. Innovation can be perceived as a state of radical uncertainty; therefore Granovetter's rejection of autonomous, isolated agents can apply. When adopting network concepts of agency one should be cautious to avoid reducing agency to structural calculations. An agent's social relations should not be seen as determining his strategies, because in that case relations are seen as resources to be mobilised. Action should not be separated from its resources (Callon, 1998a). To summarise, Granovetter (1985) addresses the classic questions of social theory concerning how social relations affect behaviour and institutions. Yet, a situation without social relations exists only in thought experiments. A dominant view in social theory is that behaviour is rational and interest-seeking, only minimally affected by social relations. This view is juxtaposed with the argument of embeddedness: behaviour is already constrained within social relations, so it cannot be studied independently.

A relational view to agency is summarised in Latour's (2005) presentation of actor-network theory. An actor does not act alone, neither is s/he the source of action; rather an actor is who is made to act by many other, it is never clear who initiates the action. Actors are described as actor-networks to indicate the uncertainties on the sources of action. Simultaneously actors are more than mere place holders, in that sense they cannot be reduced to social positions. Rather the position could be viewed as resulting from the actors' activities.

In addition to the relational view of agency in social theories, additional support to the dissolution of agency-structure dichotomy originates from conceptualisations of agency in technological entrepreneurship. In these cases, agency is considered with regard to innovative activity. Garud and Karnøe (2003) argue that technological and entrepreneurial agency are characterised by distributed and embedded nature. Agency is distributed among actors as each of them can mobilise a unique set of skill and resources required for the development of an innovative idea. Hence, agency is distributed as the feasibility of any technological path requires the contribution of expertise that resides in a number of diverse actors. This argument is consistent with Schumpeter's view of innovation as the 'making of new combinations'. Technological agency also becomes embedded as a technological path is

shaped through the actors' accumulated inputs; therefore it influences (constrains or enables) any future innovative attempts.

Relationism as one of the foundational paradigms in social theory has been explored by Emirbayer (1997). It is juxtaposed to substantialism which argues that the social world is primarily comprised of entities rather than relations. It is argues that the main question in social science should be the contradiction between substantialism and relationism rather than between agency and structure (ibid.). Relationism however is not the same as relativism (Lynch, 1993): relational knowledge for instance may be situated in context however that does not mean that it derives from individual perspectives.

On the basis of the relational perspective of agency, regimes are conceptualised as networks of actors enacting practices.

2.3.5. Niches, regimes and networks as forms of representation

What is the relevance of the MLP once regimes are perceived as networks? The conceptualisation of networks does not bode well with an analytical distinction of reality into levels, although levels in the MLP do not correspond to the micro and macro approaches. Following from Callon (1992, 1998b) it is remarked that different analytical methods can be used regarding to whether one refers to stabilised or non-stabilised networks (hot and cold situations). Therefore, it is possible to use the concept of levels retrospectively once the stabilised area and the areas where radical innovation is developed have been stabilised. There is an analogy between the two concepts of social (Latour, 2005): as a shortcut it makes sense to refer to social categories and groups. Niches, regimes and landscapes can be seen as such categories. However, when referring to the focus of analysis such categories are best used with caution. In the study of prospective innovation niches will be perceived as a retrospective construction.

It should be taken into account that networks, regimes and niches can be seen as part of the categories devised by social scientists in order to describe reality. However, science also performs the social rather than merely describe it through the categories mentioned (Callon, 1998a; Law, 2004; Latour, 2005). Along with following the deployment of controversies about the world the task of social science is also to identify boundaries and categories (Latour, 2005).Social sciences are thus a type of metrology that devises standards which make the empirical material comparable. The dissemination of the quasi-standards of social science demonstrates its effectiveness in perfoming the social (Latour, 2005). In that context it does not matter whether the categories applied (such as networks and sociotechnical systems) are realistic as long as they provide workable definitions of the social.

Niches and regimes can be perceived as representational devices. Representation is a part of method assemblage where presence can take the form of depiction (Law, 2004). Forms of representation are however also forms of deletion because there are part of reality that are other for a representation to be possible (ibid.). The concepts of framing and overflowing (Callon, 1998b) can also be applied to explain how representation is achieved.

These were introduced by Callon (1998b) in the discussion of economic externalities. Economic externalities are considered a particular form of framing although the notion itself is borrowed from Goffman (1971 cited in ibid). Effort is entailed in the framing of interactions and the containment of overflows. According to Goffman the frame provides a boundary within which interaction occurs fairly independently from the surrounding context. The framing relies on the commitment of the actors but is also established on devices in the outside world. Framing is intrinsically linked to these connections to the outside world. This concept of framing is easily applicable to the discussion of economic transactions and the understanding of externalities.

Two opposed attitudes to framing are discussed each of which emphasises a different dimension (ibid.). In the first case framing is the norm and overflows are seen as leaks that have to be contained. Such an approach is prevalent in micro-sociology. The alternative which is followed in constructivist sociology is that framing is a rare and costly outcome

whereas overflowing is the default condition. Framing is a process that is incomplete and this incompleteness makes it more effective. The contradiction between these approaches illustrates the conflict between economics and sociology and attests to the existence of overflows. In the latter approach framing is an attempt to distance the actors from a network of interactions and position them within a clearly separated space. Despite the framing the actors are also involved in other worlds from which they cannot be completely disentangled. Overflows have many sources and orientations. They have to be identified and measured so that they can be contained. Within the process it becomes possible to frame overflows.

Overflowing is observed in controversial situations which are amenable to framing by becoming calculable. Callon (1998b) distinguishes between "hot" and "cold" situations according to the degree of uncertainty. In the case of hot situations there is a lack of a clear knowledge base and the list of involved actors and their identities are uncertain. Their existence indicates that is it difficult to distinguish between the stages of knowledge production and diffusion and the decision-making process itself. Such discrepancies occur regarding scientific controversies. Framing is based on the assumption that facts and effects are known and quantifiable however in practice the framing process is more chaotic. An aspect of framing is that actors involved in the controversy may have incompatible visions. "Hot" situations have become more prevalent because of the diffusion of technosciences.

In the discussion of framing and overflowing (Callon, 1998b) also refers to the role of the social science in establishing these distinctions. For instance markets are said to emerge from constant negotiation in which economics has to participate. This point resonates with Latour's (2005) arguments on the performative role of social science.

It emerges that the MLP approach and the practice-based network approach are alternative ways of framing sociotechnical change. Sociotechnical change is followed as the result of the interaction between incumbent and emergent practices and actors embedded in networks on the basis of the relational perspective.

3. The sociotechnical system of the printed paper text

Introduction

Prior to examining the role of the electronic book in relation to sustainable transitions, the current state of the printed-paper system is considered. The print-on-paper system is the initial focus of analysis. It was suggested that transitions in progress be examined as a process of network reconfiguration. Also it was mentioned in chapter 2 how it is possible to alternate between the concepts of sociotechnical systems and networks with regard to transitions. The concept of sociotechnical system is applied in order to describe the state of affairs prior to a potential transition and explain how this state has been reached. The terms system/regime are thus applied when referring to the incumbent sociotechnical configuration. The term network refers to the contingent processes of a transition in progress. The print-on-paper sociotechnical system is described through the evolution of the involved practices and technologies.

Initially the systems boundaries have to be identified. The identification of system boundaries has not been consistently addressed in the available literature as has been demonstrated in criticism (Berkhout et al., 2004) and responses (Geels and Schot, 2007). The concept of societal function is applied in order to identify the boundaries of the print-on-paper system. In chapter 2 the limitations of the societal function concept were considered and how they need to be addressed or at least acknowledged. In addition, there is the added complication that a societal function co-evolves with the sociotechnical system it defines. In this chapter the societal function of the print-on-paper system is described. For analytical reasons the definition is limited to the role the book as this is embodied in the form of codex. The book is perceived as a specific type of printed text that is the sociotechnical artefact around which the system is structured. The distinctive characteristics of books in the era of print are identified and it is considered how they have been shaped by technological developments.

Secondly, developments in the book system are considered since the introduction of print culture. These developments show the embeddedness of the book in the media culture. Key points of evolution are identified and are interpreted according to the patterns of transitions. In that sense different dimensions of the book system can be examined historically. This is achieved through the use of historical sources on impact of printing technologies. This analysis makes it possible to draw parallels between historical and current developments and illustrate how technologies have interacted with practices in order to create the book as a cultural and sociotechnical artefact.

Thirdly, a description of the current state of the print-on-paper system is provided focusing on book production. This description is more formulaic in that it does not refer to specific actors and interactions but to categories of actors and their interrelations. In that sense, the book system is conceptualised as a value chain. The notion of regime dimensions is used in order to provide a representation of the system.

Finally, more recent developments in the print and publishing industries, which are indicative of interaction between the Information Technology and the print-on-paper

publishing world, are discussed. It is considered how these pertain to book production although they do not refer to the electronic books as such but are rather perceived as incremental interactions.

3.1. The societal function of the print-on-paper system in relation to the book

Societal functions are used as the criterion upon which the distinction between systems is made. However, there is not always a clear association between a societal function and a sociotechnical system. Furthermore, some systems may partly overlap in their societal functions or their respective function may be too generic to provide coherence. With regard to the printed-paper text the difficulty lies in that that the term encompasses a variety of documents. Considering the categorisation of printed documents, books comprise only a small part of the total (see chapter 1, Smyth and Birkenshaw, 2001). By focusing on the documents that can be termed as books the concept of function has to be restricted further. However, despite the differences in usage it is possible to identify a generic societal function that is served by the production and distribution of printed material. In that sense, the needs covered by printed paper have to be articulated so that its existence as a separate sociotechnical system is justified. Therefore, the purpose when defining the societal function of a system is to distinguish it as clearly as possible from other sociotechnical systems that may have similar functions and to ensure that there is coherence within the system in the form of shared practices. However, our discussion begins by assuming that print-on-paper comprises a particular system. In that sense it is the technology (printing) that precedes the function. Print is a communication system therefore there are analogies between print-on-paper and other media. These analogies affect the identification of points in transition.

Although the societal function of a system is discussed regarding its end purpose, functions are divided in the intermediate areas of production, distribution and consumption. With regard to the print-on-paper and similar systems based on communication separate functions can be identified regarding the actors involved.

The general function of the print-on-paper system, which links diverse types of printed material, can be identified. A definition that can serve as a starting point is that the function of printed paper texts has been to develop, preserve and diffuse (usually textual) information (Sutherland, 1996). This definition is generic enough to apply to different types of material and at the same type distinguishes the printed texts from alternative forms of communication. In addition, referring to the discussion on practice these functions only provide cursory information on how people use printed text in the course of everyday activities and how they feel this medium responds to their communication needs. The concept of reading practices addresses this limitation. Considering the variety in the forms of printed material one should consider how the function is accomplished for different types of printed text. As a means of communication print is not ubiquitous: any society has had a system for preserving and exchanging information, however, print cannot be related to basic human survival needs. As it is argued, books are a luxury for most and a necessity for few (Feather, 1993). Its importance and whether it is perceived as necessary varies historically and geographically. In chapter 2, it was discussed how the term societal function is problematic in that it has teleological connotations. In the case of the print-on-paper system the concept is applied as a heuristic device to understand some of its uses and evaluate its performance. The

theory of social practices as has been applied in the sociology of consumption provides a more detailed account of how users interact with products (Warde, 2005). Considering that print is a means of communication some media studies approaches are introduced that contribute to the critique of societal functions by suggesting alternative ways of discussing the roles of the media and this discussion is applied to the print-on-paper system. A general description has been given on the societal function of print but the different interpretations this may have on the relevant social groups are ignored in a general definition.

There is a critique of functionalism raised in media studies discussion (Couldry, 2004). Functionalism perceives that whatever activities people engage in should result in a functioning whole. This approach is implicit when the term societal function is used. Society and culture are viewed as self sufficient systems formed of parts each of which contributes to the "whole". In that sense, whatever happens in the "parts" is absorbed in the broader system and action has no unanticipated effects. Functionalism is a common approach in media studies but it obscures research on the use of the media, as it is assumed that things happen to contribute to a pre-existing function. By emphasising media practices, there is no reason to claim that whatever people do in relation to the media should add up to a functioning whole. It was considered that social practices could not be understood without the perception of society as a functioning whole, since agency as it is exhibited through practice could not be explained without social structure. Still, social order can be exhibited at the level of individual practices (ibid.).

Couldry (2004) does not refer specifically to functions or practices related to printed text. Still, one could paraphrase his questions regarding media usage: "what are people doing in relation to the media across a whole range of situations and contexts?"(ibid., p.119). By applying this question to printed text and in particular to the book, it becomes evident that the book has varied end uses that should be taken into account when considering prospective transitions in the way these are delivered. The concept of media practice indicates that the interactions between users (readers) and printed material differs according to the readers' intention and the context of the action. The interaction between books and readers differs according to the intention of the action as is shown in the literature on reading purposes (Schilit et al., 1999; Brown, 2001; EDSF, 2001b). The same action can be seen as part of different practices regarding the context and the users' motivation (Couldry, 2004). Reading practices are thus multi-faceted. It was remarked in the previous chapter how the concept of practice helps to avoid the teleological implications emerging from the focus on societal functions. In that case it was observed specifically how this is achieved with regard to the use of the media such as the printed text. In the following sections it is discussed in more detail how the function of print has been constituted and considered how books are distinguished as a particular form of reading matter.

3.1.1. Print as means of information and communication

Despite the limitation of the societal functions terminology, identifying some general functions of the printed paper text helps to understand the scope of the sociotechnical system. Because it would be extensive to consider the functions of all types of printed documents, emphasis is placed on the printed book, which in the form of the codex has been the main physical format for texts since the late Roman times when it substituted the volume /roll (Bowden and Robinson, 2000; Sutherland, 1996). Book publishing is the first cultural industry. In this section, the function of communication is firstly discussed as the printed book belongs to the communication media and its role has to do with the diffusion of information. Then, a definition of books is provided and books are distinguished from texts prior to mentioning the functions of the book more particularly. This way the technology is segregated from the content. Finally, the attributes that define the essence of the book are mentioned and it is identified how they have emerged historically and how they affect users' expectation of what constitutes a book. This way, it is possible to question the possibility of transitions in the sociotechnical regime regarding the production of books as it becomes evident that the book is a sociotechnical artefact susceptible to new interpretations.

A model for the functions of communication has been suggested by Jakobson (cited in Fiske, 1990). This is applicable to different media. The model seeks to combine the linearity of the processual approach of communication with the emphasis on *texts* in the semiotics school. The processual approach and semiotics are the main schools in the area of communication studies. Jakobson (ibid.) identifies six constitutive factors in the act of communication. The addresser sends the message to an addressee. The message refers to something other than itself, namely the context. Two factors are added: contact which signifies the physical channel and the connection between the addresser and the addressee, and the code as the shared system of meaning by which the message is conveyed. There is a hierarchy of communication functions related to these factors. The emotive function, commonly labelled as expressive, describes the relation of the message to the addresser. It conveys the addresser's attitude and emotions. The conative function refers to the effects of the message on the addressee. The referential function refers to the context and represents the reality orientation of the message. The phatic function keeps the channels of communication open and maintains the relationship between addresser and addressee. In practice, it confirms that communication is taking place. The metalingual function concerns the code used. It signifies not only the language but a system of meaning. The last function is the poetic, which concerns the relation of the message to itself regarding aesthetics. Not all functions are equally important in any communication setting. For instance the referential function is more important in factual communication or the poetic function is more prevalent in artistic communication. This conceptualisation of functions differs from that proposed in the transitions literature in that multiple perspectives are taken rather than simply referring to the end function of a co-ordinated system.

As these distinctions are applied to the printed paper text, it is remarked that functions do not only affect the end user. The phatic function includes the physical channels of the communication; in the case of print this may refer to the book as artefact. The emotive

function indicates that print provides an opportunity for the self-expression of the author rather than satisfy the readers' needs. It becomes possible to examine the function of the printed text without focusing solely on consumer practices. Couldry (2004) refers more broadly to media oriented practice rather than audience practice. In audience research consumption was the "determinate moment" in the consumption of meaning through texts (Hall, 1980 cited in Couldry, 2004). In a sense texts (in the sense of media products) constantly mediate between the world they were produced, including the economic factors of their production, and the world they are consumed (Couldry, 2004).

Generally, print is a means for the development storage and diffusion of information. More precisely, print concerns textual communication. However, since their inception printing was not intended specifically for texts (Eisenstein, 1993). By deciphering the meaning and categories of information, the question arises how print as a medium can handle different types of information. In the next section it is questioned what types of information are included in printed text and how print as a medium is effective in managing this information.

i. The nature of information in printed texts

There are different aspects in an information message other than the content itself. Tenopir and King (1996) distinguish among three components in an information message.

1. Information content , which regards the meaning of the message

2. Information form consists of two subcomponents. Information content, not in the sense of meaning, but with regard to the type of data used e.g. text or numeric and information structure, which is the means of expressing the content. One could say information structure defined this way is similar to communication code in Jacobson's factors.

3. Information medium, which is the package in which information is communicated. The medium should provide storage of the information and ensure timely access. It is of importance as the functioning of the medium can affect the use, usefulness and the value of information. Print falls into this information component. In Jakobson's categorisation information medium would correspond to the factor of contact as far as it includes the physical channel.

There are alternative classifications of information, which take into account the different purposes of documents. Hector (1997) cited in von Ungern-Sternberg and von Ungern-Sternberg (1999) distinguishes different levels of complexity in information. Data represent simple facts, information is organised data, understanding is information placed in context and inspiration regards the making of new connections. By classifying material according to its complexity one can identify how suited print is for these different roles. Regarding transitions towards an electronic format the classification also indicates market segments where electronic is more likely to substitute for print formats. Electronic format is

considered more suited for data. Information in the form of periodicals has largely shifted to electronic format. Works that enhance understanding are too complicated in the sense of making combinations and are more likely to be published in print. Inspiration concerning literature and particularly fiction appears less susceptible to computerisation. Yet, digital technologies permit the development of new genres that incorporate text. In this case the co-evolution between literary genres can be observed –indicating cultural developments-and technology. The idea that the more complex the content of information, the less likely it is to be transported in electronic format finds support in Pickering (1996): tool-texts such as reference books are likely to benefit from the hypermedia attributes in electronic format that would enhance their use value. Still, for texts that provide a narrative or a critical argument, he claims that linearity as it is inherent in the printed text is essential. However, this raises questions on the utilitarian character of text and seems to imply a hierarchy of texts placing fiction above other forms. Interestingly the texts higher on the hierarchy are seen as more embedded within the print format. This argument on whether technology corrupts the domain of culture had also been raised in Morgan (1997).

ii. Books and texts

The concepts book and text tend to be viewed as synonymous. This has not been the case during the introduction of print. Print does not necessarily equal text. Regarding the invention of print it is suggested that it would be more accurate to refer to two separate innovations: print for texts and engraving for images (Bowden and Robinson, 2000, Eisenstein, 1993). Eisenstein (1993) suggests that the potential of accurately replicating images and charts was only possible through print because in the era of scribes it was possible to replicate texts but not images in accuracy. In addition, text does not necessarily imply the use of print as medium. First there is a difference between text as string of written characters and texts as those objects whose main function is to relay written information (Sutherland, 1996). The delivery of the same content can be achieved through electronic media but the question arises whether it is content or form that defines the book. This derives from McLuhan's equation of the medium with the message. Even if there are only minor changes in content we deal with a different entity (Chernaik et al., 1996a). In that sense the meaning of texts is not totally distinct from their physical embodiment. There is a further difference between books and texts. There has been comparatively more research regarding texts rather than books. Books have commercial implications while texts are relegated to the realm of culture.

Still, for practical reasons, it is useful to remember that the text and is "physical instantiation" are distinct. In the humanist view the book tends to be perceived as an ideal, precious object, endangered by technology. Landow (1996) clarifies that the printed book is a product of technology, so any movement away from print is not a shift from something natural and human towards the artificial. This observation is a given in any discussion referring to the evolution of the book. In a sense the development of electronic text makes it possible to de-centre the book and view it as a technological object. Books are communicating and teaching machines and the functions involved in their production are as

technological as can be. Books, like computers, handle, store and display text. Sutherland (1996) claims that books are inauthentic as material objects because authors author texts but not books. Books present one authority by means of another as the text takes a material form. In that sense they are unlike other artistic artefacts such as paintings. The book as an artefact is a collective achievement as can be demonstrated from the supply chain of printed paper. In the section referring to the evolution of the books it will be discussed how technologies have changed the concept of authorship. Perceiving the book as technology helps one to conceptualise the sociotechnical system in which books are the core artefact.

iii. Attributes of the printed book

The main attributes of the printed book are described in order to define its essense. These attributes relate to the book's role in developing preserving and disseminating textual information. In Eisenstein (1993) it is noted that the development of print led to radical dissemination and much wider accessibility of texts compared with the age of scribes. Dissemination relates to the repeatability as one of the main characteristics of print as it made possible the mass replications of copies. Besides dissemination, print led to increased standardisation of texts as replication was mechanical and not subject to individual errors. Also, since books were no longer produced on demand but for a market there was a need to standardise texts for the average user rather than customize them to individual demands (ibid.) Preservation is probably the most important characteristic that has been introduced by the duplicative power of print. Prior to print no texts could be preserved without suffering gradual corruption by copyists. Durability depended on the quantity of material. Through printing quantity became more important than quality regarding preservation. The more copies available, the most likely it was for a text to survive. In the case of manuscripts diffusion threatened their preservation, however wide dissemination facilitated the preservation of printed texts (Eisenstein, 1993).

Therefore some of the main characteristics of print have been established since its introduction. The attributes of printed books can be summarised as follows: durability, multiplicity, fixity and collectivity. As a secondary attribute their mostly commercial character since the advent of print has helped to define books as a cultural industry and indicated tensions between the commercial and the cultural which can be seen to impact on its future. Regarding durability it is observed that there is a cultural concern for the preservation of material. Print was initially considered inadequate for preservation as paper is less durable than parchment. Printed books tend to be more durable than other modes of communication. Regarding electronic texts and durability, the paradox that electronic text is simultaneously more and less durable is noted. Digital text can be reproduced infinite times without wear-and-tear but since it can be recalled and disappear from a screen it is at the same time transitory (Chernaik et al., 1996a). The printed book is more durable because it provides a completed version of texts as works, in the case of digital text there is fluidity regarding the standard version of a text (Sutherland, 1996).

In addition, texts have a collective character partly because they are mass produced. Unlike manuscripts that had a degree of customisation, there is uniformity in printed text and

information is presented in the same format for all users. Printing has added two main qualities to the written text: multiplicity and fixity (Landow, 1996) these qualities have changed our perception on education and scholarship. For instance, the availability of large number of identical manuscripts has removed the aura of uniqueness that surrounded manuscripts and changes the ways that information is preserved (ibid). It is doubtful whether this collectivity and uniformity can be preserved in electronic communication as electronic means allow for customisation of content. It can be argued that as printed text is collective it adds to social cohesion. Regarding fixity one can argue that in the electronic format there is no completed version of a text. While the printed book offers a sense of completion, the electronic text lacks that (Sutherland, 1996). In the electronic realm fixity recedes in favour of reconfigurability and malleability of the text (Chernaik et al.1996a)

The commercial character is inherent in the printed book. Perhaps, surprising for a cultural industry the book has always been fairly independent from state funding (Feather, 1993). However, they are at stages subject to regulation. There are some indications of commercial activity regarding manuscripts (Eisenstein, 1993).

Finally printed text is distinctive regarding the user artefact interface. Unlike electronic communication no intermediaries are required (Chernaik et al., 1996a).In addition, books present texts in a sequential order and this affects the processes of understanding. The electronic text in the case of hypertext is diffuse open and multiple, with no defined sequence (ibid.). The linearity of printed text appears to reduce the agency of the reader; on the other hand sequential order is embedded in our understanding of texts. Linearity is seen as a property of narrative so it is claimed that only tool –like texts will benefit from their transformation to hypertext format. To a degree some hypertext functions exist in print such as indexes. The introduction of these "hypertext" functions was connected with the standardisation of texts (Eisenstein, 1993) Books that provide a narrative or a critical argument benefit from a linear sequence (Pickering, 1996). Linearity is rather an attribute of the text than of the book.

The question that arises is how important these attributes are and whether any radical change in the sociotechnical system of the printed paper text should preserve them. For instance, linearity has benefits for more complex documents. Still there are arguments on the benefits of hypertext with its open –ended structure. In a sense hypertext provides a new perception of textuality (Chernaik et al., 1996a). It is not straight forward to predict the consequences of such changes, as "we project on the future only the similar and familiar" (Morgan, 1997, p.16). Considering the effects of print as a communication revolution and the effects of information technologies on communication one can identify similar fears regarding the effects of the technology on knowledge and scholarship (ibid.).

3.2. The evolution of the print-on-paper system

The history of the books constitutes an interdisciplinary research area. Some of the issues discussed in relation to the societal function of the book have been approached with regard to book history such as the relation between the book as a material object and the text. The discussion of sociotechnical transitions refers on historical sources regarding the

development of the system in question. Yet, the transitions literature does not provide a critical discussion into the historical methodology applied for data collection. The interpretation of this historical data by transition researchers may differ. First a short overview of the approaches prevalent in the book history field is provided. This ways one can find analogies between the historian's framing of the field and the framing consistent with the sociotechnical transitions approach. Next the historical information is used in order to identify stages of its developments in relation to the various dimensions of a sociotechnical regime therefore a combination of technical and other dimensions has to be considered. The timeframes identified by book historians can be related to the criteria for defining transitions. In addition, analogies can be found between considerations brought by earlier technological developments and the challenges raised by the application of information technology.

3.2.1. The book history as a field: paradigms and main questions

Some of the main questions raised by book historians were shortly discussed in the previous section regarding societal functions. To a large degree the book history field has been concerned with the impact of books. In the field of books history different types of printed material receive equal attention as topics of study. Book historians have been concerned with text and their physical form. Books are considered medium for the material form of a text. The alternative term print culture is sometimes used instead of book history. Book historians have also emphasised that the dissemination of text is not straightforward (Finkelstein and McCleery, 2005).

In its origins book history relates to a number of fields such as Bibliography, Literary Studies and Social History. It is therefore inherently interdisciplinary. One of the incentives behind its development has been the need to identify the authoritative version of the text. As a result increased attention is paid to the material description of textual production. The role of actors other than the author's was examined in order to see how their version of the text deviates from the author's intentions. Such was the New Bibliography approach to texts. Subsequently McKenzie's (cited in ibid.) work that the physical production of texts is context- dependent and therefore the study of texts necessarily extends beyond pure textual meaning. The meaning results through subsequent acts of interpretation in the lifecycle of texts. Therefore the study of texts has to avoid boundaries posed by academic fields. McKenzie argues towards a sociology of texts: the analysis of texts should extend beyond their meaning to the circumstances of their production (ibid.). A comprehensive sociology of texts (McKenzie, 1981 cited in Finkelstein and McCleery, 2005) acknowledges that texts result from a collaborative process. This approach has been followed on by French historians that avoided deterministic discussion of the role of print considering that books are on historical agent among others ((Finkelstein and McCleery, 2005). McGann (1991 cited in ibid.) complements McKenzie on the sociology of text by arguing towards the socialisation of texts: texts are seen as embodied phenomena that should be not analysed through an exclusively linguistic approach. This is consistent with approaches in textual studies that once the format changes we are dealing with a different entity even though the text remains invariable (Chernaik et al., 1996a). One question in book history is how changes in textual production affect reading practices. .

The distinction between book history and print culture is that book history sees textual production as embedded in human communication structures while print culture is concerned mostly with the effect of texts (Finkelstein and McCleery, 2005).Broadly described book history refers to the entire history of written communication referring both to technical developments and the use of script writing on different media (Greenspan and Rose, 1998 cited in ibid.).More specific topics in book history refer to the role of authors and readers. Critical definitions of authority have been influenced the book history field and in addition there are likely to be redefinitions of authorship in the digital era. The role of readers has been a neglected topic. Reading as a social phenomenon and an individual activity is approached in book history by considering changes in reading practices (Finkelstein and McCleery, 2005).

Within the book history field concepts relevant to that of the sociotechnical system have been developed. Darnton (1982 cited in ibid.) introduced the concept of the communication circuit which suggests that books should be studied through the interaction of various agents involved. The concept allows for the understanding of textual production as a complex endeavour. The communication circuit includes the authors, publishers, booksellers , printers, shippers and readers and allows for interactions upstream and downstream the supply chain: for instance the effect of readers on authors choices in the serialised novels and the influence of booksellers on publishing decisions have been examined. It could be argued that the main advantage of Darnton's approach is that it recognised the diversity and reciprocity of the actors involved. Therefore, it differs from the linear descriptions of supply chains. Although these advantages in terms of social history are acknowledged the concept has been criticised as focusing on communication processes to the detriment of the role of books as artefacts (Adams and Barker, 1993 cited in Finkelstein and McCleery, 2005). In their bio-bibliographical communication circuit they propose a shift of emphasis towards the lifecycle of the text. Book historian have tended towards framing their work in terms of mediation: it rejects the premise that the printed text is the author's word and implies the number of factors that affect a text's transmission (Rubin, 2003 in Finkelstein and McCleery, 2005). These concepts lead to an understanding of texts as hybrid entities.

3.2.2. Stages in the evolution of the book

The history of writing discusses both changes in the production processes (technology) and the industry structures. The main stages of the evolution of the book as they have been identified by historians are mentioned and then interpreted according to the available transition pathways. The role of the printed book in historical periods is identified. Changes in publishing structure and business models are considered along with changes in technologies. In addition it is considered how the role of authors and readers has evolved. Analogies and discontinuities between the manuscript and the print era are provided. General models on the history of communication have identified three main stages (Finkelstein and McCleery, 2005). The history of the book is embedded within these transformations.

1. The movement from oral to written culture

2. The movement from literacy to printing

3. The current transformative phase characterised by the movement from print towards computer-generated content

The movement from literacy to printing refers the development of the manuscript culture, the invention and diffusion of printing and the mass consumption of print material through industrialisation. The social and cultural shifts relating to technological changes in communication have been identified. For instance, printing has been linked to the rise of individualism and a shift from magical cultures (McLuhan, 1962). Walter Ong (1982) in Orality and Literacy discussed how print imposed linearity on cognitive experiences. In addition, print has related to a sense of completion. This relates to the concept of fixity identified by Eisenstein (1993). The boundaries between these stages in communication systems are fluid and partly overlapping (Finkelstein and McCleery, 2005). The three stage model of textual communication is a useful guide however it does not account for innovations that have created equally important transformations. Examples include the replacement of the volume roll by the codex and the invention of copyright (Chartier, 1997 cited in ibid.). Regarding the concept of authority there has been a move from author to reader-based analysis. The deconstruction of the role of the author has allowed for the birth of the reader.

The shift from the role to the codex is related the writing material available. Papyrus is flexible enough but too sensitive to be cut into pages. Parchment enabled the introduction of the codex with writing on both sides since 40-103 AD. Although Romans preferred the standard scrolls Christians used the codex because it was easier to consult and to maintain. By 400 AD the parchment codex and the more expensive vellum version was roughly standard throughout Europe (Finkelstein and McCleery, 2005). The invention of the copyright in the 18th century established the authors' control over their work and transferred the emphasis on texts rather than books as an asset (Chartier, 1997 cited in ibid.).

Following these three large stages in this section the transition towards print culture is emphasised and the characteristics of its stages are mentioned. Thus, points of transition in the print of paper system can be identified. In that case transitions regarding textual communication rather are examined than the prevalent communication systems as a whole, although the role of print in relation to other communication systems is evaluated.

i. Introduction of printing to the Industrial Revolution

Regarding the development of printing itself it tends to be seen as an individual invention in popular history however is was an agglomeration of distinct innovations (Finkelstein and McCLeery, 2005). The application of moveable metal type to printing built on already established skills. Skills relating to the screw-press, wood-cutting and writing master were combined in printing (ibid.). Hence it can be perceived as a modular technology. Technologically the pattern of transition towards print was more similar to reconfiguration in that it combined pre-existing technologies in a new application. However once the societal effects are considered and the transitions is viewed in terms of textual communication the pattern is more akin to the substitution pathway as print replaces manuscripts.

It is important to remark that the diffusion of print was so rapid that it can indeed be viewed as revolutionary (Eisenstein, 1993). The fast growth of printing during its first century was attributed to the lack of trade structures that referred to other professions (Finkelstein and McCleery, 2005). Although there are difficulties in quantifying manuscript production, the introduction of print has led to mass increase in output; therefore an evolutionary model of change is not adequate for what is best described as transformation (Eisenstein, 1993).

One of the basic discontinuities between the manuscript and print culture is that books moved from collectable to tradable commodities. Some changes in written culture with the introduction of printing relate to the commercialisation of books. Printing firms were located in commercial centres rather than university or religious towns. Developments in textual communication refer to the business structure and consumer practices instead of the technology. In the incunabula period all processes related to book production and selling were undertaken in the same firm (Finkelstein and McCleery, 2005). Early books closely resembled manuscripts (Eisenstein, 1993; Finkelstein and McCleery, 2005) although gradually changes were observed in the presentation (fonts etc).Gradually early printers developed into publishing businesses that distinguished between production and sales. Printers were dependent on effective distribution because of the physical characteristics of books. Therefore the intermediaries in the sales circuit were more useful acting also as publicity agents. Until the 17th century there was however little distinction between publishers and booksellers (Finkelstein and McCleery, 2005).

Early innovation in printing was the introduction of Italic type and the use of octavo format that led to the first pocket-size editions focused for personal ownership (ibid.).

Early resistance to literacy and print culture is similar to what can be observed regarding the diffusion of digital technologies. Distrust towards printing was similar to the distrust towards literacy. Lower classes tended to be suspicious because writing was linked to privilege and power. With the advent of print there were concerns that it would lead to the commercialisation and the corruption of knowledge (Morgan, 1997).

As mentioned earlier the development of printing was not specifically related to books or pamphlets. Map making became an important activity as the new worlds were discovered.

Hence one could refer to two distinct innovations: printing for texts and engraving for images (Eisenstein, 1993)

In the Enlightenment Era (18th century) the role of print extended from the public to the private sphere as there were a new group of consumers purchasing books for use in private (Chartier, 1989 in Finkelstein and McCleery, 2005). The nature of reading in the 18th century also changes because of the increased availability of material (Finkelstein and McCleery, 2005) In addition the reading public expanded as new forms of literature (e.g. novels) were targeted to women (Briggs and Burke, 2005)

Since the invention of printing no significant changes were observed in the technologies or business models involved until the industrial Revolution. Regarding business models these remained fairly stable till the early 19th century. Printers integrated the activities of publishing and book selling but as their operations internationalised these roles began to separate into different firms (Finkelstein and McCleery, 2005).

ii. Industrial Revolution -late 18th century till mid 20th century

However it was only in the industrial revolution that significant changes were observed regarding technological developments in printing. In addition, there were social changes that changed the profile of the readers as literacy levels increased. Urbanisation increased demand for books and other reading matter. The printing industry benefited from technological development such as steam power to achieve mechanisation. This was the first time since Guttenberg when sufficient improvements were made in manufacturing processes. Industrialisation made the switch from hand to machine presses and the traditional wood-screw was replaced by metal ones. Development towards full mechanisation originated from the periodical press and newspapers. The industrialisation of book production generated growth in output. In addition the birth of new literary forms accompanied these technological developments. Finally publishing became a more commercially oriented industry (Finkelstein and McCleery, 2005).

The application of steam power in the mechanisation of printing processes is a past example where the application of a generic technology has led to technological transformation in the sociotechnical system of print. Steam was the core technology in the second technoeconomic paradigm; therefore there are analogies between the role of steam at the time and the generic technologies today.

This commercialisation of the industry led to the development of an intellectual property rights regime. This signified a change from the emphasis on the books as a material object towards the texts (ibid.).

Towards the 19th century the book trade benefited for improved communication and distribution networks as well as from the rise in literacy relating to the need for a better educated workforce (ibid.). These changes could be characterised as landscape developments. Publishing increased its commercial focus and became more professional as indicated by the establishment of relative societies.

Developments in the 20th century include the growth in the market of paperback books. More importantly print has ceased to be the main mass medium with the development

of electronic alternatives. In this sense we are already beyond the book as the main communication medium.

Regarding transitions in the print-on-paper system one can identify the initial transition from manuscript to print communication. There is ambivalence to what degree the development of print culture can be regarded as evolutionary or revolutionary (Briggs and Burke, 2005): it is questioned whether a slow revolution can count as a revolution at all. However, the diffusion of print was much faster in relation to that of manuscript (Eisenstein, 1993). The transition towards mechanisation and mass consumption is situated in the late 18th-early 19th century: in that case illustrates the co-evolution of printing technology, reading practices and business models while landscape developments affected market growth.

3.3. The current configuration of the print-on-paper sociotechnical system

3.3.1. Representations

The nature of the societal function of the print-on-paper systems and the main points in it evolution were addressed. It appears that a number of subfunctions are undertaken in sociotechnical systems. These are not considered with regard to their contribution in the end function, instead it is considered how they relate to different actants in the print-on-paper system. The components of the system are discussed viewing them as sociotechnical practices that contribute to the end practice of reading. This description does not follow the individual actors involved but discusses groups of actors related to these sociotechnical practices and the main technologies incorporated in the system.

The actors involved in the reproduction of the sociotechnical system can be categorised into different sectors although the sectoral classification would not apply because the related sectors are not fully embedded on the print-on-paper system. The approach taken for describing the print-on-paper system is to identify the groups of actors involved and how they are related to incumbent and emergent activities. Available descriptions of the print-on-paper system are used. Then some characteristics of the print-on-paper system are discussed and they are interpreted according to sociotechnical regime dimension and the notion of actors involved in the reproduction/maintenance of a sociotechnical system.

Some of the available representations of the print-on-paper system are discussed although this is not usually the terminology chosen. Instead there are descriptions either of the paper supply chain or of books publishing. In addition one should remark that book publishing tends to be a rather neglected industry in management studies (Keh, 1998). Although the field of book history is well established the book system at present has been subject only to limited study (Thompson, 2005). Examples include its description in the form of supply chain appropriating similar diagram forms. These diagrams are similar to those used in life cycle analysis.

One such example (Keh, 1998) describes the book publishing using a framework of vertical relationships. It follows the observation that the industry is vertically differentiated. This has been a characteristic of the book market since the 19th century. This framework takes into account the duality of books as sociotechnical artefacts since it considers both the activities relating to book content and those referring to the material aspects of books. It is not exhaustive in terms of the actors it includes; for instance the institutional market for book is neglected. In addition, it focuses mostly on trade publishing. Still, it provides an account of the set of relation involving book production and reveals the commercial nature of these.
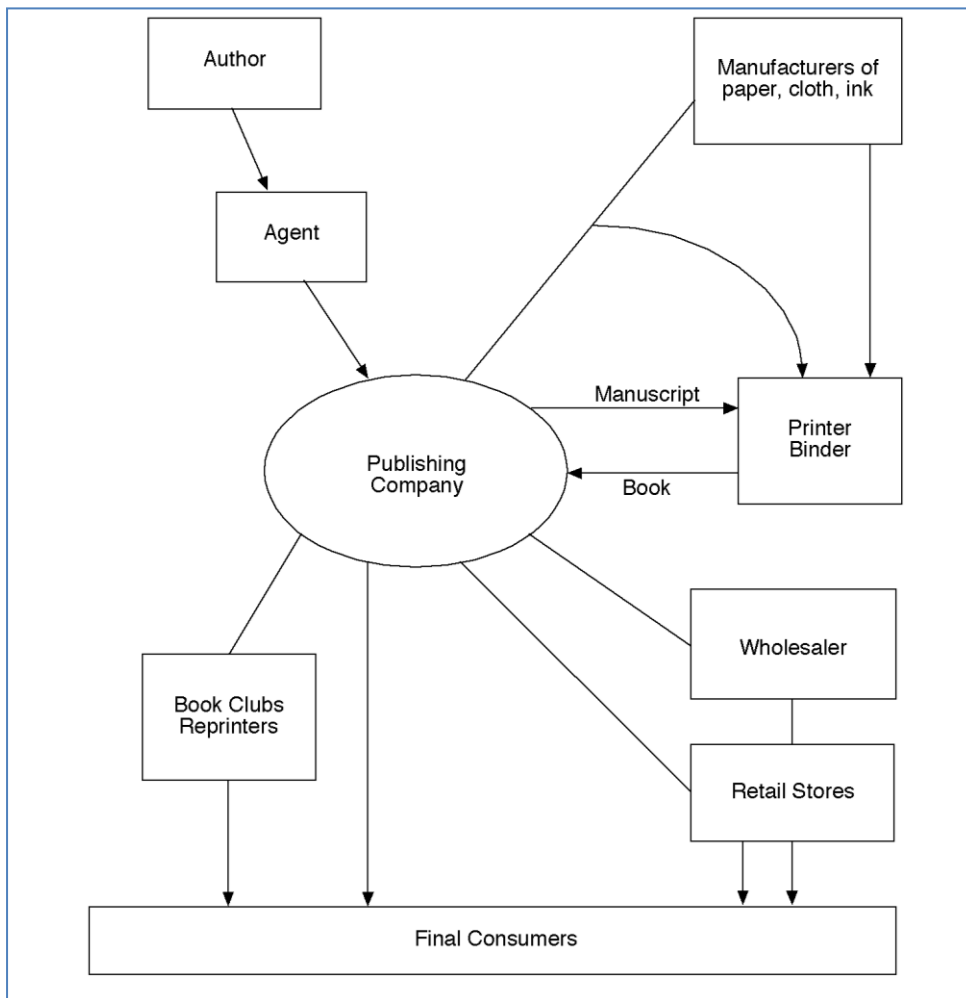
Figure 3.1: Framework of vertical relationships(Keh,1998 p.108)

The publishing company is placed at the centre of the graph as is mediates between the production and retail of books. Books as texts originate through authors that are represented by agents. Agents contribute to the transformation of the manuscript in a commercial product. The publishers outsource the manufacturing activity to the printers/binders and necessary materials are provided through the paper manufacturers. This representation emphasises the interdependence of different actors in related sectors.   The supply chain as far as it regards paper would be developed further upstream. However, this is an example of how the paper supply chain tends to be seen mostly independently from other aspects of book production.

In addition, a report by the Paper Industry Research Association (Smyth and Birkenshaw, 2001) provides an account of the print supply chain that is technology- focused: it includes the applications of conventional and digital printing technologies showing that books are only a small subset of total print output.
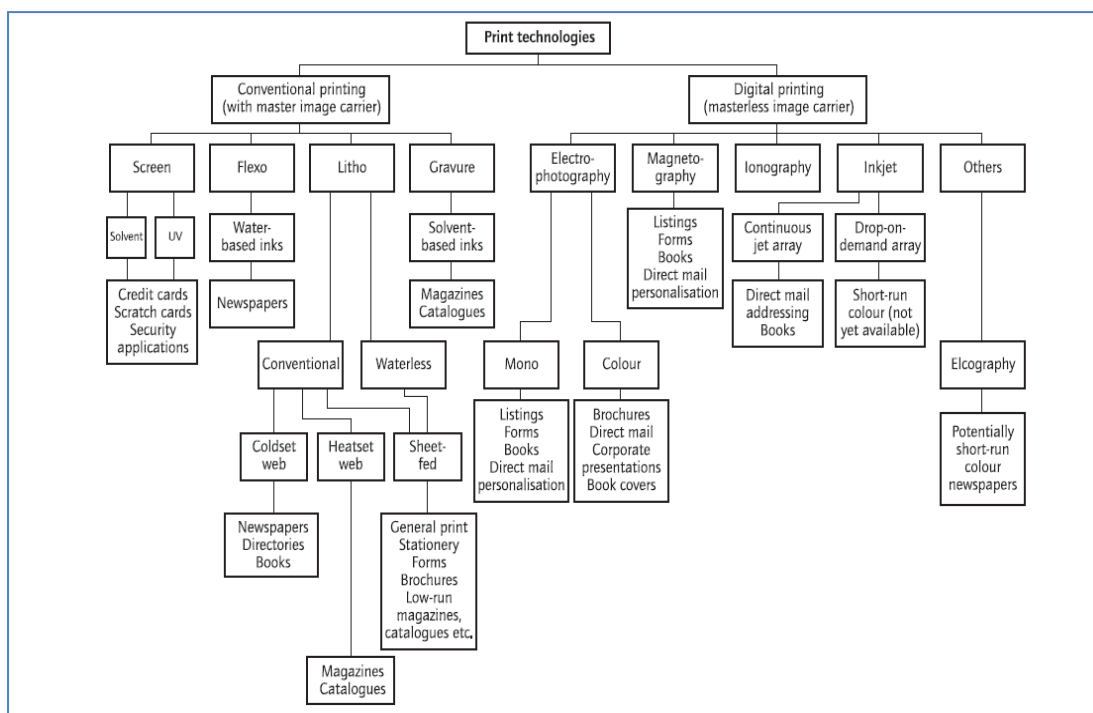
Figure 3.2: Smyth and Birkenshaw, 2001 p.22

This description begins from the distinction in print technologies and results in different forms of printed matter. It is thus technologically oriented. Books are perceived as one outcome of the printing processes and only their material aspect is considered.

The aspects of the supply chain that are more relevant to sustainability issues relate to paper production and the life cycle of paper use rather than documents as such. As remarked in chapter 1 only a small percentage of total paper use corresponds to paper used in communication and even smaller results in book printing. The fact that in representations of the publishing supply chain paper tends to be taken as a given indicates why environmental concerns become restricted to the supply of paper rather than incorporated into the whole supply chain.

The book supply chain and the publishing value chain as described by Thompson (2005) incorporate the institutional marked but do not refer to the material aspects of book production although the material process of distribution is considered. Publishing as a value chain signifies that each stage of the process adds some function otherwise the publisher would have cut off these intermediary categories. The conceptualisation of publishing as a supply chain is shown in the following graph.
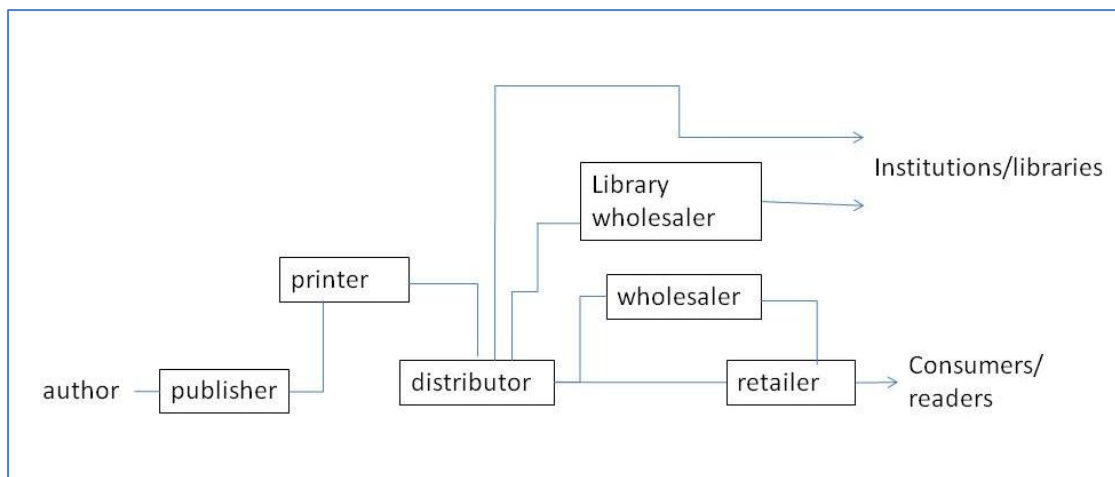
Figure 3.3: The book supply chain (Thompson, 2005 p.20)

On the basis of the sociotechnical regimes it is identified how actors involved in print-on-paper/book production correspond to the dimension of a sociotechnical regime and thus evaluate how the model of regime dimensions is suitable for the representation of the print-on-paper system. However, despite the concerns raised on the sustainability of the current book industry there is not an integrated discussion between representations of the book industry/publishing structure and the discussion of the paper industry. In this sense, considerations referring to paper are marginalised in the discussion on the evolution of book publishing as it is seen as solely the material source. However, in the discussion of sociotechnical systems artefacts and material are important. Perhaps an inherent understanding of the materiality of the social does contribute to integrating the sustainability questions.

A tentative representation of the print–on-paper system according to the regime dimensions could be perceived as follows.

The suppliers have to be distinguished in material suppliers and suppliers of content. The producer network thus includes the publishers. The public authorities involved include the regulation of the book trade. One example is the regulation on book pricing (Ansell, 1998).The financial network includes the financing structure for publishing firms. In the next section the increase in mergers and acquisition in the field shows a change in the ownership structure of the industry. The relevant research network as related to the three generic technologies that can contribute to sustainability cannot be said as included in the regime at this point. Organised user groups would include for instance library professionals.

3.3.2. Issues in book publishing and printing

As far as book production is concerned publishing is the industry that attracts the main research focus. This is expected as publishers mediate in the transformation of texts to books as commodities. However, this focus on publishing helps reproduce the idea of books as cultural products. Hence, recent trends in the publishing industry need to be identified in order to consider the likelihood of transition in the print-on-paper system.

Structural change in the publishing industry is characterised by the following factors:

- Technological change (Keh,1998;Thompson,2005)
- Demand shifts (Keh,1998)
- Merger and acquisitions, consolidation activities (Keh,1998; Thompson,2005)
- Changing structure of markets and channels to market(distribution) (Thompson,2005)
- The globalisation of markets and publishing firms (ibid.)

Technological change is discussed in the next section with a focus on the interaction between digital technologies and its effect on the publishing workflow. In addition, some textual technologies regarding display that do not fall into the realm of the electronic book will be discussed. The effects of technology are demonstrated in parts of book production that are not directly evident to the consumer. At this point one only needs to mention that the rise of new technologies have made the publishers more conscious of their intangible assets (Thompson, 2005).

Demand shifts are demonstrated in the changing attributes of the consumers. Consumers have become more accustomed to using new technologies for their reading needs. Also increased differentiation in consumer interests ensures the expansion of niche markets and the segmentation of the books industry. The interactive nature of some technologies means that publishing firms have less control over the product offerings. Worldwide the rise in literacy expands the book market (Keh, 1998).

