Dynamic perspectives on social characteristics and sustainability in online community networks

Peter Otto[a]* and Martin Simon[a]

Peter Otto is Associate Professor for Management Information Systems at Union Graduate College, School of Management. He has also a visiting teaching position at the Graduate School of Business Administration (GSBA), Zurich, Switzerland. Dr Otto has extensive consultancy experience and holds an MBA and a PhD in Information Science, with primary specialization in Decision Support Systems, from the University at Albany, New York. His present research focuses on group decision making, IT systems implementation and online communities.

Martin Simon is a teacher of Physics, Mathematics, and Computer Science at KSZ Business School, Zurich. Dr Simon holds a PhD in Cognitive Science from the Swiss Federal Institute of Technology (ETH) Zurich. His current professional focus is on modeling business processes, developing

Abstract

Online community networks can help organizations improve collaboration. However, in spite of their potential value, there has been little empirical research into two important network factors that determine their success: social characteristics of users and changes in operations that result from network evolution. Our research addresses these deficiencies by using a cultural framework. Derived from anthropology, it extends previous system dynamics research on online community networks. The framework acts as a lens, enabling a better understanding of the effects that changes in these factors bring to online community networks. Using data collected from Wikipedia for model calibration, our findings suggest that, contrary to conventional wisdom, removing policies that focus on building group commitment does not lower performance. The results also show that online networks need structural control, otherwise their attractiveness, credibility and, subsequently, content value might all decrease. To ensure sustainability the network must be monitored, especially during the early stages of its evolution, so that rules and regulations that ensure value and validity can be selectively employed. Copyright © 2008 John Wiley & Sons, Ltd.

Syst. Dyn. Rev. **24**, 321–347, (2008)

In today's highly competitive and dynamic global economy, firms need to continuously innovate if they are to prosper and survive. To do this, they need to learn faster than ever, certainly faster than their competitors. To facilitate this need for rapid learning a firm must find ways to help its workforce benefit from knowledge that exists inside as well as outside the organization. Unfortunately, traditional organizational forms (i.e., markets and hierarchies) have not been able to do this (Jones *et al.*, 1997). While practices designed to encourage learning within and across organizations have been in place for some time now, only recently have organizations become aware of the potential benefits that can accrue to them. Practices that employ computers and telecommunication networks can facilitate learning from entities outside the organization, including even competitors. Professional associations often employ electronic networks as part of their membership benefits. Successful networks include those whose participants are engaged in open source software development. Programmers voluntarily code software for the benefit of a broader community. Wikipedia is, for example, an online free encyclopedia created entirely by volunteers through a computer network.

[a] School of Management, Union Graduate College, Lamont House, 807 Union Street, Schenectady, NY 12308, USA
* Correspondence to: Peter Otto. E-mail: ottop@uniongraduatecollege.edu
Received January 2008; Accepted June 2008

System Dynamics Review Vol. 24, No. 3, (Fall 2008): 321–347
Published online 13 November 2008 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr.403

decision support systems and enhancing dynamic project management for consultancies that specialize in IT governance, in QA for pharmaceutical research and clinic management, and in project management of delivering expertise for decommissioning nuclear facilities.

Brown and Duguid (2000) distinguish two types of networks: networks of practice (NoPs) and communities of practice (CoPs). Van Baalen *et al.* (2005) argue that the distinction between CoPs and NoPs seems to be clear on the surface, but it is hard to determine precisely in advance whether the social collective should be conceived as CoP or NoP. They define an NoP as a loosely coupled system that barely initiates collective action and produces little knowledge. On the other hand, CoPs consist of relatively tight-knit groups of people who know each other well and work together directly. Lave and Wenger (1991) characterize NoPs as fluid social arrangements/relations, enacted among a self-selected group of participants. In contrast to CoPs, where people may meet face to face, to coordinate activities and to communicate with each other, NoPs consist of a larger, loosely knit, geographically distributed group of individuals engaged in a shared practice, without the need to meet face to face (Brown and Duguid, 1991). Wasko and Faraj (2005) define an electronic network of practice as a self-organizing, open activity system focused on a shared practice. It exists primarily through computer-mediated communication, where members of the network are willing to engage with one another to help solve problems or make contributions common to the practice.

One might simply look at CoPs and NoPs as examples of social networks that facilitate collaboration and knowledge sharing through the use of electronic networks. The social network can be viewed as a social exchange structure with its own governance structure and patterns of interaction, in which resources flow between independent units or individuals (van Baalen *et al.*, 2005). In such arrangements, interactions take place through computer networks and members of the social networks seldom, if ever, meet face to face. An important aspect of these online social networks is that their members create, seek, and share knowledge. So, they establish a community, where new knowledge is acquired from the network and transferred among its members.

Previous studies on traditional social networks suggest that knowledge sharing is positively related to social factors, such as strong ties (Wellman and Wortley, 1990), co-location (Allen, 1977; Kraut *et al.*, 1990), demographic similarity (Pelled, 1996), status similarity (Cohen and Zhou, 1991), and a history of prior relationship (Krackhardt, 1992). Unfortunately, these factors have not been shown to drive knowledge sharing in electronic networks of practice (Wasko and Faraj, 2005). In an empirical study of a national legal professional association in the United States, Wasko and Faraj (2005) found that network centrality is an important indicator of whether individuals choose to contribute knowledge. Actors with high-degree centrality maintain contacts with numerous other network actors. Inkpen and Tsang (2005) argue that the networks concept suffers from being overstretched. They have shown that the extent and value of the knowledge transferred varies across network types. All networks are, at their core, about social relationships and, therefore, social dimensions have applicability, regardless of the network type.

Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/sdr

While most research on social networks has focused on the existing social structure, little attention has been paid to the way these networks emerge and evolve (van Baalen *et al.*, 2005) and how an organization can intervene to encourage their growth (e.g., Kunda, 1992; Contu and Willmott, 2003). Wenger *et al.* (2002) made a first attempt to sketch the evolution of CoPs by identifying five stages of community development. These social networks typically start as loose networks that hold the potential of becoming more connected and to develop towards a tightly knit community. However, the authors do not discuss the dynamic interactions among determinants that successfully establish or sustain an online community. Recent studies (Diker 2003, 2004; Katsamakas and Georgantzas, 2007) propose a dynamic feedback framework for studying the determinants of open online collaboration communities. While these studies provide valuable insights and recommendations for improving functionality and product features that drive community growth, they do not capture the social dimensions within the different groups who contribute to online communities.

Our goal is to extend previous research by integrating a social framework and to use a system dynamics (SD) model with which we can test and better understand the effects of interventions, particularly structural interventions, as organizations establish an online community. We define structural interventions as policy levers, which organizations can use to build or to sustain an online community. An example of a policy lever or structural intervention an online community employs is the imposition of rules and regulations for individuals who contribute or share resources. If someone from the community wants to upload information, for example, he or she must adhere to rules set by the organization or its governance body. Ease of access or openness is another policy lever, which could help grow a network. As the network begins to grow, there is a need to have some rules and policies to maintain the content quality. This in turn might reduce openness and network attractiveness. Another policy lever we can test with our SD model is group commitment. Group commitment refers to activities and incentives that strengthen group ties in an online community. For example, acknowledging those who contribute to the online community can motivate them to increase their involvement in the community. This might lead to stronger ties with the online community.

The conceptual framework we use is based on the notion that, at its core, a social network is a collection of individuals who have different motivations for participating in the online community. We build on the work of Wasko and Faraj (2000), Gu and Jarvenpaa (2003), and Subramani and Peddibhotla (2003). They suggest that altruism and reciprocity appear to drive motivation for online participation. We add the notion proposed by Thompson and Wildavsky (1986): social factors, such as beliefs and values, might also greatly determine whether and the extent to which individuals participate in online social networks.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

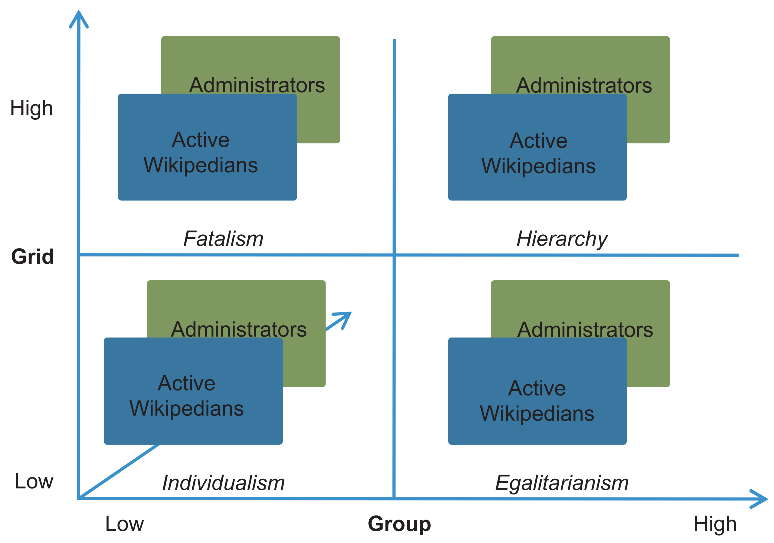


Fig. 1. The Douglas grid/group typology (adapted from Douglas, 1970)

To differentiate among the many different personalities that participate in online social networks, we employ the grid/group typology (Douglas 1970, 1978). This typology groups people to four distinct categories, based on attitudes, beliefs and values (Figure 1). This enables us to assess the role of social factors in explaining how people interact and support online social networks, and how various structural interventions might influence participant attitudes and behavior.

