

# Understanding the Revisioning of Network Pictures – Insights from an Agent Based Modeling Approach

*Competitive paper for the 28<sup>th</sup> IMP 2012 Conference, Rome*

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## **ABSTRACT**

Industrial marketing research has recently focused on managers' "network pictures". Network pictures are a manager's subjective mental representations of their relevant business environment. However, longitudinal research on changes in network pictures is scarce, although the concept is found at the core of networking and thus impacts network outcomes. Constant change in a network places a high emphasis on a manager's ability to make sense of network changes and revise the network picture. This study contributes to the discussion on the relation between network pictures, networking, and network outcomes by researching a manager's ability to revise the network picture in differing business environments. The issue is approached through simulation, and more specifically using agent based modeling. We propose that a manager who can revise the network picture faster benefits more in a dynamic business environment than one who can only do so slowly. However, in a business environment with a greater trend for change, the gap between the fast and slow reviser narrows. In addition, the combination effects of the variables of interval time and trend indicate the business environments in which a slow reviser of network pictures gains on the fast reviser. That occurs in cases where the interval time of changes is either extremely low or high, or when the trend of changes rises.

**Keywords** – Network Pictures, Business Networks, Simulation, Agent Based Modeling

## INTRODUCTION

In today's world, business is increasingly networked. The ability to understand business networks and relationships in the business-to-business context has become an important part of everyday business life, which has in turn during past decades resulted in an extensive body of academic literature on the topic (e.g. Ford, 1980; Gadde, Huemer, and Håkansson, 2003). The Industrial Marketing and Purchasing (IMP) research group has led this discussion. Actors in a network are not considered to exist in isolation but as interdependently interacting actors forming the network. Operating in these business networks is fundamentally based on a person's subjective perceptions of the network. Thus, all persons in the network have their own different, subjective "picture" of the network (Ford, Gadde, Håkansson, and Snehota, 2003). These pictures, formed of the person's perceptions, experiences and presumptions, are in essence mental structures that act as the foundation for managers' understanding of relationships, interaction and interdependencies, and thus are also fundamental to the actor's decision making process (Henneberg, Mouzas, and Naudé, 2006). According to Gary and Wood (2011), the more accurate mental models of the causal relationships in the business environment are linked to higher performance outcomes. These subjective mental structures are therefore a concept central to managing networks and in that sense a relevant issue for study. This perspective has attracted growing interest in the academic literature (e.g. Fiol and Huff, 1992, Ford, Gadde, Håkansson, and Snehota, 2003; Henneberg, Mouzas, and Naudé, 2006; Colville and Pye, 2010; Gary, and Wood, 2011).

Authors in the IMP group have developed the network picture concept to describe these mental models, which is defined as "the different understanding that players have of the business network in which their focal company is operating" (Henneberg, Mouzas, and Naudé, 2009, p. 95). Network pictures are found to be the product of subjective and ongoing sense-making, constituting characteristics of the network in which the actor operates (Henneberg, Mouzas, and Naudé, 2006). The existing literature on the network picture concept focuses on defining the dimensions of the network picture (e.g. Henneberg, Mouzas, and Naudé, 2006; Leek and Mason, 2010), discussing its nature (e.g. Colville and Pye, 2010; Geiger and Finch 2010), and creating a model to study network pictures from both the academic and managerial perspectives (Leek and Mason, 2009; Leek and Mason, 2010; Ramos and Ford, 2011). The network picture discussion has thus far addressed the development of the concept at the theoretical level, offering some empirical evidence (Henneberg, Mouzas and Naudé, 2006; Öberg, Henneberg, and Mouzas, 2007; Leek and Mason, 2009; Leek and Mason, 2010).