Mergers and acquisition have long been an aspect of publishing. Historically the industry has been susceptible to mergers because of low capitalisation. Large international conglomerates have resulted from such activities. There is a concern that mergers and acquisitions impact negatively on diversity as the small publishing firms tend to be more innovative and risk-taking. In addition, there is an increase of mergers and acquisitions across industries (Keh, 1998). This can be seen as an attempt to diversify, develop synergies or acquire complementary assets. Mergers and acquisitions across industries further influence how the boundaries of the print-on-paper systems are defined and how it interacts with alternative systems of communication. The process of concentration differs in different segments of publishing being less prominent in academic publishing (Thompson, 2005). Sociological observation has also indicated that as publishing firms transform to conglomerates the role of editors as gatekeepers becomes more pronounced (Feather, 1993). The globalisation of publishing is also related to the increased consolidation of the industry.

In addition significant changes are observed in the bookselling business, which is also characterised by consolidation. The consolidation of the bookselling industry because of the

establishment of large chains has further restricted the freedom of publishers (Thompson, 2005).

In the face of these developments in the book industry there are some observations to be made on the future of printing with regard to books (EDSF, 2001a). It is expected that the academic sector will more likely shift towards electronic format. Book printing will become more decentralised and closer to the point of use. It can be argued that this development is supported by electronic media as well.

The current state of the printing industry is affected by certain technology enablers that facilitate digital printing (Smyth and Birkenshaw, 2001).These changes allow for digital work flows. The range of services provided by printers increases while traditional services can be provided more efficiently. Centralised asset management facilitates the control of content.

3.4. Incremental technological change on the print-on-paper system

Technological change has been identified as one of the factors affecting the publishing industry. No major technological impact has been observed since the mechanisation of printing processes. In addition the premise of this research is that generic technologies could contribute to transitions in the print-on-paper system and the electronic book is identified as the artefact embodying such transition brought on by Information and Communication Technology. In this section the interaction between Information Technology and the print-on-paper system is examined limiting the focus to those applications of IT that reconfigure the supply chain for printed books but do not substitute for it. Also, reference is made to textual technologies that have resulted in niche products for the publishing industry such as examples of multi-media publishing. This section aims to examine the relation between IT and the print-on-paper system by expanding the focus of their interaction so that incremental innovation can also be considered. For this purpose those IT applications that do no impact directly on the end user or the form of the end product are considered examples of incremental change.

The application of digitisation in printing has resulted in the development of digital printing which enabled the introduction of desktop publishing. However, digital printing still represents only a small proportion of total printing output (Smyth and Birkenshaw, 2001).

Three distinct stages can be identified regarding the effects of technology on the print-on-paper system, specifically on the publishing sector. These broad phases concern the effects of digitisation on publishing. Digitisation was seen as a solution to problems in the book supply chain, for instance the cost of inventory and the problem of returns. In the mid 1990s there were what with hindsight proved unrealistic expectations regarding the development of electronic books. Industry strategy was informed on the concept of disruptive technologies and the risk of missing out on potential advantages. At the point a lot of experimentation in the area originated from outsiders in the publishing field that considered commercial opportunities in the transformation of the publishing sector. This resonates with the view of outsiders as sources of technological development (van de Poel, 2000). From the publishers' perspective there was an interest in by-passing intermediaries (Thompson, 2005).

The second stage followed the dot.com bubble and expressed increased scepticism towards digitisation as a number of products withdrew from the market and publishers who had invested heavily in electronic book imprints and the development of electronic formats had losses. This disillusionment followed a number of consultancy reports that had predicted increased growth (ibid).These two stages correspond to the hype-disappointment cycle in the technological expectations literature.

The third stage of digitisation is described as cautious experimentation. Instead of trade publishing more attention is paid to digitisation in more specialised sectors. In addition it has been recognised that a complex infrastructure has to be developed for the delivery of material in digital format. The impact of digitisation can be seen indifferent processes within publishing firms rather than solely on content delivery. Specifically there are effects at four levels (Thompson, 2005).

1. Operating systems: this aspect refers to the computerisation of the management systems. This development is not unique to publishing. Such developments also in include the management of the supply chain for printing books , for instance the installation of tracking systems

2. Content management and manipulation

3. Marketing and Service provision: the growth of the internet has provided and additional venue for publishers and authors to promote books

4. Content Delivery: this differs to the delivery of content to the final users; therefore it cannot be regarded as incremental change according to the definition of electronic book provided. Main implication would include a restructuring of the publishing value chain. The main themes as identified by publishers refer to hardware, formats, rights and pricing.

The discussion on electronic books touches mostly on the topic of content delivery. The effect of digitisation on the publishing workflow may not be prominent to the end user but it has been characterised as a hidden revolution (Thompson, 2005). The interaction between electronic books developments as such and other effects of digitisation in the publishing flows can be seen as distinct pathways in the evolution of publishing /print-on-paper communication systems and there are points of interaction such as the need for developing digitisation infrastructure.

Thompson (2005) argues that a "hidden revolution" is taking place in the publishing world as a result of these developments. It is hidden because it has not yet affected the consumer reading practices. The rise of digital workflows, digital printing and print-on-demand are aspects of these developments. Digitisation has thus begun by affecting production processes rather than consumer practices. Similar developments have also occurred in the magazine industry (Cox and Mowatt, 2005).

Print-on-demand is in some cases identified as a category of electronic books (Hawkins, 2000). Printing responds to the expressed demand of a client, so that physical stock can thus be replaced by digital warehouses. It has emerged out of the need to produce manuals for the software industry. In terms of technology it is related to short-run digital printing. It competes with traditional methods on costs depending on the desired number of copies (Thompson, 2005).

Furthermore, a set of so-called digital technologies has been identified, which have benefited from digitisation in publishing. Some of these technologies result in hybrid products that combine text with other media. Chadwyck-Healey (2007) positions these technologies within earlier expectations raised about digitisation. The earlier developments occurred in the military and academic sectors. Microfilm versions of newspapers can be seen as a precursor technology. The CD-ROM can be identified as the main precursor technology in relation to electronic books. It has to a degree familiarised publishers with producing hybrid forms of content. Interestingly, the first publisher to widely use CD-ROMs was

Microsoft rather than traditional book publishers. Other developments such as Google's Initiative to scan library content are mostly seen as contributing to the storage of textual material.

It appears that the effects of digitisation so far have affected how publishers and booksellers operate, however they remain embedded in the print-on-paper system.

4. Research Methodology

Introduction-Chapter Structure

A methodological approach is required for the study of sociotechnical transitions in progress. As noted in Chapter 2, studies of systems in transitions and the resulting typologies have emerged from the study of completed transitions as identified by the analysts. The related areas of strategic niche management and transition management are forward looking but they have a normative bias in that their interest is in identifying governance and policy methods that could steer systems towards desirable directions rather than describe potential patterns of transitions in progress or identify whether a transition may be taking place. The main aim of the chapter is to suggest a methodology towards the study of prospective innovation considering the open-ended nature of outcomes. The methodology should be consistent with the understanding of transitions and innovative activity provided in Chapter 2 and the description of regimes and niches as practice-based networks.

Firstly, the foundations of the methodological approach are discussed. Ontological and epistemological considerations are exposed. Ontological questions refer to the nature of social reality and epistemological questions regard under which conditions it is possible to acquire valid knowledge (Gioia and Pitre, 1990; Gill and Johnson, 2002). These topics are too entangled to be addressed separately. Regarding ontological questions they are addressed through the lens of science and technology studies. Therefore, the nature of sociotechnical reality is considered. In addition, as a prerequisite to developing and evaluating the methodological approach the relation between the research process and the topics under study is addressed in view of the implications of social science research on it topics

Having addressed these underlying issues, it is demonstrated how the application of Social Network Analysis could enhance the study of systems in prospective transitions, by pointing out how SNA is consistent with the relational view of innovation that has been suggested in Chapter 2. Specifically, analogies are made between arguments in innovation research and specific SNA techniques. The correspondence between innovation concepts and SNA provides the background for the selection of specific measures. Furthermore, the suggested network approach based on relationism is differentiated from strands of research in innovation networks or diffusion research that draw mostly on a structural perspective. The development the theoretical foundations of SNA as a methodology are presented taking into account the contradictions raised by its application.

Section 4.3 is dedicated to data collection issues. The methods used for collecting relational and attribute data to be used in network analysis are described. In particular, the use of documents and records as a source of network data is emphasised in the context of unobtrusive methods in social network research. Categories of data collected are discussed regarding their contribution to innovation research. These sources of network data are mentioned alongside general problems of data collection and boundary setting in network research. The three datasets resulting from different methods of data collection are presented.

The final section refers to the techniques for data codification and analysis to be used in the following chapter. It is described how the data are codified into network matrices so

that their visualisation and analysis is possible. A distinction is made between structural and relational techniques in SNA; it is described how this technical distinction relates to the relational approach as it is used for the description of innovation. Specific measures are defined and their selection is justified in correspondence to theory and practical grounds.

4.1. Ontological and epistemological assumptions

The methodological limitations in the area of sociotechnical transitions with regard to innovation in progress have been identified and it was suggested that adopting SNA methodology provides suitable tools for addressing the research questions on the future patterns of innovative activity and their sustainability implications. The theoretical justification for a particular application of SNA in the study of innovation will be mentioned. In this section the ontological and epistemological foundations of the study are provided. These concern assumptions on the nature of technology and innovative activity, the possibility to reach reliable conclusions and the relation between actors' own interpretations of innovation in relation to the analyst.

Although ontological and epistemological assumptions may reflect on one another, they should initially be treated as separate decisions. Ontology refers to issues regarding the nature of the object under study, such as whether there is a world existing independent of observation. Epistemology examines whether and how it is possible to acquire knowledge of the world, therefore it is about the philosophy of knowledge. Research paradigms are formed on the basis of ontological and epistemological positions (Gioia and Pitre, 1990).

The study of organisations draws on paradigms. In the context of organisational research, a paradigm is a way of thinking that includes fundamental assumptions on the nature of organisations. Each paradigm can have unique contributions to knowledge. Research paradigms have a position on the nature of organisational phenomena (ontology), the nature of knowledge of these phenomena (epistemology) and the nature of ways of studying these phenomena (methodology).

Burrell and Morgan (1979) introduce a 2 by 2 typology of paradigms in management research according to the dimensions of objectivity-subjectivity and a commitment to regulation or radical change. Managerial research is usually undertaken within the functionalist paradigm, which adopts an objectivist view to reality and a commitment to maintaining the status quo. In the functionalist perspective structure is seen as stable and objective.

Research paradigms provide an interpretation of the dichotomy between agency and structure. The functionalist and radical structuralist perspectives refer to structure as an objective reality, while the interpretive and radical humanist paradigm refer to structuring as an ongoing, socially constructed process(Gioia and Pitre, 1990).Specific research methodologies can be classified across a continuum between objectivist and interpretive approaches(Gill and Johnson,2002). These paradigms accept dichotomies in the agency/structure questions and in the existence of an objective versus a socially constructed reality.

4.1.1. The nature of knowledge of social reality

Despite the differences among research paradigms it can be observed that most research in the social sciences adopts certain assumptions on realism, most of which go beyond a commonsensical use. The nature of the world is inevitably messy and our existing methodological approaches are inadequate for dealing with mess and instead try to repress it (Law, 2003). In that sense, writing is ordering work (Law, 1994). Methods are said to be characterised by a form of intellectual hygiene and they should be broadened to avoid the fixation with clarity and specificity. Research has to be messy and heterogeneous because this is how the world actually is. Definite or coherent knowledge on the world is not possible. What is required is "disciplined lack of clarity". Current social methods attempt to adjust reality so that it can fit into a framework. But knowledge is inevitably elusive and that is not necessarily the result of inadequacy in our methods (Law, 2003).

Realist assumptions on "things out there" tend to inform most of natural and social science research (based on Law, 2003 and 2004).

1. What can be called primitive out-thereness assumes simply that there is indeed a reality existing beyond ourselves. This assumption is not actually implying anything more than stated but it is usually accompanied by additional assumptions.

2. Common sense realism also assumes that reality is substantially independent of our actions and perceptions. This differs from the first assumption because in principle it is possible for a reality to exist that is not independent of observation.

3. Another assumption is anteriority. This signifies that reality in general exists prior to any attempts to know it. Anteriority has effects on the understanding of causality.

4. Definiteness entails that actual reality cannot be vague, undecided, uncertain or elusive. However, this characteristic is not entailed in primitive realism (the first assumption). One should entertain the possibility that when research findings are vague, this is because that is the nature of reality itself rather than a research failing (though this may be the case).

5. Singularity is a final assumption. It is assumed that there is a single reality although it is accepted that there may be different perspectives on it. In particular, one can accept multiple social worlds but a single natural or material reality. However, this is a point on ontology rather than epistemology. It is commonly accepted that reality can be interpreted in different ways. What Law (2003 and 2004) suggests is that there can be different and possibly inconsistent realities.

One can therefore accept primitive realism without adopting the additional assumptions. The implication for social science is that the subject of study is elusive and that is not possible to know something fully. As some aspects of the world become revealed others have to remain hidden and repressed. This is not necessarily problematic as long as we avoid denying this repression (Law, 2003). The idea that some aspects have to remain hidden so that other can be brought forward is similarly expressed in the concept of problematisation (Callon, 1981). The concept of problematisation was introduced as a way of defining scientific and technological problems. Each problematisation postulates the existence of an

actor who attempts to enrol others by persuading them to adopt their own definition of the problem and an assigned role to play. However, it can be adapted as a conceptual tool for defining research projects. Each problematisation comprises three areas: the area of the unanalysed, the area of certainties and the area of suspicions. An initial frontier is set between what will be analysed or not, what is considered relevant and what will remain suppressed. This is similar to selecting and setting the boundaries of a research topic. Then another boundary is defined between what is taken for granted (the area of certainties and the problematised or unknown (the area of suspicions). All three areas serve a function. The area of the unanalysed defines the focus of the research project as it indicates what will not be included in the analysis. The area of certainties indicates that a problematisation must build on some taken for granted knowledge, hence there are usually assumptions underlying the research questions; certain elements are considered irrefutable. In that sense, there is no view from nowhere neither is there a privileged point of observation. The area of suspicion is the core of the problematisation where points of controversy and contestation are raised.

Furthermore, the assumption of anteriority implies that scientific explanations follow the phenomena under study. However, one can observe that in practice it is the social sciences that have created the objects of their study; for example the attempt to establish market conditions followed the theory on perfect competition (Callon, 1998a). Social science theories provide a metrology to make these phenomena prominent (Latour, 2005).

Finally, by questioning the fifth assumption on realism the existence of a single, unified reality is contested. This claim is elaborated in the presentation of actor-network theory (Latour, 2005). The existence of an independent reality should not be conflated with unity and indisputability. This argument is different from the one on interpretive flexibility raised on social construction theories. Instead of arguing that there are multiple viewpoints on the same thing, it is reality itself that is deployed as multiple and thus makes it possible to be viewed through different perspectives that could be unified at a later stage. There are more agencies in reality that scientists and philosophers thought possible. This is a point of difference between postmodernism (social construction) and actor-network theory. Postmodernism attempts to add multiplicity in a world unified by grand narratives, whereas actor-network theory perceives multiplicity as a property of the things themselves, not as a result of human interpretation. In that context objectivity can be reclaimed from positivism. Objectivity in positivism is best criticised by going back to the object and seeing how it is multiple rather than by adding an additional layer of human interpretation (ibid.) Multiplicity indicates that different research practices craft different realities; these realities may be indefinite as well as multiple, therefore lack of definiteness is not necessarily a methodological problem (Law,2004).Variable geometry is demonstrated (Law and Callon,1992) in that is acknowledged that artefacts have multiple identities to different actors.

That lack of definiteness relates to the notion of contingency (Law, 1994). Contingency denies the existence or a pre-ordained social order claiming that things are as they are because of local reasons. One implication is that research should make more modest claims rather than make large scale assumptions. Contingency does not mean that one does

not search patterns however these patterns are more like modes of ordering (processes) rather than expressions of established order (Law,1994).

The aforementioned arguments illustrate that in order to study sociotechnical developments in process it should be considered that the object of study is not immediately evident. Instead of imposing external explanations on innovation activities it is advisable to follow the STS precept "to follow the actors" and their perspectives while maintaining a critical distance from them (Law, 1991a).The concept of agency has to be described further to explain our interpretation of following the actors. The relation between agency and structure in the MLP has been discussed in Chapter 2. Here, the role of agency is considered in a contingent relational approach.

4.2. The application of SNA methodology and systems in transition

The ontological position need to be able to support the application of network methodology. Relationism (interactionism) is an encompassing term for social theories that do not start with fixed assumptions on agency or the motivation of agents. In this section it is described how a relational view of agency informs the use of SNA methods, drawing mostly on the concepts of agency in STS and actor-network theory. It should be noted that the application of SNA methods is not necessarily consistent with what is described as the contingent, relational approach.

Social network analysis is linked to a theory of action that may contradict some premises more commonly used in SNA. Theories of action drawing on SNA have emphasised how network position constrains action or how it provides a resource of social capital (Galaskiewicz and Wasserman, 1993). Structural approaches in explaining action are avoided in favour of a relational perspective. In addition, the concept of social capital commonly used in SNA indicates that actors by virtue of their position have access to resources through their relations, whereas relations are not an asset possessed by the actors but an interaction that has to be maintained (Callon, 1998a).

With regard to networks it should be taken into account that the term is multi-faceted and there is a risk of using it in the form of management fads (Conway et al., 2001).The term network is sometimes used as an incantation symbolising a method of thinking rather than as a concrete phenomenon(Wallemacq, 1998).

4.2.1. Potential contributions of SNA to innovation research

Relational and networked approaches to agency are presented as consistent with the applications of SNA. Regarding specific modes of application, it is considered how SNA can contribute to questions particular to innovation and transitions research. In order to justify these applications it is shown that arguments raised in the innovation network literature indicate specific questions to be addressed by SNA techniques. It is usually under the sociological rather than the economic approaches to innovation that a network perspective has been explored (Steward et al., 2004; Jones et al., 1998) but these approaches differ in the definition of network concepts and methodological choices. The term network may refer to both a method and a phenomenon but some researchers have emphasised the methodological over the theoretical aspects (Jones et al., 1998). One of the key concerns in network research is the lack of theoretical developments that could inform the use of increasingly sophisticated methods (Rogers, 1987; Conway et al., 2001).

Rogers (1995) in studies of diffusion analysed the role of communication networks for the dissemination of innovation across individuals and organisations. The concepts of homophily and heterophily are introduced to illustrate how the characteristics of network actors affect the potential for the organisational diffusion of innovation. Homophilous networks include individuals who share common attributes, so it is assumed that communication between them is more likely to be harmonious and effective. Communication between dissimilar individuals in heterophilous networks is more difficult and rarer but it may prove more influential for the diffusion of innovations: in homophilous networks most actors share similar ideas so it is harder for innovative view to emerge, whereas among dissimilar actors it is more likely that ideas novel to at least some members of the groups will be present. Moreover, communication between dissimilar actors is more likely to act as a bridge or unique point of connection between parts of the network and hence provide a link between otherwise isolated clusters of innovative activity. Hence, the degree of actor heterogeneity is a factor in the evaluation of innovation networks. Ideally, a combination of homophily and heterophily should exist for a network to be effective (Callon, 1992).

In a similar argument regarding the role of cohesion Granovetter (2005) demonstrates how increased homogeneity and standardisations is likely to exist in a denser, more cohesive network. Furthermore, the concept of structural holes (Burt, 1992&2004) suggests how innovation is generated through a combination of relatively homogeneous, cohesive subgroups where bridges between them can provide the platform for new ideas. According to Burt (2004) actors with the potential to bridge these structural holes are in a privileged position regarding access to innovative ideas. This argument resonates with the importance on the role of central actors in the diffusion of innovation.

Increased importance has been attributed to the role of gatekeepers or boundary-spanners in the innovation process. Some actors are said to be better qualified in order to enable interaction between others. The role of gatekeepers and boundary spanners has been examined with regard to the management of innovation at the organisational level (Tushman, 1977). Actors emerge as boundary spanners through their position in the overall pattern of relations. With regard to non-human actants in the innovation process the role of boundary

objects could be thought of as analogous to that of gatekeepers. Boundary objects are artefacts or technologies that despite being subject to various interpretations on behalf of the actors they contribute to the cohesion of an actor-network as they provide a reference point (Star and Griesemer, 1989).

In the MLP framework a number of niches may develop as a response to the pressures exercised on the regimes. These niches can be thought of as clusters of an emerging innovation network that is positioned as a set of sociotechnical alternatives to the regime. Also, the concept of regimes incorporates the idea of communities of actors following the same cognitive /normative rules. These communities can also be viewed as connected networks of actors. The concept of clusters of innovative activity has mainly been developed with regard to regional networks or innovations (e.g. Piore and Sabel, 1984) but it could apply to groups of actors that share a problematisation of technological issues. Networks clusters characterised by increased internal cohesion can provide the grounds for sociotechnical trajectories as cohesion is likely to lead to the standardisation required for niche innovations to break into the regime level.

Collaborative arrangements for innovation have been widely studied though not necessarily through the prism of network concepts (Green et al., 1999). The focus on these studies has been on the motives and outcomes of collaboration. However, networks should not be equated with collaborative activity as there are additional types of interaction that could result in relational data. The view of networks as collaborative mode of co-ordination between markets and hierarchies (Williamson, 1975) is replaced by a notion of networks as modes of representation of different forms of interaction.

4.2.2. Premises of social network analysis

The aforementioned arguments support a network approach to sociotechnical change and the dynamics of transitions in particular. In addition, innovation network concepts were mentioned although networks are not meant to be viewed in terms of collaborative arrangements or an intermediate form of co-ordination. It was mentioned that network research tends to lack theoretical foundations despite the increased complication in techniques. In this section, the origins of SNA and the assumptions prevalent in network research are presented.

At the most basic definition SNA is seen as a means of describing and analysing units with an explicit focus on their interrelations (Fombrun, 1982).

Although sociology aims to study broader social systems, social systems and structure, a lot of the empirical work has emphasized individual attitudes and behaviours. This has been facilitated by the development of social science statistics that has facilitated the study of larger populations. However, this empirical work produced "a sociology that decontextualised the individual (Galaskiewicz and Wasserman, 1993 p.4.).In this perception sociology focuses on categories of social actors that share similar attributes rather than on actors relating to one another. However, social relationships are both constraints and opportunities for action and at the same time they provide a source of meaning. SNA focuses on the relationships between actors and between social positions. Hence, any research programme should take into account relationships among actors and among social position (ibid.).

Social network analysis has been introduced to sociology through social psychology. Graph theory has particularly benefited the development of a social network paradigm. Sociograms (graphs and directed graphs) and the accompanying sociomatrices have been used to study social structures. Relative concepts such as centrality and reciprocity are borrowed from this transition. It was in the 1970s that a set of statistical techniques for network data was developed(ibid.) Research employing social network analysis is split into directions studying focusing on the "micro" or "macro" social order. The micro level approach emphasises subgraphs: ordered pairs, dyads or triads. At the macro level, the focus is on the description of global network structures, on the overall structure of the network (ibid.). With regard to global network structure both relational and positional methods can be used to describe them. The relational techniques emphasise direct ties between actors whereas the positional techniques focus on ties to third parties and identify "structurally equivalent" actors. Actors are structurally equivalent when they have identical relations to other members of the group (Mizruchi and Galaskiewicz, 1993). Rogers (1987) refers to the structural/positional and relational perspective on network analysis as follows: A relational analysis identifies cliques among the members of a network. A clique is defined as a subsystem whose members interact more closely with each other than with other members of the network. Individuals are classified into the same clique according to the level of their direct interaction and the proportion of individuals they share in their personal communication networks. Usually it is the flow of information through network links that is used to classify the level of interaction. This way a relational perspective examines both

direct and indirect communication flows. While Rogers (1987) tends to favour the relational approach, it is claimed that both approaches can be applied in the same networks problem. The relational approach is potentially more useful in the study of more recent networks and the structural approach may be more suited to established networks.

Although SNA distinguishes itself from a sociology that views individuals as isolated agents by focusing on relations that the distinction between micro/macro level individual actors and global structure is latently maintained. Social relationships are seen as constraints and opportunities for actions while the network appears to provide a context for individual action. However, this particular perception of agency does not seem a prerequisite for the application of SNA. Furthermore, although innovation networks tend to be viewed as collaborative arrangements there is no reason why SNA should be limited to this type of relationships.

4.3. Research Design-Data Collection

4.3.1. Unobtrusive methods in social research

Unobtrusive data collection methods are used in order to obtain relational data regarding innovation activity in the electronic book area. Specifically, different types of documentary sources are used to construct innovation networks. The use of documents is a particular form of unobtrusive research measures discussed in the next section. The logic of unobtrusive measures is described below.

The term unobtrusive measures was introduced by Webb et al. (1966) to refer to methods that do not entail direct contact or elicitation from research subjects. Hence, unobtrusive measures contradict a common-held assumption in the social sciences that meaningful information is obtained by asking people (Kellehear, 1993 quoted in Lee, 2000).Unobtrusive measures are designed to avoid the problems caused by the researcher's presence. Webb et al. (1966) identify unobtrusive measures related to data from physical traces, non participant observation and documentary sources. Therefore, documents were initially identified as one of the main sources of data obtained without direct elicitation.

One justification for the use of unobtrusive methods is to avoid the methodological weaknesses in interviews and questionnaires. Respondents attempt to adjust impressions of themselves so that they will correspond to what they perceive as the interviewer's expectations (Lee, 2000). Specific problems associated with interviews and questionnaires were identified in Webb et al. (1966) as incentives to develop unobtrusive measures. In addition, the declining response rate in surveys and the fact that participants are likely to differ from non-participants (response bias) indicate that survey methods are not sufficient in themselves. However, negative arguments on the effectiveness of surveys and reactive research methods are highly ambivalent (Lee, 2000) and in any case would not provide a consistent argument for the use of unobtrusive methods. Once problems with interviews and questionnaires have been identified, unobtrusive methods are seen as complementary rather than as alternatives: Webb et al. (1966) advocate the use of multiples sources of data in order to increase the robustness of theories. Their argument is that any results are to a degree constructed by the method of data collection; therefore, the findings are affected by the weaknesses in the corresponding method. This problem is alleviated when multiple methods are used. Specifically, unobtrusive methods avoid the problems the researcher's presence causes when direct elicitation is used.

Furthermore, advantages to the use of non-obtrusive method emerge from their adaptability. These advantages are clearly evident in research on sensitive topics or dangerous settings (Lee, 2000).Generally, unobtrusive methods are used when the alternatives are scarce; in that sense the developments of unobtrusive measures is related to the developments of the "sociological imagination"(Mills,1959 cited in ibid.).

Despite the aforementioned practical considerations leading to the use of unobtrusive research methods, theoretical developments in the social sciences can lend support to the use of unobtrusive methods. The so-termed "post-structuralist" approaches in the social sciences (Kellehear, 1993 cited in Lee, 2000) have indicated that research methods should be about a

critical understanding of social reality rather than about measurements. By extending the domain of culture these approaches also extend the domain of issues amenable to sociological inquiry as everything is seen as inevitable cultural and open to study (Lee, 2000).

Because of the variety in unobtrusive measures, there it the risk that they are presented as an inventory (e.g. Bouchard, 1976) rather than as a coherent approach. In practice it is possible to construct more measures than the phenomena under study. The original text on unobtrusive measures (Webb et al., 1966) also could be interpreted as a methodological inventory because there are no guiding principles on appropriate use. Two contrasting approaches have been adopted in the following literature: the orientational approach that emphasises the researcher's stance to particular sources of data and the taxonomic approach which focuses on characteristics of particular measures, which could be used to construct a taxonomy.

Unobtrusive methods are categorised in relation to their effect on the environment. Their subjects are physical traces left by human agents. There is a difference between accretion and attrition measures. Documentary research in all its guises comprises one category.

4.3.2. Documents as informants in Social Network Analysis

i. Potential uses and the dual role of documents in social research

It has been argued that unlike other data sources such as surveys or participant observation documents lacked recognition as a distinct category (Platt, 1981a). The use of documents does not necessarily constitute a method as it does not imply how exactly they will be used, yet the use of documents as a data source raises issues particular to this source of data (ibid.). However, the methodological literature has tended to ignore the discussion of documentary sources. This has been observed both in the seminal article by Platt (1981a) and in Prior's (2008) discussion on a revised role for documents in social research.

Documents usually fall under the category of unobtrusive measures or available data. Discussion tends to be limited to the types of documents available and the problems they raise rather than on appropriate usage. Regarding data analysis, one common approach has been content analysis which more closely approximates quantitative methods (Platt, 1981a). At the time apart on the literature on content analysis and the discussion on the use of archives, very little work was available in that area.

The seminal articles by Platt (1981a&b) have provided the impetus for a renewed interest in documentary sources (see Scott, 1990). Her comments that increasing scepticism towards more widely applied "textbook" methods indicates the need for further work on alternative sources of data collection still resonates(Platt,1981a).

Although documents are widely used in social research, they are mostly consulted as references for a specific piece of information and are therefore treated as supplementary sources to a broader research process (Scott, 1990).This use of documents by social researchers is similar to their lay use as information sources; Scott (1990) suggests that documentary research as such should be about the systematic use of documents. There is a gap in the methodological literature concerning the use of documents and some attempts have been made to address this (Prior, 2003). Limited reference is made to documents in methodology textbooks and they are commonly perceived as secondary sources (see Prior, 2008).

Systematic documentary research oscillates between two uses of documents: documents as resources and documents as topics (ibid.).The use of documents as resources is a more systematic version of their everyday use: the emphasis is on the information provided by the content of the documents, the interest lies not in the document as such but rather in the reality it refers to. Documents are used as topics when the documents themselves are treated as the product of social processes and act as the focus of analysis. In that case the point is to account for their form and content considering the circumstances of their production. Furthermore, earlier work by Platt (1981b) makes reference to the difference in content analysis between the representational and the instrumental model of what documents are doing. Hence, the dual nature of documents is well established even though there is limited methodological literature on documentary methods. Scott's (1990) argument is that the two uses are linked: when the focus is on what the documents denote about the world (documents as resources) the circumstances of their production should also be considered to evaluate their

content; alternatively, when the focus is on documents as topics, one cannot ignore what they describe. Yet, the distinction between topic and resource is not easy to maintain in empirical research (Prior, 2008).

The dual role of documents in social research is also established in Prior (2003): she considers documents both as "receptacles of content" and as agents in their own rights. There are analogies between her positioning of documents as agents and Scott's use of documents as topics (Lee, 2004). Instead of the content of documents she emphasises the circumstances of their production and their use in context, viewing documents as social agents. In that understanding of documents, content should not be perceived as the decisive factor in documentary research (ibid.). Paraphrasing Latour (1987), her suggestions is that we should follow documents in action (Lee, 2004).In fact, Prior (2003) perceives documents as agents in ways described by actor-network theory when granting agency to non-humans (ibid). For instance she suggests that text and their readers are co-constituted (Lee, 2004); this is analogous to the interdefinition of human and non-human actants in an actor-network (Callon, 1998a). In her suggestion that we should not focus on the meaning of texts but rather on what is being referenced in documents Prior (2003) is influenced by Mol's ideas on epistemology(Lee,2004). She also makes reference to the use of scientific document in STS studies and to discourse analysis as approaches that allow for agency in documents (Prior,2008).

Documents have been the primary sources of data for classical sociologists, yet discussion of sociological research methods has mostly included surveys, interview methods and participant observation. In principle, the handling of documentary sources is no different from other methods of data collection, but there are particular techniques for documentary research considering their distinctive traits (Scott, 1990). Scott (1990) builds this argument on the more general claim that the logic of social science research is fundamentally the same as that employed in the natural sciences. Thus, his argument follows a positivist approach on the unity of method although he acknowledges that theory development in the social sciences follows the "inherently "meaningful" and "value laden" character of social reality" (Scott 1990,p.1).His explicit arguments is that documents can and should be handled scientifically.

The use of documents as sources of information or as references is meant to be distinguished by their lay use (Scott,1990).This argument should be seen as part of the attempt to position the study of documents within scientific methods. However, in practice the use of documents as resources is not significantly different from their lay use. In a sense, what social researchers do with available evidence is not essentially different from what other actors are doing (Latour, 2005).

An alternative justification on the use of documents as data sources in social research draws on the concept of inscription. On the basis of the second principle of symmetry (Callon, 1986), documents are a category of non-human actants which can be perceived as agents. Once documents are granted with agency, they can be treated as informants in their own right. In that sense the relation between the researcher and documents is analogous to that between the researcher and the human subjects/research participants. Therefore it becomes possible to demonstrate that the distinction between secondary and primary data

sources is arbitrary: once data sources are treated symmetrically there is no reason to assume that the information provided directly from human subjects should be granted primacy over that provided by documentary sources.

Interestingly the role of documents as informants akin to human informants has been identified by Glaser and Strauss (1967 cited in Prior, 2008) in the influential "The Discovery of Grounded Theory". They considered documents similar to the anthropologist's informants or to interviewees. However, despite their argument that grounded theory can be applied to textual material, this aspect of their approach has been neglected (ibid.)

Social action and the resulting structures are not directly observable but they are expressed from behavioural and observational evidence. Two types of relationships are identified between the observer and the observed (Scott, 1990): the relation is one of proximate or direct access when the researcher and the subjects are "coincident" in that the researcher is a direct observer of human action. Mediate or indirect access occurs when human behaviour is observed through its material traces. It should be taken into account that the distinction between intimate and proximate access refers to the relation between the observer and human agents. However, when one considers the inherent materiality of the social (Law, 1994), the material traces of human behaviour are an intrinsic part of the social world. Therefore, it is argued that what is referred to as indirect access can be considered direct access once the domain of the social has been extended to materials. In the case of mediate access, the material traces could be perceived as "intermediaries" between the researcher and the human subjects. Texts are identified as one category of intermediaries put into circulation between human agents (Callon, 1992). In certain circumstances intermediaries achieve the status of mediator in the sense that they are not only put into circulation but also are able to mobilise others (ibid.; Latour, 2005).

There are analogies between the concept of inscription in actor-network theory (Latour and Woolgar, 1979) and the emphasis of documents as agents in a situated context (Prior, 2003) or the emphasis in documents as topics (Scott, 1990). Regarding the documents that will be used as data sources in social network analysis the interest lies on their factual content; documents are viewed as agents in their role of relaying information. In Prior (2003) there is a distinction between documents as sources of content and documents as agents, but it is argued that there is no contradiction between these approaches as encompassing and disseminating content is an activity sufficient in itself to grant agency to the documents. Of course, documents have additional roles as agents in social interaction but the documents used in the context of this study are perceived as informants.

To summarise, our interest in documents as data sources emerges from their role as containers of information. However, the role of documents is not perceived as essentially different from that of human agents that act as informants. The interest in documents derives from the factual information that they contain, therefore the specific circumstances of their production and usage are not problematised for the most part. However, there is a need to refer more specifically to the type of documents that will be draw upon and for which purposes and also to evaluate their trustworthiness, usefulness and adequacy as sources. In

the following section the role of documents as evidence in social research is addressed along with the classification of documentary sources.

ii. Documents as evidence

Having established that material traces are valid sources of information in the social science, we need to position documents among them and demarcate them from other types of material traces. Scott (1990) defines as documents those materials media that contain *intentional* messages. Hence, "a document is an artefact which has as its central feature an inscribed text" (ibid.p5, emphasis added). It is emphasised that documents contain intentional messages because other material traces also convey messages although this is not their explicit purpose. Besides their neglected role in discussions of sociological method, documents have been prominent in methodological issues raised by historians. From historians' point of view "documents are the traces which have been left by the thoughts and actions of men of former times" (Langlois and Seignobos, 1908 quoted in Scott, 1990). Generally, documents are inscribed texts regardless of their physical embodiment.

Alternative definitions of documents are not constrained by their textual content. The status of artefacts as documents is not fixed on intrinsic attributes or the intention of their makers but is dependent on circumstances beyond their boundaries. It is somewhat restrictive to limit documentary research to textual research. Also, most definitions of documents and documentary research in social sciences focus on their content rather than documents in themselves (Prior, 2003).

Some researchers draw a distinction between documents and records (Hodder, 2000 cited in Lee, 2004), however it is preferable to avoid this (Prior, 2003 pp.27-28). Such distinction is also made in early research by Sidney and Beatrice Webb (cited in Scott, 1990): they define as documents those instruments that have as an explicit purpose to influence or form the basis of an organisation's or individual activities while the remainder textual materials are termed contemporary literature. Brant (1972 cited in Bouchard, 1976) differentiates between routine records and documents.

As mentioned, documentary sources are classified alongside other unobtrusive measures. It is not always straightforward to distinguish documents from other material traces (see Scott, 1990 on examples). However, some of the issues pertaining to documents are also applicable to other types of artefacts (Platt, 1981a).

A set of criteria are identified that can be used to evaluate documents as sources for social research. These criteria are generally applicable in social research as the evaluation of data quality should not depend on the methods chosen. These criteria are listed in Scott (1990).

1. Authenticity concerns where the evidence is genuine and its origins are verified.
2. Credibility refers to the factual accuracy of the evidence.
3. Representativeness indicates to what degree the evidence is typical of its kind.
4. Meaning refers to the clarity of the evidence and its correspondence with the research purposes.

The specific characteristic of documents is that they are already available and not created upon the researcher's request (ibid.). So perhaps paradoxically, it is their availability that creates problems for their interpretation. There are thus particular considerations in documentary research concerning the following issues (Platt, 1981a).

1. How to establish the authenticity of documents.
2. Issues of availability
3. Sampling issues
4. The extent to which the document is factually accurate regarding what it describes.
5. Inference that can be drawn from documents not related to their accuracy.

These considerations correspond to the criteria mentioned in Scott (1990). It is remarked that points 1-3 relate both to documents as resources/content repositories and as topics. Point 4 refers mostly to factual content and point 5 is more relevant to documents in themselves. These specific points will be discussed in reference to the specific sources chosen. Additional problems are identified that are not specific to the use of documents but relate to issues of justification and proof; these issues concern the presentation and interpretation of documentary sources (Platt, 1981b). Interestingly Scott (1990) suggests that the primary or secondary character of the sources should not influence evaluations of their validity. This point also serves to show that the distinction between primary and secondary sources is fluid.

Regarding the use of documents as evidence earlier work has identified sociological traditions relying on documentary sources (Platt, 1981a). Quantitative content analysis, historical study, sociology of literature, linguistic/ethnomethodological approaches and use of personal documents .More peripheral uses were not included in these traditions.

Scott's (1990) contribution is to establish that documents should be evaluated on the same basis as other data sources. A similar argument was made in Platt (1981a) when she remarked that making inferences from documents is essentially the same as making inferences from other forms of behaviour. Each data source has its peculiar problems but there is evidence to suggest that distinction of methods in terms of their data sources is analytically unnecessary (ibid.). Regarding the limitations of method it is only particular rather technical problems that are specific to documentary research (Platt, 1981b). This should be seen as an additional argument for a symmetric treatment of different methods. Thus, the concept of "practical adequacy" (Gill and Johnson, 2002) can be seen as a more adequate approach for the selection of data rather than consider the choice of data collection methods as a philosophical choice. As mentioned, documentary sources are used to collect relational data. Hence, the role of documents and records in SNA studies with regard to the study design is considered.

4.3.3. Determinants of network boundaries and sources of data collection

It was mentioned that SNA provides tools for the visualisation and analysis of relational data. The methods of analysis applied are selected on the basis of their

correspondence with concepts deriving from innovation networks. Three different datasets result from different methods of data collection.

The primary question is to identify actors belonging to the innovation network. Therefore, a methodological problem arises which concerns the setting of network boundaries. Unlike systems, networks are in principle unbounded, yet it is necessary to specify limits for analytical purposes (Conway and Steward, 1998). The difficulty in identifying network boundaries has long been perceived as a conceptual problem in network research (Rogers, 1987; Emirbayer, 1997). The total network of society is defined as a set of linkages that extends within and beyond the confines of any community or organisation (Mitchell, 1969 cited in Conway and Steward,1998),Through the process of network abstraction the researcher has to select aspect of the total network to study, termed partial networks(ibid.). First one has to decide the rules of inclusion in the network or as termed by Laumann et al. "the definitional focus" (cited in Conway and Steward, 1998). This is similar to the common question in actor-network theory regarding the definition of an actor. The definition of actors in this case is empirical, not based on ontological characteristics (Callon, 1992).

There are three set of components that can define a definitional focus: actors, relations and activities. When the definitional focus is based on actors the inclusion rule is the possession of a specific attribute, hence the resulting network is termed attribute. When the rules of inclusion are based on the actors' participation in a specified exchange the result is a transaction network. Finally when the inclusion rules are based in the participation in a specific event or activity the networks are termed action sets (Conway and Steward, 1998).

Network boundaries are problematic to identify and there is inevitably a degree of subjectivity in their selection. In order to select adequate rules of inclusion adequate definitions of the electronic book are required. As it has been mentioned in the context of this study the electronic book is seen as an assemblage of technologies that provide an alternative to print for the purposes of textual display. Moreover on the basis of documentary research the starting point of an innovation network in the area can be pointed in the late 90s' as prior to that there has only been limited research in related areas although expectations on electronic books have predated this since the advent of personal computers.

A combination of data collection approaches is used in order to map the network at different points in time and to demonstrate different sets of involved actors. The first dataset refers to the early stages of network formation: early developments in the electronic bookfield may provide insights on the original formation of niches. Data on participation in industry conferences are used to map this stage of development. The second dataset provides a more comprehensive account of participant organisations in the field and it indicate attempts of the actors towards purposive organisation of the electronic book/digital publishing industry. In particular, the membership of the main industry association (IDPF) is examined. The third dataset includes more complex information on the relationships between actors. Following on the discussion of non-obtrusive data sources different types of documents are used to identify organisations, technologies and diverse linkages in the electronic book area. Electronic book ventures are mapped as an emergent sociotechnical

network and the interaction among technological artefacts and organisations is addressed on the basis of multiple relations.

Regarding social network analysis, the most frequent method for collecting relational data entails the use of surveys (interviews or questionnaires) and only little use is made of documentary evidence (Knoke and Yang, 2008).In the case when documents are used as data sources, usually historical archives are consulted: for example registry archives can be used to construct genealogical networks (de Nooy et al., 2005). However there are advantages of using non-obtrusive data collection methods for network information in that they allow for the analysis of larger amounts of information and the accuracy of the data can more easily be assessed by cross-referencing different sources. Moreover, the use of network analysis avoids the dichotomy between quantitative and qualitative information (Cambrosio et al., 2004). Below reference is made to the selected data collection sources for each of the datasets. Emphasis is placed on the third dataset due to the more complex nature of information.

i. Dataset 1: Participation in industry conferences

The initial aim is to identify the participants in the early stages of the e-book innovation network. Despite the conceptual problems in delineating the time boundaries of the electronic book as a distinct innovation area, it is defined somewhat arbitrarily as the late 90s when the initial attempts at innovation can be identified. At the time there was limited technological development and market activity to provide relational data on network development. Any such available information is incorporated in the sociotechnical network described in the third dataset. In order to provide a more comprehensive account of the actors who were active at that stage of network development data on the participation in industry events at the time are used. Therefore, an indirect method of data collection is applied: instead of selecting a set of involved actors, a set of events is identified and then its participants are analysed. Events were selected on the basis of their theme, so the first dedicated conferences on the electronic book, which took place between 1998 and 2001, are selected. These events were specifically focused on some aspects of the electronic book market hence they are more likely to provide a comprehensive representation of the emerging network. One could identify electronic book related streams in events organised by the publishing industry such as the international book fairs or in conferences related to electronics. However, these events could not provide an equally accurate representation of participation as they emphasise in each case different aspects of electronic books. The fact that the first dedicated events on the electronic book occurred at that time lends support to the idea that actors' involvement in electronic books as a distinct concept was first articulated at that time.

The conferences selected were organised as a series by the National Institute of Standards and Technology (NIST) in the United States. NIST sponsorship in these events demonstrated an interest in the standardisation and compatibility of electronic book technologies even at this early stage of development. The following events were selected.

- Electronic Book 1998 Workshop: Turning a new page in Knowledge Management
- Electronic Book 1999

- Electronic Book 2000: Changing the fundamentals of reading
- Electronic Book 2001: Authors, Applications and Accessibility

Information on the events is available through the NIST archived web pages. Full proceedings are available for the first conference. The available information includes all presenters and participants, their organisational affiliations, the conference sessions attended and presentation title. A link to the presentation is available in most cases. Besides presentations, organisations are represented in the conferences through exhibits of prototype products and technological demonstrations. To that degree non-human actants also act as participants. For the purposes of SNA applications only organisational participation in each conference is taken into account. The specific themes and content of each conference can help interpret differences in participation patterns. The contents of the presentations were usually focused on each organisation's specific products or they provided a more general discussion on issues of controversy shared by all actors. However, conference participation and participant interaction is emphasised over the specific content of the presentations.

Regarding the factual accuracy of the data the sources are used as provided by the organiser of the conferences. Concerning sampling the selection of events has been explained on the grounds of their dedicated topic.

Our interest in utilising event participation as a source of data follows a rather neglected approach in science and technology studies regarding the analysis of participation in scientific meeting. Söderqvist and Silverstein (1994a) introduce the quantitative analysis of participation in scientific meetings as a scientometric tool meant to complement citation analysis studies. The lack of interest in scientific meetings in relations to other aspects of science is identified as significant considering that meetings have been important characteristics of modern science since its inception. The reasons that Söderqvist and Silverstein (1994a&b) suggest for a renewed interest in scientific meetings relate to their role in the dissemination of ideas as comparable with that of scientific literature. They also describe scientific meeting as political-rhetorical units: they provide a forum of negotiation regarding the definition of interesting research topics and they contribute to the drawing of boundaries between cognitive territories. In that sense they are useful to the promotion of research programmes and the identification of research disciplines (ibid.).

The arguments that Söderqvist and Silverstein (1994a&b) propose in favour of scientific meeting as a topic of analysis can be applied to consider the role of meetings in technological innovation. It is of interest that they have selected scientific conferences for the study of an emerging field with unclear boundaries (Immunology 1951-1972). Likewise the electronic book is an area of innovation with unclear boundaries. The study of meetings indicates an interest in the institutionalisation of scientific and technological areas.

Söderqvist and Silverstein (1994a&b) apply quantitative analysis in conference participation data in order to incorporate their method in the scientometric tradition. Cluster analysis is applied in their data so that conferences are grouped together according to the similarity in their participation patterns. This approach is said to better illustrate the cognitive interests of scientists than citation analysis (Söderqvist and Silverstein, 1994a). Although

they do not make any references to SNA and their focus is on the events rather than the participants, it has to be noticed that cluster analysis methods on the basis of (dis)similarities are widely used in hierarchical decomposition of social networks (see Wasserman and Faust, 1994; de Nooy et al., 2005).Concerning commercial conferences/exhibitions and industry events in the area of the electronic book their purpose is mostly the promotion of the digital publishing market as a whole. The selected conferences organised by NIST indicate a conscious effort in delineating the boundaries of an emerging industry. Analysis of participation can be used to indicate organisations acting as industry champions. In addition, actors can be divided into groups that may demonstrate similar cognitive and commercial interests, although cluster analysis techniques as such will not be applied.

Although meetings have been neglected as a source of data in science and technology studies, there is a substantial body of work in SNA concerning the analysis of event-based social networks. Joint attendance at events is seen as an indirect way to measure relational data. In fact, event networks tend to be seen as synonymous with 2-mode networks as they link two distinct set of actors although they are only a specific case (Wasserman and Faust, 1994). Because of the characteristics of event-based networks such as relatively high interaction specific techniques have been developed for their analysis, which usually focus on the relations between participants rather than between events (chapter 8 in Wasserman and Faust, 1994; Borgatti and Everett, 1997; chapter 5 in de Nooy et al.,2005).

Participation in industry events is deployed as a method to map the early stages of the electronic book emergent innovation network. The aim is to identify actors occupying prominent positions at this stage and to examine whether there is evidence of clustering. These results can then be compared with later developments in the field to evaluate their significance.

ii. Dataset 2: Membership in industry organisations

In order to provide a representation of actors as the ebook area continued to grow and reach a stage of stabilisation data of organisational membership in the International Digital Publishing Forum (IDPF) are utilised. IDPF was set up as the Open Ebook Forum in 2000 and has been established as the main industry association bringing together actors involved in the areas of electronic book technologies and digital publishing. The organisation's main purposes are the development and dissemination of standardised formats for digital content, but they are also working towards the growth of digital publishing and the collection of market statistics. Data on membership are publicly available through the annual reports. The network of IDPF participants to a degree indicates attempt at purposive innovation in that it was established with specific goals. Although the organisation cannot impose any regulations or standards in its participants, its decisions on formats are perceived as a point of reference. In the field of science studies some research has been conducted on the membership of professional associations and their role in shaping emerging scientific fields (Shapin cited in Söderquist and Silverstein, 1994a).Participation in IDPF is analysed in network terms where years of joint participation are used to measure relational interaction.

In the innovation literature the role of professional associations has been considered as a form of external knowledge acquisition (Swan and Newell, 1995; Newell and Swann,1995).Professional associations position themselves as key actors in the diffusion of innovations; interaction through professional associations is one form of interorganisational interaction (Newell and Swann,1995). Their data indicate that boundary-spanning activity is an interactive process entailing both internal and external communication (Tushman and Scanlon, 1981 cited in Newell and Swann, 1995). Organisations whose members are active in professional associations are more likely to adopt innovations if those individuals are also embedded in internal communication networks that can influence decision making (Swan and Newell, 1995).