Following a description of the grid/group typology, we present a conceptual framework of a social network, which we then translate into an SD model. Our results show that, to function effectively as an online community, groups need structural parameters to adhere to but, if there is an imbalance in any one direction, i.e., too much or too little control, the network is likely to experience decay.

The grid/group typology

The Douglas grid/group typology (1970, 1978) shows that a person's behavior, perception, attitudes, beliefs and values are shaped, regulated and controlled by constraints that can be grouped into *group commitment* and *grid control*. Using the extremes of low and high for each variable yields four possible types of social life: fatalism (high grid, low group), egalitarianism (low grid, high group), individualism (low grid, low group), and hierarchy (high grid, high group). This two-dimensional characterization of social life according to four

Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/sdr

loose groupings is supported by a long and distinguished line of contributions (cf. Burns and Stalker, 1961; Harrison, 1972; Miles and Snow, 1978; Mintzberg, 1979; Handy, 1986).

According to Douglas (1978) and Gross and Rayner (1985), the strength of the group ties (high or low) represents the extent to which people are driven by or restricted in thought and action by their commitment to a social group. High group strengths result when people devote considerable time and attach great importance to interacting with other group members in their unit. The more things they do together and the longer they spend doing them, the higher the group strength is. Group strength is low when people act in ways that benefit them individually and are neither constrained by, nor reliant upon, others in the group.

"Grid" is the complementary bundle of constraints on social interaction—a composite index of the extent to which people's behavior is constrained by normative role differentiation. The strength of the grid is high whenever roles are distributed on the basis of explicit public social classifications, such as gender, race, position in a hierarchy, office, descent (by clan or lineage) or point of progression through an age-grade system. A low-grid social environment is one in which access to roles depends upon personal abilities, skills, qualifications, etc.

Looking at the effects of structural interventions in online communities, the Douglas grid/group typology has advantages over traditional approaches. First, the grid/group model accurately captures the social relationships and characteristics (beyond altruism and reciprocity) of people within a network. Second, as Inkpen and Tsang (2005) contend, the core of a network is people—and the Douglas grid/group typology captures the important cultural biases that affect group behavior. Third, the Douglas grid/group typology differs from previous studies, where the research focus was, for example, individual incentives (Bergquist and Ljungberg, 2001), impact of firms' participation on individual motives (Dalle and David, 2003), impact of community participation on individual motives (Franke and von Hippel, 2003), and relationships between incentives and technical design (Ghosh *et al.*, 2002). Unfortunately, a typical pitfall of all typologies is their limited power to explain change and transformation (Holland, 1994). To minimize this limitation, we use an aggregated view of the grid/group typology and employ SD to explore the structural causes underlying change over time.

Online social networks

An online social network is a virtual place where people collaborate for the purpose of sharing knowledge. While knowledge sharing is needed to sustain an online network, Brown and Duguid (2000) and Nonaka (1994) argue that significant levels of knowledge exchange will not develop in these networks. If

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

people who share their knowledge lose the unique value they once possessed, only the recipients of the shared knowledge really benefit (Thibaut and Kelley, 1959; Thorn and Connolly, 1987).

Coleman (1990) and Putnam (1993, 1995) provide theories of collective action to explain why individuals in a social network choose to make contributions. They argue that people contribute their knowledge because of "social capital", which Lin (2001) defines as "resources embedded in a social structure that are accessed and/or mobilized in purposive action". Studies have focused on group-level *social capital* to explain the creation of intellectual capital within organizations (Nahapiet and Ghoshal, 1998) and on individual relationships as the primary source for the generation of social capital in social networks (Wasko and Faraj, 2005). However, different network types have distinct social capital dimensions. Inkpen and Tsang (2005) examined the boundary conditions of social capital among three network types (Intra-corporate Network, Strategic Alliance, and Industrial District). Their study concludes that the three network types involve different dynamics between organizational and individual capital, and conclude that when studying network behavior it is important first to examine the nature of the network type concerned and how it differs from other types.

The online social network we chose for our study is Wikipedia, specifically the group of people who are contributing, administrating and editing the collective knowledge of this online encyclopedia and thereby represent the core of this online network. Wikipedia is an international online project that attempts to create a free encyclopedia in multiple languages. Using Wiki software, thousands of volunteers have collaboratively and successfully edited articles. Within three years, the world's largest open-content project has accumulated more than 1,500,000 articles in the English language version and more than half a million in the German language version. There are 250 language editions of Wikipedia, and 18 of them have more than 50,000 articles each (Voss, 2005).

Wikipedia defines itself as "a multilingual, Web-based, free content encyclopedia project. The name is a portmanteau of the words wiki and encyclopedia." The content of the Wikipedia encyclopedia is written collaboratively by volunteers, allowing most articles to be changed by almost anyone with access to the Web site. We have chosen Wikipedia for a number of reasons. First, it is an open-source project in a dynamic environment, where people join and leave the network and collaborate on making knowledge available to a larger audience. Wikipedia consists of a number of administrators, a small number of experts who oversee the content quality, and editors, people who contribute by editing existing articles or uploading new knowledge. Second, the structural dimension of social capital within Wikipedia involves the patterns of relationships between the network actors and thus enables analysis of how structural interventions change network ties, network configuration and network sustainability.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

Like other open source projects that rely on collective knowledge creation or sharing by volunteers, Wikipedia faces a number of challenges. For example, Wikipedia needs a lot of people to keep a project alive. Poor involvement of editors or even inactivity also challenges the sustainability of the project. Credibility of content is another issue: inexperienced editors need to build credibility. If they fail to establish their credibility or take too long to make it so, the project might falter. The success of such an online social network, with its editors and administrators at the core, depends in part on how to encourage participation and to provide the structural dimension and ties as fundamental aspects of social capital.

Again, the objective of this paper is to evaluate how structural interventions in online social networks affect sustainability. To assess how interventions change the nature of social capital, we propose a set of dynamic conditions that facilitate the creation and sustainability of social networks.

1. A loosely structured environment accelerates the initial growth of an electronic network of practice.
2. As networks begin to grow, their structural environment needs to be shaped to increase their value.
3. Strengthening social ties or group commitment will have a positive effect on the growth of an electronic social network

These dynamic hypotheses will be examined using the system dynamics method. Substantive interpretation of testing the structural policies with the simulation model will be discussed. In the next section we provide a framework and boundary of our model.

Contextual framework

As stated earlier, our aim is to develop a theory of how social networks respond to interventions, and to assess whether our structural theory, derived from the literature, is adequate to replicate observed behavior. While a simulation model should replicate real-world behavior, it is, at the same time, a lens through which the modeler views the environment. Given the challenges of operating in a rather complex environment, we believe that the feedback structure in Figure 2 represents a high-level perspective of how pertinent variables in an online community are interconnected. In Figure 2, dividing cultural bias into smaller segments might help assess personal motivations for online group participation and knowledge sharing within an online community. However, there is little understanding and empirical evidence about the interrelated nature of cultural bias in the grid/group typology.

Simulation can help assess how structural interventions might change the social characteristics in an online community and whether the number of

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

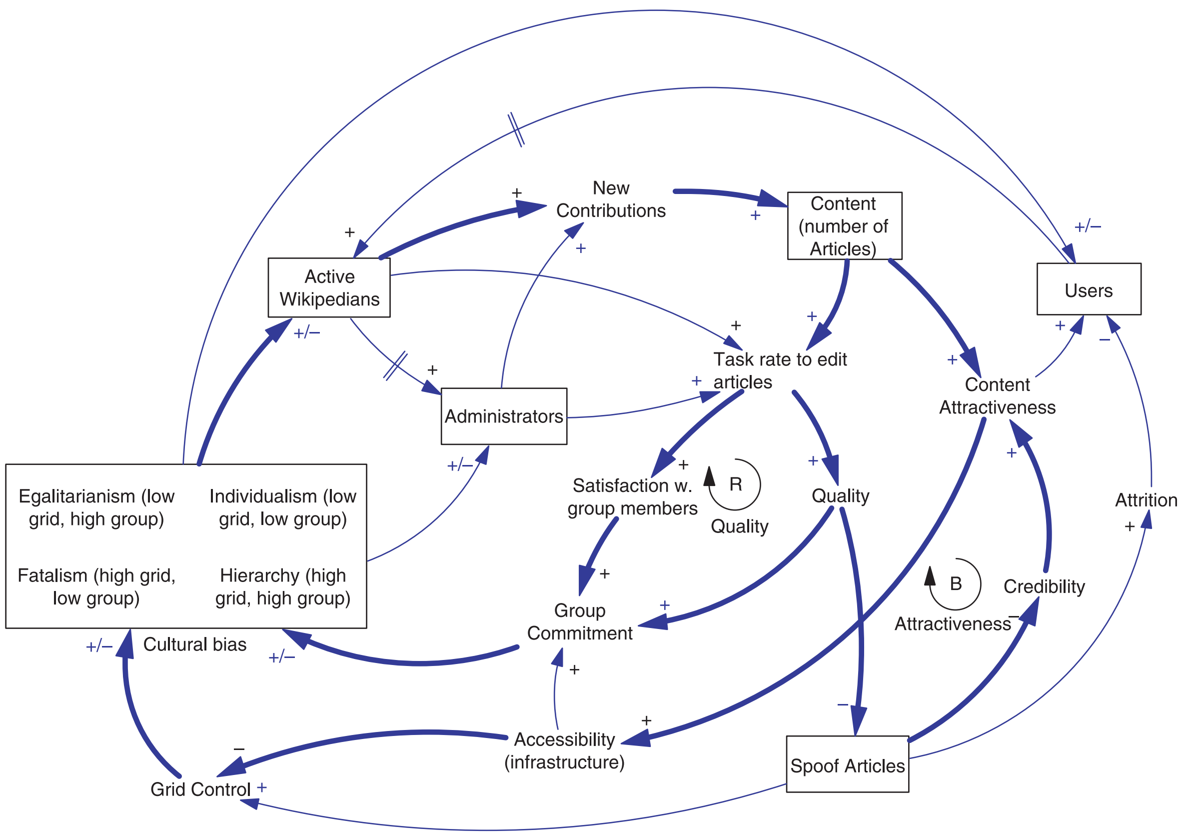


Fig. 2. Causal loop diagram for the Wikipedia network of practice

active Wikipedians (people who upload articles) and administrators (who control quality and also upload articles) will increase or decrease. The reinforcing "quality" loop drives network growth (as long as there are enough administrators to edit and safeguard content quality), which strengthens the group commitment and in effect increases the number of active Wikipedians, who grow the network. The balancing "attractiveness" loop shows that network credibility also affects its growth as the number of "spoof" articles determine content attractiveness. *Spoof* articles vandalize the online encyclopedia project's articles, in an attempt to challenge Wikipedia's credibility. If content attractiveness and quality increase so does the number of people who contribute, which in turn attracts more Wikipedia users. The rationale for this feedback effect is based on data from Wikipedia (http://commons.wikimedia.org/wiki/Category:Wikipedia_statistics, accessed December 2007). The data suggest a 0.84 correlation between the number of administrators and "reach"

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

(per million viewers) and a 0.95 correlation between active Wikipedians and reach. The term "user" refers to the viewer visiting the Wikipedia website.

Diker (2003, 2004) shows similar feedback effects in his theory of open online collaboration. For example, the positive feedback loop through which users add to the content collection and the negative loop where "density of quality problems" affects the number of users. While there are some parallels in the feedback structure between Diker's model and ours, Diker does not look at the social characteristics of online communities, nor does he distinguish between contributors with different social characteristics. Instead he uses a single, aggregated stock of "potential developers" and "developers", an aging chain where "users" become "experienced users". Indeed, at the core of a network is people (Inkpen and Tsang, 2005), so our aim is to capture the important cultural biases that affect group behavior, using an appropriate framework, such as the Douglas grid/group typology (Figure 1).

Wikipedia's founder accepts that the site's open and egalitarian nature renders it vulnerable to spoof article attacks (http://www.timesonline.co.uk/tol/news/world/article766526.ece), which can decrease Wikipedia's credibility. The loss of credibility has caused commentators to question whether Wikipedia is destined to follow the Wikitorial *LA Times*' doomed experiment in unrestricted Internet comment, which had to be closed down after just two days under a bombardment of pornographic postings. While the open and egalitarian nature of Wikipedia invites people to contribute, a network of practice cannot exist in the long run without structural components or boundary objects, such as documents, terms, policies, concepts and other controls, through which the network can organize user interactions (Wenger, 1998). Wenger suggests that if boundary objects are an important structural dimension then there may be opportunities for organizations to encourage the growth of a network of practice by creating initial boundary objects in the form of monuments (symbols), instruments (infrastructure) and points of focus (focal concepts), around which network members may congregate and interact. But too much structure is likely to result in the demise of a community.

We actualize structural intervention via three policy levers. The *first* policy lever is "grid control", a highly aggregated intervention through rules and regulations when the number of spoof articles increases. From a policy perspective, *grid control* suggests that the organization or governance body behind an online network would impose more or fewer rules or regulations, which individuals must adhere to. For example, when Wikipedia started its online encyclopedia, everyone was able to edit or upload articles. Over time, however, Wikipedia experienced an increase in vandalism, which resulted in imposing rules of conduct for people who wished to edit or upload articles. One of the rules to safeguard the quality of Wikipedia was that users who wanted to upload an article needed to go through a registration process. Another rule was that edits were reviewed by a Wikipedia administration before release. This policy change was intended to address the problem observed in

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

the *LA Times* online community experiment, where the lack of control mechanisms resulted in loss of credibility and, subsequently, the demise of the network community. Grid control is linked to cultural bias and the four clusters of the Douglas grid/group typology:

- *Egalitarianism* (low grid, high group) is a social context where the external group boundary and the social experience of users are both shaped by the "we" versus "them" ethos. All other aspects of interpersonal relationships are ambiguous and open to negotiation, with emphasis on egalitarianism and active participation.
- *Individualism* (low grid, low group) represents a social context dominated by strongly competitive conditions, volatile circumstances and prescription for individual autonomy. This context gives people maximum options for negotiating contracts or choosing allies.
- *Fatalism* (high grid, low group) is a social context dominated by insulation. In its extremity, individual autonomy is minimal, with little scope for personal transactions. The organizational environment is hierarchical and people are classified according to well-established and formal rules.
- *Hierarchy* (high grid, high group) is a social context with individual behavior and group boundary controls. Here everyone knows one's place, but that place might vary with time. Personal security is obtained at the expense of overt competition and social mobility.

The second policy lever that affects cultural bias is "group commitment". This variable is also highly aggregated since it only shapes the level of *group commitment* based on the notion that good contributions from the group may increase motivation and, subsequently, group ties. The third policy lever is "accessibility" through which we capture the characteristics of having an accessible interface to the online network of practice. For example, Wikipedia inspired users to participate in making knowledge available to a larger audience by providing a high degree of accessibility with its browser-based interface that allows editing and uploading articles.

Model development

The success of Wikipedia stems from a certain seeding structure that provided a fertile environment for the cultivation of a vibrant online community. The seeding structure was a piece of software or "Wiki": a collection of hypertext documents that can be directly edited by anyone. Every edit is recorded and thus can be retraced by any other user. Each version of a document is then available with its revision history and can be compared to other versions. But after a surge in spoof articles and vandal attacks, Wikipedia imposed a set of new rules, a controlling structure to maintain its integrity.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

While previous research focused on the interrelationship between a network and its host organization, and on the interaction around these structures (Kunda, 1992; Contu and Willmott, 2003; Thompson, 2005), we extend the boundary for our simulation model but also use an aggregated perspective. As we build an SD model to test theories about the dynamics of interventions in an online network, we aggregate from an individual to a group level, following the Douglas grid/group typology. Our model consists of the following clusters (or accumulations) of people: (1) administrators (people who control the content of submitted articles and maintain network quality); (2) users (people who use the network); and (3) active Wikipedians (people who contribute articles regularly to build collective knowledge).

Model validation

The goal of model validation in system dynamics is to determine whether a model is appropriate for a given purpose and whether model users can have confidence in it. Sterman (2000), Richardson and Pugh (1981), and Forrester (1961) argue that no model can ever be truly validated because every model represents a simplification of reality, not reality itself. Barlas (1996) proposes a narrow set of model validity tests believed to be most important. But given that the number and diversity of validity tests in the literature are so large, selecting and applying a subset is an overwhelming problem. Sterman (2000) offers 12 tests, examining models on both structural and behavioral grounds. Other tests focus on collaborative model-building projects that include both modelers and model users. Richardson and Pugh (1981) divide confidence-building tests into those that test for suitability and those that test for consistency. Suitability tests determine whether the model is appropriate for the problem it addresses, while consistency tests examine whether the model is consistent with the particular aspect of reality it attempts to capture. In validating our model, we performed direct structure tests (Forrester and Senge, 1980) and compared our model with generalized knowledge about the Wikipedia system.

As previously mentioned, some of the feedback effects in our model have been reported in previous studies (Diker 2003, 2004) or are well grounded in the literature; for example, the model sector in Figure 7 is a Bass diffusion structure (Sterman, 2000). For dimensional consistency and extreme condition tests, we used VENSIM to (a) ensure that the units of all variables are consistent and (b) to see how the model responds when changing parameters to extreme values. In order to perform a parameter confirmation test, we searched the literature for available knowledge about the real system. For parameters for which we did not have empirical values we used a "best-guess" approximation, tested the value of our assumptions using VENSIM's sensitivity analysis, and adjusted parameters to replicate the time series data in Figures 3 and 4.