The type of documents used (organisational annual reports falls under the category of administrative records (Hakim, 1983). Administrative records are collected within organisations regularly and are not usually labelled as research data. Research on these sources is usually undertaken by practitioners within organisations. However, Hakim (1983) suggests that the secondary analysis of these sources as potentially providing results that could not be obtained otherwise. In that case secondary analysis means the use of data for purposes other than those they were collected for. The main limitation of such data is that they are not created to the researcher's specifications (ibid.). In the case of IDPF data that means that certain additional information on membership in specific IDPF groups is not available (personal communication). In addition the distinction between full and associate membership would have been useful, but is only available for certain years.

iii. Data set 3: The electronic book as a multi-relational sociotechnical network

The actors and linkages in the third dataset are identified by applying a mixed two stage approach. The data collection method is more consistent with an action set that is defined by areas of technological activity. The electronic book is perceived as an assemblage of organisations, technologies and actors that provide an alternative to print-on-paper based communication for the purposes of textual communication and display. Following from this definition and the argument on the distributed nature of innovation, specific areas of activity that contribute to the development and/or diffusion of electronic books are identified. Hence, an electronic book can be perceived as a modular technological product as it requires the co-ordination of software and hardware technologies in order to manage and display digital content. Furthermore, access to textual content is required for the technology to be meaningful.

The first stage of data collection contributes to the identification of these areas of activity that are used for the classification of the actors. Use of documentary data source was made to identify types of organisational actors, types of actants (software and hardware technologies) and types of relationships. A literature search was conducted on a number of academic databases using key terms such as "electronic book", "digital publishing", "electronic publishing", "and e-paper", "electronic libraries" and the results were used for the identification of relational information. The terms were selected so that both the technical and content aspects of electronic books would be taken into consideration. The majority of the

resulting sources were information technology and library management publications, including both peer-reviewed articles and communication material. The remark that most sources were from the areas of IT and library managements reflects the fact that within the academic world the topic has been mostly studied through the perspective of practitioners in these areas. Some of the material provided an overview of available technologies/products and issues affecting the so-called e-book industry, while some referred to specific ventures or industry aspects. Besides identifying information on relations and actors these literature sources made it possible to evaluate the viewpoints of the relevant professional communities. By reading this material notes were made on the related organisations and technologies. Hence it was possible to formulate a list of e-book actors and specific linkages, identify sub-areas of technological and business activity and have a primary indication of the issues that are important in future developments acting as enablers or obstacles to innovation.

At the secondary stage a general web search was undertaken relating to the actors that have already been identified in the first stage. In a sense, the STS principle on following the actors was adopted (Law, 1991a). Additional actors were identified which had linkages with the already identified actors. The range of the search was thus expanded. The reason that the first stage of the search was limited to academic sources was that at the initial stage of the research information on technological activities was limited; hence it was preferable to use sources that could also provide a more reliable analysis. If one had initially conducted a general web based research it would have been more difficult to classify the data and ensure their reliability. However, by acquainting with the topic through search on academic material it was possible to conduct a more precise general research at the second stage. The general web search allowed for the inclusion of up-to-date information and cross-referencing of the initial material.

Regarding the use of documents in this approach academic articles were mostly used as information sources and then also material provided through the actors themselves or reference in relevant websites (e.g. information technology related web-based media). The availability of information was only limited regarding some marginal actors or actors that are no longer active, in which cases more indirect approaches were used(e.g. information available in web archives). In these cases information was more dated. However, it was possible to cross-reference the interactions mentioned using multiple sources to confirm accuracy.

The actors first identified are included in the network on the basis of involvement in innovation activities while the actors identified at the second stage are included on the basis of relations. Such methods of first and second order sampling are applied in the case where access to informants is difficult and they can be perceived as more biased than attribute based inclusion (Heckathorn, 2002). However, a counterclaim is that such approaches to data collection are more dependent on actors' own interpretation of the electronic book field. Instead of identifying all participant actors on the basis of our definition of the area only the initial network boundaries are set by the analyst's definitions, these boundaries can be extended by observing who already identified actors are linked to thus the actors are defining who should be additionally included.

It was mentioned that actor status is granted empirically (Callon, 1992). Also the innovation network described is a sociotechnical network considering that transitions are a process that incorporates technological and social change. The list of actors identified includes organisations and technologies/products. Both are recognised as actants whose relations can be analysed with the same SNA techniques. Following the second principle of symmetry in actor-network theory (Callon, 1986) humans and non-humans are meant to be treated symmetrically. Discussion on innovation networks has usually concerned formal and informal linkages between organisations. Therefore, participation in a network was restricted to human actors. Technological artefacts are included as network actors in order to avoid the dichotomy between the domains of technology and society. Actor-network theorists are not the only ones to consider the possibility of granting agency to non-humans, though they have been more influential (Ashmore et al., 1994). Through processes such as scripting (Akrich, 1992) technologies can acquire a momentum of their own.

Subsequently a method of data input was developed so that both organisation and technologies and their relations could be incorporated in the same graph. Cambrosio et al. (2004) argue that Social Network analysis is unsuitable for the task of mapping sociotechnical networks because technology or science cannot be reduced to social relations. There are few studies regarding the mapping of heterogeneous innovation networks with an emphasis on the scientific rather than technological field (ibid; Bourret et al., 2006). Still, although SNA was initially developed for the study of interpersonal networks, as a methodology it is not limited to this type of data. To be precise, SNA studies pairs of individuals (dyadic attributes); social relations are only one type of dyadic attributes (Borgatti and Everett, 1997). Therefore, SNA can be used to represent a heterogeneous network of sociotechnical relations.

Similar to the heterogeneity of the actors the relations are also heterogeneous however for the purposes of simplicity the resulting network matrix is binary, noting only the existence or absence of a link. Therefore it either indicates absence or existence of a relation between actors. The relations are reciprocal so if actor A relates to actor B the reverse applies as well. The types of relation represented could not be otherwise quantified as they emerge from qualitative data in the literature review. According to the actors included one can categorise three types of linkages:

1. Relations between organisations: these usually include formally specified equity relations such as mergers and acquisition and non equity relations such as joint venture, client-supplier relations or membership of industry associations.
2. Relations between technologies and /or artefacts: technological compatibility or interoperability between software. Also, considering the electronic book as a modular technology these relations may signify that a technology is incorporated into a product.
3. Relations between technologies/artefacts and organisation: the technology is developed or funded by the organisation; alternatively the organisation utilises the technology.

In addition relations can be classified according to the actors' ownership patterns, regarding whether they are controlled by the same corporate entity. Linkages are not graded according to importance because of the qualitative nature of the data. However, all linkages listed indicate a level of connection that is indicative of business strategies. Also, the data reflect a period of the last decade therefore some of the linkages are now defunct however, they are listed in the network to understand its evolution.

An appendix is provided including a list of the actors and a list of all linkages. In addition, the content of interaction or the relational flow is mentioned in chapter 6 (section 6.3) where the substructures of the network are considered separately.

4.3.4. Actor classification

SNA methods allow for the combination of relational data with attribute data of the actors. Attribute data may illustrate structural characteristic of the actors or derive from information external to the pattern of the network. In the selected networks the actors are characterised by their organisational type (or technology type in the case of non-human actants) and their principal area of activity. Organisational type is selected as an attribute because the nature of organisations is meant to affect their goals. The principal area of activity has been selected as an alternative to standards industrial classifications. In the sociotechnical transitions literature standardised sectoral classification is not seen as adequate for the study of sociotechnical systems (Geels, 2004a); the concept of societal functions which defines them does not necessarily correspond to sectoral divisions. The principal areas of activity correspond to areas of expertise that are required for the development of electronic books as feasible ventures.

The electronic book area can be positioned as a niche in relation to the sociotechnical system of the printed book. However, a priori categorisations of actors as niche or regime are avoided because if actors were classified this ways it would give the impression that a clear distinction is possible and that there are similarities within all actors in each category. Niches and regimes are meant to be seen as heuristic device rather than actual categories. They are not meant to be qualitatively different but they differ in their degree of structuration of activities (Geels, 2004a). Yet, the idea of niches as incubation spaces seems to reinforce the belief that radical innovation originates from marginal actors and is since its conception positioned in relation to the established regime. If structuration is seen in a continuum there it not any specific reason why three levels should be initially identified. Actors can instead be categorised as incumbent or emergent in relation to the existing regime without the emergent actors being placed within niches. As radical innovation may originate within incumbent actors or interact with them at a much earlier stage than previously thought the concept of niche as incubated space is best used retrospectively when referring to emergent innovation. In addition, if emergent networks are seen as niches in relation to one regime it appears that the variety of pathways that may originate within them is already limited: technologies developed within "niches" may have more diverse application than originally designed for.

Principal areas of activity are not strictly divided into emergent or incumbent categories although for some of these the correlation is more evident. Finally, one should consider that besides incumbent and emergent actors one could focus on incumbent and emergent activities. As the societal function of a systems is being transformed or fulfilled through different technologies the nature of required activities is likely to change as well.

In order to classify actors (in this case organisations and technologies) they are viewed as instances of more general categories (Barnes et al., 1996). Classification is not solely the result of empirical observation but also of social convention. We group things together on the basis of their similarity but our concept of similarity is not neutral (ibid.). In the case of electronic book actors some categories have already been identified in advance through the documentary research however, actors difficult to classify required the

development of new groups. Our classification is influenced by the description of publishing supply chains where actors tend to be functionally differentiated.

4.4. Data coding and analysis

4.4.1. Data coding

Relational data collected by different methods need to be codified into adequate formats prior to their representation and analysis. There are three mathematical approaches to the representation of network data: sociometric notation, graph-theoretic notation and algebraic notation (Wasserman and Faust, 1994). Algebraic notation has advantages for the representation of data on multiple relations but there is a lack of techniques of software on such analysis. Also, this notational style cannot handle valued data. Therefore, tools originating from graph-theoretic and sociometric approaches are used: graphs and sociomatrices (ibid.). Sociomatrices are used for data input and analysis while graphs are used for purposed of visual representation of both relational and attribute data and to help provide an intuitive understanding of the network.

As network graphs are commonly used, networks tend to be reduced to graphs. There is a conceptual difference in that a graph only represents a set of nodes/vertices and a set of lines between pairs of nodes, hence it includes all information on the structure of a network (de Nooy et al., 2005). Nodes represent the actors and lines the ties between them, which in the case of SNA graphs can result from any type of social relation. The network consists of a graph and additional information on the nodes and lines, such as node labels and line values which correspond to the strength or type of the represented tie (ibid.). In most network visualisations the graph itself is complemented by this additional information. Additional information on the actors which does not derive from the relational data can also be included in the graph.

Sociometry refers to the study of affective relations among a set of individuals. Sociomatrices are two-dimensional data arrays where the row dimension indicates the sending actors and the column dimension the receivers. When the same set of actors are cited as senders and receivers the matrices are square. Each X_{ij} cell in the matrix indicates and measures the tie from the actor in row i to the actors in column j. In the case of dichotomous relations the sociomatrix is the adjacency matrix for the corresponding network (Wasserman and Faust, 1994).

In the origins of SNA analysis there was a clearer distinction between sociometric and graph-theoretic approaches. Techniques relying on permutation of the rows and columns in matrices, such as blockmodelling are particular to the sociometric approach. However, with the development of SNA software it has become possible to compute graph-theoretic measures using sociomatrices. In practice the sociomatrix has become more widely used. Sociomatrices cannot however include attribute data, hence additional data arrays have to be included (Ibid.).

Sociomatrices are used in order to code collected relational data and to perform the majority of analysis. However, there are particular benefits of the network graph in providing a concise summary of networks. With regard to different methods of data collection, different approaches are taken in data coding.

Initially, participation data in a series of conferences are used. As the emphasis lies on organisational rather than individual attendance, the input data are included in a matrix where rows represent organisations and columns represent the conferences. This arrangement can be thought of as a 2-mode sociomatrix linking two distinct sets of actors: organisations and events. There are techniques that adjust standard SNA measures for the analysis of 2-mode data so that both modes can be analysed simultaneously (Borgatti and Everett, 1997).However, as the focus is on the interaction between organisations the participation data are converted into a one mode matrix where organisations are linked through co-attendance in conferences. The 2-mode matrix is converted into an affiliation network where the value of a tie between two organisations indicates how many events they have jointly attended. This matrix forms the basic input for network visualisation and analysis. It is supplemented by information on the organisations' principal area of activity and type.

Similarly, the network that results from organisational participation in IDPF is also an affiliation network. The initial data link organisations to periods of memberships; data are available for six periods. One-mode matrices are constructed where the value of a tie between two organisations indicates how many years they had both been IDPF members.

Regarding the conversion of 2-mode matrices in 1-mode affiliation matrices it is possible to select only specific columns in order to calculate the ties between organisations listed in rows. Thus, one can create consecutive affiliation networks as attendance and participation patterns change over time. Also, although emphasis is placed on organisational interaction the events represented in the columns can be chosen as the unit of analysis and patterns of relations between events can be assessed. The network of organisations participating in NIST conferences and the network of IDPF participants both include valued relational data as they result from the conversion of one mode matrices.

In the third approach to data collection documentary sources have been used in order to identify observed interaction between organisations and technologies. Because of the data collection approach information has been collected on a variety of relations. However, the data are not shown as a multiplex network. In order to represent a multirelational network in sociometric notation different matrices have to be constructed for each relation. These matrices can then be aggregated and converted in a valued network. Because of the variation in the content and intensity of interaction there is no discrete typology of relations that can be noted in different matrices. Instead only the existence or absence of a relation is noted in a binary matrix. Additional information on the exact nature of each tie is noted separately and will be used for the interpretation of SNA results. Actors may be distinguished in organisations and technologies/artefacts however this does not affect the representation of the data. All actors belong to one mode; hence a square matrix is constructed. In addition all ties are reciprocated: because of the nature of the relations there is no distinction between a receiver and a sender role. In order for the existence of a tie to be meaningful both involved actors must participate in its establishment and maintenance, for this reason it is assumed that all observed ties are reciprocal.

4.4.2. Selection of SNA techniques

This section explains the techniques that will be applied in the analysis of the networks in chapter 5. Exploratory SNA techniques are mostly applied (de Nooy et al., 2005) following on the relational perspective as hypothesis on network structure have been avoided. The SNA techniques adopted are presented top-down in that the analysis begins with network wide measures moving to the identification of subgroups and to the level of individual actors. The network wide measures focus on issues of cohesion and heterogeneity. Issues of cohesion are considered taking into account the interaction between the principal areas of activity identified by the attribute data. Then, techniques are described that lead to the division of the network into cohesive subsets of actors: a relational approach is followed leading to the identification of cohesive subsets rather than a structural perspective that divides actors into positions. The division of networks into substructures can be indicative of sociotechnical trajectories, as well as providing perspectives on the conceptualisation of electronic books. Finally, at the level of individual actors the aim is to assess their potential to act as mediators. The relevant questions concern the role of individual actors (actants) in promoting sociotechnical transformation. Specific measures, which focus on the ability to act as mediators between actors with a different knowledge base, consider the role of gatekeepers with regard to heterogeneity. The results of this analysis can be later correlated and it is possible to assess how organisational attributes affect their mediator potential. At each level of aggregation (individual actor, multiple actors as a network subgroup and the level of the aggregate network as a structured system) there is a choice between positional and relational approaches (Burt, 1980). The relational approach has been followed with the exception of actor centrality measures.

	Actor aggregation in Units of Analysis		
Analytical approaches	Actor	Network Subgroup	Aggregate Network
Relational	ego-network measures	set of cohesive subsets	Density or transitivity
Positional	occupant of network position(centrality/prestige)	status/role sets: structural equivalence of positions	Stratification of status role sets

Table 4.1: SNA techniques adapted from Burt (1980) p.80

i. Network level measures: cohesion and heterogeneity

There is an argument that cohesive networks contribute to the further diffusion of innovation (Rogers, 1995; Granovetter, 2005). In addition, the concept of structural holes has demonstrated how a balance between closure indicated through cohesion and brokerage enables the development and diffusion of innovation (Burt, 1992). Cohesion is a relational attribute referring to the level of the aggregate network (reference).

Among the selection of SNA techniques at the aggregate network level there is a distinction between the following relational and positional measures.

The relational measures emphasise on the structure of the system as dense or transitive while the positional approach stratifies the network into a set of roles that may be occupied by different actors (Burt, 1980). The relational measures are selected because they indicate cohesion.

Density is the most commonly used measure of cohesion. It can be perceived as a dyadic based measure because it provides an average degree for the embeddedness of actors in pairs. In the case of binary data the density is the proportion of ties towards the proportion of all pairs of nodes (potential ties). Because it calculates what proportion of all possible ties are actually present it can be seen as the probability of a tie between two randomly selected nodes. In the case of valued networks the density is defined as the sum of the value of all ties divided by the number of all possible ties. With valued data the density is perceived as the average strength of a tie taking into account all pairs of possible ties and not only the actual ties (Hanneman and Riddle, 2003).

Regarding the distribution of ties across a network, a paradoxical phenomenon is often observed in large, real-world networks. The average geodesic distance between two nodes may be relatively small but actors are embedded in local neighbourhoods where most others are also linked to one another. This is termed the small world phenomenon (Watts, 1999). There is a tendency towards dense local neighbourhoods that can be commonly termed clustering. The clustering co-efficient measures this tendency by calculating the density of the local neighbourhood (all actors connected to ego) for each actor excluding the ties to ego. The average of these values is the clustering co-efficient. The weighted average is a variation where the neighbourhoods' densities are weighted by their size in order to calculate the average. To avoid over-interpreting the clustering coefficient value it should be compared with the overall network density. Then it is observed if there is a tendency for higher than average interaction within local neighbourhoods. This measure of cohesion is a means to better evaluate the density measures.

In a relational perspective, the cognitive diversity of an innovation network is not only a percentage count of the actors' knowledge base but also an evaluation on the probability of interaction among them. The composition of a network is not sufficient to evaluate the degree of heterogeneity; instead the interaction between actors of different attributes has to be evaluated. The E-I index (External –Internal), a measure introduced by Krackhardt and Stern (1988) provides a more adequate evaluation of the tendency towards in-group or out-group ties. In order to calculate the E-I index the number of ties within groups is subtracted from the number of ties between groups. The result is divided by the total number of ties. From this definition it emerges that the E-I index can range from -1 to 1.It should be observed that the E-I index does not take tie strength into account. The E-I index can be calculated for the whole network, for each of the groups the network is divided into and for individual actors. Furthermore, heterogeneity is demonstrated by the blocked density matrix where the density of interaction between and within groups as defined by attributes.

ii. Network substructures

One of the research questions regards the identification of potential sociotechnical trajectories that could indicate a future transition in the print-on-paper system. Networks substructures are identified on the grounds of cohesion following the argument that greater cohesion is likely to lead to increased homogeneity of ideas and potentially to standardisation.

There are a number of techniques that can identify subgroups within a network. Two perspectives exist for the identification of network clusters: structural equivalence and cohesive subsets. Structural equivalence techniques divide actors into subgroups labelled positions according to the similarity of their relational patterns regardless of any direct connections between them. It is then assumed that actors occupying the same position are redundant. Identification of cohesive subsets is more consistent with the relational perspective applied in this study: actors are not viewed as mere placeholders, so those with similar connection patterns cannot be substitutable. Cohesive subsets are groups of actors that can be distinguished from the networks in that there is closer interaction within the group than the average level of interaction within the whole network.

There are two approaches in the identification of cohesive subsets (Hanneman and Riddle, 2003). The bottom up approach begins with the simplest, smallest groups such as the dyad and attempts to find out how these close relations can be extended to larger groupings. The bottom-up techniques lead to the identification of maximally connected subgraphs that satisfy certain conditions on the connections within the graph. What is meant by maximally connected is that the largest possible subgraphs that meet the requirements of each definition are identified. The strictest definition of a cohesive subset is a clique, a maximally connected subgraph where all possible connections exist, that is every actor is adjacent to everybody else. By modifying the definition regarding how many links should exist within the subgroups and whether they represent adjacency or connectedness, alternative cohesive subsets can be defined.

The k-core and faction analysis are used among the included measures. The valued core analysis is used for the networks resulting from datasets 1&2 as this technique is limited to valued networks.

The k-core is a cohesive subset based on nodal degree. It is a subgraph in which each node is adjacent to at least k other actors in the subgraph (Wasserman and Faust, 1994). Although k-cores are not necessarily cohesive subsets, they identify areas in the graph where cohesive subsets can be found (Seidman, 1983). All nodes within a k-core must have a nodal degree at least k. intuitively, k-cores indicate that an actor can be considered a group member as long as they interact with at least a few members of the groups, and there are situations where this is a rational claim. As k-cores are nested actors that belong to a core with a higher value of k also satisfy the conditions for inclusions in a core with lower value. However, the overlap of k-cores is not illustrated, instead each organisation is categorised to the most restrictive core that is possible.

In the bottom-up approaches network structure is seen as emerging from the extension of smaller groups. The alternative top-down approaches begins with the whole network as a

point of reference and seeks to identify substructures that are denser than the network as a whole. This approach helps in the identification of weak spots in the structure of the network, which indicate how it may be divided. The identification of factions does not seek to decompose the network into groups but it attempts to identify subgroups that are densely connected within and relatively isolated from the rest of the network. The ideal factionalised population would have the following characteristics: all actors belonging in the same faction would be adjacent and there would be no connections between factions. Hence each faction would be simultaneously a clique and a component. Of course, most real world networks do not fit this pattern but the ideal structure indicates that the basic idea behind factions is to maximise links within the subgroups and keep links between subgroups minimal. The concept of factions indicates high local density and the existence of "structural holes" between these highly dense groups (Hanneman and Riddle, 2003).

With regard to valued networks the valued core analysis makes it possible to reduce the networks to ties above a certain value and to actors that are only involved in these links (de Nooy et al., 2005). Valued cores are nested subgroups in a principle similar to k-cores. This technique is useful for highly dense networks that result from the conversion of 2-mode networks as usually only higher tie strength indicate a meaningful linkage in these networks.

iii. Actor level measures

Referring to individual network participants the aim is to identify actors that occupy a prominent position in the network. Although positional measures are used for this purpose, it should be taken into account that occupying a prominent position only means that an actor has the potential to influence others. Position, like scale, should be seen as an achievement of the actors. There are three approaches to calculating centrality including a number of specific measures: degree centrality, closeness centrality and betweenness centrality (Freeman, 1979). The can be categorised according to nodal involvement and the properties of the paths/walks in question. The table below shows a classification of the measures (adapted from Borgatti and Everett, 2006 only major measures listed).

	Radial	Medial
Volume	Freeman Degree	Freeman Betweenness, Flow Betweenness
Length	Freeman closeness	Distance-weighted Fragmentation

Table 4.2: centrality measures

In the case of radial measures the actor (node) in question is placed in the origin or terminal point of the paths and walks used to evaluate centrality. In medial measures, the paths or walks that pass through a given node are taken into account. Medial measures are selected because they can better indicate an actor's potential to inhibit or facilitate flow in the network, thus they can illustrate the concept of gatekeeping. Volume measures refer to the

number of paths/walks while length measures consider the distance of a path/walk (Borgatti and Everett, 2006). Variations of betweenness measures will be used to calculate the position of actors as intermediaries/mediators relying mostly on the widely used measure of Freeman's betweenness centrality.

Among the three main approaches to centrality betweenness measures are more adequate to evaluate an actor's potential to act as intermediary. Freeman's betweenness centrality assesses the proportion of geodesic paths that go through a given node. A geodesic path is the shortest distance between two actors. So Freeman's betweenness centrality counts how often an actor needs a given actor in order to reach any other actor (Borgatti and Everett, 2006). The mathematical definition is shown below (Knoke and Yang, 2008):

$$C = \sum_{j<k} \frac{g_{jk}(N_i)}{g_{jk}}$$

The maximum possible value of Freeman's betweenness centrality depends on network size and the total number of geodesic paths. Wasserman and Faust (1994, p.190) suggest normalising the nodes' betweenness centrality by dividing with the maximum possible values for the given network. Normalised centrality measures are useful because they allow for comparisons between. In addition the centralisation of the network indicates how the property of centrality is distributed among actors (Knoke and Yang, 2008).

$$c_g = \frac{\sum_{i=1}^{g}[C_b(N^*) - C_b(N_i)]}{((g-1)^2(g-2))/2}$$

The numerator is the sum of the differences between maximum centrality and the centrality of any other actors and the denominator it the theoretically maximum possible value of betweenness centralities for all network nodes.

A limitation of betweenness centrality is that only geodesic paths are considered. Actors who are placed on the geodesics are privileged. However, network flows do not always follow the shortest possible paths. Geodesic distances in the network are relatively short. In addition some organisations may be redundant in their intermediary role as this is measured by betweenness: even if they were removed from the network there are other organisations positioned on the same geodesics that could mediate between the same pairs of actors. The measure of flow betweenness introduced by Freeman et al. (1991) resolves the issues of redundancy by counting only paths that do not share any edges (edge-disjoint paths). Paths of any length are included. As flow betweenness calculates the proportion of edge-disjoint paths that involve a given node, it is counting the amount of flow that would not occur if the node withdrew from the network. In other words, it counts the node's potential to obstruct flow (Borgatti and Everett, 2006).

Brokerage measures are an alternative approach in evaluating network participants' role as mediators. It is a particular form of betweenness that only considers paths of length 2 (an actor and its immediate neighbours).An organisation acts as a broker between two others, if it is adjacent to both of them while they are not directly linked themselves. Brokerage measures can thus be seen as a specific variant of betweenness centrality including paths of length 2 (Borgatti and Everett, 2006). Brokerage focuses on ties within an actor's ego-

network. In that sense the relation between brokerage and centrality is analogous to the one between density and the clustering co-efficient: they evaluate the same quality but there is a shift of focus from the whole network to the actors' local neighbourhoods.

There are five brokerage roles (Gould and Fernandez, 1989) which are in practice are four for non-directed data. The role of representative (or gatekeeper) indicates that an actor acts as a broker by linking actors of its groups to other groups. The co-ordinator role indicates that the actor and the pairs it links all belong to the same group; when they all belong to different groups the broker is a liaison. An actor is a consultant when it mediates between actors that belong to the same group not being a member of the group itself.

5. Network analysis results: presentation of event-based and sociotechnical maps

Introduction: Chapter structure

In this chapter SNA is applied in order to visualise and analyse the networks resulting from the different types of relational data collected. Data collection methods were discussed in chapter 4. In addition, the network analytic techniques were introduced and their selection was justified on the basis of their correspondence to innovation concepts. The networks resulting from each source of relational data are presented individually but comparisons of their properties can be made. Each of the types of relational data concerns different aspects of the emerging electronic book aggregate innovation network, hence they are firstly analysed independently. For reasons of consistency and in order to enable comparisons the same techniques are used as far as possible. However, because of differences in the data collection methods and the resulting network structures some techniques are only meaningful in some networks, so the results are not always comparable. Still, the same techniques are mostly used in all networks because similar network properties are evaluated.

Exploratory SNA techniques are mostly applied as the aim is the description of the observed relational interaction rather than hypothesis testing. Each of the sections describes the network(s) resulting from each of the sources of relational data. Firstly, the network of participants in the NIST Electronic Book Conferences is discussed. Secondly, the patterns of membership of IDPF over the years are examined and a number of consecutive networks resulting from co-membership are constructed, though emphasis is placed on the aggregate network of members. Thirdly, the sociotechnical network of the printed paper text is described again with a focus on the aggregate network while trying to capture stages in its evolution. Prior to the network analysis the composition of each network is discussed in terms of the attribute data identified. The SNA techniques are divided in three broad sections. Firstly, the characteristics of the overall network structure are examined focusing on cohesion measures. Secondly, the networks are divided into subgroups on the basis of cohesion. Thirdly, the level of individual actors is considered through the application of betweenness and brokerage measures in order to evaluate their potential to act as intermediaries/mediators.

5.1. NIST conferences: the origins of the e-book innovation network

Data are collected regarding the participation in the NIST Electronic Book Conferences. The following four events are analysed.

1. Electronic Book 1998 Workshop: Turning a new page in Knowledge Management

2. Electronic Book 1999

3. Electronic Book 2000: Changing the fundamentals of reading

4. Electronic Book 2001: Authors, Applications and Accessibility

The available data included information on the presenters, organisational affiliation and title of presentation. A link to the full conference proceedings is available in most cases. Information on the exhibited products and the related organisations is also available. In order to construct the relational data patterns of organisational participation were examined: each exhibit or presentation by an organisation at a conference is measured as an attendance. These participation data are used in order to create a relational matrix where the value of a tie between two organisations indicates how many conferences they have both attended. For this purpose each organisation is classified only as present or absent in a conference; the total number of attendances as defined above is not used to establish co-attendance.

5.1.1. Network composition and attendance patterns

The relational data resulting from co-attendance are supplemented by organisational attributes referring to the organisational type and the principle area of activity. The classification of organisations into areas of activity illustrates the diversity of the early stages in the electronic book area; however, this classification has to be supplemented by techniques combining attribute and relational data to demonstrate the level of interaction among diverse categories.

The diagram below illustrates the representation of different areas of activity in the NIST conferences.
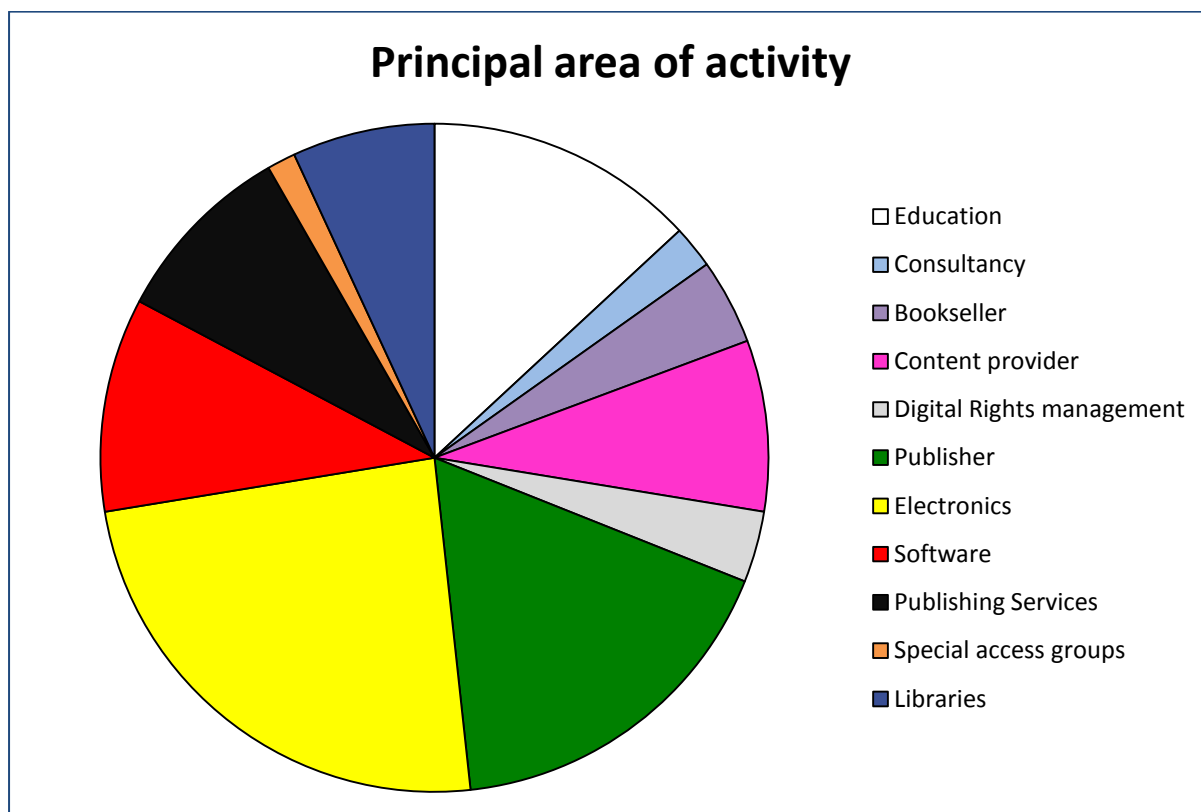
Figure 5.1: NIST-Principal area of activity

The process of classification has been described in chapter 4. At this point it is reiterated that one had to use the *principal* area of activity because most organisations are not limited to a particular area: there is a discrepancy between organisations with a specific focus, such as publishers, and those whose activities are located in more sections of the value chain. In the case of these organisations, they have been categorised according to the area where their distinct contribution rests. Moreover, this categorisation does not indicate the "level of inclusion" (see Bijker, 1987) of these organisations in the emerging electronic book market because several of them are involved in non-eBook related activities and their engagement in electronic books varies. In addition, the categories are not strictly mutually exclusive and may have unclear boundaries.

Besides their principal area of activity, conference participants have also been classified by organisational type. The results of this categorisation are shown in the diagram below.
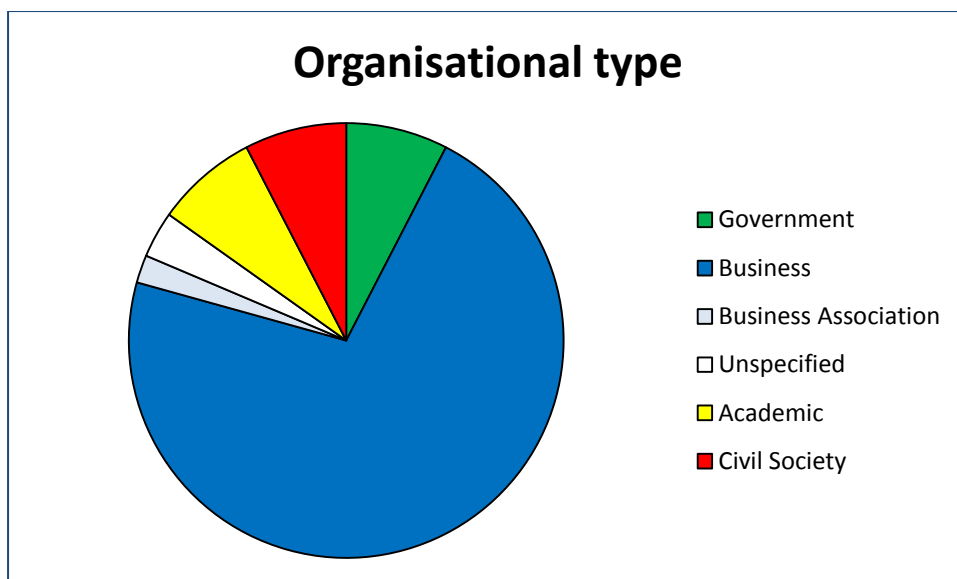
Figure 5.2: NIST-organisational type

As it can been seen from the above diagram the majority of the participant organisations are businesses, with a small representation of academic, business associations and civil society organisations. There is less diversity than observed according to the principal areas of activity. Participation in NIST conferences is largely business oriented, in accordance with the view that the firm is the source of innovation (Coombs, 1995). The absence of business associations may indicate that the innovation network at the time lacked structure and no formal attempts had yet been made to regulate or standardise innovative activity hence the lack of actors that would act as regulatory industry bodies. For example, the NIST Electronic Book Conferences provided the groundwork for the subsequent establishment of the International Digital Publishing Forum. There is a small representation of government and academic organisations, usually libraries or academic institutions that form part of the institutional market on electronic books. NIST itself is included among the government actors but the conferences themselves were not focused on regulation. Civil Society organisations include groups that promote the use of digital technologies, whose principal area of activity is usually listed under education, and special needs users.

Organisations differ according to their participation patterns. The organisational attendance is measured as the total of presentation and exhibits in all conferences.

Below the frequency of organisational attendance is illustrated.
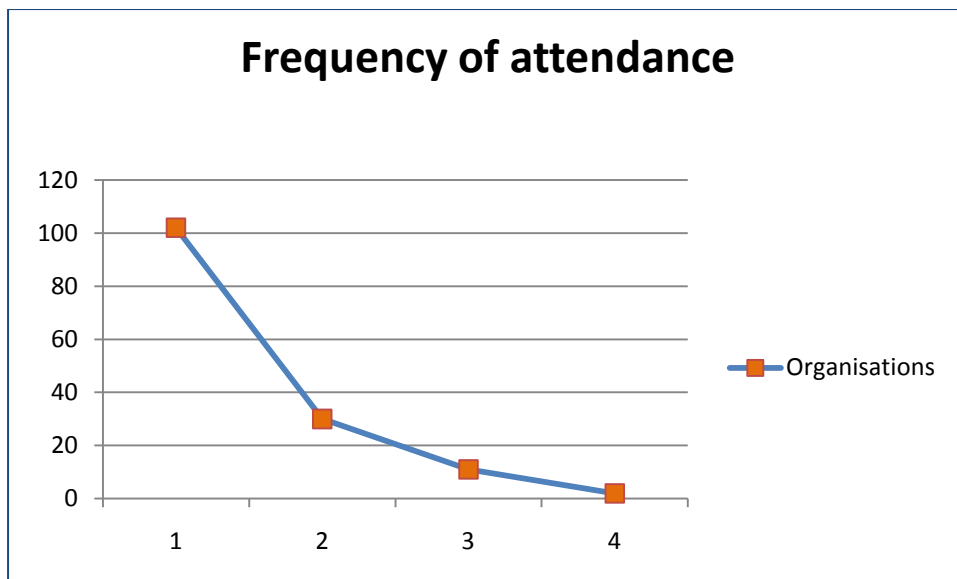
Figure 5.3: NIST conferences-frequency of attendance

As mentioned some organisations had more than one attendance at each event (as counted by presentations or exhibits). The distribution of total attendances is shown below.
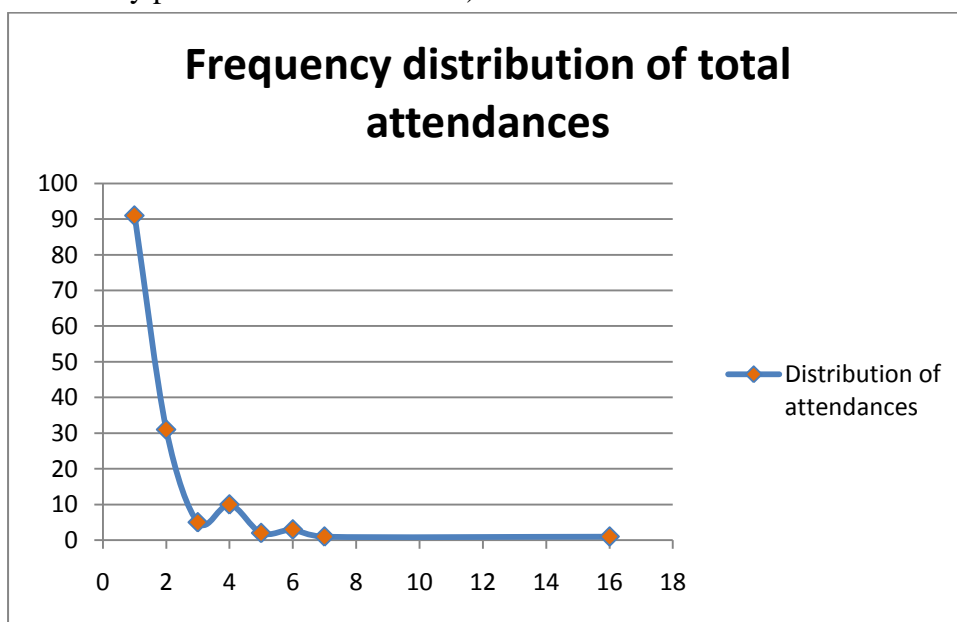
In addition it is observed how many organisations attended each conference. Because of overlaps in participation the numbers add up to more than the total (145).
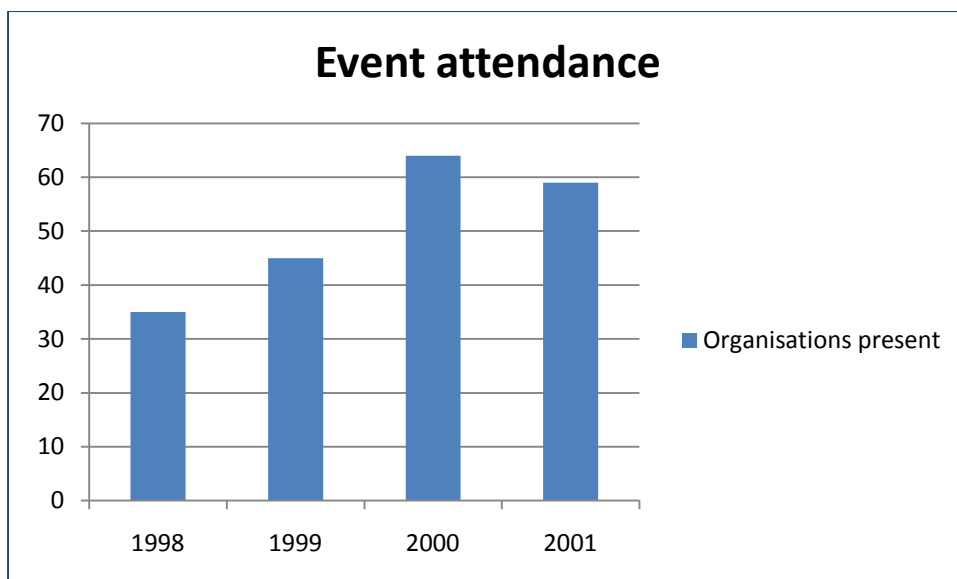
Figure 5.4: NIST conferences-event attendance

It is observed that no single event attracted more than 41% of participants. Moreover, the majority of organisations attended only one event and only two, NIST itself and the American Publishers Association attended all events. This indicates that each event remains relatively isolated as 70% of organisations can only develop linkages through one event. The possibility of most organisations to develop linkages and particularly linkages of greater tie strength is thus limited.

The events differed regarding the distribution of attendees in principal area of activity. The changes in participation patterns by category are shown in the diagram below.
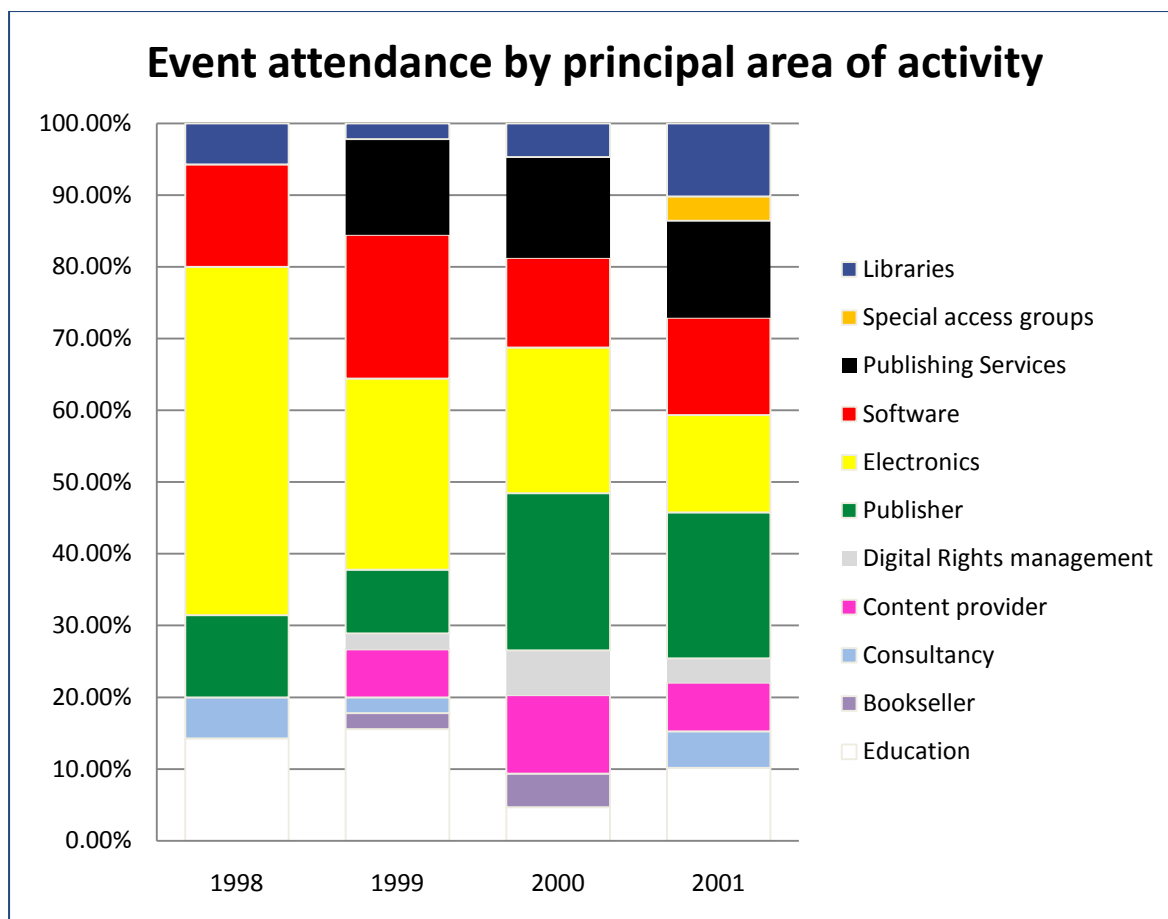
Figure 5.5: NIST-attendance by principal area of activity

It is evident that the first conference was dominated by actors in the electronics area; however their percentage has diminished over the events. On the other hand the category of publishers has shown an increasing trend.

In order to evaluate the interaction between conferences, an event-by-event affiliation matrix can be created to indicate how events are linked through common participants. The following table shows the similarity in participation patterns between events. The number of common participants between the events is normalised by the number of participants in each conference.

	1998	1999	2000	2001
1998	1	0.503	0.325	0.346
1999	0.503	1	0.535	0.3
2000	0.325	0.535	1	0.397
2001	0.346	0.333	0.397	1

Table 5.5.1: NIST conferences-event interaction

This matrix is created in a similar way as the organisation co-attendance matrix. As organisations are linked through attendance in the same conferences, conferences are linked by having participants in common. The values in the matrix cells do not represent the joint number of participant organisations because this value has been normalised according to the total number of participants in each conference. This data normalisation avoids the bias towards larger events; the value of a tie between two events is weighted by their respective

number of participants (on the normalisation algorithm see Bonacich, 1972).Naturally, the maximum possible interaction is observed in the diagonal. Values are relatively low; adjusting for size no two events have more that 53.47%   of their participants in common. The last conference is characterised by lower interaction with the others. Considering that overlaps between the conferences are not significant and that there is not a body of organisations with consistent attendance one can thus expect a rather sparse network.

So far it has been described how the organisations are categorised according to their attribute data and participation patterns. At this point the network is visualised. The organisations are represented as nodes. Their principal area of activity is illustrated by node colour and the organisational type is noted by node shape. The node colours are the same as those chosen in the pie chart showing the classification of the organisations into principal areas of activity. The organisational types are indicated by the following shapes:

▢ Government

◯ Business

◇ Academic

⊞ Academic & Business Association

The organisational ties are indicated by non-directional lines (edges). The thickness of the lines indicates tie strength. The spatial configuration of the nodes follows the spring-embedding layout (de Nooy et al., 2005). The spring embedding algorithm is run on NetDraw selecting node repulsion to avoid overlapping nodes or nodes positioned too closely together. Because the final positioning of the nodes depends on their starting position the process is repeated selecting different starting positions until a similar drawing is obtained. Some nodes have to be slightly moved manually so that the graph will be clearer to read without disrupting the overall pattern. The spring embedding layout results in a graph where the distances between nodes are more meaningful than in a random graph, as actors that have similar patterns of connections tend to be located in the same area. Generally, attempts to visualise social networks have to balance between aesthetics/clarity of representation and accuracy of positioning according to the selected algorithm. The visualisation facilitates an intuitive understanding of networks concepts that are then supported by formal analysis. However, an additional point about network graphs is that according to the algorithm chosen it is only the relative position of the nodes (distances from other nodes) that is of interest rather than the location of a node in a specific area: for example, if the graph is rotated for aesthetic or convenience reasons, it remains invariable for analysis and interpretation purposes as long as the distances between nodes are maintained.
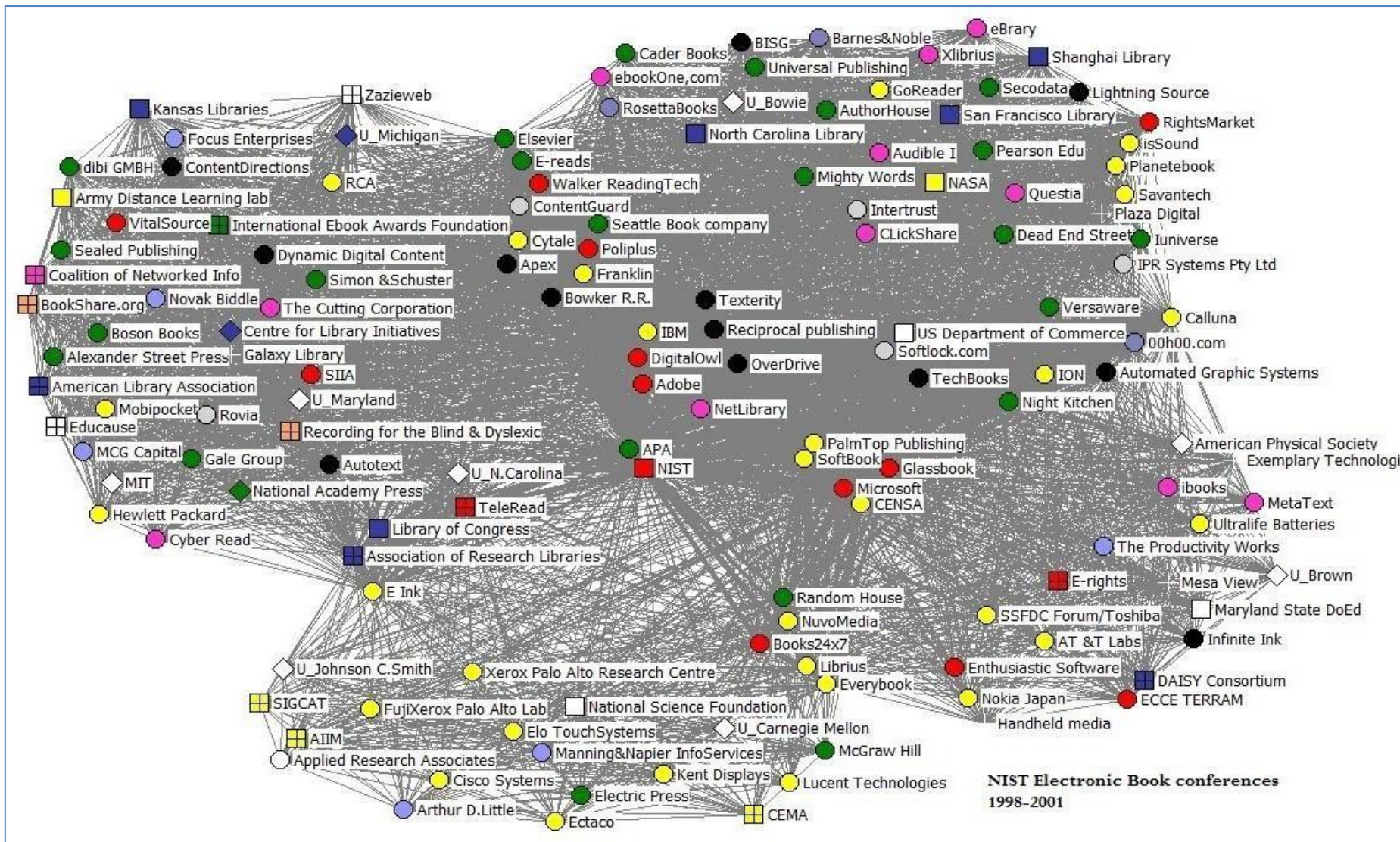
Network graph 5.1: NIST conferences

The heterogeneity of the participants' knowledge base is indicated by the diversity in node colours. In addition, it is observed that there is no distinct tendency for organisations within the same category to concentrate in the same areas of the graph, rather they are dispersed. It can thus be assumed and later tested through homophily measures that the probability of a tie between two organisations does not depend on whether they belong to the same category as indicated by the principal area of activity. However, there is indication of network fragmentation as one can observe groups of organisations located in the same area of the graph and smaller groupings located towards the centre. There are areas where a lower density of interaction is observed. For example, the groups of organisations located in lower areas of the network appear to have relatively weaker links with the other areas, whereas the smaller groups that are dispersed through the centre of the network appear to be densely connected among them. Although, the graph can provide some intuitions on network structure, specific network analytic techniques have to be applied in order to understand the pattern of interactions.