The graphs in Figures 3 and 4 show a fairly good visual fit between model data and the actual numbers showing how Wikipedia has grown since its

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

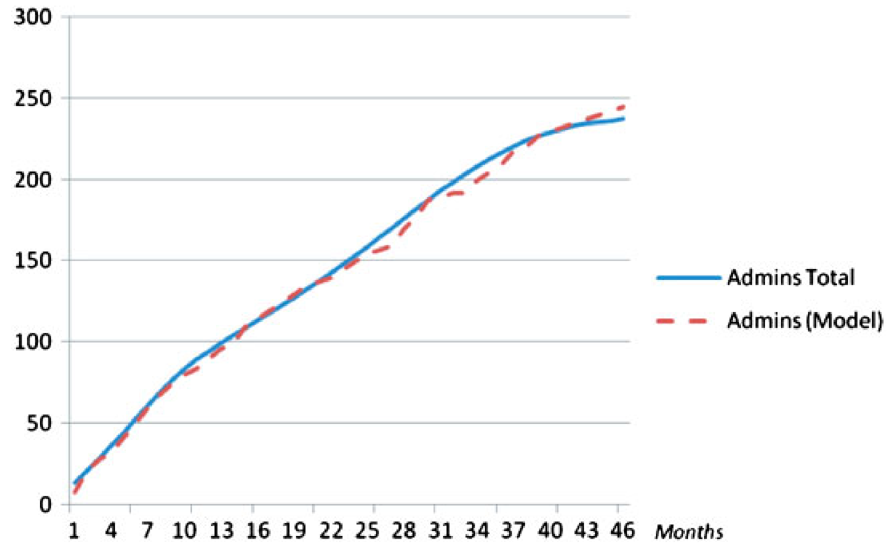


Fig. 3. Time series data for the English version of Wikipedia administrators source: http://commons.wikimedia.org/wiki/Category:Wikipedia_statistics (accessed December 2007)

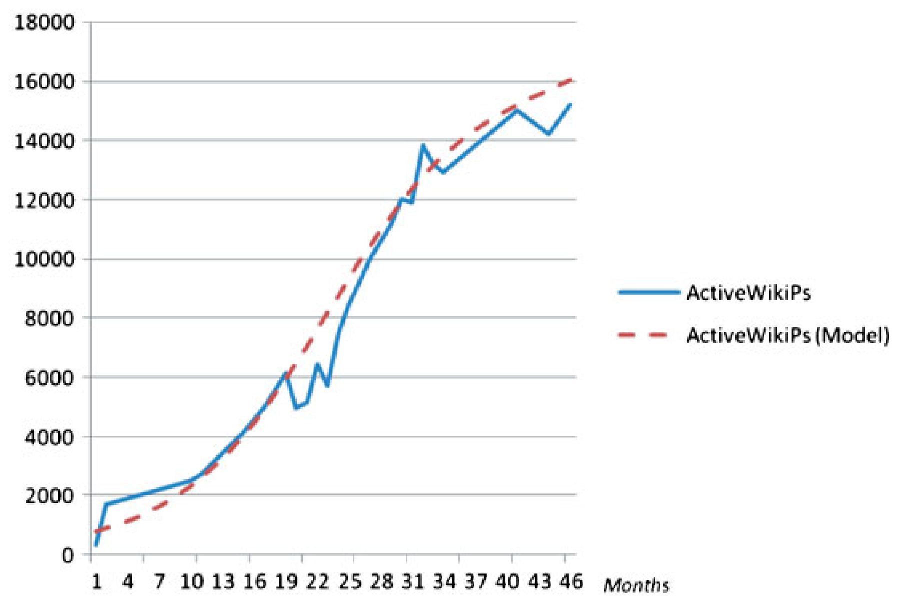


Fig. 4. Time series data for the English version of Wikipedia contributors

launch in early 2003. To calibrate the model, we adjusted parameter values, using our best judgments rather than precise statistical estimates. For example, the inflows into the stocks consist of "maturation periods" which capture the time it takes for people to either become "administrators" or "active Wikipedians". The

Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/sdr

outflows are also controlled by a time constant, which we adjusted to replicate the baseline. The timeline of the model is 45 months, which is the time since the inception of Wikipedia (February 3, 2003) and the last data point reported on the Internet (October 19, 2006). The data we were able to retrieve from the Internet were scattered both for "administrators" and "active Wikepedians", so we interpolated the missing data points in Excel to close the gaps. However, because most of the variables used in the model are hard to measure, calibrating against real data does not mean the model is valid. But those interested in seeing the detailed model, including its documentation, can download the VENSIM file from the online companion of this journal or contact one of the authors.

Model structure

A crucial element in our model is the representation of the grid/group framework. We use a two-dimensional matrix to capture the different characteristics of the Douglas typology by grouping active Wikipedians and administrators into the four clusters (Figure 1). Active Wikipedians make regular contributions to build collective knowledge for the online encyclopedia, whereas administrators control the quality of submitted articles and intervene when a spoof is discovered.

We assume that there is no spatial transfer of people among the four clusters and operationalize the two-dimensional typology with subscripts, separating the flow rates of every individual cluster, depending on the control variable. Figure 5 shows the model sector that encapsulates the grid/group typology of Figure 1.

Each of the two stocks in Figure 5, active Wikipedians and admins, consists of four clusters, appropriately subscripted ([low group, low grid], [low group, high grid], [high group, low grid], [high group, high grid]) to capture how grid control and group commitment increase or decrease the number of people in the four clusters. "Active Wikipedians" and "admins" have the same social characteristics, so they respond similarly to structural interventions. Therefore, in a symmetric manner, grid control and group commitment determine the inflow and outflow from the two subscripted stocks, representing four clusters each (Figure 5).

An example may clarify how the model relates to the conceptual framework. We start with the inflows and outflows as governed by grid control and continue upstream from there. Equations 1–5 show how grid control governs inflows and outflows. At any given time, there are people joining or leaving the number of active Wikipedians, according to their personal preferences and the working environment they find themselves in. For example, increased grid control is likely to win active Wikipedians comfortable with increased control—in Douglas' jargon, people who prefer either fatalism or hierarchy. At the same time, active Wikipedians comfortable with control tend to stay longer under conditions of increased control. Therefore, increased grid control must be modeled by both increasing the inflow and decreasing the outflow of control-preferring people:

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

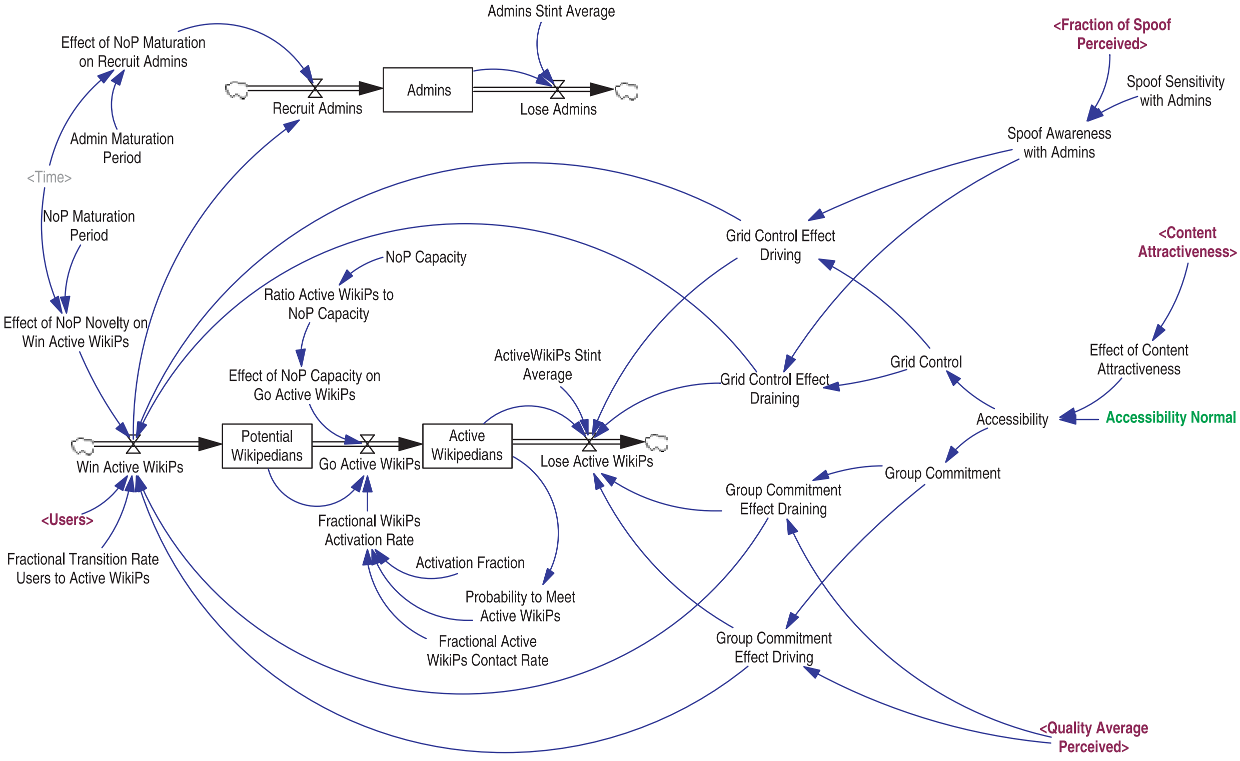


Fig. 5. The grid/group typology model sector

Win Active WikiPs[LowGroup,HighGrid] =
Users × Fractional Transition Rate Users to Active WikiPs ×
Group Commitment Effect Draining × Grid Control Effect Driving (1)

Grid Control Effect Driving, which increases proportionally to Grid Control, drives the Win Active WikiPs rate from among Users attracted by high Grid Control, who transition to Potential Wikipedians and later, to Active Wikipedians. But Grid Control Effect Driving might also gradually drive out some people. Active Wikipedians who prefer a LowGrid (control) environment and decide whether to stay or to leave after their Stint Average are likely to leave if they sense a HighGrid (control) situation. Therefore, we also should include Grid Control Effect Driving in

Lose Active WikiPs[LowGroup,LowGrid] = Max(0,
Min((Active Wikipedians[LowGroup,LowGrid] / ActiveWikiPs Stint Average) × Group Commitment Effect Driving × Grid Control Effect Driving, Lose Active WikiPs Max[LowGroup,LowGrid])) (2)

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

Lose Active WikiPs Max[LowGroup,LowGrid] belongs to the standard first-order outflow from Active Wikipedians. Getting back to the previous statement that increased grid control must both increase the inflow and decrease the outflow of control-preferring people:

$$\text{Lose Active WikiPs[LowGroup,HighGrid]} = \text{Max}(0, \text{Min}((\text{Active Wikipedians[LowGroup,HighGrid]} / \text{ActiveWikiPs Stint Average}) \times \text{Group Commitment Effect Driving} \times \text{Grid Control Effect Draining}, \text{Lose Active WikiPs Max[LowGroup,HighGrid]})) \quad (3)$$

In this equation, the loss of Active Wikipedians with an affinity to High Grid Control is decreased by Grid Control Effect Draining, which around its equilibrium value decreases proportionally to Grid Control.