5.1.2. Network Cohesion

i. Density

The NIST conferences network is valued hence its density is first calculated taking into account tie strength. Then the data are dichotomised and the density in the binary network is calculated. The data are dichotomised so that a tie is indicated as long as the organisations have co-attended at least one event.

The respective density values are as follows.

- Valued network density: 0.5088.

- Dichotomised network density: 0.0703

The density of the dichotomised network would be generally considered high for a network of this size. However, considering that affiliation networks tend to be quite dense that value does not indicate particularly strong interaction .The density of the valued network is actually the average tie strength. Tie strength ranges between 0 and 4 as it represents the number of conferences co-attended. Within that range a density of this value is fairly low, probably because the value of 1 is the more frequent tie strength. The average tie strength can be accounted for by the initial participation data. Since the majority of organisations attended only one conference this limited both the strength of all their ties to 1 and the number of organisations they were connected with to the participants of this event. On the other end of the participation spectrum the organisations that attended all events are linked to everybody and also the tie strength is the highest possible in all occasions.

When attribute data are available it is of interest to calculate the density of interaction between organisations in the same category. By comparing the density of interactions between different categories with the overall network density it can be observed which categories have stronger than average interaction hence assessing whether attribute data affect network cohesion. The principal area of activity is selected as the attribute to divide the organisations in categories. The resulting categories differ in size but since density calculates the proportion of ties the results between/within categories and the result of the overall network are comparable. Grouped densities are calculated using the valued data.

The data result in a grouped density matrix which is symmetrical in the diagonal; it can be interpreted following either the rows or columns. An image matrix can be created by comparing these density values with the overall network density. Image matrices are binary: interaction between within groups is registered only if the density is greater than the overall network density (Wasserman and Faust, 1994).The grouped density matrix is treated as a network of relational data where the actors are the categories. Hence, a network graph is constructed from the image matrix where the nodes refer to principal areas of activity. Node size reflects category size. A tie is indicated only if the density of the relation between groups is higher than overall network density. The diagram also includes loops indicating a node's tie to itself; in this case loops indicate that the density of interaction within a category is greater than average.
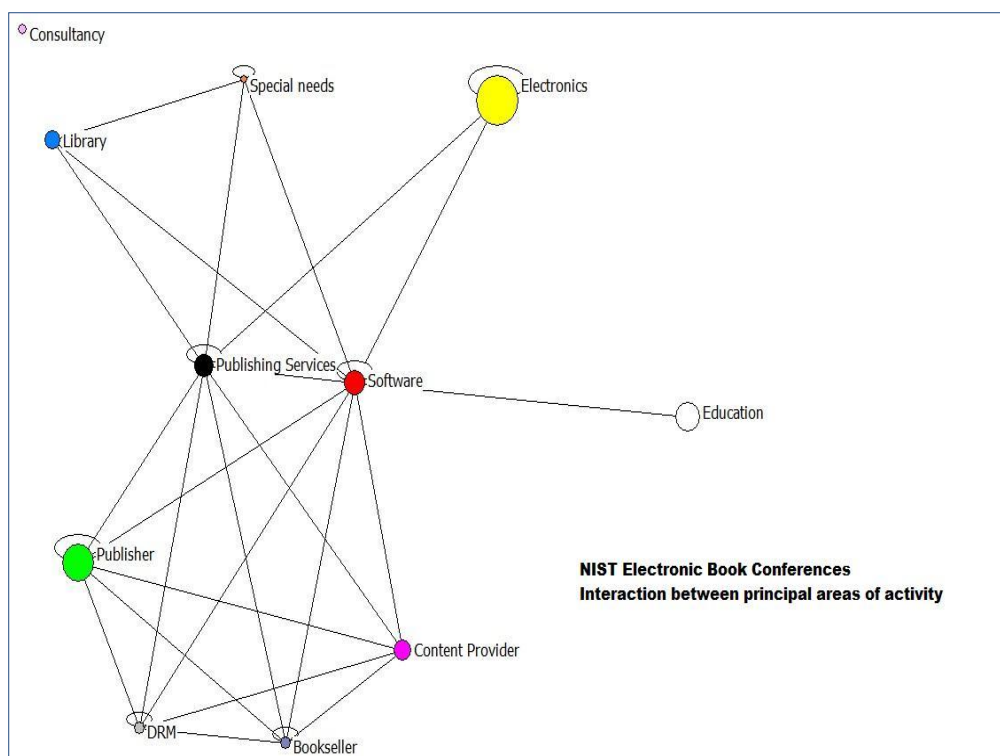
Network graph 5.2: NIST-Interaction between principal areas of activity

Organisations in the area of education tend to be poorly linked, having higher than average density of interaction only with those in the software category. The category of consultants, which is very small, is not well embedded in the network as the density of interactions is always weaker than average. The booksellers, on the other hand, are well embedded since they have stronger than average links both with incumbent categories of actors such as publishers, but also with organisations such as DRM, publishing services and software whose participation in the book industry represents the emergence of information technology in the sector. With the exception of electronics organisations, booksellers are well linked to these emergent actors. Content providers, who are in some ways the digital equivalent of booksellers, have stronger than average interaction with publishers and DRM organisations. This is somewhat expected as they rely on publishers for content and DRM is an unresolved issue in digital distribution. However, a lower than average interaction is observed with electronics organisation indicating lack of integration of device manufacturers in the content distribution process. By observing the respective densities, it appears that actors in the electronics category are not as well embedded with other groups as are those in the software category. There is however higher than average interaction between electronics and software actors. The electronic book can be seen as a modular technology comprising hardware and software therefore the discrepancy between the linking patterns of these groups should be noted. Publishing services organisations act as facilitators by their nature and they are well embedded in the overall network. The groups representing libraries and special needs users are relatively isolated and this fact could correspond to their status as distinct market segments.

In general the NIST conferences network is not particularly dense for an affiliation network and the frequency of interaction varies according to the organisations' principal area of activity. The grouped density data can contribute to understanding the interactions between different areas of expertise at the early stages of the e-book industry.

ii. Small world phenomenon: clustering co-efficient

The values for the overall and the weighted overall graph clustering co-efficient are 1.063 and 0.893 respectively. The weighted value is usually lower because neighbourhood size is taken into account; since larger neighbourhoods tend to be less dense the value drops. Both these values are higher than the overall network density (0.5088); hence there is a clear indication that actors are embedded in relatively dense local neighbourhoods.

iii. Homophily

Network graph 5.2 illustrates the interaction between different areas of activity in relation to the average network interaction. In addition, it is of interest to what degree overall interaction in the network takes place within principal areas of activity rather than between different areas. For this purpose E-I Index analysis is applied. The results are values for the whole network, for each of the categories and for individual actors. The results for the network as a whole are shown in the table below

Observed E-I Index	0.715
Expected E-I Index	0.734
Rescaled E-I Index	0.009
Minimum possible E-I Index	0.425
Maximum possible E-I Index	1.000

Table 5.2: NIST-E-I Index

The observed E-I index results from the calculation described in the definition: it indicates that there is a strong tendency for actors to network out of their groups. In order to assess whether the observed E-I index differs from a random result a permutation test is run and the expected E-I Index is calculated. A number of trials (5000) are run where the overall network density and the group categorisation are maintained but the actual ties are randomly distributed. The expected E-I is slightly higher than the observed. For greater precision the rescaled E-I index is also calculated. The range of the possible E-I Index values can be further limited by the number of groups, relative group size and overall density. The minimum and maximum possible values are noted in the table above. When the restriction is significant the E-I Index is recalculated to fall within this range and avoid bias because of the relative group size. The rescaled E-I Index still indicates a tendency towards external ties but it is significantly reduced from the observed value.

Regarding network cohesion it is observed that it is relatively low for an affiliation network. Density is not equally distributed among different combinations of organisational categories, although overall there is a tendency to form out-group ties.

5.1.3. Cohesive groups and network sub-structures

The network cohesion measures have indicated that interaction is not equally distributed among the network. In addition, the networks visualisation indicates evidence of clustering. Three approaches are applied in order to identify network subgroups in the NIST conferences network. First, the k-core approach is applied which is considered more suitable for affiliation networks as these tend to be quite dense. Then faction analysis is applied as a top-down approach to the identification of substructures. Finally, the valued cores approach is used which is specific to valued networks, therefore useful for affiliation networks.

i. K-core analysis

The k-core analysis can be demonstrated graphically by added indications on Network graph 5.1. K-cores are not mutually exclusive categories rather they are nested; actors within a core of higher k-value also belong to the lower cores. The diagram shows the actors in the core they have been categorised indicating the related k-value.
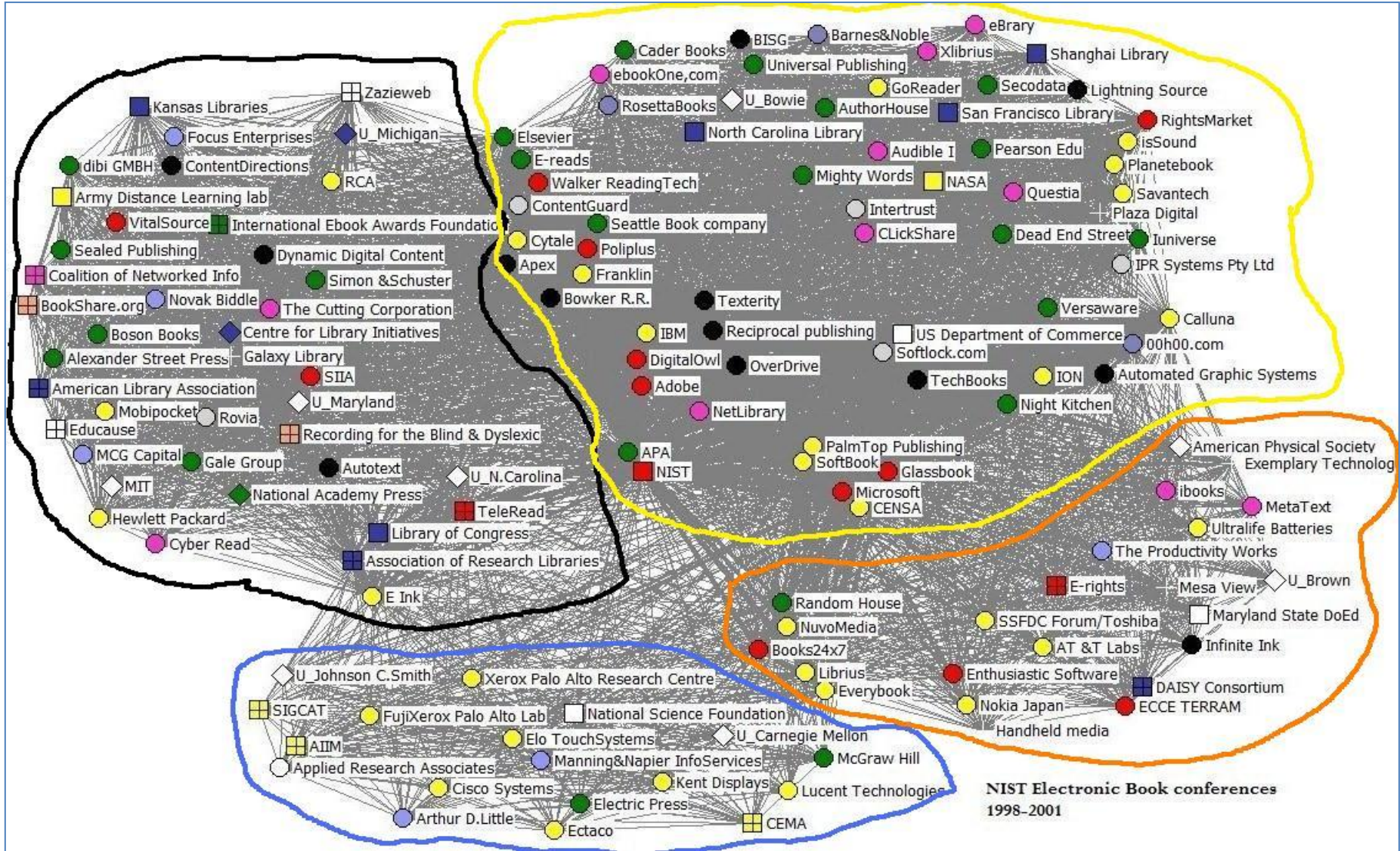
Network graph 5.3: NIST k-core analysis

ii. Faction analysis

   The number of desired faction is decided by the analyst. In that case, it is attempted to divide the network in four factions, because the network results from four events and is divided into four k-core groups. The network is then divided into four groups that satisfy the conditions on faction identification as far as possible. The density matrix shown below includes the density between the factions. Diagonal values should be large and values off the diagonal should be minimal.

	Faction1	Faction2	Faction3	Faction4
Faction1	1.040	0.22	0.18	0.14
Faction2	0.22	1	0.18	0.24
Faction3	0.18	0.18	1.08	0.42
Faction4	0.14	0.24	0.42	1.09

Table 5.3: NIST-Faction grouped densities

   Considering that the density values result from the valued data, denser than average interactions result within factions and low interactions between them. However, this division is far from optimal. The final number of errors is used to assess how well this division fits the ideal structure. There are two types of error: ties missing within faction and ties being present between factions. Once the network is blocked into four factions the number of errors equals 3046. This represents a substantial reduction from the initial number of errors (7948).

   Below the network is visualised identifying the different factions.
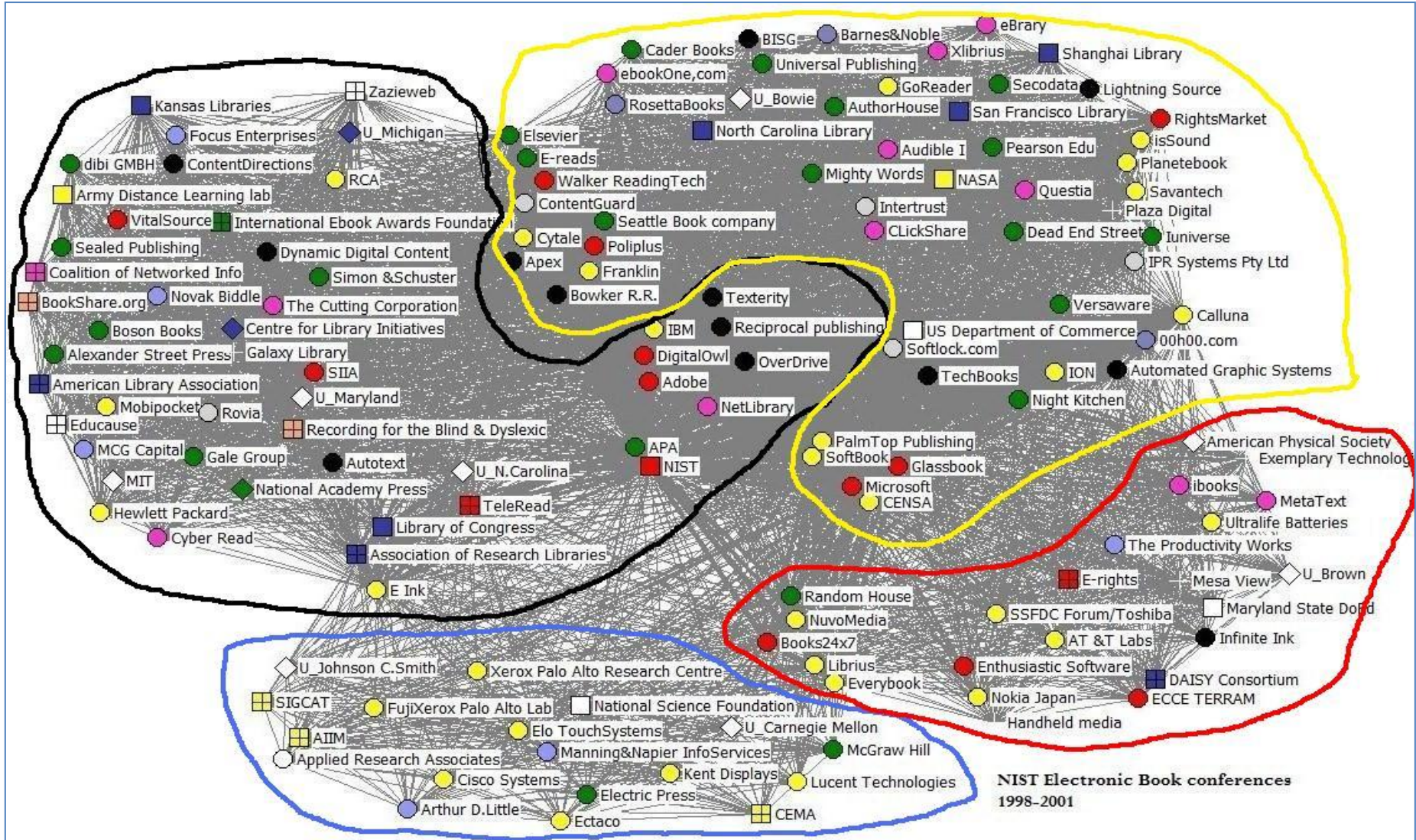
Network graph 5.4: NIST factions

iii. Valued core analysis

The aforementioned measures do not take into account the strength of the tie. The distribution of tie strength is shown below.
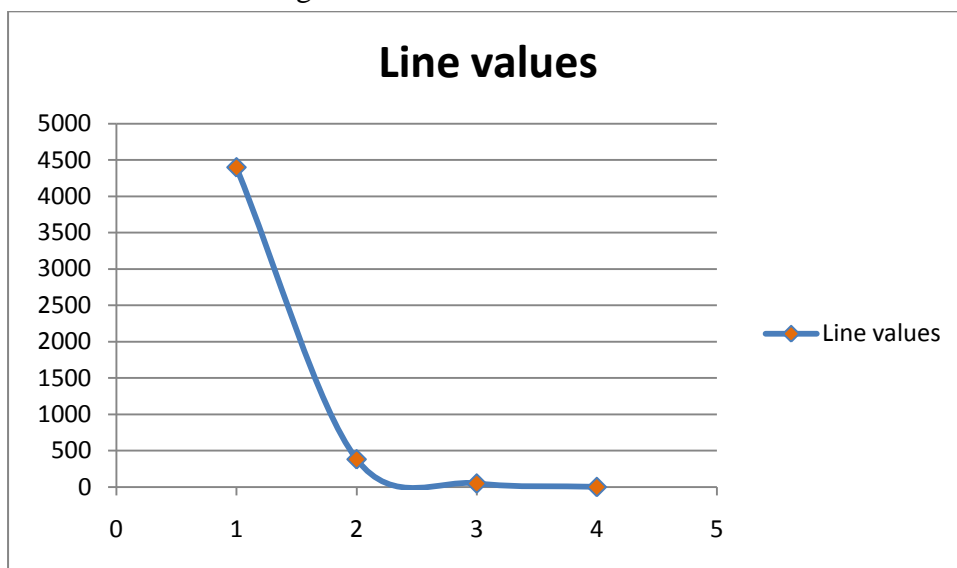
Figure 5.6 : NIST-tie strength

An alternative option for valued networks is to divide the network in valued cores (m-slices). Like k-cores they result in nested groups (de Nooy et al., 2005). Ties weaker than two and the actors who have no ties greater than one are ignored. This results in a reduced version of the network which is visualised below. In order to visualise the network only ties of value at least 2 are accepted thereby the majority of ties are ignored. Then only the actors that are connected through these ties are retained. A reduced version of the NIST network is thus obtained and visualised in the next diagram. In that case greater tie strength indicates more continuous interaction.
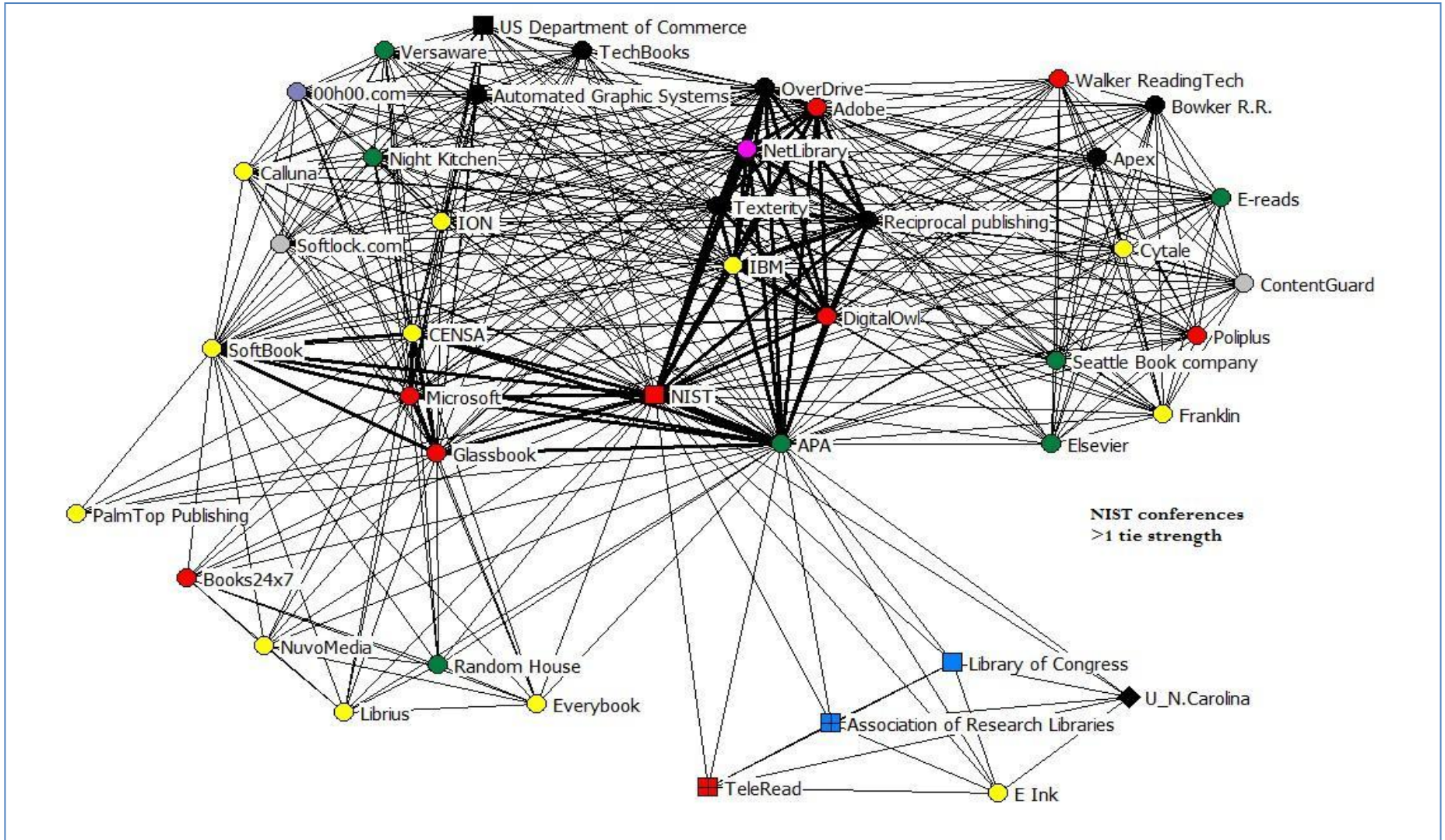
Network graph 5.5: NIST reduced network

5.1.4. Nodes as intermediaries: centrality and brokerage

The participants in the NIST Electronic Book Conferences network have been classified into groups according to attribute data independent from their participation patterns. In addition, SNA measures were applied to divide the participants into subgroups according to the distribution of ties within the network. Nodes differ with regard to their embeddedness in subgroups. There may be isolate nodes, nodes that act as bridges among groups and nodes that contribute to the cohesion of a particular subgroup. In the analysis so far focus was placed on overall network cohesion and on the identification of subgroups. In this section, the potential of individual actors to act as intermediaries and contribute to the cohesion of a network is assessed. Betweenness centrality and brokerage measures are applied for this purpose.

i. Centrality: betweenness measures

Firstly Freeman's betweenness analysis is applied which yields the following results. It should be taken into account that the network is dichotomised in order to calculate centrality.

	Betweenness	normalised Betweenness
Mean	38.697	0.376
Standard Deviation	79.343	0.771
Minimum	0	0
Maximum	454.303	4.412
Centralisation	60263.007	0.0406

Table 5.4: NIST-Freeman's betweenness

It is remarked that there is large deviation in relation to the mean. A large number of organisations (102) have betweenness value of 0. This indicates an uneven distribution of betweenness. Centralisation measures are introduced to measure to what extent betweenness values differ across the network. Betweenness centralisation sums the differences in betweenness centrality values for the node with the highest value and all other nodes. The betweenness centralisation index (normalised centralisation) divides this value by the maximum possible centralisation for a network this size. This index is not perfect because it assumes that geodesic paths between any two nodes are unique (Knoke and Yang, 2008). However, it facilitates comparison between networks of different size. The network centralisation index is low in this case, considering that a majority of actors have no betweenness value. The distribution of Freeman's betweenness is shown below.
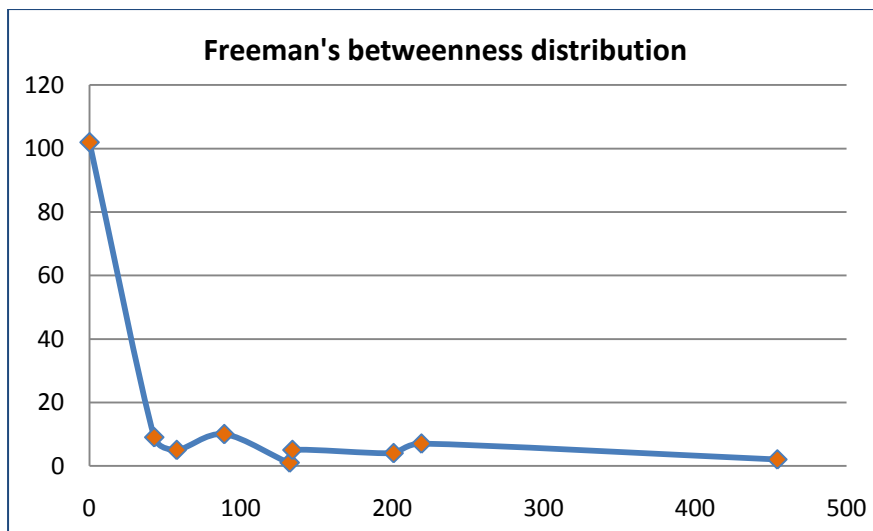
Figure 5.7: NIST- Betweenness distribution

The results of flow betweenness analysis are shown below. Flow betweenness addresses the limitations of Freeman's betweenness. Normalised flow betweenness and centralisation are calculated following the same logic as in the Freeman's betweenness measures.

	Flow Centrality	Normalised flow centrality
Mean	142.78	0.693
Standard Deviation	77.383	0.376
Minimum	63.886	0.31
Maximum	437.953	2.127
Centralisation		0.01443

Table 5.5: NIST: Flow betweenness centrality

Flow betweenness results in lower network centralisation than Freeman's betweenness. Mean value also rises while standard deviation is reduced in relation to the mean and all nodes have a value higher than zero even if it is minimal. It appears that when all paths are taken into account rather than the geodesics the network becomes less dependent on certain central nodes.

The distribution of flow betweenness is as follows.
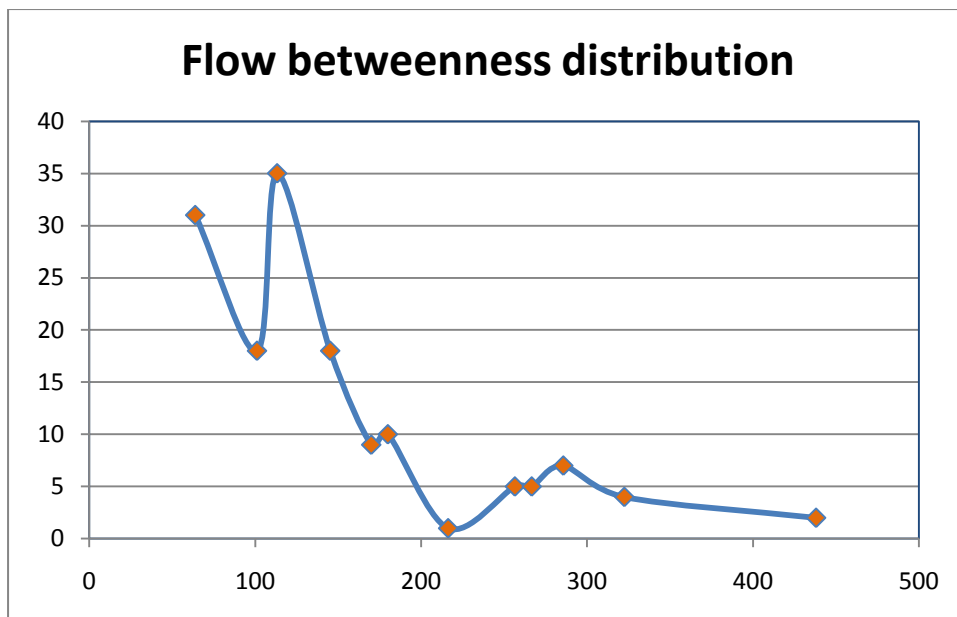
Figure 5.8: NIST-flow betweenness distribution

ii. Attribute-based partitioning of betweenness centrality

Both Freeman's betweenness and flow betweenness centrality assess an actor's potential to mediate between other regardless of their attributes. Freeman's betweenness can be adjusted to indicate which actors are more likely to mediate within the same subgroup and between different subgroups. Subgroups may be identified either by attribute data or by structural/relational analysis. Hence the overall betweenness value of a node is the sum of two values: internal node betweenness measures the proportion of geodesic paths passing through a given node, measuring all the geodesic paths that connect nodes in the same group, and external node betweenness measures the proportion of geodesic paths going through a given node, including only the geodesics that connect actors belonging to different groups.

The organisations are partitioned according to the principal area of activity. Each is assigned a value for internal and external betweenness centrality. Theoretically, it would be possible to partition overall betweenness in more detail by limiting the geodesic paths within a specific group or between two particular groups, but there is not an available routine for this computation. Organisations that rank higher in internal betweenness are better positioned to facilitate interaction among organisation with a similar knowledge base, while those with high external betweenness are better place to act as bridges between groups. Correlation analysis is applied to examine how internal and external betweenness are associated. In this case there is almost perfect correlation between internal and external betweenness indicating that there is hardly any difference between actors' potential to mediate within or between the principal areas of activity.

iii. Fragmentation

The centrality measures presented above evaluate an organisation's potential as intermediary. Fragmentation evaluates how each actor contributes to network cohesion (Borgatti and Everett, 2006). Because the NIST conferences network has only one component

(all nodes are mutually reachable) node fragmentation measures were calculated weighted by distance. The overall network fragmentation has a low value (0.269). Although the density measures did not indicate high network cohesion, low fragmentation indicates difficulty in deconstructing the overall network.

iv. Brokerage

The brokerage measures were introduced by Gould and Fernandez (1989). They calculate overall brokerage according to the above definition as a sum of specific brokerage roles. These roles consider the partitioning of actors into groups. Again the principal area of activity was used as the partitioning attribute. The weighted method was selected so that brokerage values are adjusted to reflect to what degree other actors can replace the ego as a broker between the same pairs. This way it was attempted to address the issue of redundancy. There are five brokerage roles, which are in practice are four for non-directed data. The role of representative (or gatekeeper) indicates that an actor acts as a broker by linking actors of its groups to other groups. The co-ordinator role indicates that the actor and the pairs it links all belong to the same group; when they all belong to different groups the broker is a liaison. An actor is a consultant when it mediates between actors that belong to the same group not being a member of the group itself. Below, descriptive statistics are provided on the weighted brokerage measures.

	Coordinator	Gatekeeper	Consultant	Liaison	Total
Mean	1.945	9.175	7.724	49.375	77.393
Standard Deviation	5.492	19.038	15.255	94.911	141.314
Minimum	0.000	0.000	0.000	0.000	0.000
Maximum	30.040	97.729	88.699	539.513	703.270

Table 5.6: NIST-Brokerage statistics

In relation to the average values standard deviation is significant which indicates that brokerage is unequally distributed. It is also remarked that the role of liaison accounts by far for the larger proportion of the total brokerage in the network. Actors are more likely to broker between organisations when they all belong to different categories. The correlation matrix below indicates how the different brokerage measures are connected.

	Coordinator	Gatekeeper	Consultant	Liaison	Total
Coordinator	1	0.905	0.316	0.342	0.546
Gatekeeper	0.905	1	0.651	0.668	0.824
Consultant	0.316	0.651	1	0.993	0.962
Liaison	0.342	0.668	0.993	1	0.972
Total	0.546	0.824	0.962	0.972	1

Table .5.7: NIST network- correlation of brokerage measures

As it could be expected there is an almost complete correlation between the liaison role and total brokerage. The co-ordinator role has the lowest correlation with the total.

5.2. IDPF membership network

The International Digital Publishing Forum was initially set up as the Open E-book Forum. Its main aim is the development and promotion of standardised format for digital documents. It also provides a venue of interaction between organisations that are involved in technical development of electronic books or digital publications. Membership data on the IDPF are available for six periods (corresponding to seven years because joint membership information is available for 2002 and 2003). This information is perceived as a 2-mode network including organisations and membership periods. Firstly, the attribute data of the organisations involved and the frequency of participation are described. Subsequently, the participation data can be converted into affiliation networks where the value of a tie between two organisations indicates how many years they had both been IDPF members. In order to observe how network structure changes overtime, consecutive affiliation networks are constructed using cumulative data for each year. Changes in networks structure reflect both new entrants and organisations leaving IDPF. Hence, the final network includes all organisations who have at some point participated in IDPF.

5.2.1. Network composition and participation patterns

       The network actors are categorised according to type and principal area of activity. The same categories that have been applied in the NIST conferences network are used. The classification presents both the total frequencies and the percentages for ease of comparison. The data for each year refer only to organisations that have been IDPF members this period as listed on the annual reports; they are not cumulative. The final column in each table provides the classification for all organisations that have been IDPF members at some point. First, the classification by organisational type is presented.
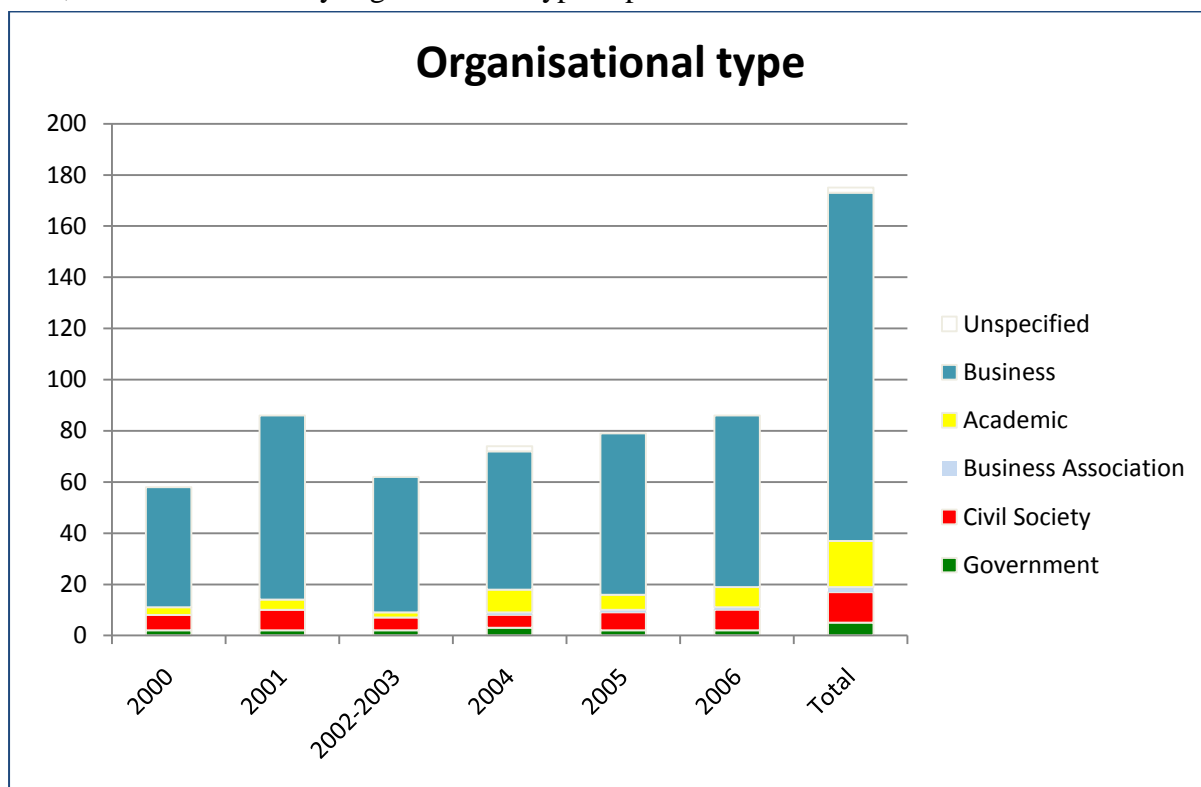
Figure 5.9: IDPF-organisational type

       It is observed that the majority of member organisations have been business oriented; this reinforces the conception of IDPF as a business association. There are however some fluctuations in the representation of smaller categories. On account of the latest available data (2006), government representation is small but there is an equal representation of civil society and academic organisations which detract from a fully business oriented network.

       Below the organisations are classified into principal areas of activity following the same presentation style.
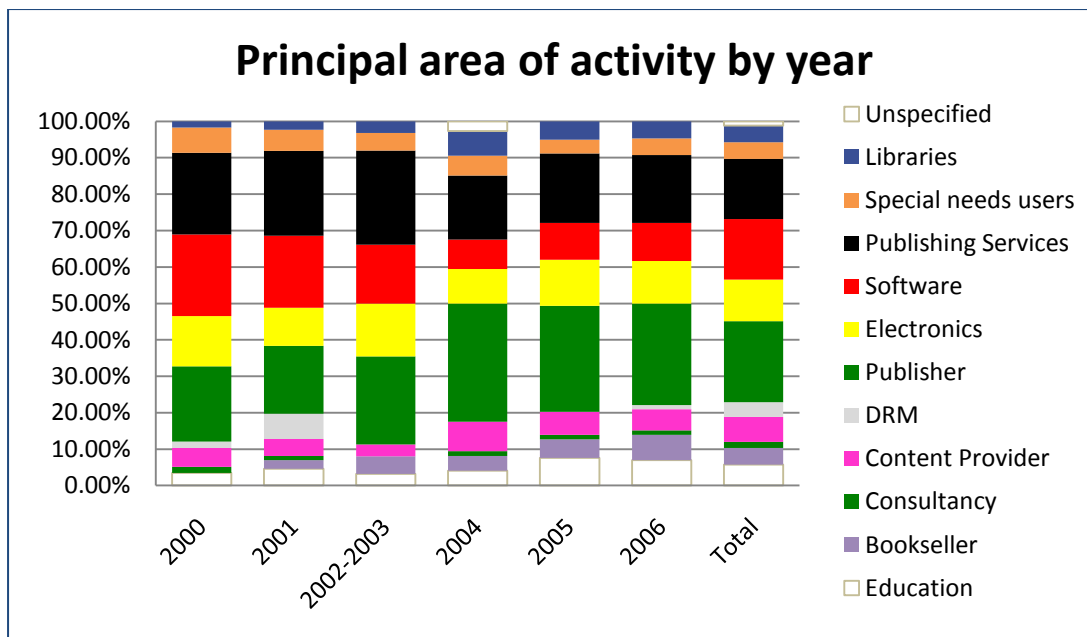
Figure 5.10: IDPF-Principal area of activity

The classification into principal area of activity indicates greater diversity that the classification by organisational type. Overall, publishers have the highest representation at 22.29% of the total. Publishing services and software both at 16.57% rank second in their proportional representation. It is observed that there is variation in the representation of principal area of activities over the years. For example, publishers' participation has increased from 20.69% in 2000 to 27.91% in 2006. Yet, organisational diversity regarding the knowledge base is observed throughout the years.

i. Participation patterns

Organisational membership patterns vary. First of all, there is difference in the frequency of participation regarding how many years each organisation had been a member and also regarding which specific years they were IDPF members. A categorisation of IDPF participants according to years of membership is indicated in the diagram below.

Membership frequency
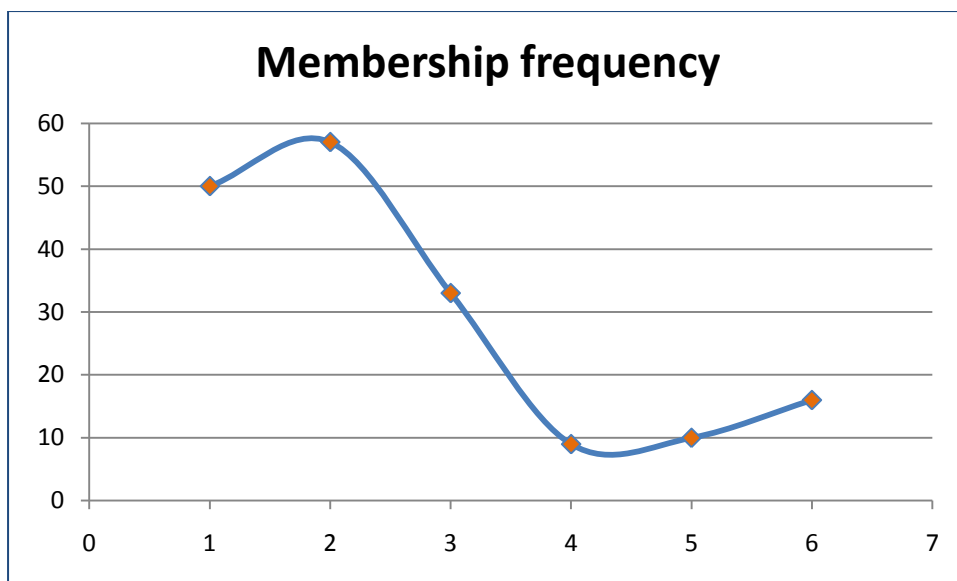
Figure 5.11: IDPF membership frequency

A small group of 16 organisations is identified hat have been continuously involved in IDPF. The more common participation choice was to attend IDPF for two years. There can be a differentiation between organisations that were among the initial participants and left IDPF later on and those that may have joined later but are still members. In addition, some organisations showed intermittent participation by leaving IDPF and rejoining later on.

Data are also collected regarding country of origin. In the case of multinational organisations, country of origin refers to the location of the headquarters or the location of the department that is represented in IDPF. Organisations from twenty countries are listed in IDPF although there is a significant majority of US based organisations. However, as the organisations' commercial or research activities are not necessarily restricted to the country of origin there is a risk in attributing undue importance to this information.

5.2.2. Co-membership networks

The attribute data of IDPF members and the frequency of participation are presented. The relational data indicate how organisations are linked through co-participation in each period of membership. The affiliation network evolves over time; in order to demonstrate this the 2-mode participation networks can be modified by focusing on participation in specific years. Hence, one can construct consecutive affiliation networks beginning from the one including interaction between participants in the first two years and extending to the final network that includes al IDPF participants and co-membership data for all six periods. The resulting affiliation networks are valued and symmetrical; tie strength between two organisations indicates how many years they had both been members. Hence in the final network tie strength may range from zero to six

The consecutive affiliation networks are visualised below. All network graphs are drawn according to the spring embedding algorithm. The attribute data are indicated by node shape and colour same as in the NIST Electronic Book Conferences network. The same notation is used as in the NIST conferences networks. The colour notation is the same as the one used in the figures that demonstrate network composition according to principal area of a activity. The network diagrams indicate intuitively changes in network composition over time. However, differences in network size and composition limit the potential for comparisons. The analysis following the visualisations mostly focuses on the final network.
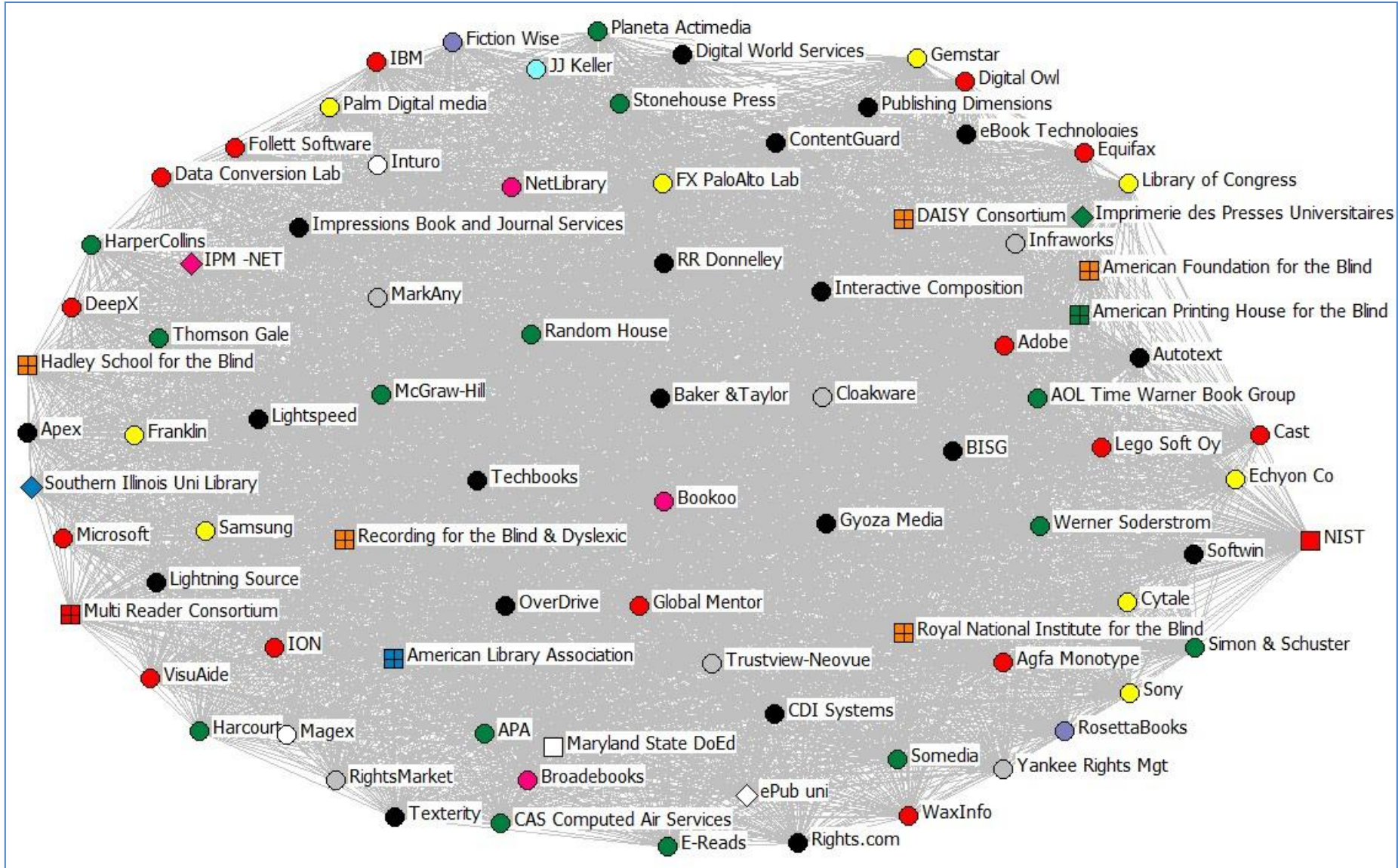
Network graph 5.6: IDPF 2000-2001
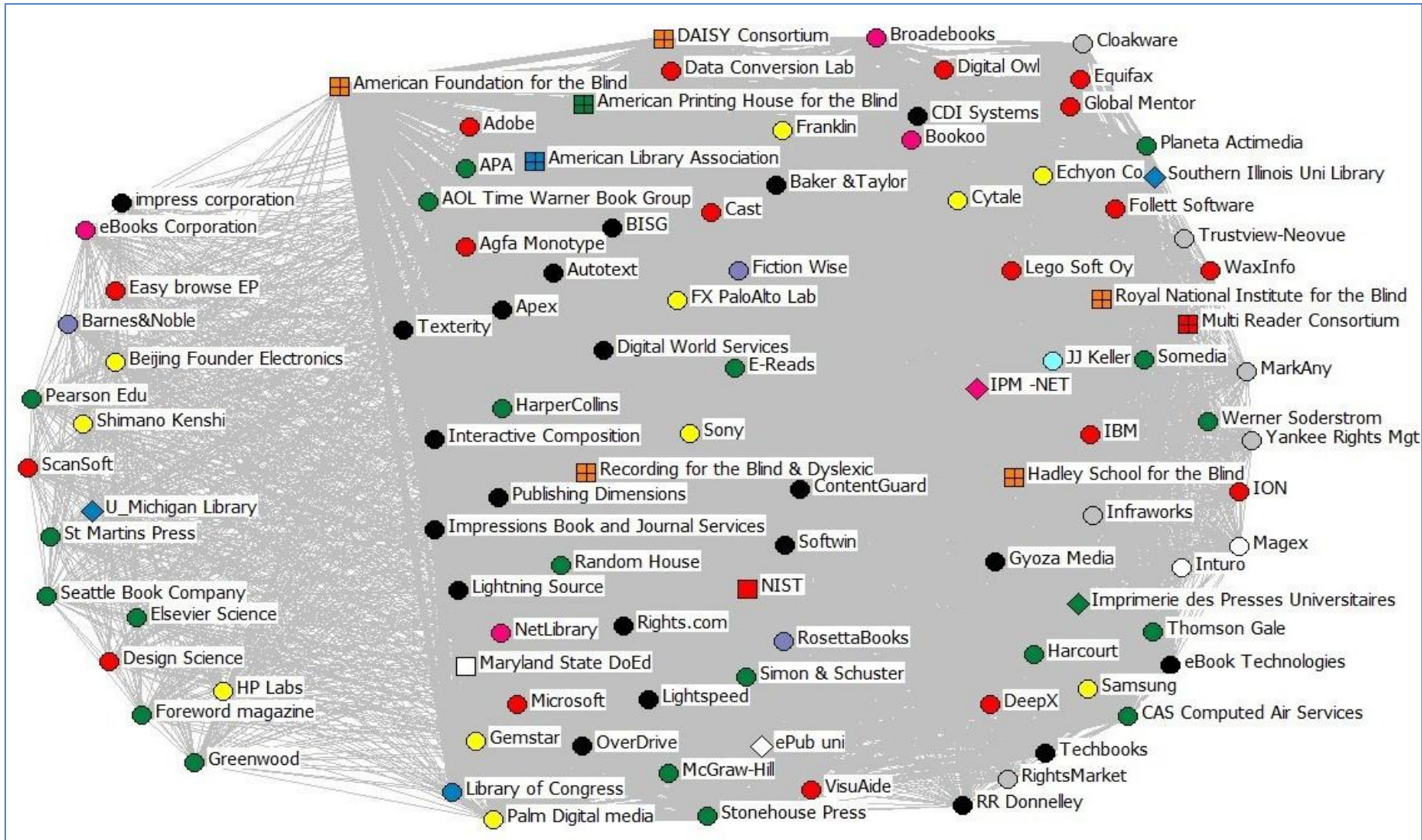
Network graph 5.7: IDPF 2000-2003
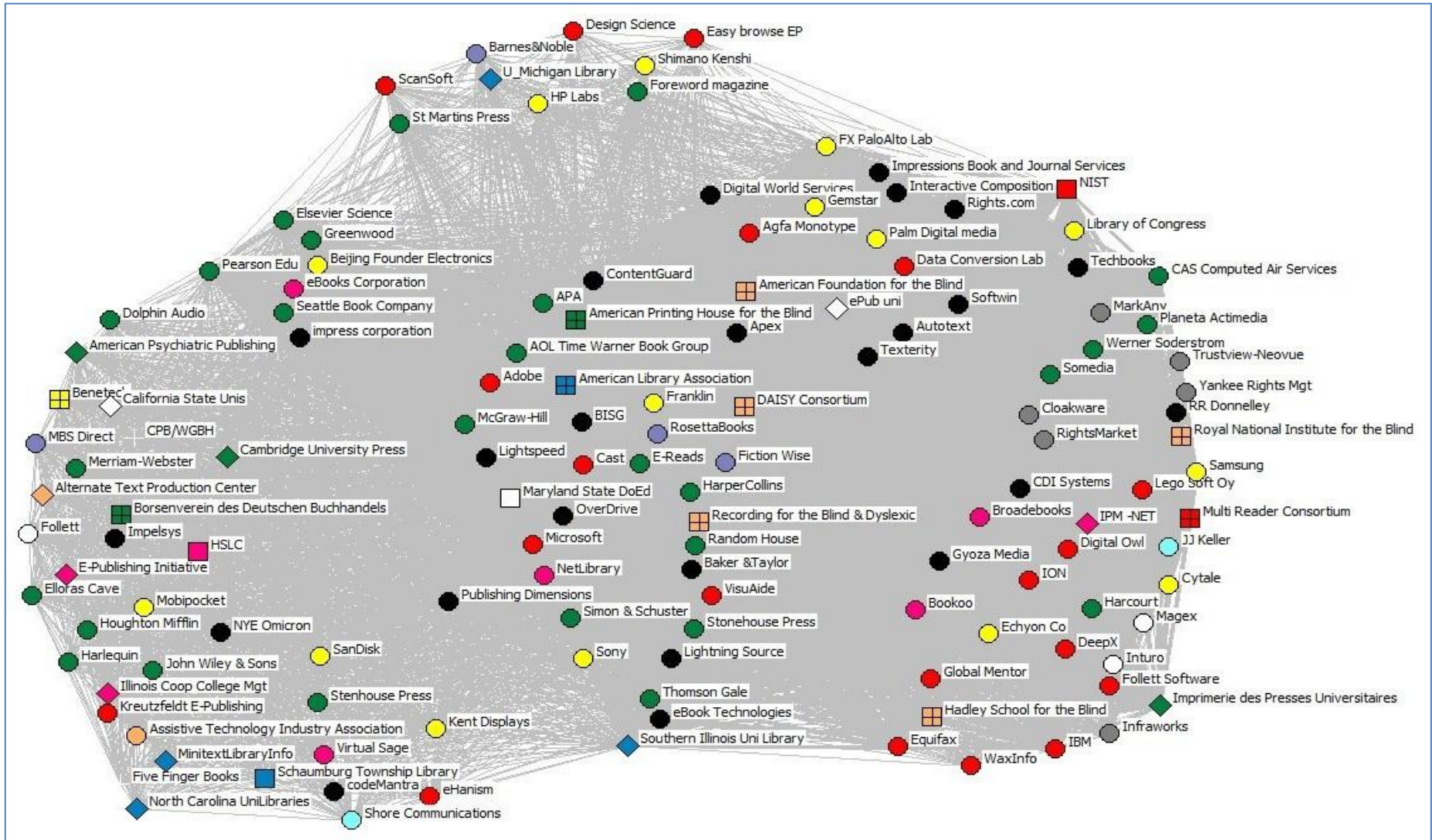
Network graph 5.8: IDPF 2000-2004
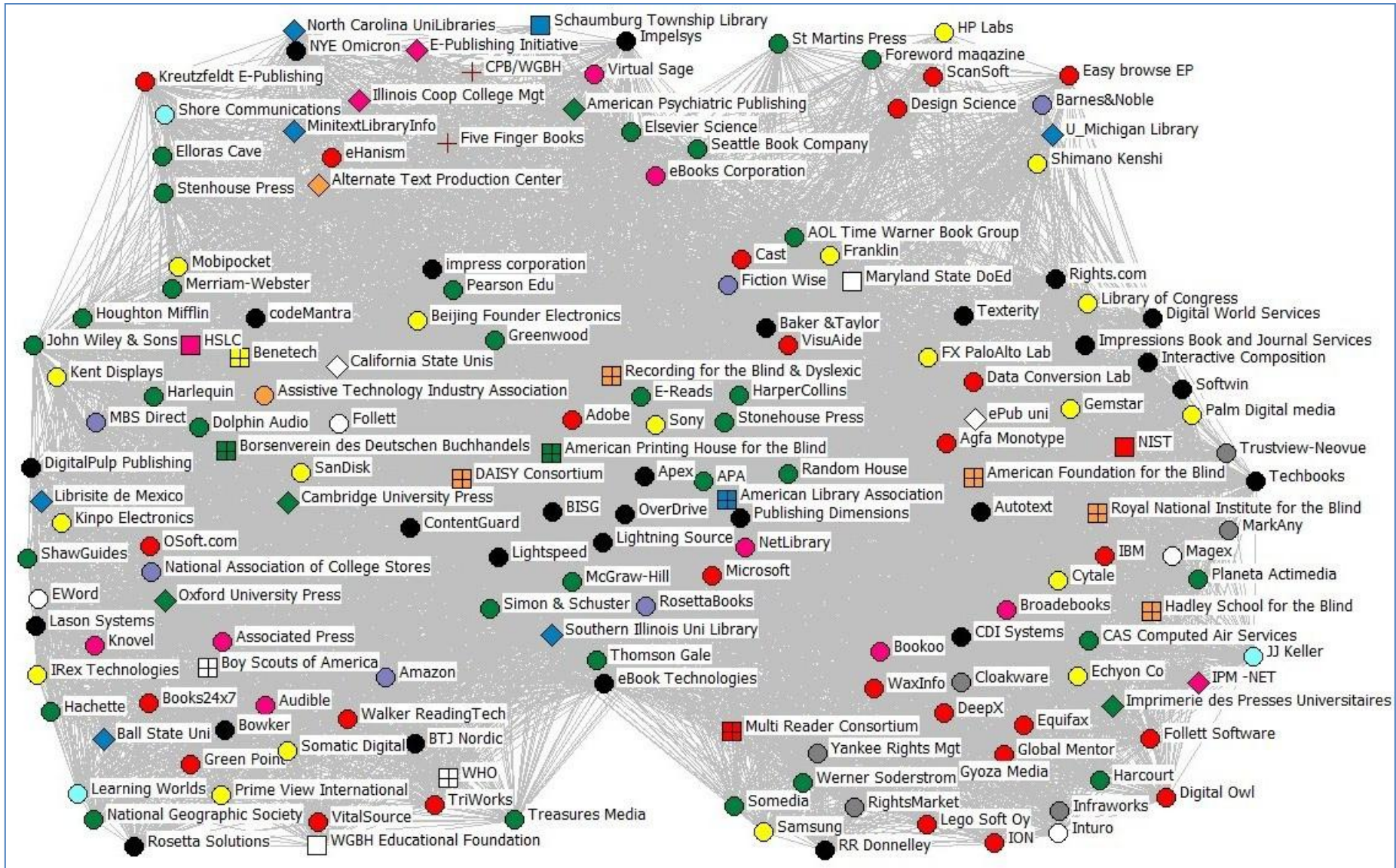
Network graph 5.9: IDPF 2000-2005
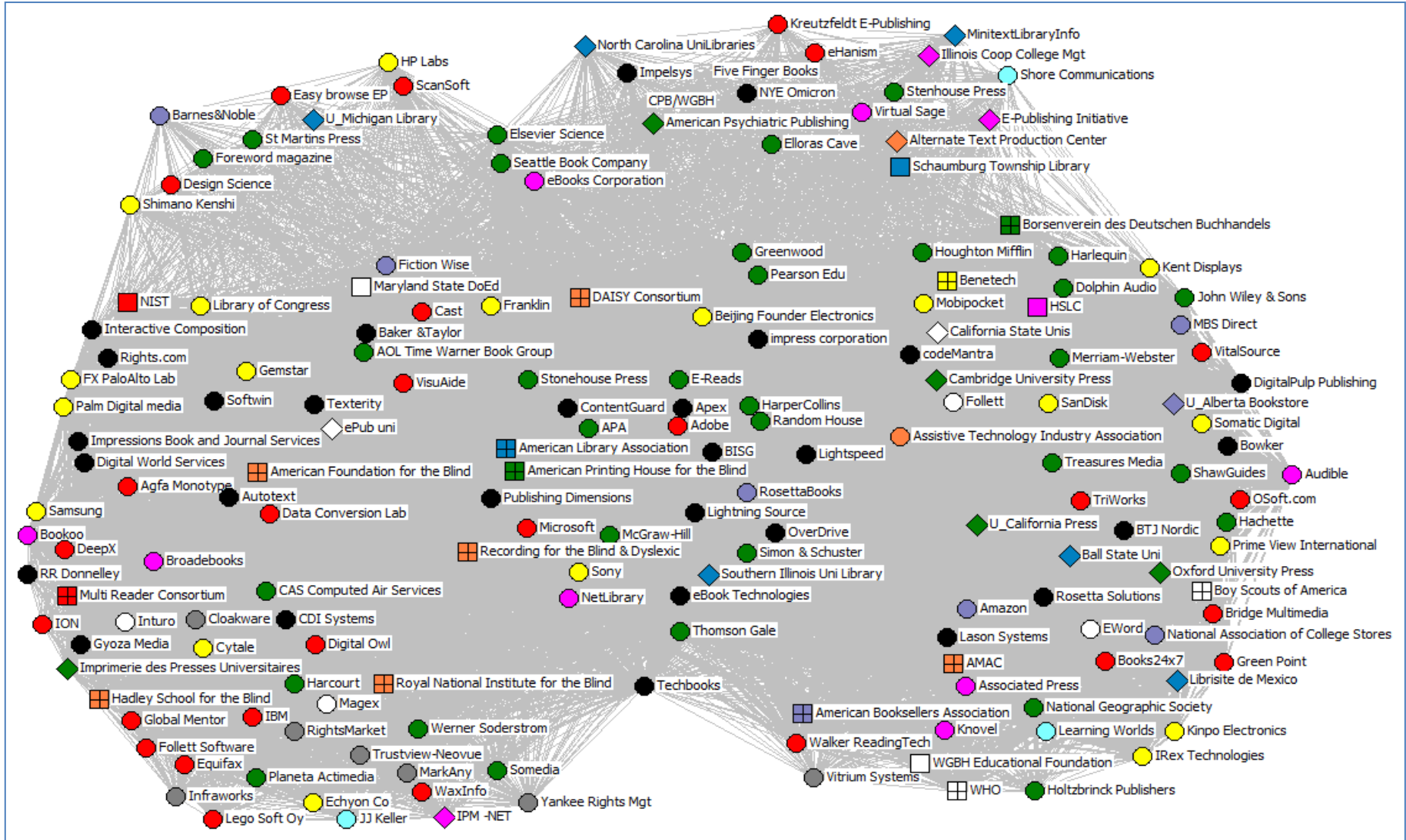
Network graph 5.10: IDPF aggregate network

5.2.3. Cohesion

i. Density

Firstly, the focus lies on overall network cohesion as it is indicated by density measures. As the networks are valued, density indicates the average tie strength across all possible ties. Because, maximum possible tie strength rises in each consecutive stage of the network, the data are not comparable across the years. However, the networks can be dichotomised and then calculate density according to the binary data of interaction.

	Stage1	Stage2	Stage3	Stage4	Stage5	Stage6-Final Network
Density	1	1.452	1.398	1.078	0.925	1.093
Standard Deviation	0	0.498	0.848	0.975	1.011	1.193
Density(binary)	1	1	0.8758	0.7029	0.6026	0.5963

Table 5.8: IDPF-density values

It can be argued that as the network grows it becomes less dense in relation to the maximum possible density. The first stage is the ideal form of a network where all actors are connected, hence density is one and there is no standard deviation. In the final stage of the network the average value of a tie is small related to the maximum possible value of six. It is to be expected that as the network grows both the likelihood of a tie and the strength of any existing ties are likely to decrease; it would be required for organisations to maintain continuous presence in the IDPF in order to be connected to new entrants and increase the strength of their already existing ties. Moreover, it is observed that standard deviation increases in relation to the average tie; as the network develops there is more variation in tie strength distribution. Densities that result from the dichotomised networks are easier to interpret and compare. The dichotomised network densities are high although they decrease in consecutive stages of the network. The density data indicate a highly cohesive network.

ii. Clustering co-efficient

All consecutive networks are highly dense. However density only provides an average measure of cohesion. The respective clustering co-efficients are calculated to evaluate whether network cohesion is more likely to develop within actors' local neighbourhoods. The clustering co-efficient are compared with densities to evaluate the role of ego-networks in cohesion. The weighted clustering co-efficient is selected to account for the fact that local neighbourhoods are of different size. The results for the consecutive co-membership networks are shown below. The clustering co-efficient refer to the valued data, so they are compared with the average density in the valued networks.

	Stage1	Stage2	Stage3	Stage4	Stage5	Stage6-Final Network
Clustering co-efficient	1	1.452	1.55	1.41	1.357	1.614
Density	1	1.452	1.398	1.078	0.925	1.093

Table 5.9: IDPF-clustering coefficients

Except for the first two stages, the clustering co-efficient is greater than density indicating that there are higher levels of cohesion within local neighbourhoods.

iii. Homophily

In order to observe interaction between organisations with a different knowledge base the network data are blocked according to the principal area of activity and density values are calculated within and between blocks. This analysis is only shown for the complete network. The analysis results in a network linking principal areas of activity.
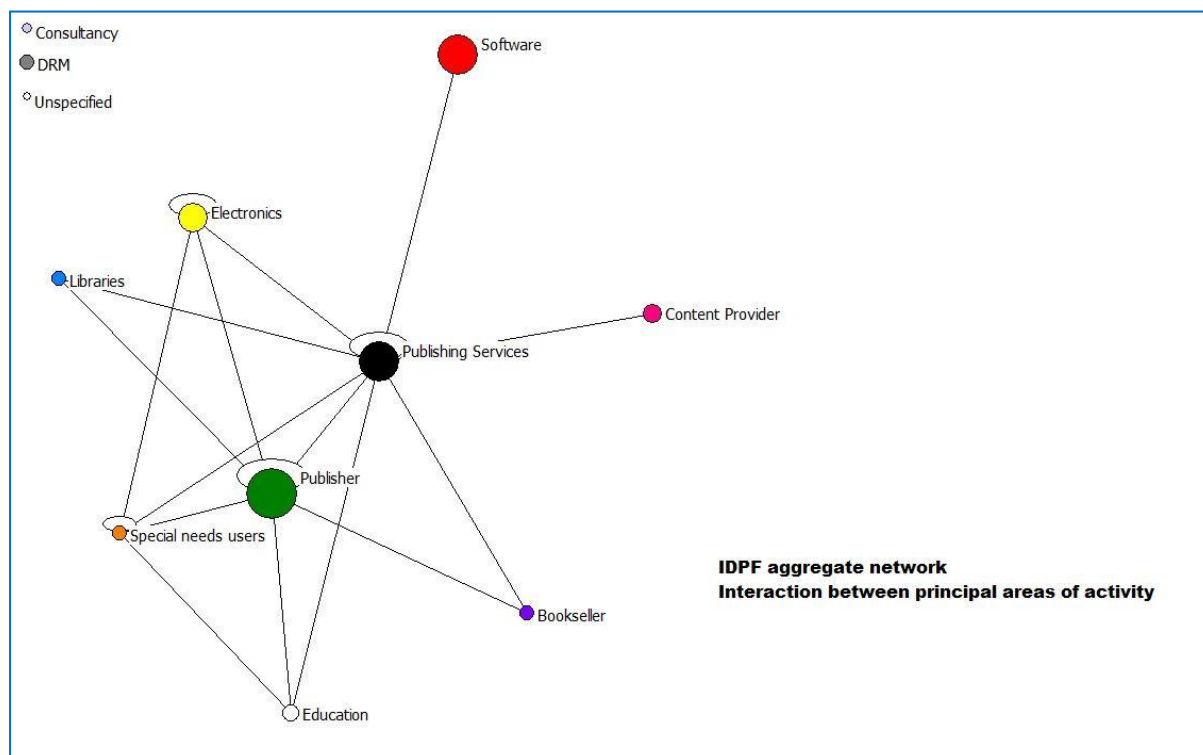
Network graph 5.11: IDPF-grouped density

There is no tendency for densities within groups to be higher than average. This is only observed in four categories. Among these, strong levels of interaction are observed between publishers. Organisations involved in publishing services are well integrated with other groups as their density of interaction is usually higher than average. On the other hand, it is remarked that software and DRM organisations are involved in lower levels of interaction with other groups.

The blocked density graph indicates how interaction levels between and within categories compare to the average level of interaction across the network. Comparing diagonal to off-diagonal values one can intuitively observe whether there is a higher tendency towards interaction within the group. E-I Index analysis provides a more formal evaluation of tendencies towards homophily. The following results refer to the IDPF aggregate network.

Network level E-I Index	
Observed E-I	0.722
Expected E-I	0.742
Rescaled E-I	-0.284
Minimum possible E-I	0.568
Maximum possible E-I	1

Table .5.10: IDPF-E-I Index

The observed E-I Index indicates that there is greater tendency towards out-group ties, although this is lower than would be expected of a network of the same size and density. Once the differences in group size are taken into account, a negative E-I Index value is obtained indicating a greater tendency towards in-group tie formation. It appears that the observed value towards heterogeneity can be attributed to the fact that there are more opportunities for organisations to form ties out of their group because of relative group size; it does not represent any deliberate choice on part of the actors. The group-level observed E-I index values are all positive; therefore the observed tendency towards out-group ties is characteristic of all groups.

5.2.4. Cohesive subsets and network substructures

K-core analysis, faction analysis and valued cores are applied to divide the network into subgroups.

i. K-core analysis

The following values of k result from the k-core analysis.

K-cores	
K-maximum nodal degree within subgroup	Organisations
85	146
73	20
61	9

Table 5.11: IDPF-k-cores

Organisations that are included in the highest core must be linked to at least 85 organisations in that subgroup. Regarding the lower cores it may appear counterintuitive that in a group of 20 and 9 actors the minimum nodal degrees have to be 73 and 61 respectively. However, it is known that k-cores are nested so that members of the higher core also belong to the lower ones. For organisations in the second core that means they have to be linked at least to 73 actors in the first and second group, and for those in the third core that they must have a minimum overall nodal degree of 61.

Below the IDPF participation network is visualised circling the k-cores. The diagram illustrates that the k-cores correspond to cohesive subgroups. In particular, the actors in the first and thus more restrictive core are connected, although usually members of a higher core tend to be connected through members of lower cores. The third core is also cohesive within itself although it is not as well integrated in the overall network.
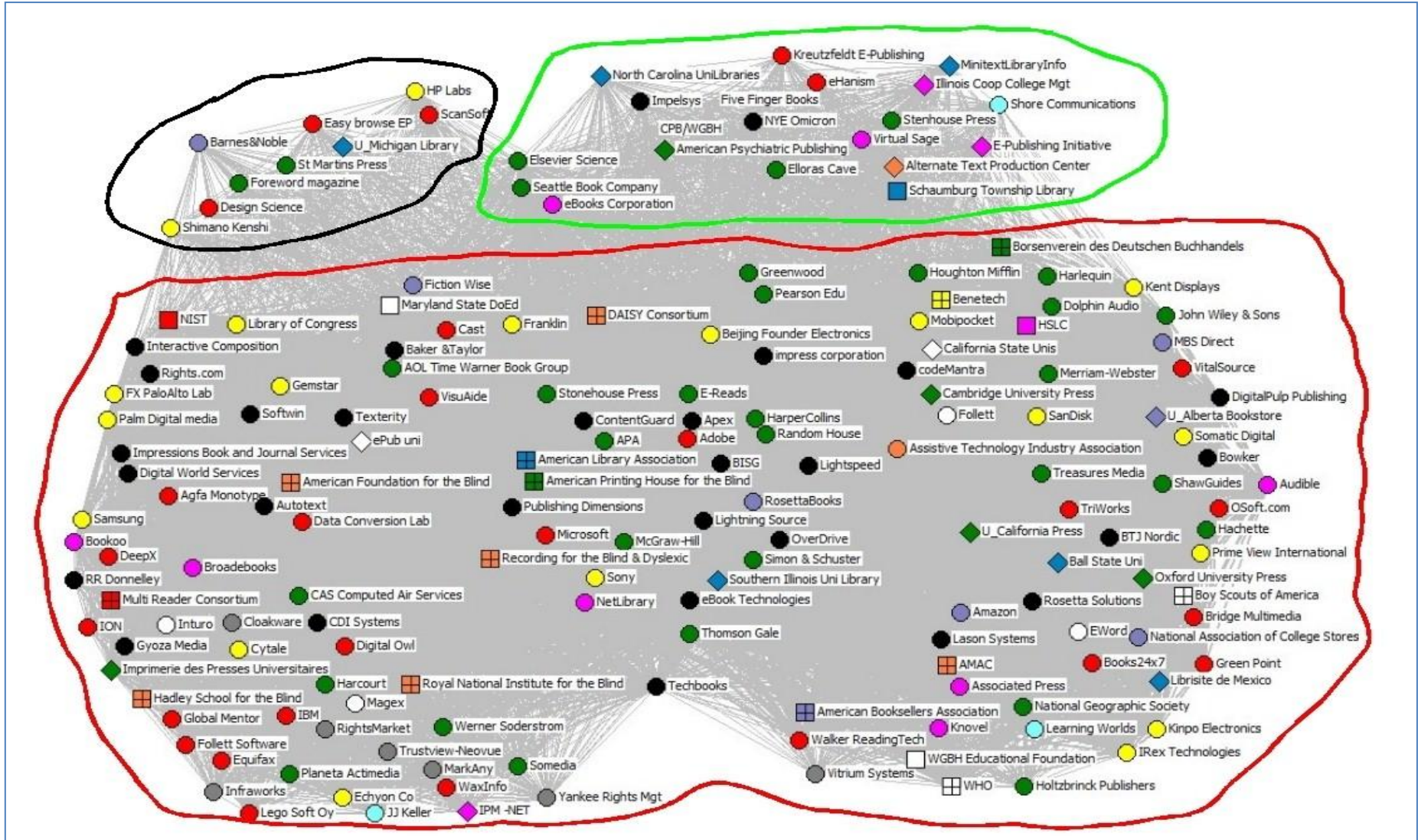
Network graph 5.12: IDPF k-cores

ii. Faction Analysis

Following the top-down approach to cohesive subgroups, faction analysis is applied in the IDPF network. Faction analysis differs from alternative approaches in that it does not result in nested or overlapping subgroups. Instead the algorithm attempts to maximise densities within subgroups and minimise densities between them. The algorithm was run on the basis of identifying three factions. The factional division is shown on the diagram below. The matrix permutation during faction analysis improved the goodness of fit by more than halving the number of errors. Following the matrix permutation the density matrix (on the basis of valued ties) yields the following results.

	Faction 1	Faction 2	Faction 3
Faction 1	1.68	0.93	0.52
Faction 2	0.93	1.55	0.87
Faction 3	0.52	0.87	1.64

Table 5.12: IDPF-Faction-based densities

The densities within factions are higher than the overall network density whereas lower density values are observed between factions, indicating greater cohesion within factions. However, faction size and composition differs significantly as the graph below illustrates.
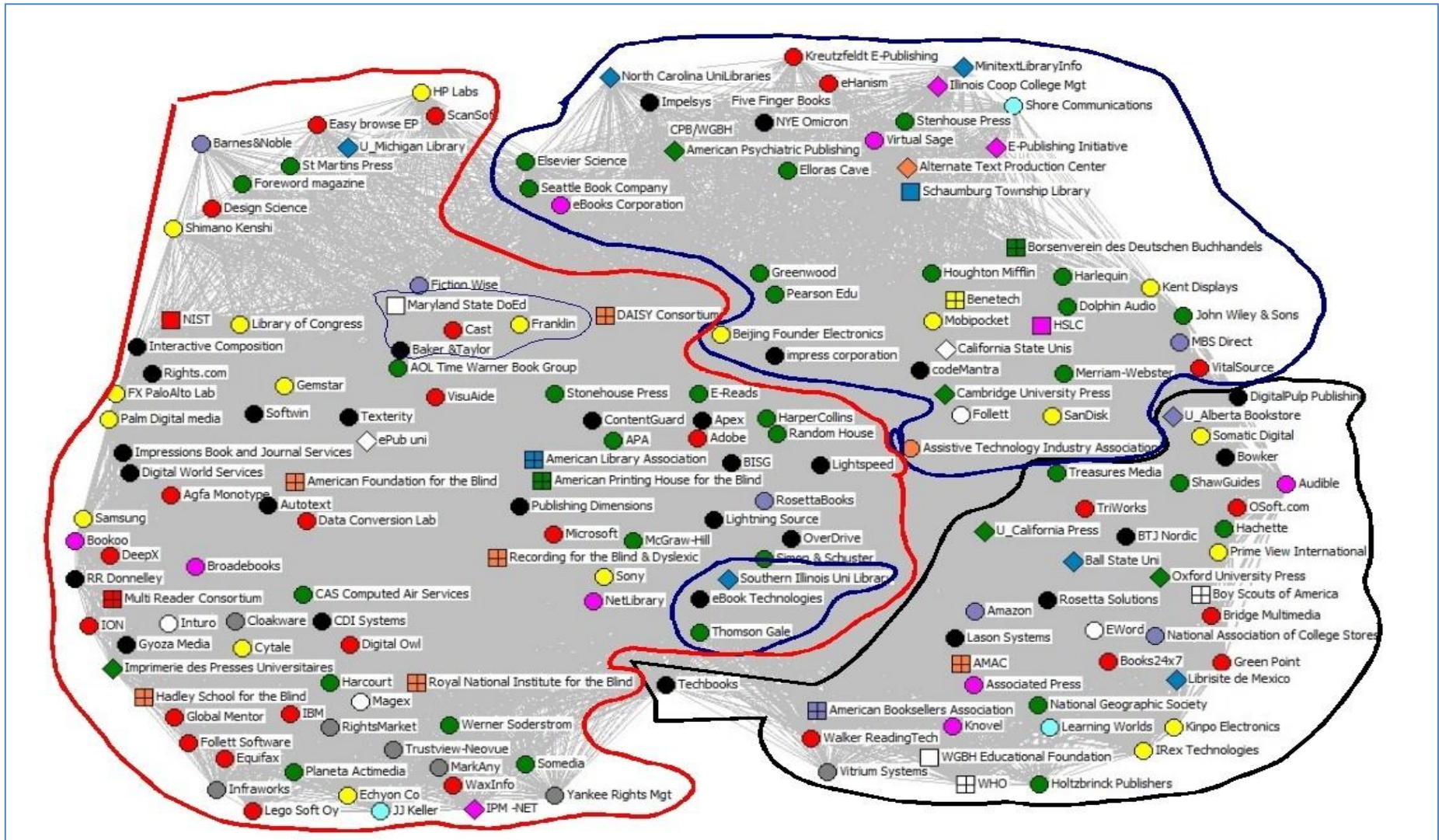
Network graph 5.13: IDPF factions

iii. Valued core analysis

The aforementioned cohesive subsets do not incorporate tie strength. Valued cores or m-slices are nested subgroups formed on the basis of line values. They are nested in the same way as k-cores are nested: the organisations that satisfy the conditions for inclusion in an m-slice also satisfy the condition for m-slices corresponding to lower values of m. In the IDPF participation networks values of m correspond to the tie strength values ranging from 1 to 6. In the IDPF network diagram below the nested m-slices are indicated.

The tie strength distribution is illustrated below.
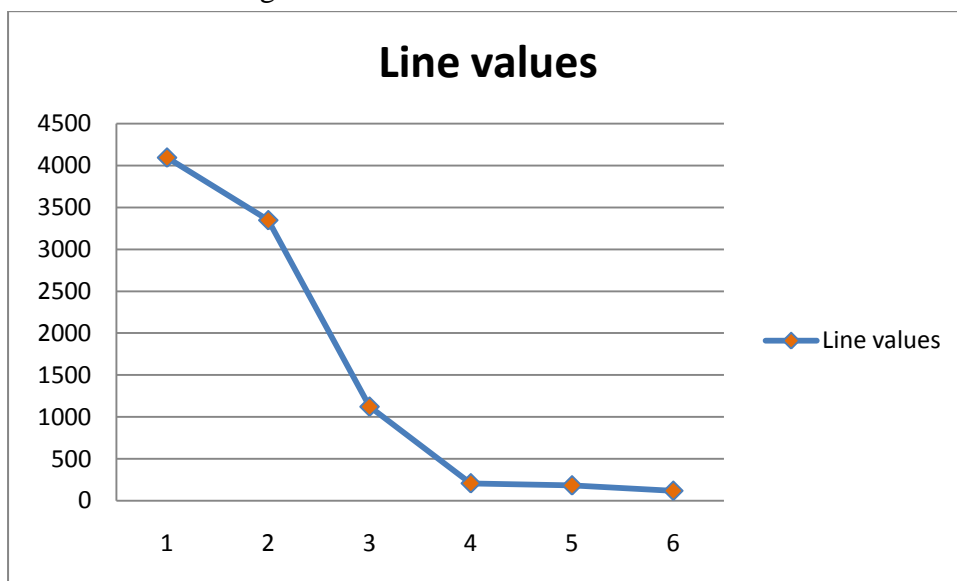
Figure 5.12: IDPF-tie strength distribution
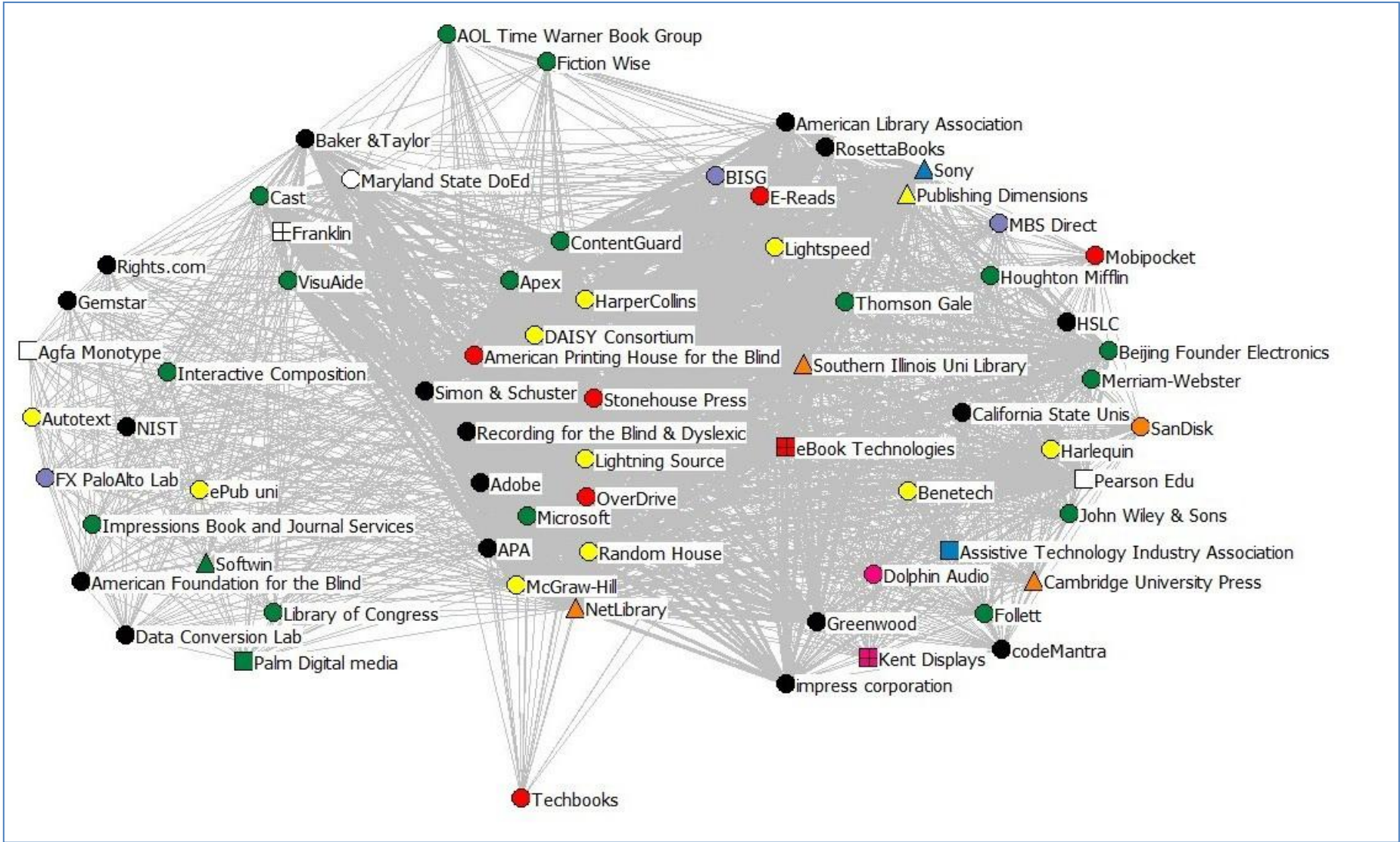
Network graph 5.14: IDPF reduced network

5.2.5. Centrality and brokerage measures

i. Freemans' betweenness centrality

Betweenness and flow betweenness centrality were applied to the aggregate IDPF network in order to evaluate which organisations demonstrate mediator potential. Betweenness centrality is represented in the respective graph by node size.

	Betweenness	Normalised Betweenness
Mean	35.12	0.233
Standard Deviation	62.023	0.412
Minimum	0	0
Maximum	179.073	1.19
Centralisation	25191.809	0.0096

Table 5.13: IDPF-Freeman's betweenness

Although standard deviation is high in relation to the mean, the low centralisation index indicates that betweenness is not overly concentrated on certain influential actors. Betweenness is strongly correlated to the number of years an organisation has participated in the IDPF. It is remarked that organisations that have only attended for one year have betweenness value of zero. As with the NIST conferences network, one participation is insufficient to provide a gatekeeping role. Those organisations that have been members continuously have the maximum betweenness value.
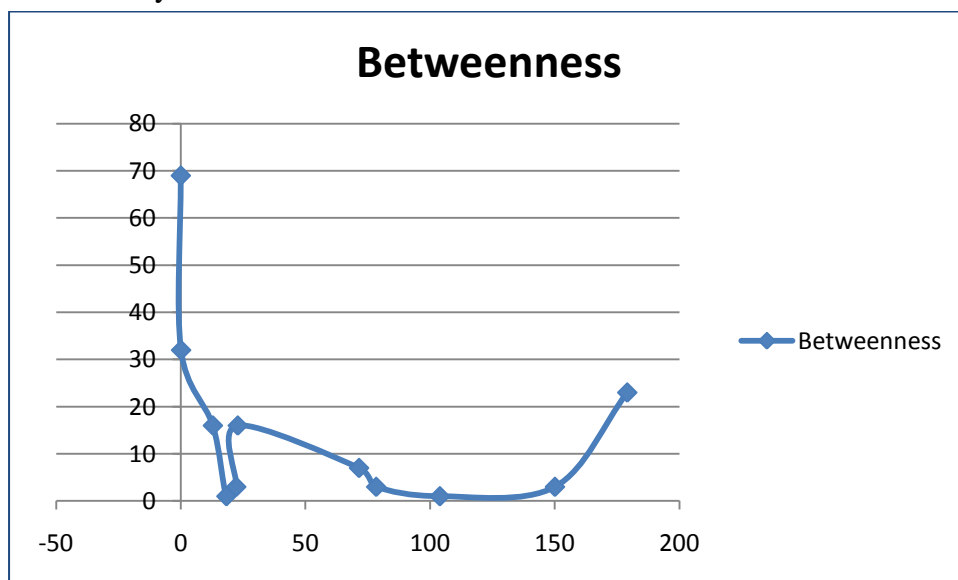
Figure 5.13: IDPF-Betweenness distribution

ii. Flow betweenness centrality

As mentioned, flow betweenness can be thought of as more adequate measure to assess actors' ability to withhold flow in that it considers only the paths that are unique to a

particular actor. Flow betweenness analysis in the IDPF membership network has the following results.

	Flow betweenness	nFlow betweenness
Mean	173.627	0.577
Standard Deviation	104.889	0.348
Minimum	61.726	0.205
Maximum	403.28	1.34
Centralisation		0.00767

Table 5.14: IDPF-Flow betweenness centrality

Flow betweenness analysis results in lower network centralisation, primarily because when redundancy is bypassed by including only vertex-disjoint paths all actors have a positive value.
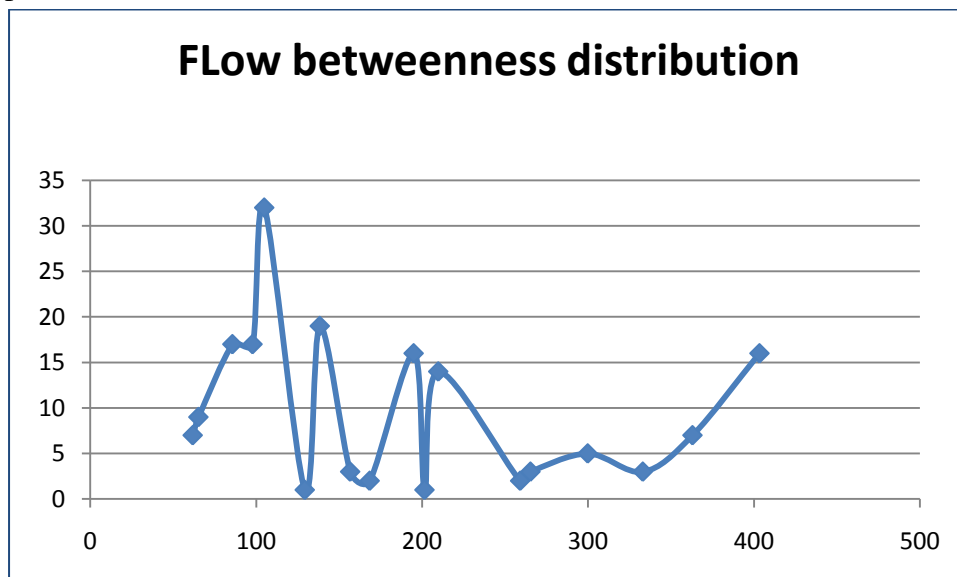
Figure 5.14: IDPF- flow betweenness

Regarding betweenness measures it results that the centralisation of the networks may not be uniformly distributed but it is not overly concentrated on a few easily identified key actors.

iii. Attribute- based partitioning of centrality

Overall betweenness centrality is broken into internal and external betweenness according to attributes. The principal area of activity is used as the partitioning attribute. Internal betweenness is calculated on the basis of geodesic paths linking actors belonging to the same group and external betweenness uses paths that link actors belonging to different areas of activity. Perfect correlation is observed between internal and external betweenness; those actors that are well placed to mediate within groups are also place to mediate between different areas of activity. Besides their high correlation, the absolute values of internal and external betweenness differ greatly. In fact 88.56% of the betweenness present in the network as a whole refers to external betweenness.

iv. Brokerage

Brokerage is perceived as a specific kind of betweenness centrality as it includes only actors in the organisations' ego-networks. The weighted brokerage method is selected and the Gould and Fernandez measures are also calculated with the principal area of activity selected as the partitioning attribute. The weighted method adjusts the brokerage scores taking into account to what degree the actors are redundant (substitutable) in their brokering role. Also, the non-normalised brokerage scores are used; that means that the observed values are noted without being compared to the expected values. The descriptive statistics for the weighted brokerage measures are as follows.

	Coordinator	Gatekeeper	Consultant	Liaison	Total
Mean	1.139	6.698	4.804	35.541	54.880
Std Dev	5.978	26.531	14.929	109.400	179.669
Sum	199.323	1172.206	840.677	6219.609	9604.023
Minimum	0	0	0	0	0
Maximum	55	251	134	973	1664

Table 5.15 : IDPF-brokerage

Standard deviation is high in relation to the mean both for the total brokerage and the constituting brokerage measures. As in the NIST conferences network, the liaison role constitutes the greatest part of total brokerage indicating that when organisations act as brokers they mediate between organisation belonging to different categories both of which are different from the broker's own category. Hence in the type of brokerage that is more frequent none of involved actors share the same knowledge base.

The correlations between the brokerage measures are demonstrated below. It appears that all measures have a high correlation with total brokerage, in that a high percentage of total brokerage variation can be explained through changes in these measures. The lowest correlation observed is between the co-ordinator and the consultant role but it is still good enough (0.808) to link these measures.

	Coordinator	Gatekeeper	Consultant	Liaison	Total
Coordinator	1.000	0.965	0.808	0.841	0.897
Gatekeeper	0.965	1.000	0.897	0.923	0.964
Consultant	0.808	0.897	1.000	0.992	0.979
Liaison	0.841	0.923	0.992	1.000	0.992
Total	0.897	0.964	0.979	0.992	1.000

Table.5.16: IDPF-Brokerage measures correlation

v. Fragmentation

Betweenness and brokerage measures assess to what degree an actor occupies an intermediary position that could be translated into active mediation. Fragmentation is an alternative view on individual actor's network role as it assesses to what degree they contribute to network cohesion. In that sense fragmentation supplements network wide

cohesion measures such as density. When fragmentation is calculated according to the proportion of mutually reachable nodes, the result is zero because the aggregate network is one component. Overall network fragmentation weighted by distance rather than reachability has a value of 0.202, still quite low.

5.3. The sociotechnical network of emergent innovation in the electronic book area (1998-present)

Both the NIST Electronic Book participation network and the IDPF co-membership network result from the conversion of 2-mode networks and are thus affiliation networks where the relational data are valued. Therefore, the same techniques can be applied in their analysis. Also, both networks had a temporal dimension resulting from participation in conferences or organisational membership during specific years. Regarding data collection, the participation patterns were available in the archives of the related organisations (NIST and IDPF, respectively) and all ties in the networks refer to a single relation. Network boundaries are clearly delineated once the event set is selected. The notion of a network defined as a set of actors, links and flows becomes more complex in what is described as the sociotechnical network of innovation in the electronic book area. The actor set is conceptually expanded to include artefacts along with organisations. In addition the sociotechnical network includes ties reflecting relations which are different in kind whereas in the case of the affiliation networks there are only differences in tie strength. However, it is not represented as a multiplex network for the purposes of SNA application; instead, the relational data are dichotomised: only the existence of a tie is noted. With regard to the temporal dimension, the final version of the network includes all ties and actors that have been identified regardless of whether they are still active.

5.3.1. Network composition

Actors are categorised according to type and their principal area of activity. Type mainly refers to organisational type; technologies and artefacts that are included as actors form one category. However, one could distinguish between physical artefacts and immaterial technologies. The classification of actants according to organisational type and principal area of activity is shown below.

Actor types

- Business
- Industry association/civil Society
- Academic
- Artefacts-technologies

48% 47% 3% 2%
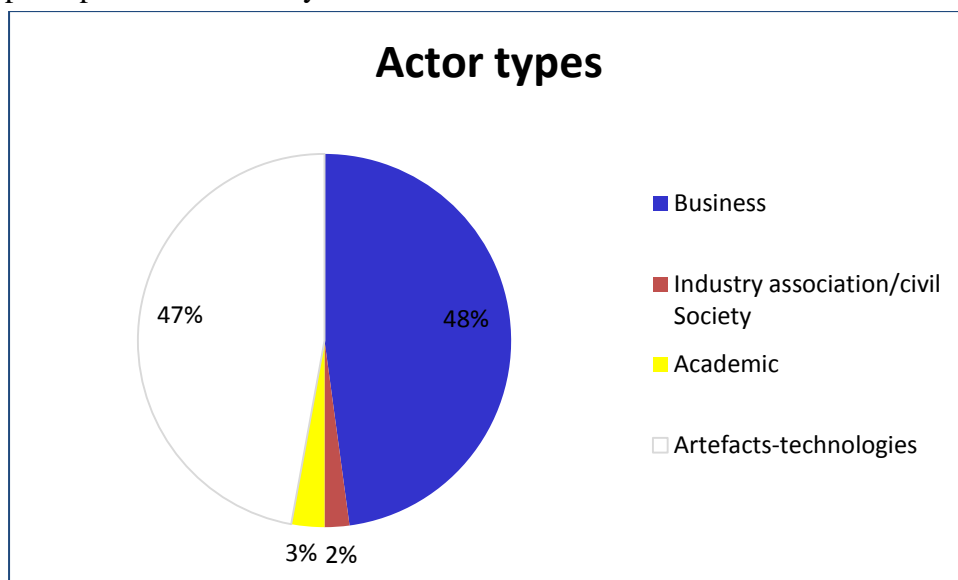
Figure 5.15: Type of actants

With the exception of a small number of industry associations and academic institutions, network participation is equally divided between business organisation and non-human actants. Non-human actants comprise both tangible and immaterial products. 29 of these represent "hardware" tangible technologies and the remainder 37 refer to software or DRM related innovations. It is evident that this is a highly business oriented network including both incumbents and new-entrants in the e-book industry; however any organisations with explicit social concerns are not represented. The equal representation between business and technologies is indicative of their interdependence in the innovation process.

The following diagram shows the classification of network actors into principal area of activity.