Similar but opposing arguments hold for those who feel less comfortable with increased control—in Douglas' jargon, people who tend either towards individualistic or egalitarian structures. So, with increased grid control, individualists and egalitarians will tend to become Active Wikipedians at low percentages and to stay for a short time. To summarize, under increased grid control more fatalists and hierarchists tend to join or to stay longer, whereas individualists and egalitarians tend to keep out or to stay less under decreased grid control, respectively.

Similar arguments hold for increasing and decreasing inflows and outflows to and from the clusters, according to increased group commitment, again with the opposite effects for decreased group commitment, respectively. Therefore, the model equations for every inflow and every outflow from any one of the four clusters reflect both changes in grid control and changes in group commitment.

Following the causes upstream, the set of equations controlling the flows split effects into Grid Control Effect Driving, Grid Control Effect Draining, Group Commitment Effect Driving and Group Commitment Effect Draining. Then, having an appropriate two-effects combination represents the joint effect of grid control and group commitment on every inflow and outflow to and from each of the four clusters of Active Wikipedians. The following equation describes the effect used both in Eqs 1 and 2 to increase the inflow of people who prefer high Grid Control as well to increase the outflow of people who prefer low Grid Control:

$$\text{Grid Control Effect Driving} = \text{Max}(0, \text{Grid Control} \times \text{Discrepancy in Spoof Awareness with Admins} + \text{Grid Control OP}) \quad (4)$$

When among quality articles the Fraction of Spoof Perceived rises, Spoof Awareness with Admins rises, too. If it rises above a value that Admins consider normal, then Grid Control gets tight. If it sinks below that value then Grid Control gets loose. This way, Grid Control Effect Driving is a type of P-control, with an operating point at Grid Control OP. Similarly, Grid Control

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

Effect Draining is also driven by the discrepancy in the administrators' actual awareness of spoof articles, but changes grid control in the opposite direction, indicated by the (–1) factor below:

$$\text{Grid Control Effect Draining} = \text{Max}(0, (-1) \times \text{Grid Control} \times \text{Discrepancy in Spoof Awareness with Admins} + \text{Grid Control OP}) \quad (5)$$

Lastly, Grid Control determines how high discrepancies effectively increase or decrease the various flows. Grid Control is reduced with the network's increasing accessibility for Wikipedians. Accessibility captures an internally self-perfecting networking structure, with a set of policies that gradually raise accessibility with increasing Content Attractiveness.

But we also want to test different policies of grid control, especially policies of structural interventions that may run counter to self-referencing network dynamics. "MgmtGrid Override" allows phasing in or out externally premeditated levels of Grid Control Normal. To avoid clutter, however, we have omitted these parts from Figure 5, and from Eqs 1–5.

Switching to the description of Group Commitment Effect Driving and Group Commitment Effect Draining, there are two differences from the grid-controlled part of the model: (a) Group Commitment Effect Driving/Draining is driven proportionally by discrepancies between Quality Average Perceived and Quality Average for Group Commitment Normal; and (b) growing Accessibility proportionally also raises Group Commitment.

How are then are Users becoming Active Wikipedians? In Figure 5 the reservoir of Potential Wikipedians is fed by a Fractional Transition Rate of Users to Active Wikipedians. This rate is modified by an Effect of NoP Novelty on Win Active WikiPs that assumes higher transition rates due to the novelty of the network, gradually diminishing to more modest values over the NoP Maturation period. Potential Wikipedians became Active Wikipedians through word-of-mouth stimulation. However, this growth mechanism is limited by the network of practice's capacity: NoP Capacity. Thus the network of Active Wikipedians cannot simply grow infinitely large before communication and production processes among participants become ineffective or unattractive and no further Potential Wikipedians become integrated into the network.

Figure 6 shows the content sector, which keeps track of serious (Content Volume Q) and spoof (Content Volume S) articles. These two types of article differ in their lifespan (spoof articles are soon edited or removed, while serious articles remain) and their effects on future contributions.

Administrators and editors control spoof articles. Their efforts drive the (Weed Spoof Content) outflow, a function of the edit rate, based on resources, and a perceived ratio, based on content quality and spoof. Other variables in this sector, not shown in Figure 6, are "content attractiveness" (determined by total content, content normal and attractiveness normal) and "credibility perceived" (determined by the spoof fraction and credibility normal).

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

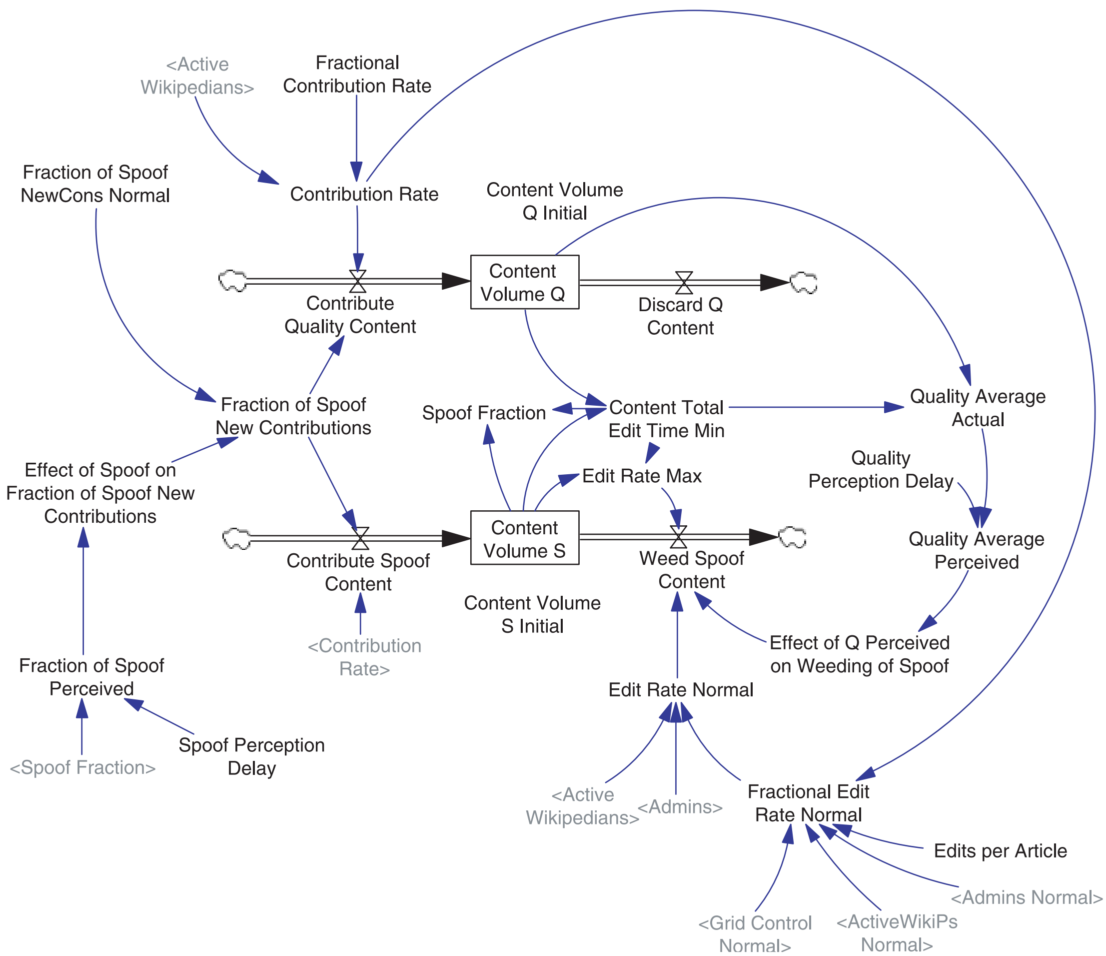


Fig. 6. The spoof and quality article content sector

The sector in Figure 7 encapsulates the growth of users, operationalized as the number of Internet users visiting Wikipedia each day (measured in millions). Winning new users is a function of word of mouth (with a generic WOM structure) and effects from content attractiveness and the perceived quality of the network, which increase the probability of becoming a user. Losing users, on the other hand, is determined by a fractional attrition rate and perceived credibility.

Base Case Simulation

Figure 8 shows the number of active Wikipedians, administrators and the content volume of users in reach of millions (Internet users visiting Wikipedia

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

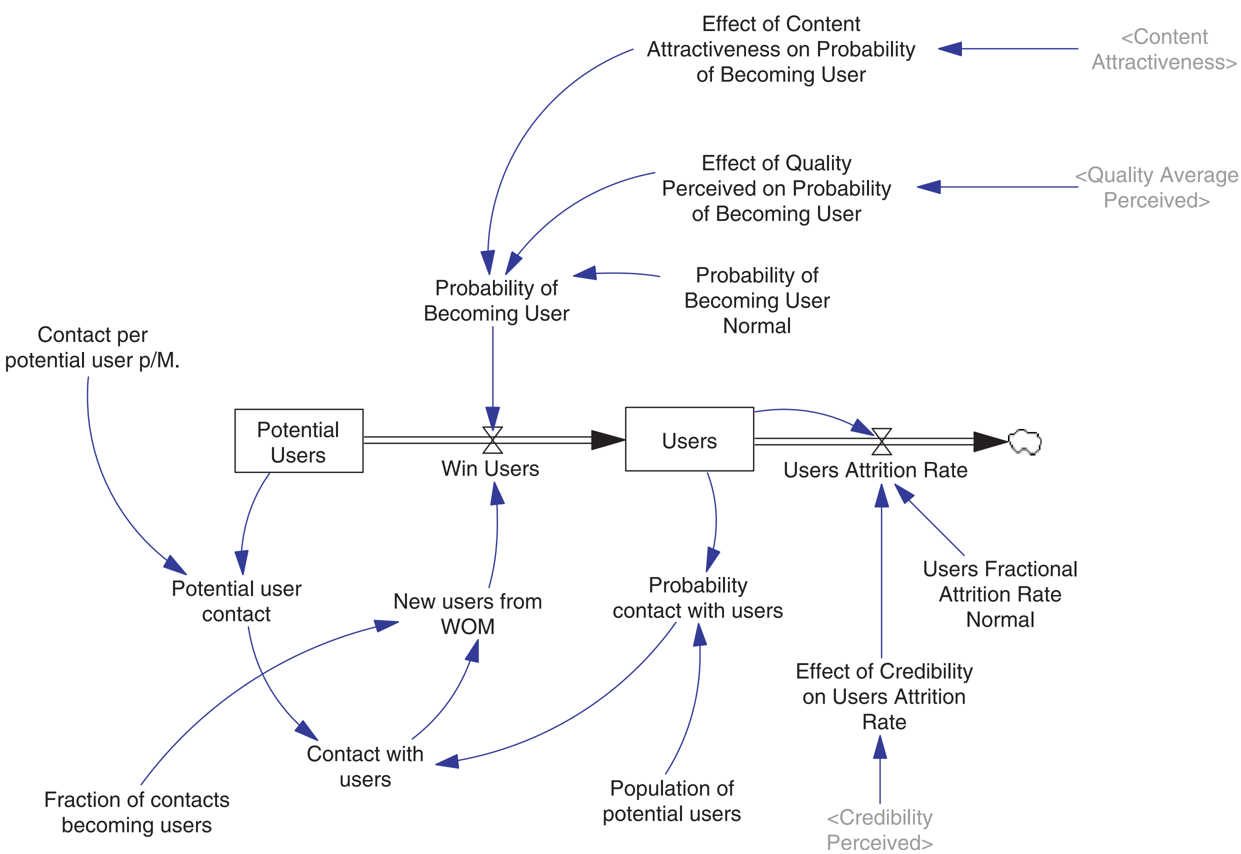


Fig. 7. The network user model sector

each day). The model visually fits the data from the English Wikipedia site (Figures 3 and 4). We have set the model parameter values in the base case to match the environment of the network of practice (accessibility, group commitment, and grid control) to our best judgment of the historical values for Wikipedia over this timeframe, rather than to precise statistical estimates. The values for "accessibility normal" and "group commitment normal" are set to 0.5 (on a scale of 0–1), assuming a moderate level of accessibility and group commitment at the inception of the network. Grid control normal is set to 0.3 (on a scale of 0–1), which reflects an environment with moderate control and rules of conduct.

The initial values for the stock of active Wikipedians is 200 people for each of the subscript clusters, assuming that at the time of inception the network had already created some interest to participate. Given the aggregated approach in our model and the lack of statistical estimates, we assumed that each of the

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

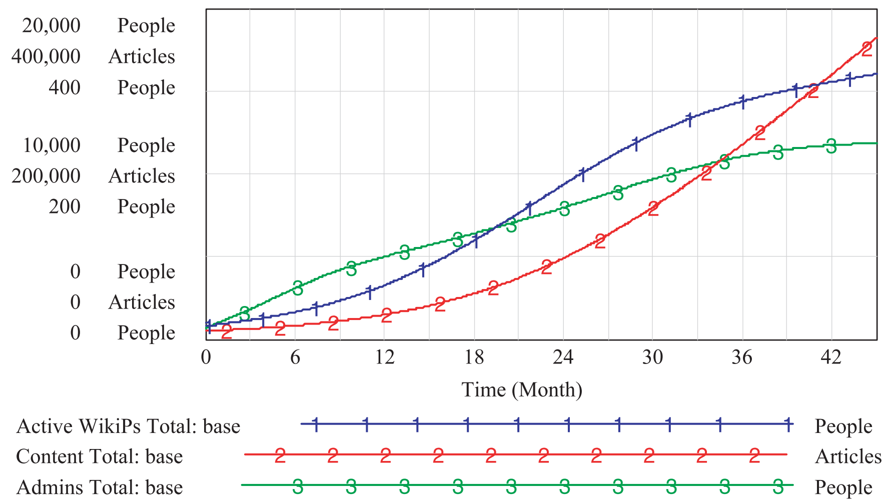


Fig. 8. Base case for the Wikipedia network of practice

four clusters will have the same initial value of 200 people. For the user group we chose an initial value of 1000 people, considering the buzz created before the network was launched.

The graph in Figure 9 shows the base condition for the "Active Wikipedians" stock, with its four subscripts from the grid/group framework (Figure 1). The ratio of active Wikipedians to administrators is constant (it has not changed

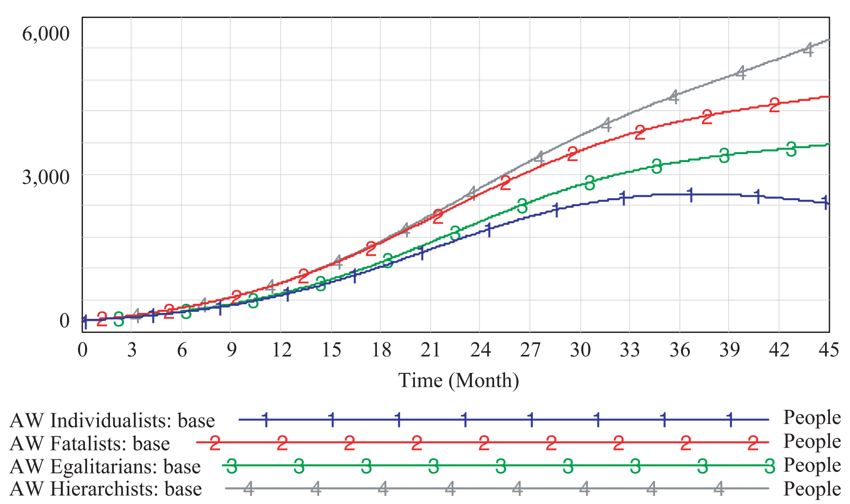


Fig. 9. Grid/group dynamics for the base case

Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/sdr

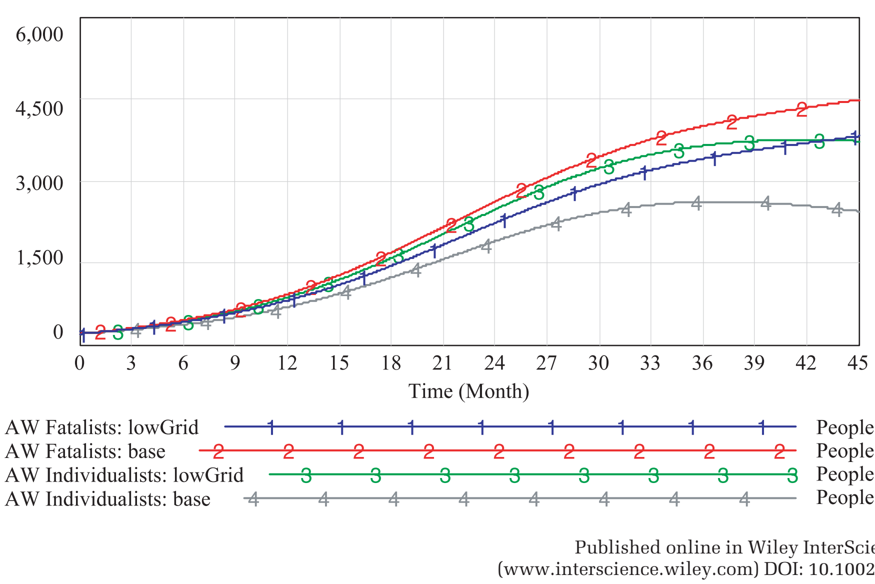
since the inception of the network) and the behavior of two stocks (each with its four subscripts) is symmetric, so we only plot the graph of active Wikipedians to show how the network is populated.

Following the Douglas grid/group typology, the highest growth among the four groups is for hierachists and fatalists, in the high-grid/high-group and high-grid/low-group cluster, respectively. We attribute this behavior to how these clusters respond to changing levels in the fraction of spoof and content attractiveness. An increase in the fraction of spoof contributes to the growing need for more grid control (e.g., more rules and regulations), which attracts hierachists and fatalists, i.e., people who need clearly defined boundaries and a rather bureaucratic environment. The other two clusters, individualists and egalitarians, experience slower growth. Altman and Baruch (1998) suggest that the low-grid/low-group cluster is determined by a high degree of self-responsibility, so people in this cluster tend to resist group commitment or rules and regulations interfering with individual autonomy.