Principal area of activity

Legend:
- Search Engine
- Software
- Electronics
- Display
- DRM
- Content Provider
- Publisher
- Publishing Services
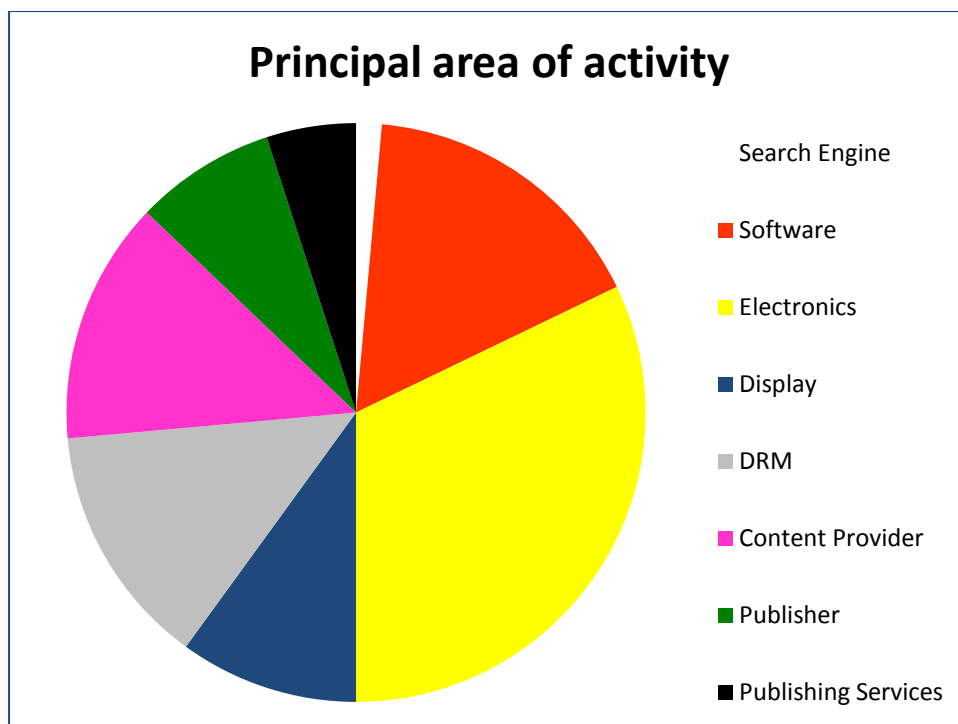
Figure 5.16: Principal area of activity

Actors in the electronics area form the largest category comprising nearly one third of the aggregate network. This area of activity includes organisations in the electronics industry whose involvement in the electronic book concerns mostly the development of physical products that could provide textual storage and display and the associated artefacts and technologies. In this classification electronics and display appear as separate areas, although display technologies could also be perceived as specific applications of electronics. Instead, the term display refers to activities focused on improving the visual quality of electronic surfaces where text may be shown and thus enhance the visual aspect of the electronic reading experience. In that sense display technologies are seen as component of electronic devices designed for the dissemination of texts. The software category concerns the development of products that are meant to produce, manipulate and display different types of text files. Digital rights management concerns the protection and the management of access to such documents. Software and DRM are meant to encompass the intangible aspects of the technological component of digital books. The aforementioned categories do not refer to the production and dissemination of electronic books as text; instead they provide the physical embodiment and the interface required for digital reading. Publishers and content providers form the categories of actors who are responsible for the production, marketing and distribution of documents. The publisher category includes both the digital division of traditional publishers and exclusively electronic publishers. The term content provider includes online booksellers of printed books and aggregators/vendors of digital content. The remaining categories include publishing services organisations which undertake various supporting roles as publishers explore digital activities. The smallest category includes search engines. Search engines of digital content are distinguished by digital aggregators in that they do not disseminate or sell material but make it searchable and provide only limited access.

Structure of relational interaction

All interactions between actors are listed as binary. Qualitative differences in relational kind or quantitative differences usually reflected in tie strength are not represented. Converting multiplex relational data into one binary relation facilitates analysis taking into account that the majority of SNA techniques have been designed for binary data and even valued relational data are usually dichotomised so that these techniques are applicable. In addition regarding the variety in the observed interactions codifying relations would have been overly complex and would have led to an agglomeration of sparse networks, thus inhibiting any structural analysis involving the majority of actors. Details on the relational content of each tie are available and can be used for interpretation of the structural patterns that emerge from the dichotomised data.

The network graph is shown in the following diagram. The nodes are positioned according to the spring embedding algorithm; therefore the location facilitates the understanding of network relations as the distances between nodes signify similarity in their patterns of relations. However, node repulsion and a substantial degree of repositioning were required in order to enhance visual clarity. Yet, the spatial configuration of the nodes and their relative distances provide indications as to how they may be categorised. Also, the network included one main component of connected actors, two small independent components and a numbers of isolate actors. The fact that the overall network is disconnected affects the application of certain SNA techniques; for that reason some measures will be applied only to the main component.

The principal areas of activity are represented by the same colours as in figure 5.16. The node colours in the network graph represent the principal area of activity. Regarding shapes the triangles indicate technologies. Up-triangles indicate hardware and down-triangles software technologies. The other shapes have the same notation as the earlier graphs.

☐	Government
◯	Business
◇	Academic
⊞	Civil Society and Business Associations
△	Hardware actants
▽	Software actants
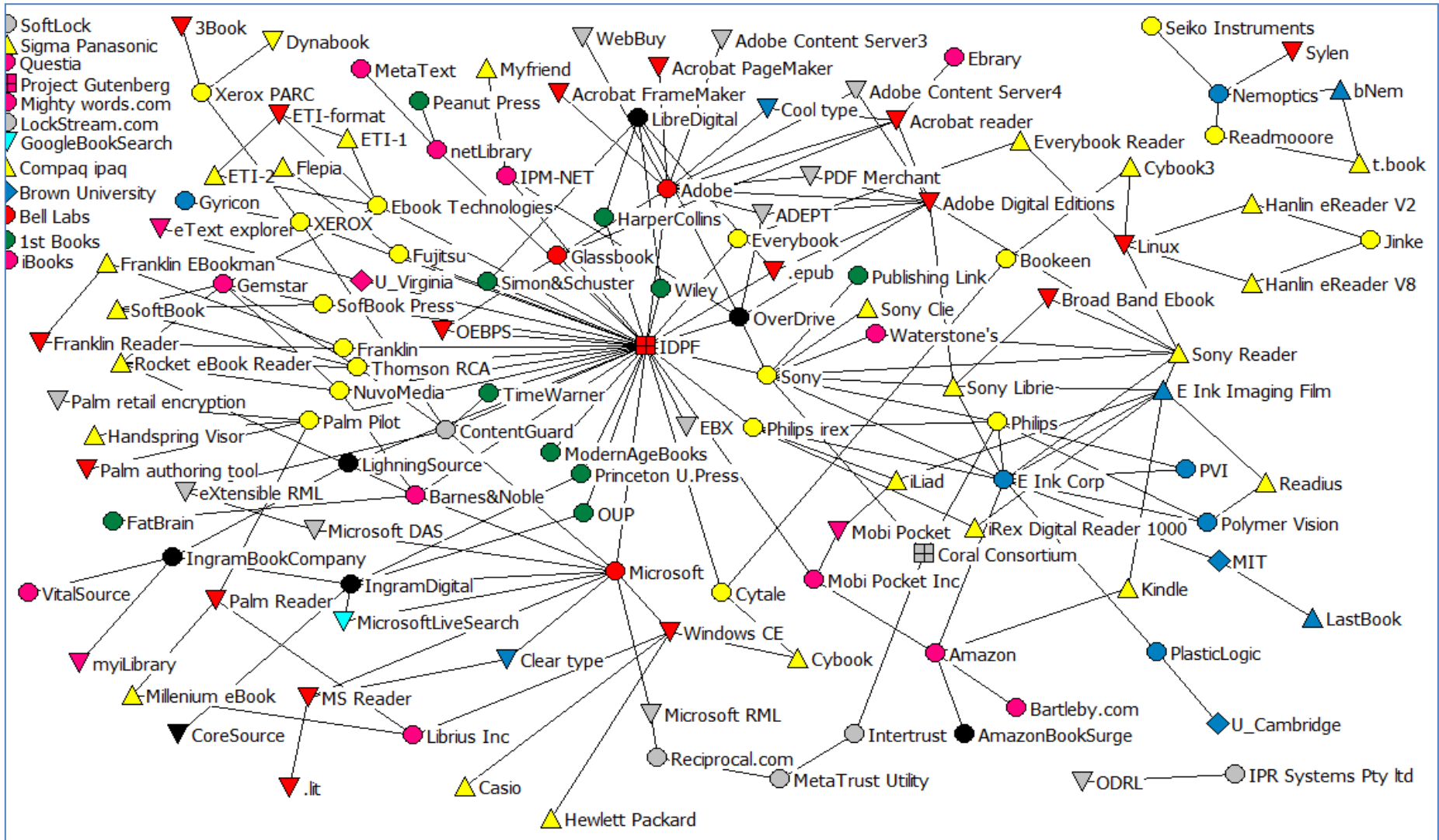
Network graph 5.15: The sociotechnical network of the electronic book

5.3.2. Cohesion

Firstly, the cohesion of the overall network and is distribution across categories of actors is examined. Cohesion can be examined both at the dyadic level through density measures and at the triadic level through transitivity.

i. Density

In the case of a binary network, density represents the proportion of observed ties in relation to all possible ties. Hence, it is the most evident dyadic measure of cohesion. Density is thus easier to interpret with binary data, though standard deviation of density values is not meaningful. Density values are calculated for the overall network, the overall network excluding isolate actors and the main component. The division of a network into components is a clear indication of fragmentation, hence separate densities are calculated.

	Density
Aggregate network	1.98%
Main component	2.61%

Table 5.17: Density

The resulting densities are all low as it can also be observed from the network graph. However, one must take into account that network ties represent more concrete interaction than they do in the affiliation networks. In addition as network participation increases, the ability of actors to maintain ties with a greater proportion of other participants is limited.

ii. Nodal degree

As mentioned density values provide a description of the general level of interaction. In order to evaluate how different actors influence network cohesion, the degree centrality of a node can be calculated. Degree centrality in an undirected binary network measures how many actors are adjacent to each node. Average degree centrality equals network density when self ties are excluded.

The distribution of degree centrality values is shown below.
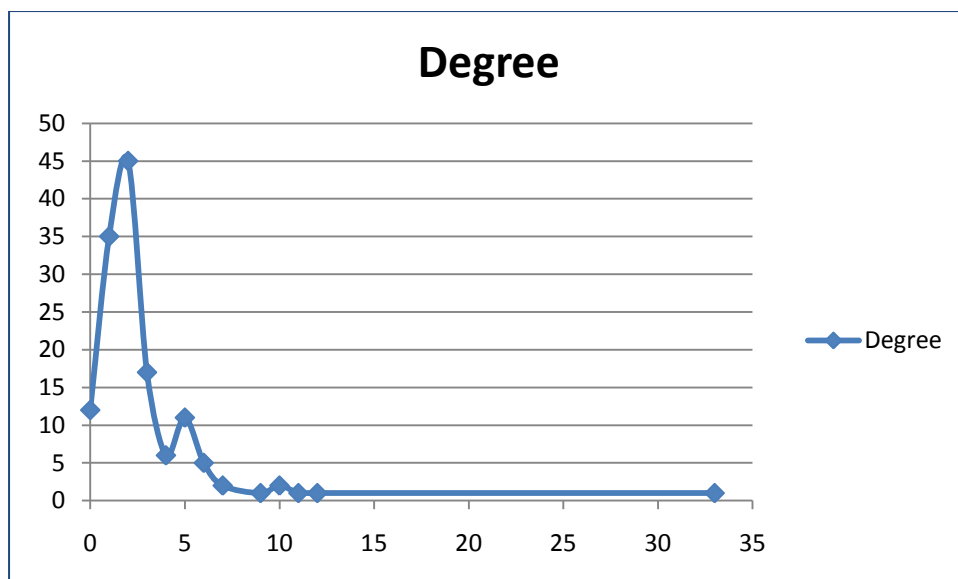
Figure 5.17: Degree centrality

The x axis represents node centrality value and the y axis the respective frequencies. The peak of the distribution shows that the most frequent nodal degree value is low. When nodal degree rises above ten the corresponding frequencies are too small to seriously impact on the average value. For example, only one actor reaches the maximum value of 33. The number of isolate actors (nodal degree=0) explains the decrease in density values between the aggregate network and the network excluding isolates. A substantial number of actors (35) are pendants meaning that their degree centrality equals one. The implication for network cohesion is that for a significant proportion of actors inclusion is fragile as they can only utilise one tie.

iii. Clustering co-efficient

The clustering co-efficient is the average density of all actors local neighbourhood. Therefore, it indicates the cohesion of actors' ego networks. Comparing the clustering so-efficient with the respective density values it is possible to evaluate whether interaction is concentrated in local neighbourhoods. The results of the clustering co-efficient analysis are shown below.

	Density	Clustering co-efficient	Weighted clustering co-efficient
Aggregate network	1.98%	25.52%	10.04%
Main component	2.61%	26.67%	10.12%

Table 5.18: Clustering co-efficient

Regarding the calculation of the clustering co-efficient it has to be remarked that isolate and pendant actors are not assigned a value. The isolate actors do not have a local neighbourhood by definition and the pendant actors have a local neighbourhood of one so the

concept of density does not apply. This is why there is no difference between the clustering co-efficient of the overall network and the clustering co-efficient when isolates are excluded. Clustering co-efficient values are in all cases significantly greater than density values indicating that interaction tends to be concentrated within local neighbourhoods. An intuitive understanding of the network graph supports this finding. The weighted clustering co-efficient adjusts the actors' clustering co-efficient values by their nodal degree. This process is based on the assumption that the size of an ego-network should influence how their density is reflected in the average value shown as the overall network clustering co-efficient. The weighted clustering co-efficients are lower than the non-weighted values, indicating that actors with higher degree have less dense local neighbourhoods. However, even the weighted clustering co-efficients are greater than the corresponding density values.

iv. Homophily

An assumption in SNA tends to be that actors are more likely to form ties with those sharing the same attributes. In addition, densities are likely to differ between and within particular combination of groups. The principal area of activity is selected as a partitioning attribute and the blocked density values are illustrated in the following graph.
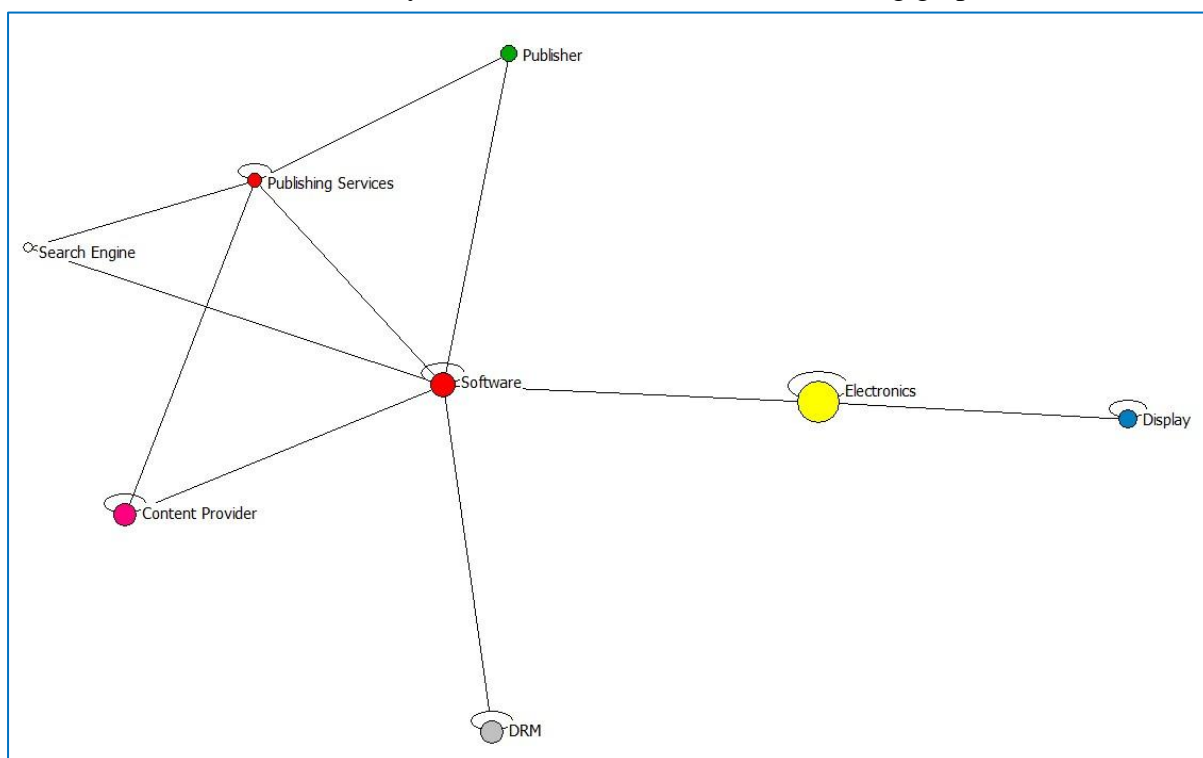
Network graph 5.16: Principal area of activity interaction

With the exception of search engines and publishers, densities within groups are higher than average. In general publishers demonstrate lower network embeddedness. Electronics and software appear show higher levels of integration. As it could have been expected there is good interaction between the electronics and display actors and between software and DRM. Publishing services is one of the categories that has closer than average interaction with publishers. Content providers do not show a high degree of integration either.

E-I Index analysis was conducted to evaluate whether in-group or out-group ties are more frequent. The observed E-I index equals the rescaled E-I Index at a value of 0.326 because there are no limitations on the range of potential values due to density and relative group sizes. Hence, a tendency towards out-group ties is observed which is nonetheless lower than what would be expected if the ties were randomly distributed (Expected E-I Index=0.640).

v. Transitivity

Transitivity evaluates cohesion at the level of triads. In the case of a binary, non-directed network a triad consist of actors A, B and C is transitive when if there is a link between A and B and a link between B and C there is also a link between A and C. Therefore, in transitive triads the existence of a path between A and C indicates a link between the two. The triad is the basic social structure where the notion of closure is relevant. Transitivity is in some respects a measure of network closure; in a transitive triad actors cannot act as brokers because there are no structural holes (Wasserman and Faust, 1994). Only a minority of all triads in a network are transitive. In order to evaluate overall network transitivity the transitive triads as a proportion of all triads that have a potential to be transitive are counted rather than as a proportion of all triads. Hence transitive triads are divided by the number of all paths of length two (triads where a path exists from A to C).

The resulting values are the following.

	Proportion of transitive triads
Aggregate network	10.04%
Main component	10.17%

Table .5.19: Transitivity

The transitivity results indicate higher degree of cohesion than density values. Considering that the network includes a substantial number of pendant actors that cannot be part of transitive triads, the transitivity values indicate elements of network closure.

5.3.3. Cohesive subsets and network substructures

The fact that the relational data are binary enables the division of the network into cohesive subgroups because the majority of these measures had been designed for binary data. The bottom-up and top-down approaches can both be applied.

i. K-core analysis

K-core analysis is applied as a method for the identification of cohesive subsets on the basis of nodal degree. The distribution of k-values frequencies is shown in the following figure. The analysis is applied to the main component only.
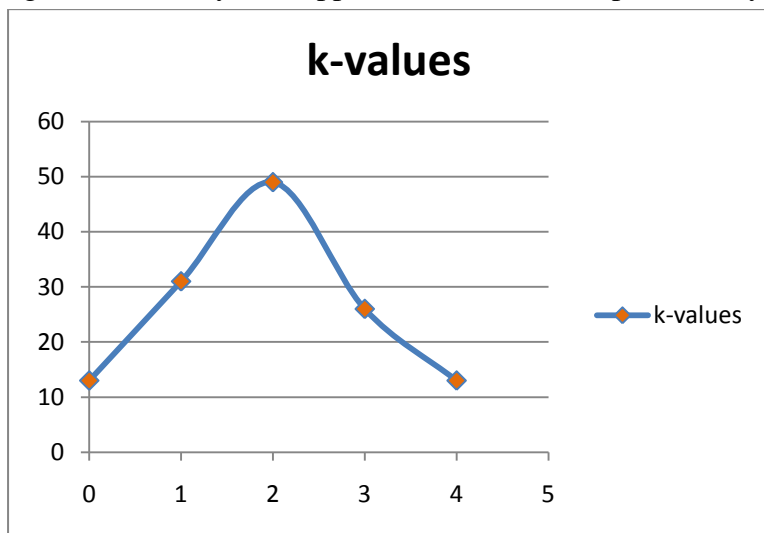
Figure 5.17: k-values

The most restrictive core comprises 13 actors. All actors also belong to cores of lower values as k-cores are nested subgroups. The network diagram below indicates how actors in different level cores are spatially distributed. Nodes in the higher core are indicated in grey.
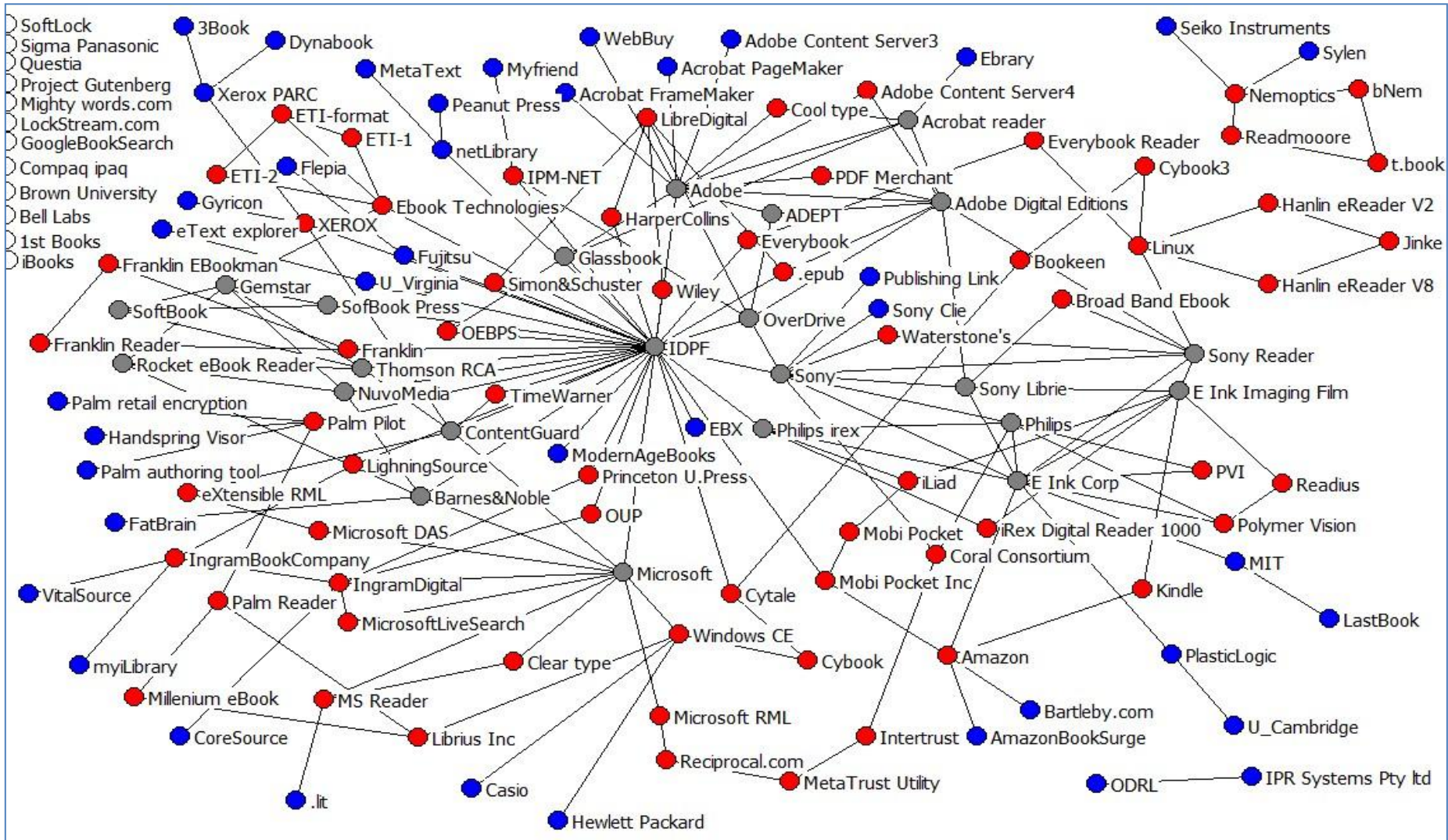
Network graph 5.17: k-core analysis

ii. Faction analysis

Faction analysis is applied to the main component because cohesive subsets are easier to interpret when the connectivity criterion applies among all actors belonging to one faction.

The algorithm is run in order to identify four factions. The blocked density matrix according to factions is as follows.

	1	2	3	4
1	0.1	0.01	0	0.02
2	0.01	0.07	0	0
3	0	0	0.1	0
4	0.02	0	0	0.08

Table .5.20: Interaction between factions

However, division into four factions does not result into significant reduction in the number of errors (a reduction from 5174 to 3242).
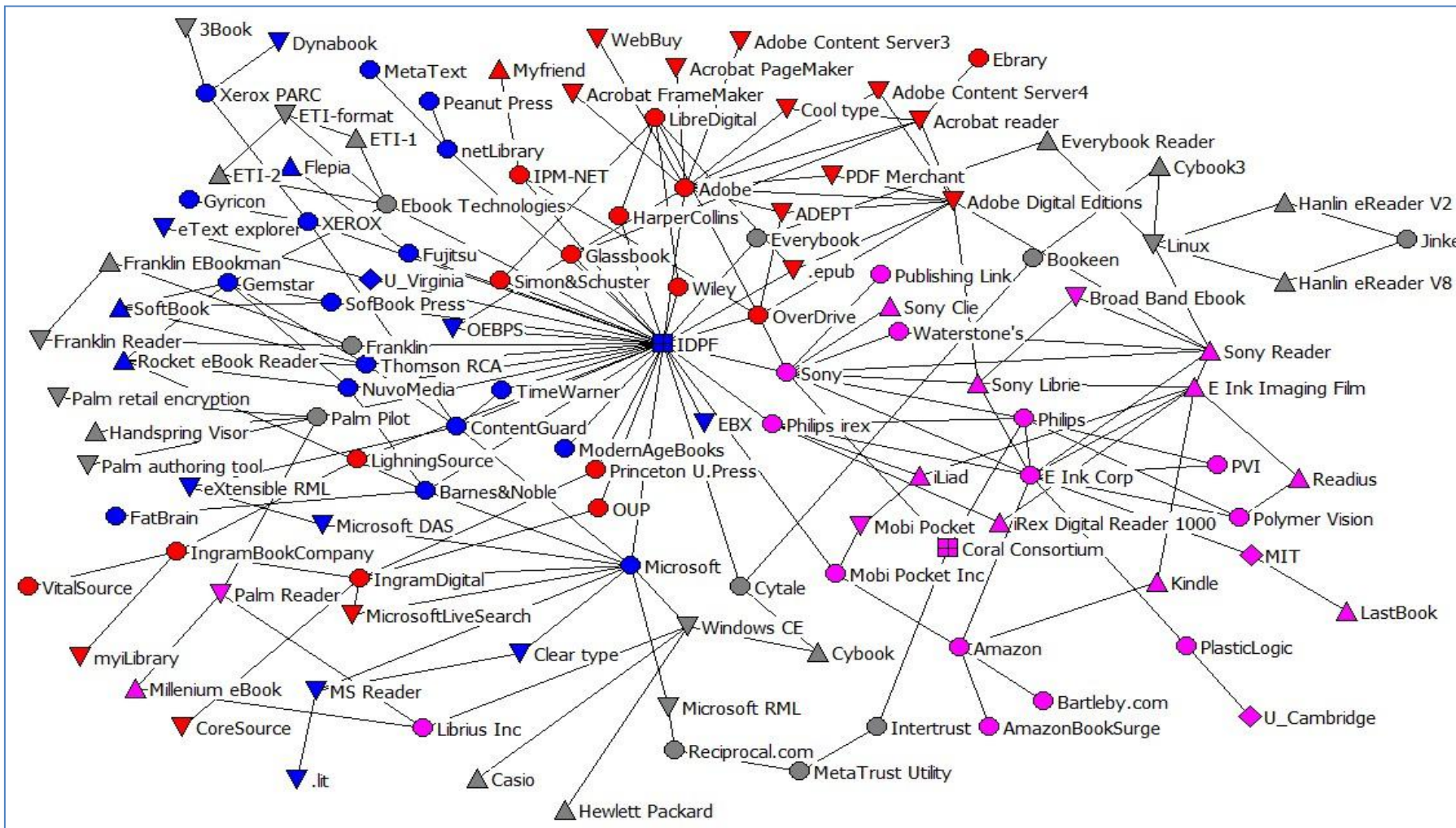
Network graph 5.18: Faction analysis

5.3.4. Node level measures: centrality and brokerage

When the on the role of individual actors our main interest is their potential intermediary roles. Betweenness centrality and brokerage measures are applied for this purpose.

i. Betweenness centrality

Freeman's betweenness centrality calculates the proportion of geodesic paths that and actor appears on. Assuming that network flows are more likely to follow the shortest possible path it is a good approximation of actors' potential intermediary role. Descriptive statistics on the betweenness centrality of the total network are shown below.

	Betweenness	nBetweenness
Mean	138.221	1.441
Std Dev	492.184	5.132
Minimum	0	0
Maximum	5399.778	56.3
Centralisation	736618	55.25%

Table 5.21: Betweenness

A significant deviation from the mean is observed. The network centralisation index signifies a highly centralised network where the potential for mediation is limited to certain influential actors.

In the following diagram the distribution of betweenness centrality can be observed.
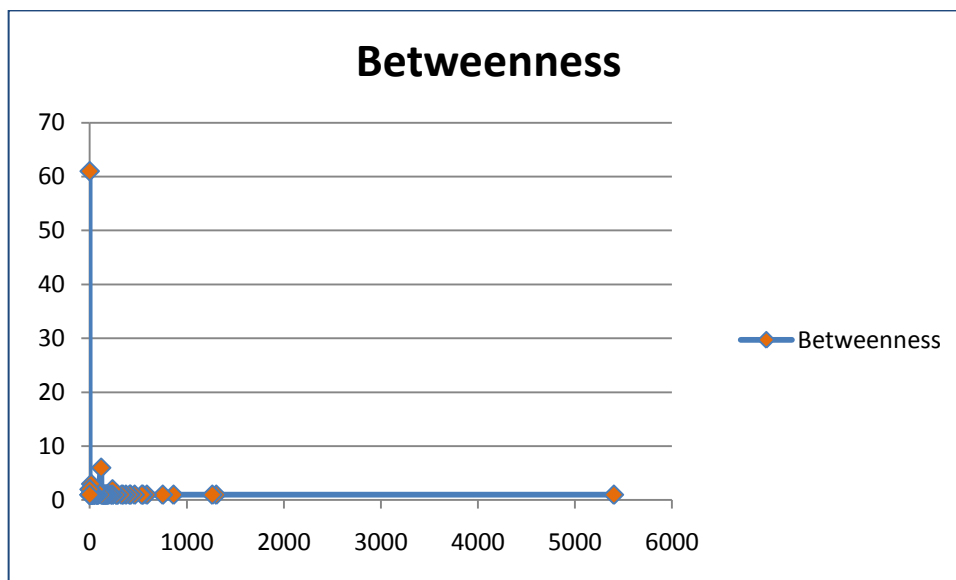
Figure 5.18: Betweenness distribution

A number of actors (63) have zero betweenness centrality thus affecting the curve of the histogram. Otherwise the majority of the actors are located below a centrality of thousand. There are few points corresponding to higher centrality.

In the network graph, the high centralisation of the network is not directly evident, which indicates that actors with high betweenness occupy central positions in different areas of the network (among different groups of actors).

ii. Flow betweenness centrality

The flow betweenness approach to centrality evaluates actors' intermediary position by taking into account only actor specific paths regardless of length. Flow betweenness analysis in the aggregate network yields the following results.

	FlowBet	nFlowBet
Mean	177.028	0.923
Std Dev	445.724	2.324
Minimum	0	0
Maximum	4466.429	23.284
Centralisation		22.52%

Table 5.22: Flow Betweenness

Standard deviation is high in relation to the mean. According to flow betweenness the network is quite centralised. Even when paths of all lengths are considered, a group of influential actors can still be identified. The distribution of flow centrality is demonstrated in the following diagram.
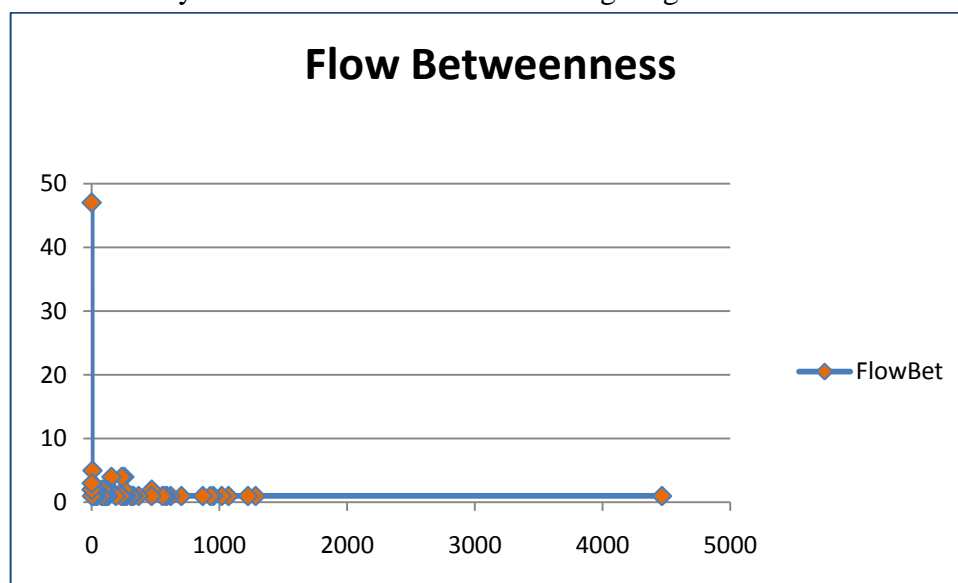
Figure 5.19: Flow betweenness

The shape of the flow betweenness distribution curve is similar to that of the Freeman's betweenness curve. A significant proportion of actors are still assigned a value of zero but there is a narrower range of values compared with betweenness.

iii. Attribute based partitioning of centrality

Betweenness centrality is the sum of internal and external betweenness centrality. It calculates what percentage of overall Freeman's betweenness indicates

that actors are intermediaries within or between groups. It results that 17.22% of overall betweenness refers to betweenness within groups. When actors occupy an intermediary position they are more likely to link actors belonging to different groups.

iv. Brokerage

Brokerage is a restricted version of betweenness that assesses actors' potential in bridging structural holes. The weighted method was used so brokerage values are adjusted depending on the number of alternative brokers. In that sense, redundancy is taken into account in calculating the values. Descriptive statistics for brokerage measures are illustrated below.

	Coordinator	Gatekeeper	Representative	Consultant	Liaison	Total
Mean	0.791	2.298	2.298	2.309	5.332	13.029
Std Dev	2.766	11.687	11.687	15.883	45.395	85.185
Minimum	0	0	0	0	0	0
Maximum	20.667	132.167	132.167	185	538	1001.333

Table 5.23: Brokerage

The most common brokerage role is that of a liaison where the broker and the actors it links all belong to different groups. It is followed by the roles of gatekeeper/representative which can be aggregated as the network is non-directed. Together they account for 35.28% of total brokerage. In these roles the broker and one of the linked actors belong to the same group and the other linked actor to another. Hence, the broker is placed to mediate between someone from their group and an outsider.

The correlation between the brokerage roles is shown below.

	Coordinator	Gatekeeper	Representative	Consultant	Liaison	Total
Coordinator	1	0.654	0.654	0.465	0.445	0.536
Gatekeeper	0.654	1	1	0.949	0.962	0.985
Representative	0.654	1	1	0.949	0.962	0.985
Consultant	0.465	0.949	0.949	1	0.976	0.982
Liaison	0.445	0.962	0.962	0.976	1	0.993
Total	0.536	0.985	0.985	0.982	0.993	1

Table 5.24: Brokerage Correlation

The most common brokerage roles, liaison and gatekeeper/representative are highly correlated. The coordinator role is more weakly correlated with the other roles and total brokerage.

v. Fragmentation

The overall network is divided into components. Fragmentation centrality evaluates actors' contribution to network cohesion. Fragmentation is calculated with

regard to the potential to either disconnect the network into further components or to increase node distances. Because the network is already divided into components overall fragmentation is calculated both for the overall network and the main component.

	Distance-weighted fragmentation
Network	0.771
Main component	0.690

Table .5.25: Fragmentation

Fragmentation according to distance is higher. The main component has zero fragmentation based on the proportion of mutually reachable nodes indicating that connectivity in the component is not fragile.

The following chapter elaborates on the results of the network analysis in order to demonstrate how SNA techniques can address innovation research issues with regard to the electronic book case.

6. Discussion of the emergent electronic book networks

In Chapter 5, Social Network Analysis was applied as a descriptive and analytical tool to depict aspects of the electronic book field. Emphasis was placed on the exploratory techniques. Networks are used as a representational device. As discussed in chapters 2 and 4 representation can be perceived as a form of allegory (Law, 2004). Like other forms of representations, network visualisation and analysis is reductionist because the available attributes and relational data are codified in order to be subjected to visualisation and analysis; during the data collection and coding process there are things that have to be silenced (or othered) so that others can be made prominent . Othering is intrinsic to the research process (Law, 2003) and one has to observe how it is achieved in the networks described. As discussed, the process of othering is somewhat paradoxically essential for an effective representation because when a representational device encompasses all available information/data it risks becoming uncritical and meaningless (Law, 2004). With regard to the definition of network boundaries, a form of othering occurs in the definition of research questions and their effect on the data collection process. When networks are discussed as a form of representational device it emerges that a network that attempts to encompass all aspects of reality risks losing focus and meaning. Representations are by definition reductive. In the case of networks the information on actors and relations that comprise it cannot realistically be fully represented in network graphs or matrices, therefore reduction is observed through the coding process. A similar point is made in Borges's essay (cited in Prior, 2003) "On the exactitude of science": the analogy between a map and a territory is used to illustrate the dangers of a complete representation.

A benefit of networks as a representational form is that because of the evidently reductive nature of network graphs, the danger of conflating the descriptive form with what is actually being described diminishes (Latour,2005). As mentioned in chapter 2 social sciences devise a number of categories to construct reality (Ibid. Law, 2004). Unlike other categories such as social class networks are less likely to be perceived as a replacement for the realities they describe precisely because of the simplicity in representation (ibid.). The aim of this chapter is to expand on the results provided by SNA in order to discuss what is not shown prominently in the graphs and technical analysis. The formal analysis of relational matrices and networks graphs is co-ordinated with qualitative information on network participants and their interactions. The reduction of the data in networks matrices and graphs was necessary in order to conduct analysis on the basis of SNA concepts and techniques. Firstly, the actors' characteristics and relational information have been codified in order to apply formal analysis using SNA as a foundation. At this point qualitative and subjective information is used to interpret results from SNA and these results

themselves inform our approach to the qualitative information such as the actor's perspectives. In addition, the sources used in order to categorise the actors' attribute data and to develop the relational matrices are now utilised in order to identify issues of controversy influencing actors' activities in the electronic book field. At this point, the documentary sources on the electronic book are also used qualitatively

The structure of chapter 5 is followed by discussing the networks resulting from each of the datasets individually. Although the same techniques were applied in their analysis the nature of the relations described is different, therefore the interpretation takes into account the reason these networks were selected as described in the methodology. Results from chapter 5 are used to discuss network cohesion and heterogeneity and their impacts on innovative activity. Then the subgroups that have been identified by relational measures are analysed. The representations of different categories of actors within each subgroup is utilised to indicate how subgroups can be indicative of future developments in the form of sociotechnical trajectories. Interaction and the degree of autonomy between groups are considered in relation to cohesion. Finally, the role of individual actors as network intermediaries/mediators is emphasised utilising betweenness centrality and brokerage measures. The overall distribution of these attributes in the network as well as the role of highly ranked actors is considered. In addition the classification of actors into areas of activity is taken into account with regard to cohesive patterns. As the network analytic measures were selected on the basis of their correspondence to innovation concepts it is discussed how the results of this analysis illuminates aspects of innovative activity with regard to electronic books.

Finally, the limitations of network analytic techniques with regard to the case are mentioned and it is discussed how they will be addressed. The question of embeddedness and the degree of actors' network involvement has to be considered.

6.1. NIST electronic book conferences network

The NIST conferences are seen as signifying the beginning of an electronic book industry. One of the points raised by Emirbaryer (1997) was that networks are also defined according to their time frame through this point has been addressed in less detail. Like other framings, this time frame is not meant to be definitive as expectations on the issue of paperlessness and electronic communication were raised in various forms prior to what is identified here as the origins of the electronic book industry. As mentioned in chapter 2 with regard to the time frame of transitions the notion of expectations indicates that a transition develops in advance to any actual technological or market developments. The conferences provided a forum where issues of controversy were expressed by a diversity of actors. Their participation is perceived as representative of actors interested in the electronic book at the time regardless of whether they actually developed related products. As these networks refer to the early stages of development results can be interpreted with the hindsight of recent developments. Therefore, it is considered how the ideas developed at the time may still bear relevance to the development of the industry. The content of individual presentations was not examined instead only the general themes raised in the conferences are mentioned.

6.1.1. Network cohesion in relation to organisations and events

In order to evaluate the cohesion in a valued network the density and clustering co-efficient values were used. Density and clustering co-efficient are not as easily interpreted in valued networks therefore they are complemented by the distribution of tie strength values. Network density once the data are dichotomised indicates how many pairs of actors are linked in relation to all possible pairs. In the case of the NIST conferences network this is quite low as approximately 7% of all possible ties are present. Network density is a proportional measure but it is inevitably related to network size because as a network grow it becomes more difficult for individual actors to maintain more relations (Bruggeman, 2008). However, the type of relations in question should be examined. Considering that joint participation in an event is sufficient to account for a tie and hence affiliation networks tend to be quite dense the network dichotomised density is quite low. In addition, even when the tie strength is taken into account the density value remains low as the majority of ties are of value 1.The low densities are explained because the patterns of co-attendance between events are low. As the majority of organisations attended only one event it results that there is no consistent community of actors resulting from these events as they remain poorly linked.

There are effects of low density on the diffusion of norms and ideas among a group of actors. Usually, a denser network is likely to lead to more homogeneity in the form of shared norms and ideas (Granovetter, 2005). The fact that there was limited density in the networks indicates that there was low likelihood for consistency in ideas to emerge. In addition, there was dissimilarity in conference themes which made it more difficult for actors to have continuous participation. Therefore no shared viewpoint on electronic books has emerged from these events although they provided an opportunity for individual actors to demonstrate their concerns and participate in joint sessions. However, a consensus has emerged from the events in that they led to the subsequent establishment of the Open E-Book Forum (later IDPF) with an explicit interest in standardisation. Standardisation thus emerges as a theme of interest in early stages.

The role of cohesion is related to the small world hypothesis (Watts, 1999) by considering the clustering co-efficient values. The clustering co-efficient calculated on the valued data is greater than the density value indicating a tendency for actors to concentrate in their immediate neighbourhood. Therefore the role of local neighbourhoods is more significant for the diffusion of ideas developed in the conferences. However, low average distance means that actors across different local neighbourhoods could fairly easily be exposed to the ideas of others. Hence, dense local neighbourhoods do not inhibit the wider diffusion of ideas.

Network cohesion is reflected on the interaction between the events as shown in table 5.1. This reflects how the theme of individual conferences affected the

patterns of co-participation. Besides the 1999 conference all events had a specific theme. The last conference focusing on Authors, Applications and Accessibility is more related to electronic books as they relate to writers and consumers/end users. The 2000 conference theme addresses the role of consumers through its emphasis on reading practices. One could then expect greater interaction between these two events than what is observed. In fact the latest event appear to be less integrated with the other which indicates that contrary to what one would expect if network growth had been consistent over time. On the other hand the interaction between the first three events indicates that consecutively they shared slightly more than half their participants accounting for event size so there was an attrition rate between events. One would expect a more cohesive network if there was a more targeted theme linking the events and allowing for substructures to develop on the basis of common interests. On the other hand attrition in participation also indicates that a number of actors were not consistently involved in the electronic book area.

6.1.2. Network heterogeneity

Network cohesion indicates that common norms are more likely to be shared among participants (Granovetter, 2005). This is why density and related measures were applied. In the context of innovation it can be argued that cohesion is more likely to lead to standardisation. This is a common assumption linking cohesion and heterogeneity. It has been identified (Callon, 1992) that a balance between homogeneity and heterogeneity facilitates the diffusion of innovation. However, network diversity can be evaluated by beginning with an already accepted division of actors into groups and evaluate their interaction. Actors are divided according to organisational type and the principal area of activity. Network diversity refers both to the division of actors into different groups and to the interaction between these groups.

The division of actors into different organisational types reflect that it is mostly a business-oriented network. This appears consistent with the view of the firm as the source of innovation (Coombs, 1995).As discussed in Chapter 1 this argument is consistent with the Constructive Technology Assessment view on the sources of technical innovation.   There is a small and almost equal representation between academic, government and civil society organisations. Government organisations had specifically a regulatory or a potential lead user role. Examples include NIST as the organiser of the events and the US Department of Commerce in its role in controlling market standards. The academic organisations have a dual role. They can either be developers of particular technologies or users. However, the role of users particularly in the case of lead users sometimes overlaps with the role of developers. Therefore, the distinction between the research and development stage and the diffusion stage is not always clear as has been illustrated in actor-network theory (Callon, 1998b; Akrich et al., 2002). Civil Society actors are not-for-profit organisations some of whom focus on technology issues and can be seen as representative of users while others are interested in the area mostly on the issue of access which results from their interest in disabilities. Although it is attempted to frame the actors as user-oriented or technology-oriented some of their activities defy this classification. For instance, NIST standardisation activities entail technological development and market negotiations.

In addition, the organisations are divided according to their principal area of activity. As mentioned this is a somewhat simplified representation of an actor's interests. Classification is a form of othering. Yet classification by principal area of activity attempts to take into account the degree of embeddedness that actors have in category although there was not a formal classification available to follow. Therefore, the division of actors into principal areas of activities is another form of reduction required to facilitate analysis. As mentioned it does not indicate how involved organisations are in the electronic book area as opposed to other activities

and it does not account for the fact that organisations may have a hybrid nature in that they may be involved in varied activities related to different end products. The suggested classification may thus not coincide with the actors' self-classification or formal industrial classification. This is consistent with the discussion on framing where it is accepted that different frames may be available.

The following comments can be made on the categories selected. Among the categories identified, libraries and education are positioned as users. They can be said to represent the institutional market for electronic books, which develops alongside the consumer market. Additional information on the role of libraries has been considered in the electronic book literature mainly in the form of experiments and case studies of university libraries (Armstrong and Lonsdale, 2005). The results have so far been inconsistent. The relation between the institutional and consumer market is a point to be explored further considering how electronic books interact with the incumbent print-on-paper publishing regime. There are no consumer groups representing electronic book users/ digital readers but there is a small presence of special needs organisations, such as organisations for the visually impaired. These groups of readers have specific needs regarding their access to documents and they represent a niche market where accessibility issues are more important, hence it is to be expected that they would indicate an interest in new technologies that could resolve access issues. In that sense, the notion of the niche is perceived as a market that requires specialised technologies and has different selection criteria. Publishers and booksellers could be said to represent the incumbent print-on-paper regime, although electronic publishers are also classified under the publisher category. The role of publishers is a specific point of interest in the literature (Morris, 1999) and in the prediction of relevant business models. Content providers can be seen as the digital equivalent of booksellers, since they aggregate and distribute digital content acting as intermediaries (or mediators) between publishers and end users. Organisations classified under the electronics or software categories are meant to provide the technologies required for the production of electronic books as an alternative form of textual display. They could be perceived as new entrants since they were not formerly involved in the sociotechnical system of the book. However, some of these organisations were already established in different markets/technological fields so they somehow defy the description as new entrants. Although the thesis focuses on the applications of IT regarding textual display, one should keep into account that there is a record of earlier, incremental applications into publishing which were about increasing the efficiency of the print-on-paper system. The remaining categories represent organisations that act as facilitators in the interaction between developments in IT and content. Some consultancies are listed separately because they are not directly engaged with the book industry. The Publishing Services category includes a variety of usually specialised organisation

that focus on specific points that could facilitate the creation of an emergent digital book supply chain. Examples are companies that convert publishers' backlist into different digital formats, content repositories of digital material and print-on-demand services. Digital rights management (DRM) organisations could be thought of as part of the publishing services category since they provide a supplementary service that has been deemed necessary (and then not universally)only as printed content is converted to digital and thus becomes more vulnerable to copyright violations. Yet, because issues regarding access and copyright emerge as one of the reasons delaying the engagement of publishers in the electronic book area DRM organisations are classified as a separate category. The areas of activity identified help to draw a distinction between the emergent and incumbent actors and thus can substitute for the niche and regime distinction observed in the transitions literature. The distribution of actors according to principal areas of activity differs across the events as seen in the respective diagrams. The first event was largely dominated by actors in the electronic sector. This event was organised as a workshop and it focused on knowledge management rather than electronic books as such. In that sense it is more consistent with technocentric ideas on electronic books (Gall, 2005). However over the years there is a relative reduction in this area while the role of publishers and publishing services increases. Publishing services organisations have the potential to act as new types of intermediaries in the reconfiguration of publishing supply chains. Special needs groups that focus on access issues joined the network at later stages particularly at the 2001 event that referred to access issues.

The representation of different areas of activity is only one indication of network heterogeneity. Heterogeneity is more accurately evaluated by considering the degree of interaction between different categories. A density image matrix where the actors are classified into different area of activity was formed and visualised in network graph 5.2.

This is used to evaluate the nature of interaction between different areas of activity. Different areas of activity represent a different knowledge base so in that sense the different knowledge types required for the formation of electronic books can be examined. In the notion of innovation as distributed activity (Garud and Karnøe, 2003) a combination of skills residing in different actors is necessary for innovation. One is mainly interested in the interaction between what can be termed as established areas on the print-on-paper system and those that can be seen as emerging from or mostly related to Information technology. The pattern of interaction between categories indicates a good integration between the more established and emerging categories of actors. In the case where such interaction is missing such as between publishers and actors in the electronics area one could remark that other categories are well placed to act as intermediaries particularly the publishing services group. Therefore, there are indications that publishers allocate

part of their involvement in electronic books to types of actors that could undertake a mediator role rather than interact with technology developers directly. Although the development of electronic publishing was perceived as bypassing intermediaries, it can be argued that new forms of intermediary actors occupy a gatekeeping role. However, as this particular network refers only to co-attendance patterns one needs to evaluate to what degree this finding appears in other networks.

Network heterogeneity indicates that there was interaction between actors with different knowledge base. The degree of heterogeneity is meant to enhance innovative activity however a balance is required between homophily and heterophily in order to increase the network's effectiveness in the exchange of ideas. The E-I Index is a measure that indicates how introverted specific groups are. The groups were mostly outward oriented as perceived by the general E-I Index however once it is rescaled it becomes evident that overall the level of interaction between different areas was only marginally more than that within the same area. Actors within the same area of activity are competitors in that they provide similar products services, however they also share similar interest in relation to the other categories. Hence, the content of interaction is likely to be different within rather than between categories. Homophily that is forged through in-group interaction has to be complemented by the recombination of the knowledge base related to different areas of activity so that innovation can emerge.

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6.1.3. Network substructures

The k-core and faction analysis indicate that the division of the network in substructures is merely representative of different patterns in event participation as each subgroup resulting from these measure tends to be mostly correlated with one of the conferences. The m-slices analysis was used to extract a part of the network selecting only ties of greater strength. The figure below compares the overall network composition with that of the reduced network resulting from the m-slices analysis.

The percentage of publishers remains fairly stable but the representation of electronic and software actors increased in relation to the aggregate network. Therefore it can be argued that the network resulting from more highly involved actors is more technocentric. The increased participation of publishing services actors increases the potential for mediation between incumbent and emergent categories however the booksellers and content providers are not well represented to take advantage of this aspect.
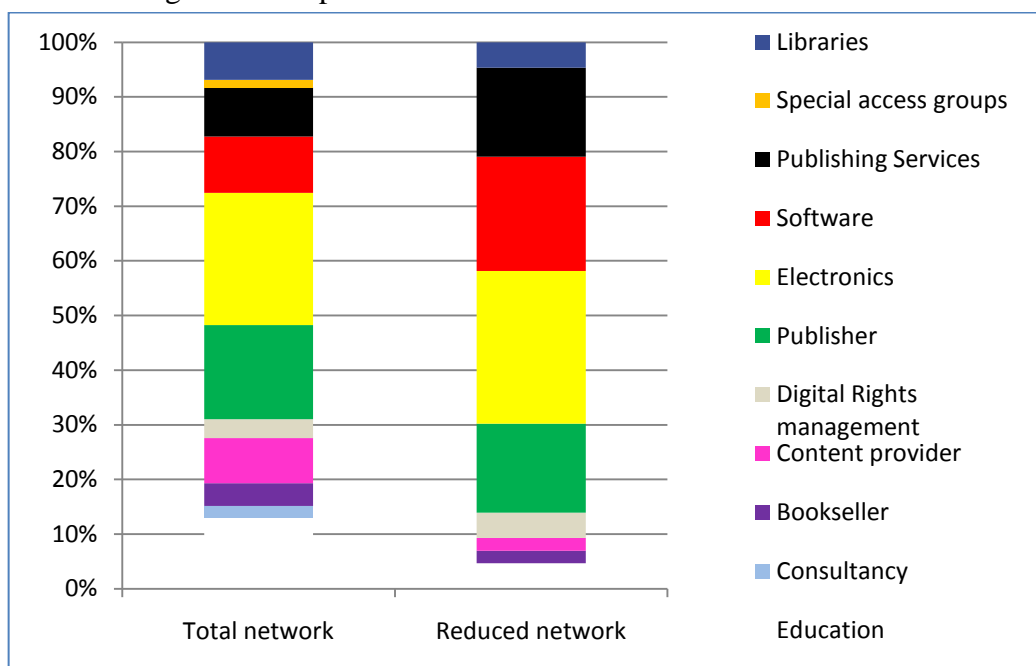
Figure 6.1: % NIST Principal area of activity-comparison

6.1.4. Intermediaries and prominent actors

Betweenness centrality and brokerage were used in order to identify actors that were likely to be more influential. Betweenness is influenced by the actors' principal area of activity. The fact that the network is highly centralised according to betweenness and also flow betweenness centrality signifies that the role of high ranking actors is more important than it would be in a less centralised network. The following actors have been identified as high ranking according to betweenness values.

Actors ranked by centrality
NIST
APA
Texterity
Reciprocal publishing
OverDrive
NetLibrary
IBM
DigitalOwl
Adobe

Table 6.1: NIST central actors

The actors that correspond to the two highest centrality values have been selected. The Association of American Publishers indicates the relevance of professional Associations. In Chapter 4, the role of these associations regarding diffusion has been mentioned. The electronics category is represented by IBM which has not shown later involvement in the area. Adobe, as shown in the participation of sociotechnical networks, remains an active actor through the development of software applications.Net Library has also been acquired by Adobe and demonstrates developments in the institutional/academic markets. OverDrive is also still active in the domain of publishing services and there are examples of its role in specific ventures. Texterity currently specialises in services for the electronic editions of magazines (www.texterity.com). DigitalOwl was involved in software for content management and Reciprocal Publishing is currently affiliated with OverDrive. Therefore, there are examples of more concrete relationships emerging between these central participants.

Regarding brokerage it is remarked that among all brokerage roles the predominant was the role of liaison. In the case of such interaction all actors belong in different categories so it becomes more difficult for the broker to utilise his position in that they do not share many commonalities with either of the actors they link. With regard to the betweenness analysis when attributes are taken into account by calculating the attribute-based betweenness, there is practically no difference

between mediation within groups and mediation between groups. The fact that betweenness between groups accounts for the majority of aggregate betweenness indicates that the gatekeeping role occupied by actors of high betweenness provides links between categories. However, it is not tested whether this would have arisen by chance alone. Therefore, the notion of gatekeeping potential as indicated by betweenness and the notion of diversity as demonstrated by the categorisation in principal areas of activity are not dependent.

Although the network of participants in the NIST conferences lacked cohesion, some of the related themes (e.g. standardisation) are still of interest in current developments. Furthermore, actors emerging as influential in this network have also shown more concrete interaction.

6.2. IDPF Membership network

IDPF was established with the specific goal of developing standardised formats regarding electronic books and promote their adoption throughout the industry. Despite the specific scope of the organisation, its membership is a comprehensive account of the actors involved in different aspects of the electronic book development. One needs to question why the most prominent association in the field was set up with a particular focus on format standardisation. In chapter 2 the role of standards in social science was discussed as devices set up by sociologists. In addition the role of standardisation in technological development is acknowledged in the concept of dominant designs (Abernathy and Utterback, 1978).

The evolution in IDPF membership to a degree resonates with industry changes. Firstly, it is considered how network cohesion has evolved over time. Then the interaction between actors in different areas of activity and the role of actors who could potentially act as mediators is considered. This discussion will be supplemented by information on the organisation's output. In Chapter 5 the network was visualised in subsequent stages but the analysis focuses on the aggregate network. The time issue on network analysis was addressed by providing snapshots over time rather than a dynamic representation. The goals of the network are explicitly related to standardisation with regard to document format but in practice standardisation attempts refer to different aspects to electronic books as will be observed in the discussion of the sociotechnical network.

6.2.1. Network cohesion

The density values and the clustering co-efficient values are used in order to assess the evolution of cohesion over time. As shown in tables 5.8 the density based on dichotomised data diminishes with time as would be expected according to network growth. However, the end network remains quite dense and cohesive. Cohesion facilitates the establishment of standards considering that actors in a cohesive network are more likely to be exposed to the same ideas (Granovetter, 2005). Overall conflict between the IDPF participants is not explicitly manifested in the organisation context, primarily because they prioritise overall market growth due to the small size of the market (personal communication). Hence, it can be argued that cohesion within the network hides conflict may be manifested in market competition. The relation between manifest and explicit absence (Law, 2004) can provide an interpretation of this situation, where conflict is not prominently expressed.

The clustering co-efficient analysis indicates higher degree of embeddedness within the local neighbourhoods. There is evidence of actors' segregation according to their distances as local neighbourhoods are more cohesive.

Networks cohesion relates to the patterns of membership. As shown in figure 5.11 regarding frequency of membership attendance for two periods was the most likely membership pattern. Membership by year illustrates that there is a gap between those organisations that attended IPDF in the first years and those that joined in later. These different participation choices are reflected in the network subgroups.

6.2.2. Network heterogeneity

Network heterogeneity depends on its composition and the level of interaction between the groups. The classification of the actors uses the same categories as the NIST conferences network.

Concerning the organisational type the participants are mostly business organisations whereas academic and civil society actors are represented in fairly the same degree (Figure 5.9). The same business orientation was also shown in the NIST conferences network. Although the overall market is still small it appears from these data that most participants are commercially oriented.

Changes in the organisation's participation according to the principal areas of activity of the participants are shown in Figure 5.10. The fluctuations in the percentage of specific areas do not appear significant. Actor diversity is maintained throughout the years. Therefore, there are not periods in the development of the network that are specifically influenced by some categories. Because the diversity was evident throughout the years each participant could have been exposed to actors with a different knowledge base. However, more detailed information on specific organisational events and working groups would have led to a better evaluation of this interaction.

The interaction between actors representing different areas of activity is shown in network graph 5.11. The role of the publishers' category in this network becomes more central as they have developed more links than any other categories. Unlike the NIST network there is direct contact between publishers and actors in the electronics area. These categories can be seen as the primary representatives of the established print-on-paper regime and the incumbent actors. Yet the DRM category has lower than average interaction with all other categories while software actors and content providers are not well integrated in the network either. Again, it can be argued that the publishing services category provides an intermediary between publishers and electronics actors. In that sense, there is a link between bibliocentric and technocentric approaches.

Network heterogeneity is also evaluated by the degree that actors in each category are more likely to develop links within rather than link across categories. The network E-I Index as defined by principal areas of activity shows that publishers are the most inward oriented category. Generally categories that are more relevant to either technological or market developments are more inward oriented. This degree however depends on the relevant sizes of each category.

6.2.3. Network subgroups

Network subgroups are defined by k-core, faction and valued core analysis. The k-core analysis is consistent with the positioning of the actors in the spring embedding layout. Contrary to what usually occurs the more restrictive core is also the largest. Faction analysis in that case is not effective in resulting in cohesive subgroups as part of one faction may be in different locations. As mentioned in the last section of chapter 4, the valued core analysis is more relevant when identifying subgroups in valued networks. The reduced version of the network resulting from valued core analysis is shown in network graph 5.14. The constitution of this network in terms of principal area of activity compared with the aggregate IDPF network is in the following figure.
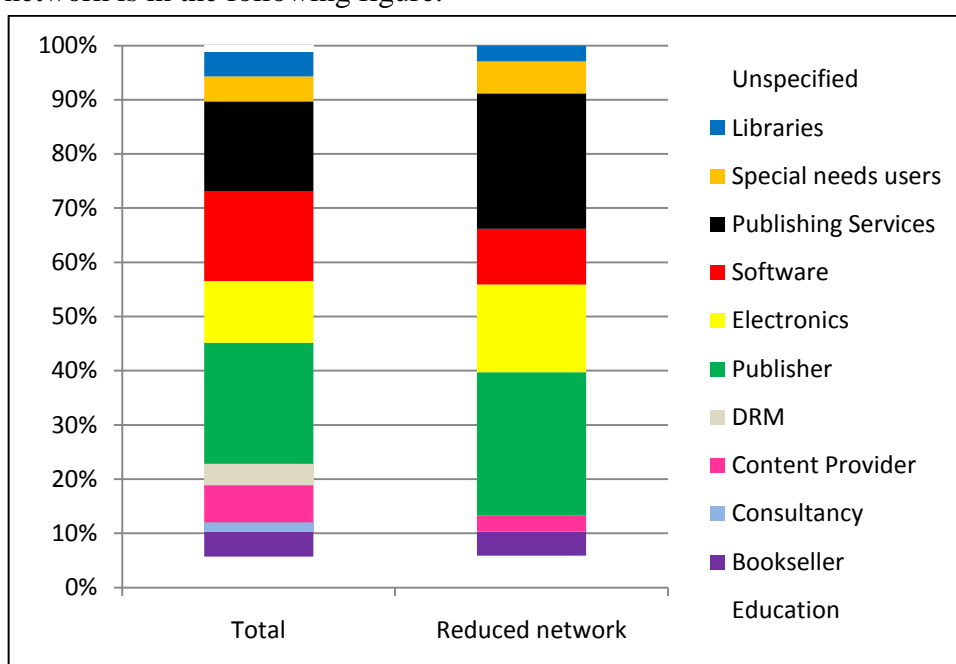
Figure 6.2: IDPF-Principal area of activity comparison

The graph demonstrated that the dominant categories when the reduced version of the network is selected are publishers and publishing services actors. However, there is not a critical differentiation between the aggregate network and the network resulting from actors with greater tie strength among them.

6.2.4. Centrality and brokerage: Influential actors

Betweenness centrality and brokerage values are used in order to identify actors who could act as mediators. In an affiliation network betweenness centrality is dependent on actors' attendance patterns. Those actors that have only participated in the organisation for a year lack betweenness centrality. Betweenness centrality is correlated with the frequency of participation. Actors that have shown more consistent participation in IDPF have higher betweenness centrality and are in better position to mediate among others. However, what remains hidden in the centrality and brokerage analysis is how actors utilise their position. Betweenness centrality is a positional measure of analysis (Burt, 1980). To paraphrase Callon and Latour (1981) position is regarded as an achievement of the actors rather than as an asset to be utilised. The list of the actors with the highest betweenness centrality and their area of activity are shown below.

	Principal Area of Activity
Stonehouse Press	Publisher
Sony	Electronics
Simon & Schuster	Publisher
RosettaBooks	Bookseller
Recording for the Blind & Dyslexic	Special needs user
Random House	Publisher
Publishing Dimensions	Publishing Services
OverDrive	Publishing Services
NetLibrary	Content Provider
Microsoft	Software
McGraw-Hill	Publisher
Lightspeed	Publishing Services
Lightning Source	Publishing Services
HarperCollins	Publisher
E-Reads	Publisher
DAISY Consortium	Special needs user
ContentGuard	Publishing Services
BISG	Publishing Services
Apex	Publishing Services
American Printing House for the Blind	Publisher

American Library Association	Library
Adobe	Software
APA	Publisher

Table 6.2: IDPF central actors

The included actors share the maximum centrality value. In that group there is a higher than average representations of publishers and publishing services actors. The distribution of centrality according to attributes also demonstrated that linking actors between different areas of activity is more common than linking actors within the same area. In that sense betweenness centrality has a connecting role between actors with a different knowledge base. The distribution of total brokerage between brokerage roles also demonstrates that linking actors between different groups is more common. As the correlation between brokerage measures is high it is inferred that mediation between and within groups are substitutable.

In the following chapter the concept of standardisation with regard to various aspects of electronic books will be addressed and compared with the results on IDPF membership patterns.

6.3. The electronic book as a sociotechnical network

The sociotechnical network of the electronic book is multi-relational and has derived from qualitative information on the actors' linkages. It is unlike the other two networks not only because it includes diverse relations but also because these relations are more complex in their content and indicative of stronger interaction. One example of reduction in network representation is that ties of different relational content have been classified only in terms of presence or absence. It is a common approach in SNA to convert multiple relations to one as there are few efficient techniques for multiplex networks (Hanneman and Riddle, 2003). However, it is necessary to reconsider the relational content in order to interpret the results of the network substructures and actor position. Networks are seen as comprising actors, links and flows (Conway and Steward, 1998). Unlike chapter 5, the emphasis shifts on the content of relational flows and their qualitative differences.

As mentioned with regard to data collection the information on actors' linkages refers mostly to the last decade. A number of the included links are no longer active but they are included in the network representation because the aim is to provide a comprehensive account of all observed relations.

To enable the interpretation, ties have been classified according to the nature of interaction. The ties are classified according to whether they link organisations and non-human actants. The actors' ownership status shows whether they are controlled by the same corporate/organisational entity. The relational flows may differ when the order of actors is taken into account; however the network is structured as undirected. Therefore, the main characteristics of the tie are classified. There is a main distinction between technological flows, ownership/equity and investment flows and other partnerships such as distribution. Technological flows refer to technology generation or adoption regarding ties between a technological artefact and an organisation. In the case of links between technologies the flow is either one of compatibility or interoperability or the case when a technology is integrated as input in a product. Analogies can be found between these patterns of relations and the mechanisms or forms of anchorage in sociotechnical transitions. Therefore, results of the network analysis can be interpreted according to the transition mechanisms.

The discussion of the network is structured around the idea of cohesive subsets that indicate potential sociotechnical trajectories. Firstly, the implications of cohesion measures are addressed. The discussion of network substructures provides a more detailed view of the content of interactions. The role of central actors is then discussed according to their nature as organisations or technologies so that the hybrid nature of the network is considered.

6.3.1. Cohesion

Firstly, it is considered how network cohesion affects the potential of the network to generate and disseminate innovation. The related analytical measures were presented in section 5.3.2. Density and clustering co-efficient values refer to cohesion at the dyadic level while transitivity is used to indicate how the actors' embeddedness in triads reinforces certain relational patterns. In addition, the presence of isolate actors in the network and the fact that excluding the isolates it is divided into three components affect the overall distribution of cohesion.

Network cohesion relates to the flow and homogeneity of ideas. Network density is used as an indicator of cohesion. Norms are easier to enforce in dense networks. The higher the network density, the number of paths along which information is diffused increases. Hence, social norms are more likely to become established as actors are more likely to be exposed to the same perspectives. In addition, deviant behaviour is more easily remarked and sanctioned (Granovetter, 2005). With regard to innovation, it is hypothesised that dense innovation networks are more likely to share the same routines and heuristics resulting in standardised technologies. However, increased density may also be the results of already shared norms. Like other network measures the direction of causality is unclear.

Network density is low, although as expected it increases when it refers only to the main component. This indicates the likelihood that there will be heterogeneity of ideas. This is consistent with the existence of different approaches to content delivery models and great variation in end formats for electronic books. It is however complex to evaluate what high density would mean in an essentially multi-relational network. In the discussion of network heterogeneity some types of linkages can be thought of as higher strength. Also, network fragmentation is consistent with strong cohesive subgroups (Granovetter, 2005).

Network density is low which is to be expected because of its size and the more complex nature of relations. According to the distribution of degree centrality (Figure 5.17) being connected to two other actors is the more common pattern. Considering the discussion on the nature of density (Granovetter, 2005) this limits the diffusion of norms within the networks therefore increased degree of diversity is likely to persist. One could also argue that in a network of lower density the role of high betweenness actors becomes more important as there are less alternative paths for actors to follow.

The clustering co-efficient is significantly greater than density indicating a greater degree of actors embeddedness in their local neighbourhoods. Therefore low overall cohesion is combined with highly dense local neighbourhoods (Granovetter, 1973).

Regarding the embeddedness of actors in triads the results on transitivity are indicative of a more cohesive network. Transitivity provides elements of closure

although it should be combined with discussion on the strength of ties to evaluate this role (ibid.). The categorisation of ties according to the organisational relation of the actors can be used to classify them as strong or weak. Roughly more than half the relationships (106 out of 193) link actors under different organisational ownership. This tie attribute is however only a proxy measure for tie strength.

Before discussing the overall network cohesion the role of isolate actors and secondary components in the network is discussed.

6.3.2. Network components and cohesive subsets

Besides the overall network cohesion measures described above, the presence of isolate actors and components in the network is a mark of network fragmentation that impacts on the distribution of overall cohesion. The division of a network in components is the most evident characteristic of network fragmentation. First, the role of the isolate actors and the two secondary components are discussed. Then the subgroups resulting from faction analysis in the main components are described. Finally, points of contacts (actors or linkages) between the factions are identified to explain how this interaction leads to network cohesion or fragmentation.

i. Isolate actors

The role of isolate actors is somehow contradictory. As discussed in Chapter2 2 and 4 a relational approach to technological agency is adopted. Hence the question arises whether an actor who is unconnected qualifies as an actor at all. The majority of these isolate actors were indentified in the literature on the electronic book however it was not possible to find any linkages between them and others. Some of the isolate actors are most likely no longer in operation. They are also likely to have had some external contacts (e.g. customers) which could not be identified. In most cases they were actors who developed a specific technology which was not incorporated into any other application. One example is DRM actors whose platform was not adopted any further such as SoftLock and LockStream.com.

A more interesting case of isolate actors includes those who are in practice integrated in networks related to digital text although no specific connections are traced. In this group one could classify GoogleBookSearch and Project Guttenberg. GoogleBookSearch is a dedicated search engine which provides limited access to scanned copies of books provided by public libraries rather than publishers. Considering that no specific software is required to use it one could claim that it is essentially similar to other search engines used for different types of content. As long as it provides only restricted access to content it does not really need to develop any additional connections with content providers or publishers. However there has been reluctance on the part of publishers to engage more closely with GoogleBookSearch so that the search engine could for example be integrated with their websites or a vendor's website. Project Guttenberg is a voluntary venture which converts content on the public domain into the ASCII format. This format is very basic and somewhat unusual to read from but precisely because of its simplicity it has the advantage that it can be read with any type of reader software and on any device. Even as software changes the ASCII format remains readable. In that sense Project Guttenberg does not require any specific connections with device and software manufacturers and because it only collects content on the public domain it does not have any specific relations with publishers or content providers. Probably, because of that reason there

has not been any opposition towards it. Its position as an isolate is linked with its ability to integrate with any available technology. It is an example where the use of a basic technological format facilitates integration. In addition its voluntary, not-for-profit nature is an interesting contradiction to the role of other content providers, however it is not perceived as direct competition. Also, it acts as a repository of material that is out of copyright rather than solely as a content provider. However, it was mostly meant for content to be downloaded into personal computers.

The fact that most isolate actors seem to be inactive indicates that a lack of linkages impacts negatively on market position. Yet, as shown by the examples of Project Guttenberg and Google Book Search, lack of specific ties may actually facilitate integration.

ii. Secondary components

Besides the isolate actors the network contains one main component and two secondary components. The smaller component includes two actors the organisation IPR systems Pty Ltd and the related technology ODRL (Open Digital Rights Language). This component focused on Digital Rights Management. Initially ODRL was positioned as a competitor to the eXtensible Rights Management Language developed by ContentGuard. ODRL is meant to provide more flexibility regarding the restriction on content. The ODRL format places less restrictions on content and one can hypothesise that this fact accounts for the lack of adoption. The format is still active but organised on the principles of Open Source communities (Coyle, 2001).

The largest secondary component has the organisation Nemoptic as a focal actor. Nemoptic is a French company which specialises in electronic ink technology. Electronic ink applications are not limited to the electronic book. In the case of Nemoptic only one electronic reader device has been identified that incorporated its technology. The t.book is produced by British company Readmooore and incorporates the bNem (bistable Nematic) technology (www.readmooore.com). Certain advantages to the use of bNem versus alternatives have been identified. The t.book reader is designed as a dedicated device catering to mass market fiction rather than specialised material. However, Readmooore does not list any specific agreements regarding access to content. The t.book is positioned strictly as a reader device without any additional applications and it is clearly differentiated from personal computers in that sense. Besides, its linkage to Readmooore, Nemoptic has a manufacturing agreement with SEIKO Instruments and has received government funding for its SyLeN project. The SyLeN (système de lecture nomade) focuses on creating a multi-format electronic paper reading device that could be used for electronic newspapers and textbooks. It is therefore an attempt to diversify in the software area and this may account for the fact that Nemoptic has not developed any

alternative linkages with software developers. In addition it indicates increased engagement in electronic book related activities. The project is still at research and development stage. This secondary component has a degree of autonomy in that end products and a feasible technology have been developed while remaining unconnected with overall network developments. It is remarked that differentiation in the component technology correlates with lack of network embeddedness. Overall there is little diversity in the electronic ink and display technology, however albeit a marginal actor Nemoptic has managed to construct a sub-network.

iii. Faction analysis

Faction analysis was applied only to the main component of the aggregate network as the existence of components was already an indication of substructures. Hence, cohesive subsets are identified on the basis of density: density within the same faction is by definition greater than density between factions.   As observed in the respective section the division into factions is an improvement in the initial matrix configuration but still differs significantly from the perfect fit. Each faction is described individually and then it is evaluated how points of interaction between factions are identified. Factions as cohesive subsets are meant to provide indication of future sociotechnical trajectories and at more fundamental level different conceptualisations of the electronic book. It was mentioned how network density correlates with the likelihood that the actors will share similar norms. In the case of factions the greater than average density within indicates that actors in the same faction are more likely to share similar norms. However, as shown in the respective diagram actors in some of the factions are dispersed in different areas of the network. The diagram illustrates how different factions are dispersed across the network. In addition the degree of interaction between factions means that their respective trajectories do not develop independently.

Each of the faction is extracted and represented as an independent network in order to be analysed in more detail. This allows for clearer representation of network ties. The blue faction is discussed first.
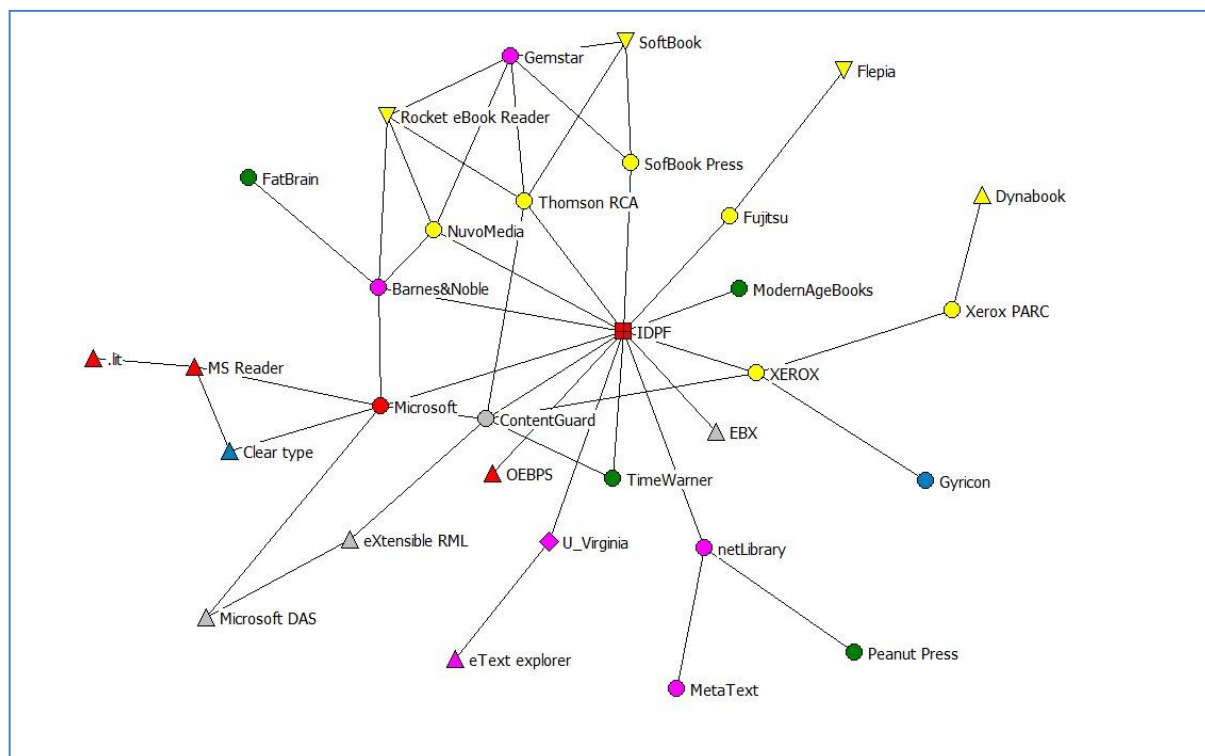
Network graph 6.1: Faction 1

IDPF is the organisation with the highest betweenness centrality. Its patterns of membership have been analysed regarding standardisation. Its connections refer to membership. Two of the standards that were developed by IDPF belong in this faction as well: the OEBPS (Open E-book Publication Structure) and the EBX (Electronic Book Exchange standard) but they are now superseded. OEBPS has been replaced by .epub and EBX never became adopted because IDPF no longer develops standards regarding Digital Rights Management (personal communication). Actors in the electronics area are also included but some refer to ventures that are no longer active. The Rocket eBook Reader and the SoftBook reader have been developed by separate companies and then sold to Gemstar. This was an example of a media company (Gemstar) diversifying into electronic books by marketing reader devices. The manufacturing was outsourced to Thomson RCA. Hence the technological abilities required for production were treated as a complementary asset that was acquired through outsourcing. However, the project was abandoned due to lack of profitability (Hawkins, 2000b). Another reader device in this faction is Flepia developed by Fujitsu (http://www.frontech.fujitsu.com/en/release/20070420.html) . Unlike other reader devices it uses display technology that was developed in house. Xerox has also shown interest in electronic book development through subsidiary companies. Gyricon initially focused on electronic ink technology however it later refocused its activities on improving de-inking processes for recycling paper (Khimasia, 2007).

Other aspects of this faction refer to content providers. Some of these relations are now defunct. For instance Barnes&Noble agreement with Microsoft has been abandoned (Hawkins, 2000b). The eText explorer developed by the University of Virginia is a non-profit venture developed within an academic context (Hawkins, 2000b). NetLibrary is another commercial content provider that focuses on the academic market (Connaway, 2001). In this faction there are indications that the electronic book is perceived as an educational tool and in this case the emphasis is placed on content provision although this occurs through commercial transactions. In that sense electronic book databases that work on a subscription basis do not differ in their business models from electronic journal databases.

Microsoft and some of its affiliated technologies belong in the same faction. It includes the MS reader and the associated .lit format for electronic books (Rao, 2004). No widespread diffusion for this format has been observed. Material in this format can be purchased from a number of providers though not from Amazon.com. Although the format is readable by the MS reader for electronic book portable devices, it can be easily converted to other formats subject to controls. There is an ambiguity regarding the accessibility of different formats: the ability of conversion is helpful but it requires the initiative of the end user whereas a format readable by different types of programme bypasses this problem. Besides its own reader Microsoft was involved in the area of Digital Rights Management as it has co-founded ContentGuard with Xerox (Coyle, 2001). The ContentGuard language is compatible with the Microsoft Digital Asset Server (DAS).

This faction demonstrates diversity in that it includes both defunct and still active actors and linkages and that different perspective on the role of electronic books can be identified. There are examples of the electronic book as an electronic reading device and the electronic book as accessible databases of content. Also, it is observed how developments originating in personal computing overlap with the electronic book area.

Next the actors in the 2nd faction are discussed (coloured grey in the network graph). When this faction is visualised as a separate network it is divided into components thus the division of a network into factions does not result into what onewould graphically perceive as a cohesive subset.
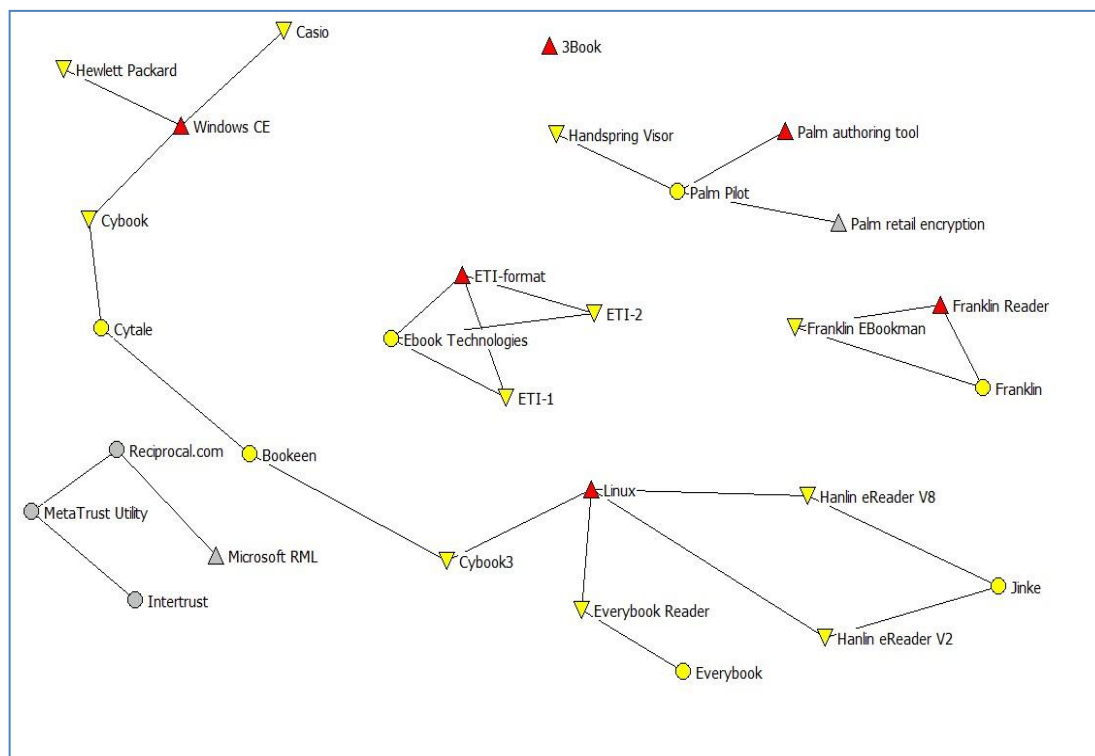
Network graph 6.2: Faction2

One of the resulting components refers to a set of agreements relating to Digital Rights Management. The Microsoft Rights Management Language is included there. The MetaTrust Utility platform has been developed by Intertrust (www.intertrust.com). Reciprocal.com (Rao, 2003) utilises Microsoft RML for encryption purposes and is also a partner to the MetaTrust Utility. It is interesting that there is interaction between different organisations in the development of DRM technologies. However, DRM technologies become influential as they are adopted by content providers. Yet DRM products that develop through collaborations are more likely to receive acceptance. Besides this DRM component this faction includes a number of dedicated reader devices. The Everybook reader and the Franklin eBookman are among the earliest examples of dedicated devices (Rao, 2003). The Hanlin eReaders have been developed by the Chinese company Jinke utilising proprietary technology (www.jinke.com). In addition eBook Technologies has produced two readers and a proprietary format catering for the educational market (www.ebooktechnologies.com). The company was developed by former Gemstar managers when Gemstar exited the electronic book market. In the same faction one can observe devices that were not conceived as electronic readers but also incorporate electronic reading capabilities such as the Handspring Visor that was acquired by Palm Pilot and devices using the Windows CE operating system (Burk, 2001). Electronic book readers range from dedicated devices to what would be best as Personal Digital Assistants that incorporate reader software. The devices mentioned in this faction were developed in-house by the respective companies.

As it can be observed by the distribution of actors into principal area of activity the second faction relates mostly to the embeddedness of electronic books within the electronics sector perceiving them more as tangible hardware rather than as digital content. The inclusion of general devices with e-book reading capabilities illustrates this aspect

The third faction is characterised by a recent rise in activity as demonstrated by new product launches.
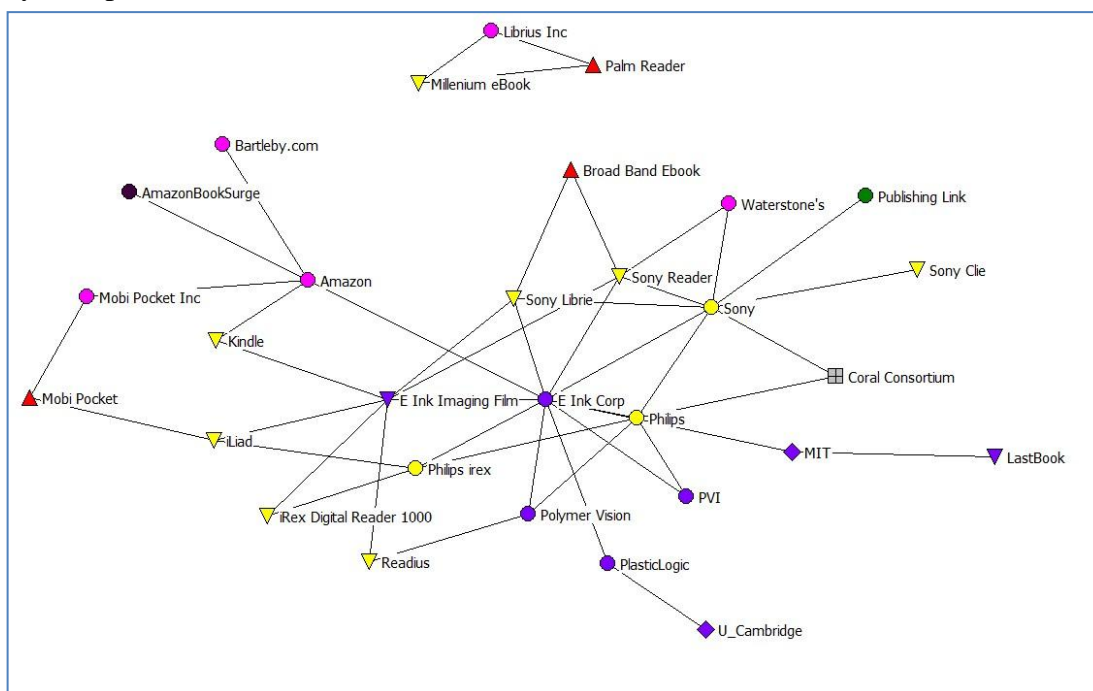
Network graph 6.3: Faction 3

Visualised as an independent network it contains two components. It includes the Millennium eBook which was developed by Librius and used Palm Reader software (Rao, 2003). This belongs to the early developments in dedicated reader devices. The main component of the network indicates increased activity regarding electronic ink display technology. The E Ink Corporation through its imaging film technology has managed to build linkages with a number of electronic book ventures referring to dedicated devices. The technology originated from research in the MIT Media Lab (www.eink.com).Its technology is used as a display component in the Sony devices and also in the iLiad and Readius which have been developed by Philips subsidiaries. Philips has demonstrated its involvement in the area through its subsidiaries which work on variations of the technology. For instance, Polymer Vision focuses on the development of scroll-like display. However, Philips has sold its electronic ink activities to PVI. Although most reader devices seem to emerge from organisations in the electronics sector and display sector, it is observed that Amazon has developed the Kindle device which also incorporates the E Ink imaging film. Except for Kindle and the failed Gemstar devices, all other reader devices have

been developed by organisations in electronics. The Amazon device can be seen as an attempt to vertically integrate its activities. In this faction it is mostly shown how the electronic book overlaps with areas relating to electronic ink and improved display technologies.

The question of network embeddedness arises again. Actors show different levels of inclusion within the electronic book network. This becomes evident in the case of electronic ink technologies: there is an account of their incorporation in reader devices but they also have different applications (see Khimasia, 2007).

In addition, there is an input of academic research into the activities relating to display. The E Ink Corporation has resulted from MIT research. The Last Book was an additional research project undertaken by the MIT. In the UK, Plastic Logic has developed from research in Cambridge University and financed by venture capital. It has presented its yet unnamed own version of a reader device in exhibitions. It is positioned as a device for electronic newspapers rather than for electronic books. Among the goals of PlasticLogic was to introduce two versions of its reader one for the consumer market and one for professionals in which case it would be used for the distribution of documents in a pooled environment (personal communication). That version of the reader would be perceived as a workplace tool, however different from laptop computers or PDAs.

This faction is mostly focused on the conceptualisation of electronic books as reader devices. A degree of standardisation appears to have been achieved in that most devices incorporate a version of E Ink Corp. technology and they are positioned as electronic products. With the exception of Amazon there is limited interaction with content providers and publishers in this section. On the part of Sony there is an exclusive distribution agreement with Waterstone's bookstore. The nature of the interaction regards the use of sales outlets. Access to content still remains limited. However the recent activity in this network subgroup indicates towards market feasibility.

A final point regarding the third faction has to do with the fact that it is practically unrelated to all other according to the density table. Therefore it can be seen as an autonomous network in its own right. Along with the first faction it is also the most internally cohesive.

Finally, the fourth faction is visualised as a network below.
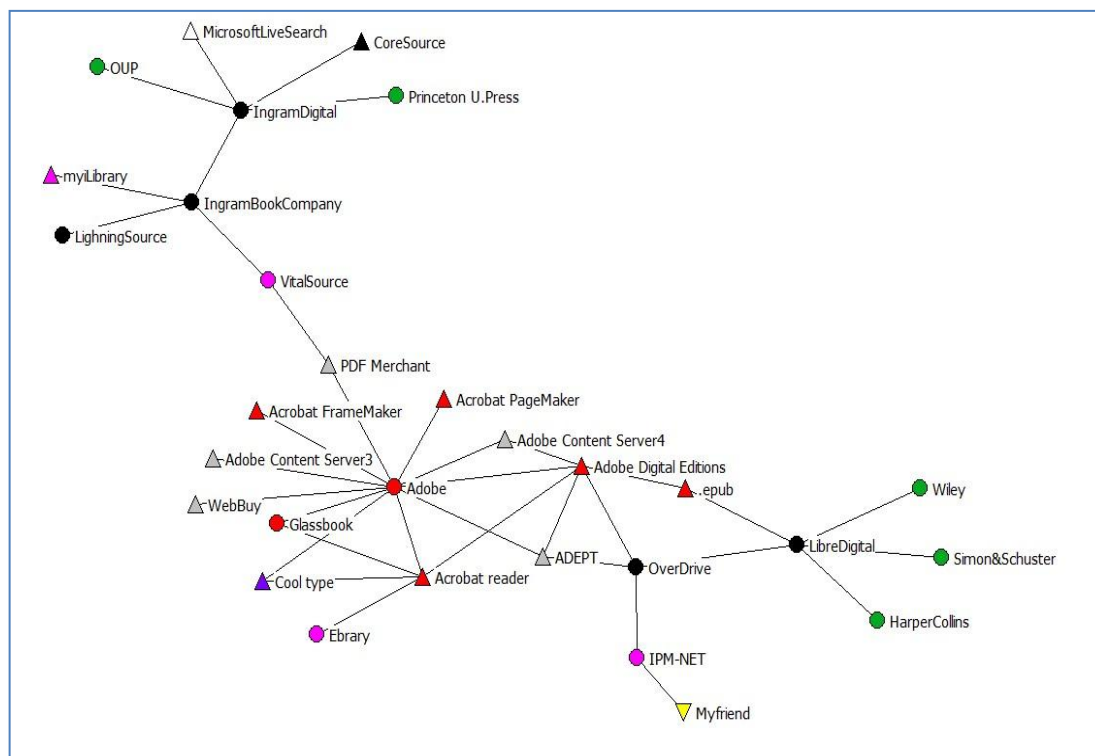
Network graph 6.4: Faction 4

Adobe is a central actor in this subgroup. Its main activity regards the development of formats and associated Digital Rights Management activities. The question of embeddedness in the electronic book area is considered by taking into account that the Acrobat reader (.pdf format) was not developed as a format for reading documents on screen. Adobe Digital Editions is more specifically related to electronic books and it has been incorporated in the recent versions of Adobe reader. Also it is available on the Sony devices, thus building a link between this faction and the third faction.

Organisations in the publishing services sector are included in this subgroup. Such organisations have an intermediary function in the sense that they focus on the conversion or provision of publishers' material in electronic format. OverDrive, LibreDigital and companies in the Ingram group undertake this role. Activity in this faction does not impact directly on the consumer market however; it is required for the development of an infrastructure that will enable the flow of digital content. Diversity is demonstrated by the fact that content conversion has to be able to support different end –products. However, the conversion of text into digital content does not necessarily indicate that the end product will be in electronic format. This is demonstrated by the role of print-on-demand companies. With regard to the Ingram Book Company, its subsidiary Lightning Source is active in the print-on-demand sectors. Print-on-demand can be seen as a form of incremental innovation in the sense that digital technologies are applied to improve printing efficiency (personal communication). As it is incorporated in a company that provides general services in

the book trade there is potential of future synergies. However, the activities of Lightning Source and the other companies in the group are not yet integrated partly because publishers may select different strategies in their print and digital activities (personal communication). This faction is meant to relate more to the concept of digital documents rather than electronic books as an alternative to print.

The distinction between the factions is not perfect as they do not represent the ideal fit. Specific actors can be identified with the potential to mediate between factions or act as gatekeepers. These can be identified by attribute-based betweenness centrality and brokerage analysis. However the results do not differ significantly from those for overall betweenness. As expected, IDPF has the main intermediary role which is in accordance with its role as an industry association. Regarding the other actors their degree of engagement in the electronic book field should be evaluated regardless of the SNA results.

6.3.3. Heterogeneity

Issues of diversity in the network refer both to its composition and to the interaction between actors belonging in different categories. In terms of its representation, the network shows sufficient diversity among actors that relate more to the print-in-paper regime and those relating to the IT regime. However, the density of interaction between different areas of activity is a more accurate measure of heterogeneity as the existence of different categories that do no interact does not make for a diverse network. In Network graph 5.8 one can observe the interaction between different areas of activity compared with overall network density.
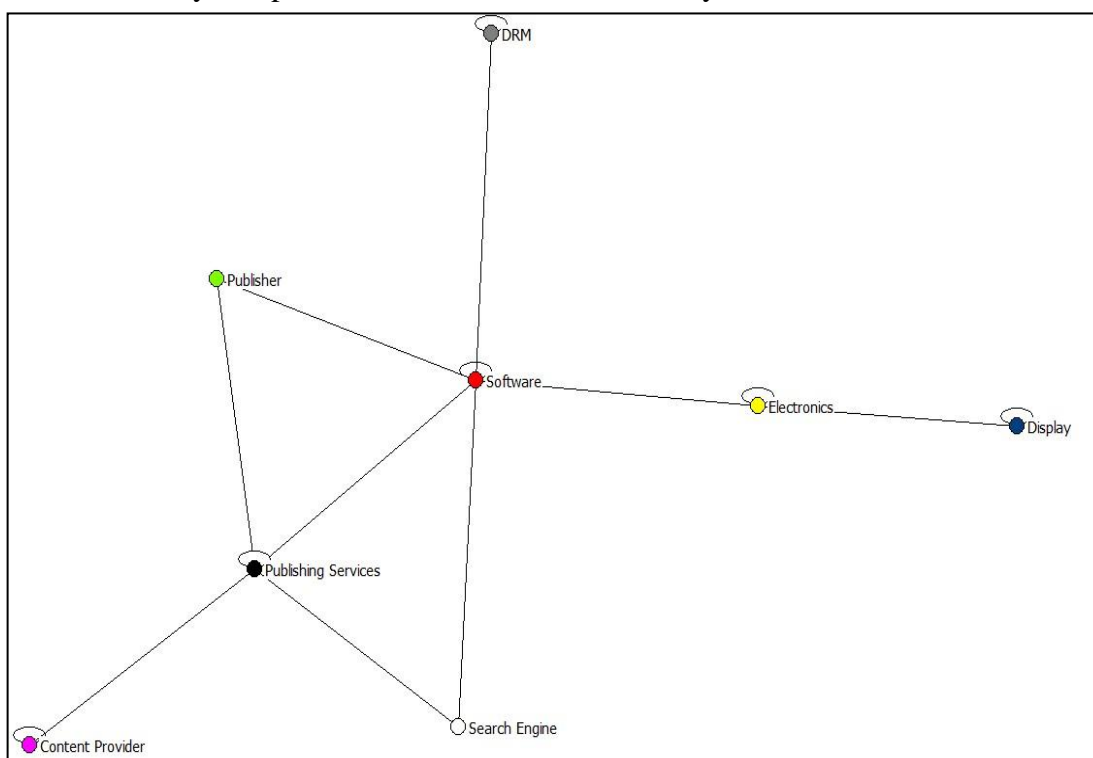
Network graph 6.5: Interaction between areas of activity in the sociotechnical network

A dichotomy is observed between actor categories that relate to the print-on-paper regime and those that refer to Information technology. This lack of interaction might explain why limited access to content is seen as one of the primary factors inhibiting market growth. There is a distinction between technocentric and bibliocentric approaches to electronic books. The lack of interaction between these approaches prevents standardisation and diffusion. The software category holds a more central position in a network of categories.

Nonetheless it could be questioned whether there is a need of greater interaction between all categories. For examples the category of display which includes electronic ink developments is only closely related to the electronics category. Since electronic ink is incorporated into electronic reader devices this degree of engagement is likely to be sufficient for this category's contribution in the overall networks. On the other hand, as e-reader manufacturers are included in the

electronics category the lack of interaction with publishers is likely to be problematic unless other categories undertake a brokering role among them. Hence, the question arises whether organisations that act as brokers by definition are more effective than having direct interaction between established and emergent categories. For instance, there are past examples of reader devices that failed due to limited content.

The heterogeneity analysis illustrates the intermediary role of certain categories. In particular the category of software appears to have a greater contribution in network cohesion. In the following section the role of individual actors as mediators is considered.

6.3.4. Centrality roles

Because of the varied nature of relations in this network the role of centrality becomes more meaningful. As a positional /structural approach to networks is avoided and centrality is by definition a positional measure it has to be acknowledged that similar centrality values may require different interpretation. In the case of organisations they can be seen as mediators rather than intermediaries only when they act more as place-holders, hence when their individual input in the network is not substitutable (Latour, 2005). The technologies with high centrality on the other hand are positioned as obligatory points of passage (Callon, 1986) or as boundary objects (Star and Griesemer, 1989). While an obligatory point of passage appears to constrict the course of action available to others, boundary objects provide freedom for multiple translations. Therefore actors can be brought to a shared space without having shared goals. The technologies that have emerged as relatively central such as the E-Ink imaging film operate more as obligatory points of passage because once they reach a particular scale they become established as a standard.

The distribution of betweenness as shown by the relevant centralisation index the network is highly centralised. This confirms the assumption that in the case of low density the role of highly central actors becomes more pronounced.

Regarding the role of central organisations their degree of embeddedness in the network has to be evaluated by considering the alternative outlets for their innovations. In that case most of the influential actors in the network are positioned as technology developers rather than users. It should be taken into account that high network betweenness may result from the role of actors in only certain areas of the network (Borgatti and Everett, 2000).

The highest ranking organisation according to betweenness is IDPF. However, it provides a forum where other actors interact rather than pursue its own strategies. For instance it does not collect detailed market statistics because of the participants' reluctance. Sony, Microsoft and Adobe follow in the ranking and each of these has a central role in their network substructure rather than in the aggregate network. Regarding the technologies the role of E Ink Corporation and the corresponding E Ink Imaging Film indicate a degree of standardisation only in technological components. However, as far as software technologies and reading formats are concerned there is a greater degree of diversity which is seen as inhibiting industry growth. Interesting Linux software ranks higher which shows a deviation from personal computing usage.

The analysis has indicated the degree of diversity of developments and points where closer interaction would be desirable. In addition differentiation between the institutional and the consumer market is shown in the actors' orientation whereas the degree of business to business activities is demonstrated by publishing services actors. Therefore, the idea of electronic books as a consumer product is limited.

However, network analysis techniques cannot account for the degree of actors' commitment in the area or the actors' own perception of the market.