Policy experiments

To investigate how structural interventions may determine growth or decline in an online community network and how the social clusters described in the Douglas grid/group typology are affected, we use the "group commitment" and "grid control" policy levers. We keep accessibility unchanged to assume a moderate level of access for users and those who want to contribute to the growth of the network. Figure 10 shows how the system might respond when

Fig. 10. Policy test for low grid control



Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

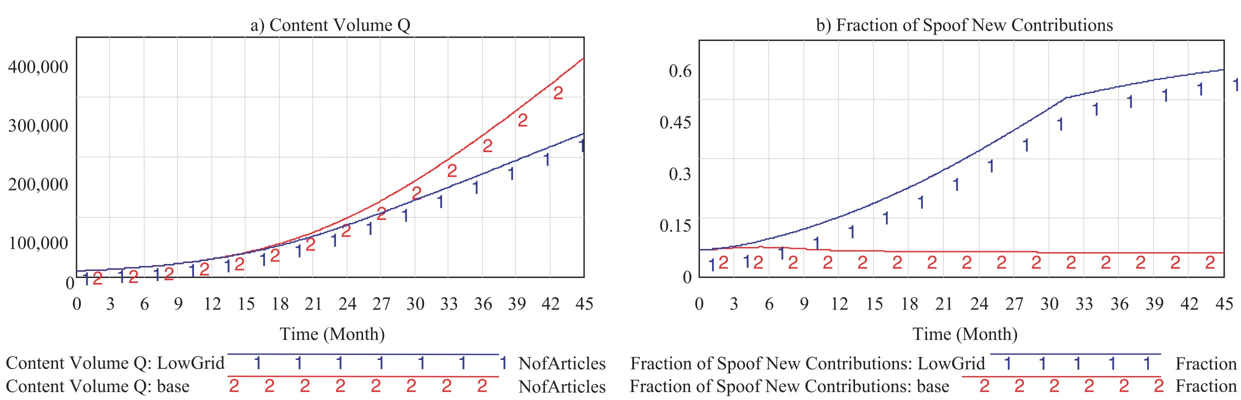


Fig. 11. Quality content volume of Wikipedia and fraction of spoof

an organization imposes no rules and regulations, which we simulate by changing the lever "grid control normal" from its initial base value of 0.3 to 0. This policy for "grid control" suggests that the organization or governance body behind a social network would not impose any rules about how people contribute or facilitate exchange within the network.

In Figure 10 we only compare the two clusters with either low or high grid characteristics, i.e., fatalists and individualists. Removing all rules and regulations from the network results in losing people who are following rules of conduct, i.e., fatalists, while gaining people with a high degree of self-responsibility (individualists). Individualists are inclined not to need rules of conduct. They feel that each person is responsible for oneself and for whomever else he or she chooses. The results of this policy (Figure 11) show that the fraction of spoof for new contributions is increasing, while the content volume of quality articles is decreasing. Without any structural interventions, Wikipedia could have experienced the Wikitorial *LA Times*' doomed experiment in unrestricted Internet comment. Intuition certainly suggests that an open unrestricted environment in an online network of practice should result in fast growth. Yet intuition is a notoriously poor tool for predicting the time-dependent effects of management policies in complex systems (Sterman, 1989).

The next policy test assumes no efforts to build and to nurture group commitment, which means that we change the policy lever "group commitment" from its baseline value of 0.5 to 0. In this policy test, we compare social actors for whom group commitment might be important, i.e., hierarchists and egalitarians. However, we do not change the value for accessibility and grid control, assuming the network does have defined boundaries and control mechanisms to respond to changing quality levels.

Figure 12 shows that imposing no interventions for group commitment in an online network means losing people guided by group boundaries (hierarchists).

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

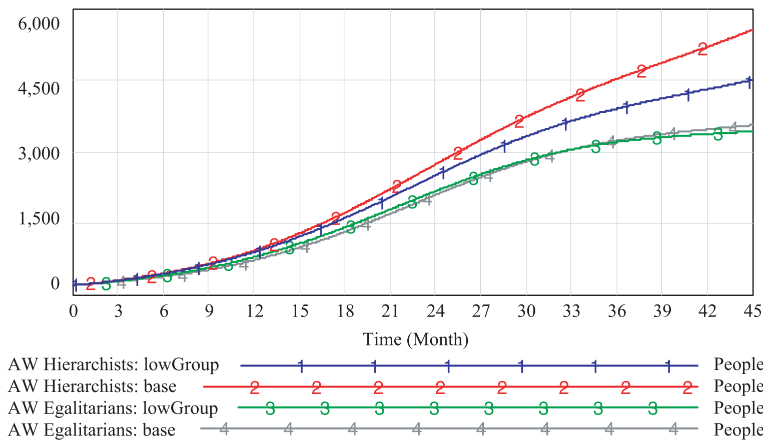


Fig. 12. Results for policy test without group commitment

Examples of this social dimension include bureaucracies, with individual roles based on seniority rather than merit. Removing group commitment marginally changes the size of the "egalitarian" cluster, typically dominated by considerations as the social experience of individuals is shaped by "we" rather "them" (Altman and Baruch, 1998). Changing this policy lever in a real system means that the organization or governance body behind the social network would not make any efforts to create mutual commitment for members of the community to collectively pursue common means. Wikipedia, for example, strengthens group ties by providing people who regularly contribute and share knowledge with special privileges, such as easier upload or editing capabilities. After removing group commitment, we observe that the content volume of quality articles and the fraction of spoof articles do not change compared to the base run (Figure 13). We attribute this behavior to the feedback effect in our model, where the fractional spoof rate increases spoof awareness with administrators (the content quality gatekeepers), which subsequently increases grid control.

This policy test shows that focusing on group commitment results in counterintuitive behavior. Removing this lever does not lower performance, as long as boundary-related policies hold. This insight is contrary to our third proposition that group commitment is positively related to the growth of the network. Thus management policies aimed at building group commitment might not achieve the desired result. This finding supports Bagozzi and Dholakia (2006), who investigated participation in the Linux user group (an open source initiative through an online network of practice). Their study found that subjective norms failed to significantly predict intentions to participate.

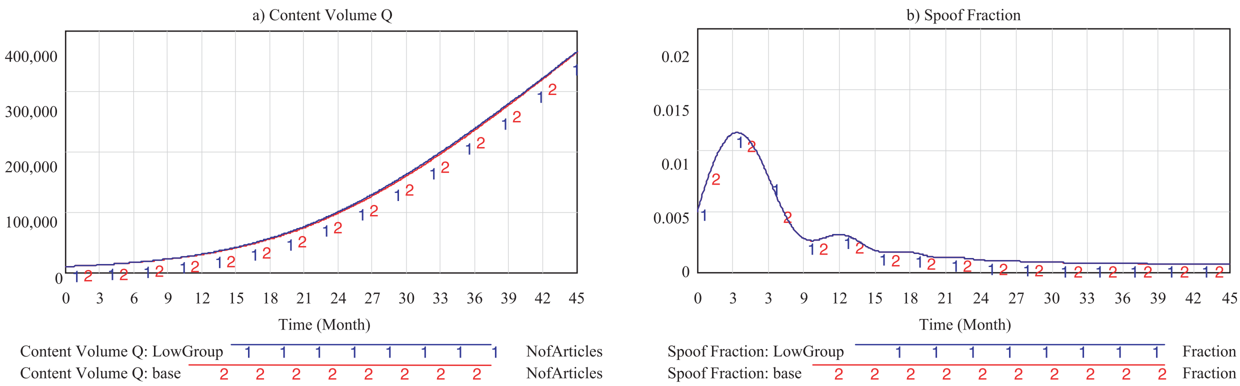


Fig. 13. Content volume and spoof fraction without group commitment

Discussion

Online social networks are an important architecture for the distribution and sharing of knowledge and show promise to become an important medium for resource sharing in different domains. However, in spite of their potential importance, there has been little empirical research into the impact of user behavior and the dynamic nature of their operation.

Our research seeks to bridge this gap by integrating a cultural framework, derived from anthropology, to determine the effects of structural interventions in an online social network. The grid/group framework may also help in developing an understanding of how policy interventions affect the social dimension of the network, as well as how to align organizational characteristics with personal attributes. However, the use of a cultural typology for organizational analysis has an implicit limitation: culture, a multifaceted construct, cannot be easily captured by a two-dimensional typology, or any other simple framework for that matter (Sackmann, 1992). The grid/group typology too has only limited explanatory power.

A number of tangible and timely recommendations emerge from the simulation experiments that evaluate policy options. Some insights contradict our initial expectations about policies that would help establish a sustainable online community network. For example, counter to our beliefs, policies aimed at building group commitment might not achieve the desired result. We attribute this behavior to changes in the social characteristics of the network, i.e., lowering group commitment results in losing people who look for hierarchy and group commitment, while gaining people with a high degree of self-responsibility. These two quadrants ("hierarchy" and "individualism") represent what is known in the grid/group typology as the "stable axis" (Thompson *et al.*, 1990). Changing

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

the social characteristics in these two quadrants may affect the stability of the network. It is therefore suggested that an online social network focusing too much on group commitment might not achieve sustainability. On the other hand, the simulation experiments supported our proposition that online networks need structural control. Having no control decreases attractiveness, credibility and, subsequently, content volume. An implication for an actor in a real system is to carefully monitor the growth of the network in the early stages and then impose rules and regulations as soon as the network begins to grow. While an open environment accelerates the growth of an online network at the early stage, openness may negatively impact quality and subsequently the attractiveness of the network, so that users will be less inclined to join or to participate in the network. The findings of our study have practical implications that can be used in corporate settings, given that at the core of an online network are social dimensions. Network operators can use our model to assess how structural interventions shape online network growth and what policies must be in place to achieve sustainability.

While many factors, internal as well as external, may contribute to the success of an open social network, our aim was to gain insights into how high-level interventions change the shape of the network. Despite the limitations associated with our cultural typology for organizational analysis, experiments with the simulation model can provide useful insights to help manage an online network effectively.