7. Findings and conclusions

Introduction: chapter structure

This chapter discusses the findings of the study in relation to their theoretical, empirical and methodological implications. The discussion provides linkages between arguments that may have been raised in individual chapters, therefore it is explained how a cohesive approach is followed throughout the thesis. In the analysis of the electronic book case study the concept of sociotechnical transitions was adopted as a framework for the discussion of prospective sociotechnical change that may have sustainability implications. In addition, the electronic book case study serves as a platform to illustrate how Information and Communication Technology could contribute to environmental sustainability, thus it is situated in the broader context of interaction between digital technologies and the environment. The SNA methodology applied is grounded on a relational view of agency and innovation that is distinguished from the MLP framework, which is prevalent in transition studies. The tentative links between these conceptual issues on the nature of long-term sociotechnical change are correlated with the research findings on the emergent electronic book networks.

The main objective of the research was to explore how the electronic book could contribute to environmental sustainability goals by providing an alternative form of textual display to the printed text. Hence, some of the initial questions discussed in chapter 1 referred to the relation between environmental sustainability and technology emphasising the role of digital technologies in that effect. Developments in the electronic book field are thus considered in relation to their potential environmental benefits. At this point one needs to evaluate what the findings on electronic books correlate with the discussion on the environmental sustainability of the print-on-paper system. The potential sociotechnical trajectories relating to electronic book developments can be considered in relation to envisioned trajectories in the print-on–paper system and their overall relation to generic sustainability strategies. The role of sustainability has been somehow obscured in the preceding chapters where the development of the electronic book was followed and discussed. Therefore, sustainability has to be brought forward so that what was the original objective of the research can be evaluated. The concept of value chains on the print-on-paper system is used in order to evaluate how sustainability can emerge. Similar to the points of breakthrough from niches to regimes one can identify points in the value chain where considerations and solutions towards sustainability are more likely to emerge.

The notion of sociotechnical transitions is initially selected because of its emphasis on long-term, systemic innovation. However, the related concepts are used as heuristics rather than prescriptively. In chapter 2, a review of the relevant

literature was provided followed by an alternative conceptualisation of transitions as the reconfiguration of networks of organisations and technologies. In addition, a practice-based view of sociotechnical regimes was proposed by analysing the more abstract notion of societal functions. Although the print-on-paper system is described as a regime organised around the practice of textual communication, the MLP is not applied regarding developments in the electronic book. However, it was mentioned that the MLP can be applied retrospectively in order to identify niches and regimes after the analysis of the network data. Hence, the findings from the analysis of electronic book as emergent networks can be examined in terms of their correspondence to patterns and pathways identified in the transitions literature under the MLP. In addition it is questioned how the long-term approach emphasised in transitions resonates with the electronic book case.

Besides the transition pathways and mechanisms, patterns of change are examined regarding the origins of innovation, the interaction between incumbent and emergent actors and the balance between variation and standardisation in the electronic book field. These patterns of sociotechnical change may be less formulaic than the transition pathways resulting from a strict interpretation of the MLP; however they are also reflected in the transitions literature. The degree of radicalness and the scope of radical change are also discussed. In addition developments in business models related to the potential sociotechnical trajectories derived from the electronic book networks are mentioned in order to identify the co-evolution between technological and organisational structures. In the development of business model analogies with other content-base industries can be made. The concept of standardisation regarding aspects of the electronic book can be considered across the value chain. The role between incumbent and emergent organisations should also reflect the interaction between incumbent and emergent practices.

Then, some of the implications of the methodological choices are considered regarding the interpretation of the results. The notions of contingency and multiplicity should be taken into account in the relevance of the results. On the basis of the discussion on representational forms in social science (Law, 2004), it is considered how the forms of representation selected reflect on the data and what alternative representations would have been possible. Non-obtrusive methods were used in data collection and SNA techniques were used in the analysis. Network graphs are seen as a form of visual representation. In addition the three areas of problematisation (Callon, 1981) and the notion of representation as a form of reduction indicate that some aspects have to be silenced for any type of representation to be possible. In that context some aspects that were not included explicitly in the network representation are discussed. Specifically, the degree of actors' embeddedness in the relative networks is discussed drawing on the concepts

of regime membership and level of inclusion. In the view of networks as a form of representation the nature of the depicted networks is clarified.

Regarding the methodological choices it emerges that a common thread connecting the research questions as discussed in different chapters relates to the notions of framing and the identification of boundaries. The notions of framing and overflowing were discussed in chapter 2 regarding regimes, niches and networks as different forms of representation. In this chapter it is discussed how the notion of framing and overflowing are observed with regard to the research questions. Framing refers to the methods used for the identification of networks and sociotechnical regimes. In addition, the conceptualisation of the electronic book provides a framework for the design of data collection. With regard to innovation networks the identification of boundaries is a specific type of framing. Besides the frameworks imposed by the analyst, it should be taken into account that the actors themselves develop their own framings. The adoption of different frames can affect the interpretation of innovation as radical or incremental and the identification of innovation sources as internal or external to the topic in question.

The notion of framing and the acknowledgment that there are multiple possible framings available is consistent with the characteristics of social research that have been identified in chapter 4, in particular the notions of contingency, multiplicity and indefiniteness of research outcomes. Multiplicity is adopted as an alternative to the social constructionist idea that there are varied interpretations on reality (Latour, 2005). However despite the lack of common goals it is possible for the actors to agree on a common space. The concept of boundary objects (Star and Griesemer, 1989) and variable geometry (Law and Callon, 1992) are indicative as to how this common space can be achieved. Multiplicity can be juxtaposed with the notion of standardisation in order to consider contradictory developments in the innovation process.

7.1. The hidden role of sustainability

The following remarks can be made regarding developments in the electronic book area and sustainability.

The relation between environmental sustainability and technological innovation was discussed in chapter 1. The theoretical approaches mentioned included Constructive Technology Assessment and the concept of green technoeconomic paradigm. The justification for the research is based on the assumption that generic technologies can contribute to sustainability goals on the print-on-paper system. Although generic technologies relate to changes in technoeconomic paradigms their expressions and the way they are expressed in specific technologies differ. Three generic strategies towards sustainable development were identified: sufficiency, efficiency and consistency (Huber, 2000). With regard to observations on developments in the electronic book field and the identification of emergent sociotechnical trajectories the relations between these sustainability strategies and these developments are considered.

The sufficiency strategy involves a voluntary or enforced reduction in consumption. Emphasis was placed on the role of books as the central artefact of the print-on-paper text. The application of sufficiency strategy with regard to this context would thus entail the reduced production of books either through reduced demand or with regulatory attempts to contain this demand. This interpretation of the sufficiency strategy is valid –though difficult to achieve-as long as the print-on-paper system is taken as the unit of analysis. This approach is also linked to the understanding that paper use is the main environmental challenge related to the production of books. The question of materiality is related to that view of sufficiency, where environmental effects emerge from the qualities of paper. In that context sufficiency would entail a reduction in the demand for printed books without any technological substitution. Instead, if the demand for printed paper/books is viewed as a particular expression of the demand for textual information then the sufficiency strategy would entail a containment of the demand for textual communication regardless of the physical embodiment of texts. This is unrealistic considering the projection on the growth of publishing and particularly the projections on the growth of information and its accumulation as information tends to be better preserved.

The framing of the sufficiency strategy thus depends on the relation between different types of demand. Because paper is used as the physical embodiment of texts demand for printed paper can be seen as deriving from the demand for textual communication. A decoupling between these two forms of demand can help identify different versions of the sufficiency strategy. When the electronic book is perceived as a substitute for print, this decoupling becomes possible. It has however been

observed that digitisation may contribute to the growth of printing by increasing the availability of information and providing ease of access.

Also, the relation between these different types of demand confuses the distinction between the sufficiency and efficiency strategies. It is acknowledged that the classification of different measures into these strategies is not always clear: for instance, the increased durability of products which results from better materials and manufacturing techniques is often positioned within the efficiency strategies. However, longer product life cycles also depend on change in consumption and lifestyle patterns that promote quick disposal (Huber, 2000). In order to understand how the strategies are conflated with regard to the print-on-paper system one should consider the role of consumption within production: paper is consumed by publishing and printing organisations as the material component of books. Efficiency strategies concerning books production include recycling and the rationalisation of the printing supply chain. These strategies mostly relate to activities within the paper industry and they do not specifically refer to the role of paper in printing. They are located upstream in the supply chain of the printed text.

The discussion of the electronic book as a network and the analysis of these networks into subgroups have led to an identification of potential sociotechnical trajectories. Their state of diffusion is yet limited and quantitative data are not widely available to evaluate their effects on sustainability goals. The conceptualisation of electronic books as reader devices is more consistent with a particular form of dematerialisation as it disentangles print and text. However, approaches that refer to electronic book as digital text without identifying a specific mode of delivery to the end user are more ambivalent regarding their potential environmental effects.

One of the conclusions regarding sustainability is that it is not represented in the network depiction of the electronic books. In addition, conceptualisations of sustainability in the book system ignore the role of digital technologies as they emphasise patterns of paper use. Therefore, the area of digital innovation and sustainability in the case remain unlinked.

7.2. Patterns of sociotechnical change and the electronic book

The theory of sociotechnical transitions has been accepted as an introductory framework for the study of long-term systemic innovation. Because systemic innovation is better positioned to address current environmental challenges, the transitions theory and the associated transition management approaches are oriented towards the goals of sustainability. Niches are identified as places for the incubation of innovation and consequently they are positioned as sources of sustainable solutions. The multi-level perspective has mostly been applied with regard to historical transitions. In the conceptualisation of transitions as a reconfiguration of networks it was argued that concepts from the MLP can be applied retrospectively once a transition has been identified. In addition, the MLP itself incorporates ideas from evolutionary economics and Science & Technology Studies. Some of the patterns identified through the MLP are considered with regard to the electronic book case. Then, more generic concepts on innovation are applied to discuss the findings.

7.2.1. The emergence of the electronic book according to patterns and pathways in sociotechnical transitions

According to the MLP sociotechnical change is perceived as the result of interaction among niche, regime and landscape. Although these levels are not meant to be qualitatively different and they are meant to be interpreted as heuristics rather than as distinct ontological categories, the MLP is dependent on a classification of actors in different levels where as a consequence they are allocated distinct roles. Specifically the classification of transition pathways is dependent on the distinction between the levels. It is considered how actors and practices relating to the printed paper text and the electronic book areas correspond to the levels comprising the MLP. In addition, sociotechnical trajectories identified in the network analysis correspond to aspects of the patterns and pathways in the transitions literature.

The landscape is the level where all regimes are embedded and which provides the background for human action. Compared with the other levels it has been discussed in less detail in the transitions literature. As mentioned in chapter 2, the landscape contributes to transitions by exercising pressure on the regimes thus rendering them more malleable to change. There are different types of landscape change that are of relevance to specific regimes. With regard to the print-on-paper system some of the relevant landscape developments are discussed below.

The aspects of the landscape that influence the print-on-paper system refer to cultural developments and changes in pervasive technologies. The cultural changes in the landscape are indicative of the fact that the book has ceased to be the main cultural artefact. Therefore any considerations on transitions in the print-on-paper system should take into account that print-on-paper no longer holds the prevalent position among communication systems and that we are already beyond the book as the dominant medium (Chernaik et al, 1996a; Briggs and Burke, 2005). There are documented claims in communication studies regarding a move away from the typographic era and how this has affected patterns of thought (Birkerts, 2006). In a way communication systems are intrinsically linked to the landscape precisely because modes of communication impact on the development of ideas and are somehow constitutive of them (Ong,1982). The main changes in the cultural landscape result from the diffusion of the internet and the facilitation of communications. Observations regarding overall patterns of media usage support the decreased importance of the printed word in current culture. An additional development in the landscape refers to the general diffusion of digital technologies. Some of their pervasive effects were discussed in Chapter 1, regarding the development of a green technoeconomic paradigm. The cultural and technological developments are not independent: changes in communication systems are one expression of technological developments in the diffusion of IT and the cultural changes in communication patterns effect further technological change. An example

of that interaction is the impact of IT in new forms of scientific practice for example in the field of environmental monitoring (Foray and Grûbler, 1996; Berkhout and Hertin, 2004). Although the landscape is mostly examined in terms of its effect on regimes it can be argued that changes in the landscape result as an accumulation of the effects in different regimes. In the case studies of historical transition the role of the landscape was emphasised mainly regarding its societal effects. In that case however, the role of the landscape is manifested mostly through cultural and technological developments.

An additional point is that the natural environment is positioned in the context of the landscape. Hence, it can be argued that considerations of sustainability are othered as they are placed outside the system/regime, which is the usual focus of analysis. One way to bypass this issue is to localise the landscape considering how landscape developments actually emerge as an effect of changes in different regimes. The landscape can be said to be constituted of local practices like other macro aspects (Latour, 2005).

The print-on-paper system is representing the regime level and it is defined by the function of textual communication. However, the discussion of actors in the electronic book area also indicates the presence of the IT/electronics regime. Therefore instead of considering potential transitions towards the electronic book as the interaction between the incumbent print-on-paper regimes and the electronic book niche it can be conceptualised as a process of interaction between the incumbent regimes of print-on-paper and electronics. The interaction is illustrated in the networks depicting electronic book developments as the level of homophily between different principal areas of activity. In that sense, technological niches being development in the electronics regime have to be modified into market niches in order to affect the print-on-paper publishing regime

In the literature there is acknowledgement of transitions patterns that involve more than one regime (van den Ende and Kemp, 1999; Raven and Verbong, 2007). In van den Ende and Kemp (1999) regimes are seen as growing out of a combination of pre-existing regimes. In Raven and Verbong (2007) patterns of interaction between regimes are mentioned. In the interaction between the print-on-paper and the electronics regime a form of spillover is observed in that technological developments occurring in the electronics regime such as the development of electronic ink and digital workflow models are incorporated within the print-on-paper regime and result in new practices in a segment of publishing. In addition the fact that some of the electronic reader devices are modelled as personal digital assistants (Burk, 2001) also indicates a form of spillover from the electronics/computing regime towards the publishing sector.

The electronic book field can be seen as comprising niches that relate to different set of different markets and technologies. The technological niches involved

such as those involved around electronic ink and software technologies can be perceived as protected spaces from the perspective of the print-on-paper regime. However, these technological niches are initially developed within the context of the electronics regime therefore they do not require protection from developments in the print-on-paper regime. In addition market niches that have been identified through the participant in the network analysed reflect existing divisions within the publishing industry. For example, libraries and universities are seen as representing the institutional market for electronic books whereas the development of electronic book reader devices is either targeted towards the professional market or towards the market for trade publishing. Therefore, the technological development can be seen to adapt to existing market patterns.

In addition the development of the publishing services actors is indicative of a new form of hybrid actor as the enabler of innovative activity and a new form of mediator. This finding is consistent with the importance of hybrid actors identified in Elzen et al., 2008).

Developments in the electronic book networks can be seen as examples of mechanisms in sociotechnical transitions. A pattern of niche cumulation can be observed regarding market developments. Niche cumulation is observed as some technologies which are first adopted by the academic/institutional market or in the business to business market are later on adopted in trade publishing. A pattern similar to niche cumulation is that some technological practices that are first used in-house or only in business to business transaction are also adopted in the consumer market. An example is the diffusion of the .epub format: currently it is mostly used between publishers in the digital workflow however some of the reader software (e.g. Adobe Digital Editions) on consumer devices is adapted to directly read .epub documents without conversion. Also patterns of interlocking are observed regarding the interaction between hardware of software technologies. These are visualised in the sociotechnical network of the electronic book as links between technological artefacts.

Finally changes in reading practices and the notion of the book brought about by digitisation (Lynch, 2001) are indicative of the fit and stretch patterns in transitions regarding the co-evolution between societal functions and technologies. The electronic book in the bibliocentric perspective is meant to imitate the printed book however technologies such as the hypertext equip it with distinct functionalities.

7.2.2. The electronic book case and perspectives on innovation

In this section the findings are interpreted on the basis of more general concepts of sociotechnical change. The analysis is based on dichotomies regarding the radical or incremental role of innovation and the degree of standardisation versus diversity/heterogeneity. In addition the sources of innovation are considered. The use of general terms can be helpful in that when the terms used by the analysts are simplified it becomes easier to examine how the controversies are deployed by the actors themselves (Latour, 1999).

The conception of innovation as radical or incremental has been included in the Freeman and Perez typology (1988). In addition, the potential of a technology to create a new market is also characteristic of its degree of radicalness (Green, 1992). In the discussion of the electronic book there is a distinction between developments involving hardware (display technologies and devices) and those referring to software developments. Under the definition of the electronic book as those applications of IT that can replace printing as a form of textual display radical innovation in the area entails the technical developments that involve new modes of display. However, the different areas of activity represented in the emergent electronic book innovation networks illustrate that besides technical innovation in hardware and display more intermediate forms of innovation are also required for electronic books to be feasible. Such innovation includes the development of digitisation services for publishers' backlist and the development of Digital Rights Management systems. Furthermore, in chapter 3 the interaction between the print-on-paper system was discussed in a more general context where it was identified how digitisation has affected the workflows within publishing firms and the distribution of books. Although these developments are not evident to the consumer they provide the necessary foundations for further developments. It could be said that they open up the regime by familiarising the regime actors with digital technologies and thus making electronic books as a substitute for print more likely. However, digital technologies may be applied in the sense of reinforcing the established practices: one example is the application of digitisation for print-on-demand systems. Elements on the importance of such incremental interaction are demonstrated in the subgroups of the sociotechnical network which are mostly focused on software.

In the sociotechnical transitions literature it is supported that niche technologies should be formed into a dominant design prior to interacting with the regime actors (Geels, 2002a). The standardisation of hardware technologies in observed in one of the network subgroups emerging from the analysis of the sociotechnical network (Dataset 3, 3rd faction). It is this network subgroup that indicates greater potential for electronic books as a consumer product. The notion of dominant design implies the standardisation of technologies. In the network literature regarding diffusion (Rogers, 1995) and in the actor-network approach (Callon, 1992)

it is mentioned that a combination of homophily and heterophily is required for the effective dissemination in innovation. In the electronic book case there is co-existence of diversity and standardisation in different stages of the value chain. Standardisation was mentioned with regard to format and DRM standards and it is identified as one of the reasons inhibiting market growth (Coyle, 2001). This phenomenon has been more generally observed in Information Technology (Williams and Edge, 1996). It was remarked that the IDPF as an industry association is mostly focused on the development and diffusion of standards. However, the diversity of different standards sometimes proprietary to specific products is partly explained by the fact that manufacturers see formats as a way to differentiate their products (ibid.). The emergence of dominant design can be observed regarding the development of electronic reader devices. In one of the factions of the sociotechnical network it was observed that the majority of devices incorporate the same display technology (E-Ink Imaging film) and are marketed as consumer products. A degree of standardisation has thus emerged regarding how a reader device is meant to appear and this has resulted in a conceptualisation of the electronic book. It is remarked that the more technical elements are more standardised rather than the elements that mostly refer to the electronic book as digital text.

Regarding the sources of innovation the technological developments as such have emerged primarily in the electronics sector; they are hence external to the print-on-paper regime. However, additional innovation in business models is required in order for electronic books to be feasible. In that sense the already incumbent actors are acting cautiously in regard to the opportunities deriving from these technical developments. There is an interest and investment among publishers regarding the development of a digital infrastructure however attempts at market growth are limited (personal communication). So far only the institutional market has reached feasibility benefiting from developments in education.

It should be emphasised that the idea of electronic books as an alternative form of display is dependent on developments regarding the management of digital content which are currently taking place independently of display developments.

7.3. Issues of framing and multiplicity: implications for transition studies

It has emerged from the analysis that the identification of boundaries provides a common thread between the chapters. To begin with, the research questions resulting from the research objective imply a setting of boundaries as they indicate what is relevant and has to be addressed prominently and what is to remain marginalised. The definition of electronic books provided initially sets these limitations. In order to address the research questions different forms of boundary setting were applied in the subsequent chapters. In addition the transitions literature relies on forms of boundary definition as sociotechnical systems area selected as the units of analysis. In retrospect the following forms of boundary definition have been remarked in the preceding chapters.

In the literature review chapter it was discussed how the boundaries of sociotechnical systems are identified on the basis of societal functions. This approach differs from other innovation systems approaches that identify system boundaries on the basis of location, technology or sector. The question of identifying regime boundaries has been addressed both analytically and empirically. It is dependent on varied interpretations of societal functions. However, it results from this discussion and observations of historical transitions that the regime boundaries are identified by the analyst (Genus and Coles, 2008). In the reinterpretation of societal functions as sociotechnical practices it is argued that regime boundaries are identified through ongoing negotiations as the notion of practice is more fluid.

In the introduction and the research objectives the electronic book was defined as those applications of IT that could contribute to the sustainability of the print-on-paper system by providing an alternative form of textual display to paper. This definition entails a form of boundary setting as it excludes alternative IT application in the print-on-paper system that may have negative or beneficial effects on sustainability goals. This definition is consistent with an understanding of sustainability strategies where the substitution effects of IT are emphasised. In that sense the boundary setting of the research topic emerges from boundary setting in the notion of environmental sustainability and its strategies. It can be claimed in retrospect that the goal of dematerialisation was privileged over other interpretations of sustainability.

The boundaries of the printed paper text are defined by the function of textual communication. As shown in chapter 3 it is defined by its role in the dissemination of textual communication and by the application of printing technology. A co-evolution has been observed between societal and technological developments in the practice of reading: for instance the development of mass production methods in printing has coincided with demographic and economic developments that led to a

growth in the reading public. In the discussion of the print-on-paper system the focus was limited on books as the main artefact of the sociotechnical system. Therefore, distinctions were made between books and other more ephemeral forms of printed text. It emerges that the common understanding of books was only made possible through technological developments that have helped create its defining characteristics. In that case, boundary setting was a form of limitation to the research questions. The boundaries of sociotechnical regimes and the identification of transitions also involve a framing in time. However, the timing of transitions is retrospectively identified by the analyst (Genus and Coles, 2008).Considering the long-term perspective on transitions more attention has to be paid to the identification of time frames.

With regard to the research methodology boundaries were identified regarding the role of emergent innovation networks. Boundary setting refers to the selection of data sources. In the SNA literature there is a discussion on the on the different methods of boundary identification. However, networks are in principle unbounded (Jones et al., 1998). The process of setting network boundaries is based on the assumption that specific networks are an abstraction of the total network of society. Furthermore, there is a temporal dimension in identifying network boundaries that has received less attention partially because of the limitations in available techniques. Unobtrusive methods of data collection were used on the basis of the relational approach and codified according to SNA methodology. An additional form of boundary setting refers to the classification of actors according to their principal area of activity. The boundaries between these areas of activity were meant to ignore overlaps and to facilitate analysis. Some aspects of the actors' activities are thus silenced in the course of analysis.

The results of the analysis in the sociotechnical network indicate the existence of sociotechnical trajectories. These trajectories are correlated with network substructures. Because these substructures (factions) are not isolated distinct boundaries cannot be established in this case although some factions tend to be more isolated. In that sense, although research relates to the identification of boundaries the findings contradict clear distinctions.

At this point the concept of framing and overflowing (Callon, 1998b) that were introduced in chapter 2 are applied to reflect on the research process considering framing as an activity undertaken by the analyst and overflowing an effect emerging from the data themselves.

The boundaries of sociotechnical regimes are defined by the analyst. The concept of societal functions provides a form of framing which is goal-oriented in that the component of systems regimes are included according to their contribution in the systems goals. As mentioned in chapter 2 sociotechnical systems explicitly include the user side in the analysis (Geels, 2004a). Societal functions are usually

generically defined. The conceptualisation of societal function as sociotechnical practices provides additional regarding how actors interact with technologies. It can be argued that the concept functions relates to framing whereas practices are more related to overflowing. This is because functions provide a distinct definition while practices indicate the somehow messy ways users interact with technologies. Overflowing occurs because the actors can be creative in their use of technology and the evolution of the book system has demonstrated that. The notion of alternative system framings dependent on the actors' perspective is also identified in Smith and Stirling (2008).

Regarding the definition of the book as a particular form of printed matter provided in chapter 3, framing was attempted in the differentiation of books form other types of more ephemeral, less standardised text. However, overflowing is also observed in the sense that digital technologies redefine what is meant by books (Lynch, 2001). The definition provided on the electronic book emphasises its aspect as a display technology. However the data on the related technological developments cause overflowing because the role of additional software technologies and interaction with incumbent actors is also identified leading to an alternative framing of the electronic book as digital text.

The framing of sustainability is initially achieved by focusing on the aspect of dematerialisation. Once the effect of digital technologies on printing are assessed in chapter 1, it becomes evident that the relation between digitisation and the environment in that case is more complex and that additional aspects of sustainability should be considered. The fact that there exist different ways to prioritise sustainability is identified as a political concern in transition management (Smith and Stirling, 2008).

It was identified that there are alternative ways to conceptualise the electronic book other than a mode of textual display. The concept of variable geometry (Law and Callon, 1992) introduced in chapter 4 with regard to multiplicity can be applied. An artefact demonstrates "variable geometry" as it represents different things to different groups but it is also simplified as each actor views it form a distinct standpoint. Simultaneously, the actors are simplified and reduced to a certain role while some of their interests and motivations remain hidden and irrelevant to the artefact. Regarding actors in the electronic and display area that electronic book is seen as a market for specific technologies. From the perspective of the publishing sector they are instead viewed as a model for the delivery of content. As discussed in chapter 6 additional points of interaction are required between these identities of electronic books. Finally, from the perspective of the artefact each area of activity is seen a providing distinct knowledge inputs contributing to innovation.

The implication of multiplicity with regard to prospective transitions is that actors do not necessarily need to share the same objectives as long as a negotiation space can be crafted.

7.4. Summary of findings: limitations and future directions

7.4.1. Research limitations

The research approach utilises Social Network Analysis in order to visualise the networks around emerging technologies and address questions regarding the potential direction of future transitions. SNA enables the analysis of a large set of qualitative relationships and the identification of patterns that are not easily perceived when the same data are presented in narrative form. In practical terms, the codification of the data into network matrices and graphs is an effective form for the organisation of diverse forms of information. In addition, the non-obtrusive data collection methods make it feasible to collect more data than would be possible by individual interviews. This benefit is important when a more comprehensive review is required.

It was mentioned that networks are seen as a form of representation. There is a dual side to networks as a method and a phenomenon (Jones et al., 1998). In the aspect of networks as phenomenon they tend to be viewed in the form of collaboration, as an intermediate form of co-ordination between the market and hierarchy (Williamson, 1975). In addition the widespread use of the term has led to the danger of using networks as a fad (Conway et al., 2001) or as a totem (Wallemacq, 1998). Once networks are viewed as a form of representation it can be acknowledged that they have similar limitations to other representational forms. Each representation suppresses aspects of the phenomenon under study. The methodology applied in the thesis studies the actors only in relation to their involvement in the electronic book area. However, actors are not embedded in a single network but their knowledge base is manifested in different activities. Therefore it is difficult to evaluate the relative importance of their involvement in the electronic book area without examining their involvement in different forms of networks. For example, electronic ink technologies have other applications besides electronic book devices. The relative importance of these applications for electronic ink firm may affect developments in the electronic book market. Yet, through following the electronic book networks there is some evidence regarding activities that extend the definition provided. The concept of regime membership (Berkhout et al., 2004) was introduced to demonstrate the actors' degree of embeddedness within regimes. Furthermore the actors' level of inclusion (Bijker, 1987) cannot be addressed through SNA unless information on alternative networks is also available. Considering that the process of network sampling regards the abstraction of the total network of society by deciding the rules of inclusion it becomes clearer that actors are included in overlapping networks.

With regard to the data collection methods non-obtrusive methods do not allow for a more detailed investigation of specific ventures but there is the possibility

to supplement network research with additional case study analysis once specific network areas have been identified.

Finally, a further limitation of networks analysis is that there is still ambiguity on how to address the dynamic aspects of network change. This issue has been identified regarding the research paradigm of relationism (Emirbayer, 2007). With regard to the third dataset, the option taken was to include all identified actors and relations in the same network as even now defunct relationships can provide insights on the development of subsequent business activities.

7.4.2. Summary of findings and future research directions

Regarding the implications of innovation in the electronic book area on the sustainability problems in the print-on-paper regime, it is difficult to evaluate these effects because of the limited diffusion of electronic book use. Considering the effect of digitisation so far, it should be noted that digitisation does not necessarily result in dematerialisation.

The wider context of digitisation in publishing chains indicates that the demarcation between radical and incremental change is ambiguous. It has emerged through network analysis that one of the obstacles inhibiting market growth is limited content available in electronic format. The applications of digitisation that do not strictly refer to electronic books as alternative mode of display can lead to the infrastructure required for increased availability of content.

The emergent innovation networks incorporating electronic book actors provide evidence that different perceptions of electronic books co-exist. The defunct linkages and actors in the networks indicate turbulence associated with emergent technologies. The main perspectives on the electronic book relate to the display technology or content. In addition, the electronic book as technology particularly in the form of device engages more with consumer electronics rather than supply chains. Regarding users, a differentiation is observed between the consumer and the institutional market. Although, the institutional market is further developed technological developments with regard to display mostly focus on the consumer market.

Finally, a divergence is observed between technical developments where a degree of standardisation has been achieved regarding display technologies and developments in content delivery where a variety of formats and business models are still used. The differentiation between the e-book as an artefact and the e-book as a content delivery medium emphasise the fact that diffusion of the technology is inhibited because of lack of digital content.

The contribution of the thesis lies in defining a conceptualisation of sociotechnical transitions as a process of network reconfiguration. According to the literature on the Multi-Level perspective transitions in sociotechnical systems are achieved through the interaction between the system/regime and the niche and landscape levels where the completion of transitions is defined with regard to the fulfilment of societal functions. Instead the thesis proposes that sociotechnical systems involve the enactment of practices rather than functions. The concept of practices contributes to the examination of transitions because it allows for a clearer understanding of the co-evolution between technologies and the user aspects of a regime, thus indicating how regime boundaries are fluid and how technologies and users are interdefined. The MLP on transitions combines the quasi-evolutionary and the structuralist foundational paradigms in social theory. Instead, the thesis utilises

the relational paradigm mainly as it has been manifested in actor-network theory. In that context the methodological contribution is in the use of SNA without conflating its application with structural interpretations of agency. A limited view of networks as collaborative forms of co-ordination between markets and hierarchies (Williamson, 1975) is replaced by a relational approach based on the distributed character of innovation and the notion of agents as relational effects. In addition the third dataset demonstrated how the principle of symmetry can be followed by suggesting how sociotechnical networks can be analysed using the same techniques available for networks of individual or organisations, instead of being limited to a 2-mode representation. The application of SNA suggests a different way of identifying patterns on potential transitions. In the MLP transition pathways are categorised according to the interaction between formerly identified levels. When a network approach is taken, niches and regimes become more fluid categories. Patterns to transitions can be identified by network substructures following on the principles that increased cohesion is more likely to result in a feasible new configuration.

The implications of further research in the area of prospective transitions is that the goals served by the existing sociotechnical configuration should be examines from the perspective of the actors rather than assuming an immutable societal function. In addition, the application of SNA suggests that is it possible to formally analyse a wide variety of interactions without resorting to case studies of a normative policy orientation.

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Appendix

Dataset 3: Account of linkages

		Nature of tie	relational flow	According to linked actors	Ownership relation
.epub	LibreDigital	Acceptance of technology as standard	Technology	Organisation-technology	Different
.epub	Adobe Digital Editions	Compatibility between reader software and e-book format	technological compatibility	technology-technology	Different
.epub	IDPF	Standard developed by organisation	Technology	Organisation-technology	Same
.lit	MS Reader	Format developed by organisation	Technology	Organisation-technology	Same
3Book	Xerox PARC	Format developed by organisation	Technology	Organisation-technology	Same
Acrobat FrameMaker	Adobe	Software developed by organisation	Technology	Organisation-technology	Same
Acrobat PageMaker	Adobe	Software developed by organisation	Technology	Organisation-technology	Same
ADEPT	OverDrive	OverDrive as service provider wrt technology	Technology expertise flow	organisation-technology	Different
ADEPT	Adobe Digital Editions	Technological compatibility	Technological compatibility	technology-technology	Same
ADEPT	Adobe	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	IDPF	membership	Technology-standardisation	organisation-organisation	Different
Adobe	Glassbook	Acquisition of Glassbook	Investment	Organisation-organisation	Merger
Adobe	WebBuy	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	Cool type	Display software developed by organisation	Technology	Organisation-technology	Same
Adobe	Adobe PDF Merchant	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	Adobe Digital Editions	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	Adobe Content Server4	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	Adobe Content Server3	Software developed by organisation	Technology	Organisation-technology	Same
Adobe	Adobe Acrobat reader	Software developed by organisation	Technology	Organisation-technology	Same

Adobe Acrobat reader	Ebrary	Format endorsed by organisation	technological compatibility	organisation-technology	Different
Adobe Acrobat reader	Glassbook	Adoption, acceptance as standard	Technological adoption	organisation-technology	Merger
Adobe Acrobat reader	Cool type	Display technology incorporated into software	Technological input	technology-technology	Same
Adobe Acrobat reader	Adobe Digital Editions	Software developed by organisation	Technology	Organisation-technology	Same
Adobe Content Server4	Adobe Digital Editions	Technological compatibility	Technological compatibility	technology-technology	Same
Adobe Digital Editions	Sony Reader	The format is readable in the device	Technological compatibility	Technology-technology	Different
Adobe Digital Editions	Sony Librie	The format is readable in the device	Technological compatibility	Technology-technology	Different
Adobe Digital Editions	OverDrive	The format is used by OverDrive to store content	Technological adoption	Organisation-technology	Different
Adobe Digital Editions	Adobe PDF Merchant	Technological compatibility	Technological compatibility	technology-technology	Same
Amazon	E Ink Corporation	E Ink corporation provides the display technology for Amazon reader	Supplier relationship-technology flow	organisation-organisation	Different
Amazon	Bartleby.com	Takeover by Amazon	Ownership/equity relationship	organisation-organisation	Merger
Amazon	Kindle	Reader developed by organisation	Technology	organisation-technology	Same
Amazon	AmazonBookSurge	Subsidiary organisation	Ownership/equity relationship	organisation-organisation	Same
Barnes&Noble	Rocket eBook Reader	Retail agreement		organisation-technology	Different
Barnes&Noble	NuvoMedia	Retail agreement		organisation-organisation	Different
Barnes&Noble	FatBrain	Acquisition of FatBrain	Finance flow	organisation-organisation	Different
Barnes&Noble	Microsoft	Agreement for the sale of ebooks	Distribution	organisation-organisation	Different
Barnes&Noble	IDPF	membership	Technology-standardisation	organisation-organisation	Different
bNem	t.book	Display technology incorporated into reader device. Developed by different companies.	Technology/supply relationship	technology-technology	Different
Bookeen	Cybook3	Reader developed by organisation	Technology	organisation-technology	same
Bookeen	Cytale	Successor organisation	Managerial flow	organisation-organisation	Different
Broad Band Ebook	Sony Reader	Format readable on device	Technological compatibility	technology-technology	Different

Broad Band Ebook	Sony Librie	Format readable on device	Technological compatibility	technology-technology	Different
Casio	Windows CE	Operating system	Technological compatibility	technology-technology	Different
Clear type	Microsoft	Display software developed by organisation	technology	organisation-technology	Same
Clear type	MS Reader	Display technlogy incorporated into software	Technological input	technology-technology	Same
ContentGuard	TimeWarner	TimeWarner main investor in ContentGuard	Ownership/equity relationship	organisation-organisation	Merger
ContentGuard	Thomson RCA	Thomson RCA main investor in ContentGuard	Ownership/equity relationship	organisation-organisation	Merger
ContentGuard	eXtensible Rights Management Language	DRM language developed by organisation	Technology	Organisation-technology	Same
ContentGuard	XEROX	XEROX among the co-founders	Ownership/equity relationship	organisation-organisation	Merger
ContentGuard	IDPF	membership	Technology-standardisation	organisation-organisation	Different
ContentGuard	Microsoft	Microsoft among the co-founders	Ownership/equity relationship	organisation-organisation	Merger
Coral Consortium	Sony	membership	Technology-DRM standards	organisation-organisation	Different
Coral Consortium	Philips	membership	Technology-DRM standards	organisation-organisation	Different
Coral Consortium	Intertrust	membership	Technology-DRM standards	organisation-organisation	Different
CoreSource	IngramDigital	Technology developed by organisation	Technology	organisation-technology	Same
Cybook	Windows CE	Operating system used by device	technological compatibility	technology-technology	Different
Cybook	Cytale	Reader device developed by organisation	Technology	organisation-technology	Same
Cybook3	Linux	Operating system used by device	technological compatibility	technology-technology	Different
Cytale	IDPF	Membership	technology-standardisation	organisation-organisation	Different
Dynabook	Xerox PARC	Technology developed by organisation	Technology	Organisation-technology	Same
E Ink Corporation	Sony Reader	Supply relationship	Technological input	organisation-technlogy	Different
E Ink Corporation	Sony Librie	Provision of technical input on display	Technological input	organisation-technlogy	Different
E Ink Corporation	Sony	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different
E Ink Corporation	Polymer Vision	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different
E Ink Corporation	PlasticLogic	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different

E Ink Corporation	Philips irex	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different
E Ink Corporation	Philips	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different
E Ink Corporation	PVI	Supplier relationship regarding display	supplier relationship	organisation-organisation	Different
E Ink Corporation	MIT	E Ink Corporation developed as MIT spin-off	Technology	organisation-organisation	Different
E Ink Corporation	E Ink Imaging Film	Technology developed by organisation	Technology	organisation-technlogy	Same
E Ink Imaging Film	iRex Digital Reader 1000	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
E Ink Imaging Film	iLiad	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
E Ink Imaging Film	Kindle	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
E Ink Imaging Film	Sony Librie	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
E Ink Imaging Film	Readius	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
E Ink Imaging Film	Sony Reader	Display technology incorporated into reader device.	Technological input	technlogy-technology	Different
Ebook Technologies	IDPF	membership	technology-standardisation	organisation-organisation	
Ebook Technologies	Gemstar International	The former set-up by Gemstar management	Expertise-labour	organisation-organisation	Different
Electronic Book exchange standard	IDPF	Standard developed by organisation	technlogy	organisation-technology	Same
ETI format	ETI-1	Format included into the device	technological compatibility	technology-technology	Same
ETI format	ETI-2	Format included into the device	technological compatibility	technology-technology	Same
ETI-1	Ebook Technologies	Reader developed by organisation	Technology	organisation-technology	Same
ETI-2	Ebook Technologies	Reader developed by organisation	Technology	organisation-technology	Same

ETI-format	Ebook Technologies	Reader format developed by organisation	Technology	organisation-technology	Same
Everybook	Everybook Reader	Reader developed by organisation	Technology	organisation-technology	Same
Everybook	IDPF	Membership	Technology-standardisation	organisation-organisation	Different
Everybook Reader	Linux	Operating system used by device	technological compatibility	technology-technology	Different
Flepia	Fujitsu	Reader developed by organisation	Technology	organisation-technology	Same
Franklin	Franklin Reader	Reader software developed by organisation	technology	organisation-technology	Same
Franklin	Franklin EBookman	Reader developed by organisation	Technology	organisation-technology	Same
Franklin	IDPF	membership	technology-standardisation	organisation-organisation	Different
Franklin EBookman	Franklin Reader	Reader device and dedicated reader software	technological compatibility	technology-technology	Same
Fujitsu	IDPF	membership	technology-standardisation	organisation-organisation	Different
Gemstar International	Thomson RCA	Thomson RCA manufactured the devices for Gemstar	Licensing relationship-manufacturing	organisation-organisation	Different
Gemstar International	SoftBook	Reader marketed by the organisation as part of acquisition	Merger-takeover	organisation-technology	Merger
Gemstar International	SofBook Press	Acquisition	Acquisition	organisation-organisation	Merger
Gemstar International	Rocket eBook Reader	Reader marketed by the organisation as part of acquisition	Merger-takeover	organisation-technology	Merger
Gemstar International	NuvoMedia	Acquisition	Acquisition	organisation-organisation	Merger
Glassbook	IDPF	membership	Technology-standardisation	organisation-organisation	Different
Glassbook	OEB Publication structure	Compatibility/acceptance as standard	Technological compatibility	organisation-technology	Different
Gyricon	XEROX	Subsidiary organisation	Ownership/equity relationship	organisation-organisation	Same
Handspring Visor	Palm Pilot	Reader acquired by organisation/adopted operating system	Ownership/equity relationship	Organisation-technology	Same
Hanlin eReader V2	Linux	Operating system used by device	Technological compatibility	technlogy-technology	Different
Hanlin eReader V2	Jinke	Reader developed by organisation	Technology	Organisation-technology	Same

Hanlin eReader V8	Linux	Operating system used by device	Technological compatibility	technlogy-technology	Different
Hanlin eReader V8	Jinke	Reader developed by organisation	Technology	Organisation-technology	Same
HarperCollins	IDPF	membership	technology-standardisation	organisation-organisation	Different
HarperCollins	LibreDigital	Customer-supplier relationship	content access	organisation-organisation	Different
Hewlett Packard	Windows CE	Operating system used by device	technological compatibility	technlogy-technology	Different
IDPF	netLibrary	membership	technology-standardisation	organisation-organisation	Different
IDPF	XEROX	membership	technology-standardisation	organisation-organisation	Different
IDPF	Wiley	membership	technology-standardisation	organisation-organisation	Different
IDPF	University of Virginia	membership	technology-standardisation	organisation-organisation	Different
IDPF	TimeWarner	membership	technology-standardisation	organisation-organisation	Different
IDPF	Thomson RCA	membership	technology-standardisation	organisation-organisation	Different
IDPF	Sony	membership	technology-standardisation	organisation-organisation	Different
IDPF	SofBook Press	membership	technology-standardisation	organisation-organisation	Different
IDPF	Simon&Schuster	membership	technology-standardisation	organisation-organisation	Different
IDPF	Princeton U.Press	membership	technology-standardisation	organisation-organisation	Different
IDPF	Philips irex	membership	technology-standardisation	organisation-organisation	Different
IDPF	Palm Pilot	membership	technology-standardisation	organisation-organisation	Different
IDPF	OverDrive	membership	technology-standardisation	organisation-organisation	Different
IDPF	OUP	membership	technology-standardisation	organisation-organisation	Different
IDPF	OEB Publication structure	technology developed by organisation	technology-standardisation	organisation-technology	Different
IDPF	NuvoMedia	membership	technology-standardisation	organisation-organisation	Different
IDPF	ModernAgeBooks	membership	technology-standardisation	organisation-organisation	Different
IDPF	Microsoft	membership	technology-standardisation	organisation-organisation	Different
IDPF	LighningSource	membership	technology-standardisation	organisation-organisation	Different
IDPF	IPM-NET	membership	technology-standardisation	organisation-organisation	Different
IngramBookCompany	VitalSource	Subsidiary organisation	Ownership/equity relationship	organisation-organisation	Merger

IngramBookCompany	myiLibrary	Subsidiary organisation	Ownership/equity relationship	Organisation-organisation	Same
IngramBookCompany	LighningSource	Subsidiary organisation	Ownership/equity relationship	organisation-organisation	Same
IngramBookCompany	IngramDigital	Subsidiary company	Ownership/equity relationship	organisation-organisation	Same
IngramDigital	MicrosoftLiveSearch	IngramDIgital contracted to digitise backlists	content access	organisation-organisation	Different
IngramDigital	Microsoft	Customer supplier relationship	Content access	Organisation-organisation	Different
IngramDigital	OUP	Customer supplier relationship	content access	organisation-organisation	Different
IngramDigital	Princeton U.Press	Customer supplier relationship	content access	organisation-organisation	Different
Intertrust	MetaTrust Utility	MetaTrust Utility platform developed by intertrust	Technological input	organisation-organisation	Different
IPM-NET	OverDrive	OverDrive provided input for device development	Technological input	organisation-organisation	Different
IPM-NET	Myfriend	Reader developed by organisation	Technology	organisation-technology	Different
IPR Systems Pty ltd	ODRL(Open Digital Rights language)	Technology developed by organisation	Technology	organisation-technology	Same
LastBook	MIT	Technology developed by organisation	Technology	Organisation-technology	Same
LibreDigital	Wiley	Customer supplier relationship	content access	organisation-organisation	Different
LibreDigital	Simon&Schuster	Customer supplier relationship	content access	organisation-organisation	Different
LibreDigital	OverDrive	Partnership		Organisation-organisation	Different
Librius Inc	Windows CE	Librius Inc ebookstore compatible with windows CE devices	Acceptance of technology	Organisation-technology	Different
Librius Inc	Palm Reader	Librius Inc ebookstore compatible with the format	Acceptance of technology	Organisation-technology	Different
Librius Inc	Millennium eBook	Reader device developed by organisation	Technology	organisation-technology	Same
Linux	Sony Reader	Software incorporated into hardware	Technological compatibility	technology-technology	Different
MetaText Inc	netLibrary	Acquisition	Investment	Organisation-organisation	Same
MetaTrust Utility	Reciprocal.com	Reciprocal is a partner to MetaTrust Utility	Technology	Organisation-organisation	Different

Microsoft	MicrosoftLiveSearch	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Microsoft	Microsoft Right Management Solutions	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Microsoft	Microsoft Digital Asset Server	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Microsoft	Windows CE	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Microsoft Digital Asset Server	eXtensible Rights Management Language		Technological compatibility	technology-technology	Merger
Microsoft Right Management Solutions	Reciprocal.com	Reciprocal uses the latter for encryption	Technology adoption	organisation-organisation	Different
Millennium eBook	Palm Reader	Material for millennium eBook in palm reader format	Technological compatibility	technology-technology	Different
Mobi Pocket	Mobi Pocket Inc	Format developed by the organisation	Technology	Technology-organisation	Same
Mobi Pocket	iLiad	Mobi pocket readable on iLiad	Content access	technology-technology	Different
Mobi Pocket Inc	IDPF	Membership	Technology-standardisation	organisation-organisation	Different
Mobi Pocket Inc	Amazon	Subsidiary company	Ownership-equity relationship	organisation-organisation	Same
MS Reader	Microsoft	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Nemoptics	Sylen	Software developed by organisation	Technology	organisation-technology	Different
Nemoptics	Seiko Instruments	Customer-supplier relationship. Seiko undertakes manufacturing for Nemoptics	Technology	Organisation-Organisation	Different
Nemoptics	bNem	Technology developed and supplied by organisation	Technology	Organisation-technology	Same
Nemoptics	Readmooore	Customer-supplier relationship, Nemoptics provides the display technology.	Technology	Organisation-Organisation	Different
NuvoMedia	Rocket eBook Reader	Reader developed by organisation	Technology	Organisation-technology	Same
OverDrive	Sony	OverDrive had some input into Sony Reader development	Content access	Organisation-organisation	Different
Palm Pilot	Palm retail encryption server software	Technology developed/used by organisation	Technology	Organisation-technology	Same

Palm Pilot	Palm e-book authoring tool	Technology developed/used by organisation	Technology	Organisation-technology	Same
Palm Pilot	Palm Reader	Reader developed by organisation	Technology	Organisation-technology	Same
Peanut Press	netLibrary	sold by netLibrary	Investment	Organisation-organisation	Merger
Philips	Philips irex	Philips provides investment	Investment	Organisation-organisation	Partly
Philips	Sony	Philips designed the screen for the Librie	Technology	Organisation-organisation	Different
Philips	Polymer Vision	Philips provides investment	Investment	Organisation-organisation	Partly
Philips irex	iRex Digital Reader 1000	Reader developed by organisation	Technology	Technology-organisation	Same
Philips irex	iLiad	Reader developed by organisation	Technology	Technology-organisation	Same
PlasticLogic	U_Cambridge	Company developed as university spin-off	Technology	Organisation-Organisation	Different
Polymer Vision	Readius	Reader developed by organisation	Technology	Technology-organisation	Same
Publishing Link	Sony	The former provides content for Sony devices	Content access	organisation-organisation	Different
PVI	Philips	PVI acquired Philips e-ink unit	Technology	Organisation-organisation	Different
Readmooore	t.book	Reader developed by organisation	Technology	Technology-organisation	Same
Rocket eBook Reader	Thomson RCA	The reader marketed by the organisation	Distribution-commercial	Organisation-technology	Merger
SofBook Press	SoftBook	Reader developed by organisation	Technology	Organisation-technology	Same
SoftBook	Thomson RCA	Licensing for manufacture	Licensing relationship-manufacturing	Organisation-technology	Licensing
Sony	Waterstone's	Retail-distribution exclusive	Distribution	organisation-organisation	Different
Sony	Sony Reader	Display device mostly developed by organisation	Technology	Organisation-technology	Same
Sony	Sony Librie	Display device mostly developed by organisation	Technology	Organisation-technology	Same
Sony	Sony Clie	Display device mostly developed by organisation	Technology	Organisation-technology	Same
Sony Reader	Waterstone's	Retail-distribution exclusive	Distribution	organisation-technology	Different
University of Virginia	eText explorer	Technology developed/used by organisation	Technology	Organisation-technology	Same
XEROX	Xerox PARC	Research centre	Technology funding	organisation-organisation	same

Interview data

Interviews were conducted with the following individuals.

Alan Patrick, director of Broadstuff consultancy: the interviewee had provided consultancy services to PlasticLogic Company regarding the launch of its e-reader.

Ashley Lodge, Corporate Sustainability Manager at Harper Collins and chair of the Publishers Green Network provided information on the perception of environmental issues within the publishing industry.

David Roth-Ey, director of Digital Business Development at Harper Collins discussed the involvement of publishers in digital ventures and reasons for lack of further engagement.

Suzanne Wilson-Higgins, Commercial Director at Lightning Source regarding the role of publishing services actors and specifically print-on-demand services.

Michael Smith, IDPF executive Director provided information on the organisation and general potential of the electronic book market.

Helen Fraser, Managing Director of Penguin Press provided information by email regarding digitisation activities.

Elke Christiane MacKscheidt of Readmooore provided information by email regarding the development of the t.book device.

The interviews were not conducted as a means of the collection of relational (network) data. Rather their role was exploratory in identifying potential areas of activity relating to electronic books and digital publishing. In addition the interview data contributed to the interpretation of the network maps regarding the role of interaction between different areas of activity.