Of course, a number of issues remain open. For example, future research must identify explicit measures for the grid/group dimensions in the organizational context. This paper is based on a dynamic theory to help develop an understanding of how structural interventions affect the sustainability of an online network. The task remains, however, to establish reliable, valid and distinctive measures for the social dimensions of the grid/group typology and to empirically assess the simulation model. Given the growing importance of online social networks to facilitate information exchange, and given the small number of system dynamics models that have addressed the dynamic nature of online networks over the years, we believe that the SD community can and must contribute to this research agenda.

Notes

1. Alexa.com defines "reach" per million viewers. When Wikipedia's reach per million hit 10,000 in June 2005, it meant that 1% of Internet users with the Alexa toolbar were visiting Wikipedia each day. In September 2006 this figure reached 50,000 or 5%. The percentage of Internet users who visit Wikipedia in a longer period, such as a week or a month, will be higher than that, as further Internet users visit it each day, but it cannot be calculated from the information published by Alexa.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

2. Wikipedia hit by surge in spoof articles, http://www.timesonline.co.uk, December 15, 2005.

Supporting information

Supporting information may be found in the online version of this article.

Acknowledgements

The authors wish to thank the guest editors of this special issue and two anonymous referees for their detailed suggestions, which improved the quality of this paper. We also wish to thank participants of the System Dynamics Conference in Boston, 2007, for their suggestions when we presented an earlier version of this paper. Furthermore, we are indebted to George Richardson for providing us with insightful comments and detailed discussions.

References

Allen TJ. 1977. *Managing the Flow of Technology*. MIT Press: Cambridge, MA.

Altman Y, Baruch Y. 1998. Cultural theory and organizations: analytical method and cases. *Organization Studies* **19**(50): 769–785.

Baalen P, Bloemhof-Ruwaard J, Heck E. 2005. Knowledge sharing in an emerging network of practice: the role of a knowledge portal. *ERIM Report Series: Research in Management*, Erasmus University Rotterdam, The Netherlands.

Bagozzi RP, Dholakia UM. 2006. Open source software user communities: a study of participation in Linux user groups. *Management Science* **52**(7): 1099–1115.

Barlas Y. 1996. Formal aspects of model validity and validation in system dynamics. *System Dynamics Review* **12**(3): 183–210.

Bergquist M, Ljungberg J. 2001. The power of gifts: organising social relationships in open source communities. *Information Systems Journal* **11**(4): 305–320.

Brown JS, Duguid P. 1991. Organizational learning and communities of practice: toward a unified view of working, learning, and innovation. *Organizational Science* **2**(1): 40–57.

——. 2000. *The Social Life of Information*. Harvard Business Press: Boston, MA.

Burns T, Stalker GM. 1961. *The Management of Innovation*. Tavistock: London.

Cohen BP, Zhou X. 1991. Status processes in enduring work groups. *American Sociological Review* **56**: 179–188.

Coleman JS. 1990. *Foundations of Social Theory*. Belknap Press: Cambridge, MA.

Contu A, Willmott H. 2003. Re-embedding situations: the importance of power relations in learning theory. *Organization Science* **14**(3): 283–296.

Dalle JM, David PA. 2003. *The Allocation of Software Development Resources in 'Open Source' Production Mode*. Discussion paper 02-27. Stanford Institute for Economic Policy Research: Stanford, CA.

Diker V. 2003. Building a theory of open online collaboration using system dynamics.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

In *Proceedings of the 21st International Conference of the System Dynamics Society*, July 20–24, New York City, USA. (CD–ROM).
——. 2004. A dynamic feedback framework for studying growth polices in open online collaboration communities . In *Proceedings of the Tenth Americas Conference in Information Systems*, New York, August 2004.
Douglas M. 1970. *Natural Symbols: Explorations in Cosmology*. Barrie & Rockliff: London.
——. 1978. *Cultural Bias*. Royal Anthropological Institute: London.
Forrester JW. 1961. *Industrial Dynamics*. MIT Press: Boston, MA. Now available from Pegasus Communications, Waltham, MA.
Forrester JW, Senge PM. 1980. Tests for building confidence in system dynamics models. In *System Dynamics*, Vol. 14, Legasto Jr AA *et al.* (eds). North-Holland: New York; 209–228.
Franke NE, von Hippel E. 2003. Satisfying heterogeneous use needs via innovation toolkits: the case of Apache security software. *Research Policy* **32**(7): 1199–1215.
Gosh RA, Glott R, Krieger B, Robles G. 2002. *Free/Libre and Open Source Software: Survey and Study*. Working Paper. International Institute of Informatics, University Maastricht: Maastricht, The Netherlands.
Gross JL, Rayner S. 1985. *Measuring Culture*. Columbia University Press: New York.
Gu B, Jarvenpaa S. 2003. Online discussion boards for technical support: the effect of token recognition on customer contribution. In *Proceedings of the 2003 International Conference on Information Systems*, Salvatore T. March, Anne Massey (eds), Seattle, WA, 14–17 December.
Handy C. 1986. *Understanding Organizations*. Penguin: London.
Harrison R. 1972. Understanding your organization's character. *Harvard Business Review* May–June: 119–128.
Holland JL. 1994. Separate but unequal better. In *Convergence in Career Development*, Savickas ML, Lent RW (eds). CPP Books: Palo Alto, CA.
Inkpen AC, Tsang EK. 2005. Social capital, networks, and knowledge transfer. *Academy of Management Review* **30**(1): 146–165.
Jones C, Hesterly WS, Borgatti SP. 1997. A general theory of network governance: exchange conditions and social mechanisms. *Academy of Management Review* **22**(4): 911–945.
Katsamakas E, Georgantzas N. 2007. A system dynamics model of open source software development. In *Proceedings of the 25th International Conference of the System Dynamics Society*, 30 July, Boston, MA.
Krackhardt D. 1992. The strength of strong ties: the importance of philos in organizations. In *Organizations and Networks*, Nohria N, Eccles R (eds). Harvard Business School Press: Boston, MA; 216–239.
Kraut RE, Egido C, Galagher J. 1990. Patterns of contact and communication in scientific research collaboration. In *Intellectual Teamwork*, Kraut RE, Egido C, Galagher J (eds). Lawrence Erlbaum Associates: Hillsdale, NJ.
Kunda G. 1992. *Engineering Culture*. Temple University Press: Philadelphia, PA.
Lave J, Wenger E. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press: Cambridge, UK.
Lin N. 2001. *Social Capital*. Cambridge University Press: Cambridge, UK.
Miles RE, Snow CC. 1978. *Organizational Strategy, Structure, and Processes*. McGraw-Hill: New York.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr

Mintzberg H. 1979. *The Structuring of Organizations: A Synthesis of the Research*. Prentice-Hall: Englewood Cliffs, NJ.
Nahapiet JSG. 1998. Social capital, intellectual capital and the organizational advantages. *Academy of Management Review* **23**(2): 242–266.
Nonaka L. 1994. A dynamic theory of organizational knowledge creation. *Organization Science* **5**(1): 14–35.
Pelled LH. 1996. Demographic diversity, conflict, and work group outcomes: an intervening process theory. *Organization Science* **7**: 615–631.
Putnam R. 1993. *Making Democracy Work: Civic Traditions in Modern Italy*. Princeton University Press: Princeton, NJ.
Putnam R. 1995. Bowling alone: America's declining social capital. *Journal of Democracy* **6**: 65–78.
Richardson GP, Pugh AL III. 1981. *Introduction to System Dynamics Modeling with DYNAMO*. MIT Press: Cambridge, MA. Now available from Pegasus Communications, Waltham, MA.
Sackmann SA. 1992. Culture and subcultures: an analysis of organizational knowledge. *Administrative Science Quarterly* **37**: 140–161.
Sterman JD. 1989. Modeling managerial behavior: misperceptions of feedback in a dynamic decision making experiment. *Management Science* **35**(3): 321–339.
——. 2000. *Business Dynamics: System Thinking and Modeling for a Complex World.* Irwin/McGraw-Hill: New York.
Subramani MR, Peddibhotla N. 2002. Contributing to document repositories: an examination of prosocial behavior. Working paper, Carlson School of Management, University of Minnesota, MN.
Thibaut BK, Kelly HH. 1959. *The Social Psychology of Groups*. Wiley: New York.
Thompson M. 2005. Structural and epistemic parameters in communities of practice. *Organization Science* **16**(2): 151–164.
Thompson M, Wildavsky A. 1986. A cultural theory of information bias in organizations. *Journal of Management Studies* **23**(3): 273–286.
Thompson M, Ellis R, Wildavsky A. 1990. *Cultural Theory*. Westview: Boulder, CO.
Thorn BK, Connolly T. 1987. Discretionary data bases: a theory and some experimental findings. *Communication Research* **14**(5): 512–528.
Voss J. 2005. *Measuring Wikipedia*. Reprint 2005-04-12, Institute for Library Science, Humboldt University, Berlin.
Wasko MM, Faraj S. 2000. Is it what one does: why people participate and help others in electronic communities of practice. *Journal of Strategic Information Systems* **9**(2–3): 155–173.
——. 2005. Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. *MIS Quarterly* **29**(1): 35–57.
Wellman B, Wortley S. 1990. Different strokes for different folks: community ties and social support. *American Journal of Sociology* **96**: 558–588.
Wenger E. 1998. *Communities of Practice*. Cambridge University Press: Cambridge, UK.
Wenger E, McDermott R, Snyder W. 2002. *Cultivating Communities of Practice*. Harvard Business School Press: Combridge, MA.

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/sdr