There still seems to be a dearth of longitudinal studies on network picture changes, albeit with some exceptions (e.g. Ford and Redwood, 2005; Öberg, Henneberg, and Mouzas, 2007). The constantly changing network emphasizes an actor's ability to make sense of changes and revise the network picture. Thus, understanding the dynamic nature of the network picture is essential in constructing theory around it (Colville and Pye, 2010). The purpose of this study is to increase understanding of the dynamic nature of network pictures, and is approached through a longitudinal examination of the relation between a change in the network and a person's ability to revise the network picture. The research question is phrased *How does a manager's ability to revise the network picture affect the quality of decisions in a dynamic business environment?* It is presupposed that if the network picture corresponds broadly to the network conditions at a given point in time, decision quality is high. And vice versa, if the network picture does not correspond to the network conditions at a given point in

time, decision quality is poor. High quality decisions are supposed to lead to positive network outcomes.

The research question is approached by means of simulation, a form that has been used since the 1950s to understand dynamic behavior (Forrester, 1958). Recent papers have recognized simulation as a suitable tool for management research (Warren, 2005; Gary, Kunc, Morecroft, and Rockard, 2008; Gary and Wood, 2011), B2B marketing research (Watkins and Hill, 2009), and for modeling industrial networks (Folgesvold and Prenkert, 2009). In addition, simulation has attracted growing interest among the IMP group researchers (Wilkinson and Young, 2011). The form's particular strength is that simple models can be employed to support research on abstract phenomena that are hard to study quantitatively using traditional research methods, and especially when a longitudinal research approach is needed. Both factors are central to our research focus, since we are interested in the effect of revising the network picture on decision making quality. First, the network picture concept is inherently abstract, making its measurement empirically challenging. Second, the interest in the change process requires a longitudinal approach, as change occurs over time. Since the research focuses on individual entities, agent based modeling was perceived to be a good approach to modeling the problem (Schelling, 1969; Macal and North, 2006; Gilbert, 2008). Agent based modeling concentrates on individual decision makers, who employ local information and make local decisions to reach their desired goal (Wooldridge and Jennings 1995).

We develop a simulation model of a changing network between firms and the perceived network picture of a variety of decision makers who are assumed to have different abilities in renewing their picture. The primary test variables are endogenous and control the process of change; variables such as interval time, amplitude, or trend intensity of change. The simulation is executed using agent based modeling, which enables the creation of freely forming and developing network structures. The developed model describes how the relationships in a network created by firms at three different levels develop over time, and how managers with different aptitudes to revise network pictures perform in trying to make sense of that network. The selected test variables are shown to control the value of being able to be a fast network picture reviser.

## **COGNITIVE PERSPECTIVE ON THE RESEARCH OF BUSINESS NETWORKS**

Network research has a long tradition, being the object of interest in several disciplines (e.g. sociology, social-psychology, computer sciences, business studies). A collective feature of these disciplines is that an actor is perceived to be related to a theoretically unlimited number of other actors forming a network, wherein individual actors' actions are perceived to affect other actors and their actions. Thus, the object of interest is usually the network itself rather than a single actor. In the business studies domain, networks are discussed in several forms (e.g. supply networks, communication networks, relationship networks). A study on business networks can be grounded on several perspectives, such as organizational networks (Wasserman and Faust, 1994), social networks (Laumann, Galaskiewicz, and Marsden, 1978), and egocentric organizational networks (Gulati, 1998). In addition, among Industrial Marketing and Purchasing (IMP) group researchers, the network perspective has evolved (Ford, 1980; Ford, Håkansson and Johanson, 1986; Håkansson and Johanson, 1992). That perspective is based on the ontological view that markets are interconnected webs of dependent exchange relationships (Anderson, Håkansson and Johansson, 1994; Easton and

Håkansson, 1996). Furthermore, according to the IMP perspective, a core requirement in understanding networks is to understand the interactions of the parties within that network (Ford and Håkansson, 2006). These networks are perceived as relativistic in nature and it is said that there is no single, objective network. A network is not owned by any company, nor can it be centrally managed, although all firms try to manage in it. Also, no company is the hub of the network as there is no “center”, although many companies may believe that they are at the center. (Ford, Gadde, Håkansson, and Snehota, 2003).

The interactions in the network take many forms and one of the main challenges for a manager in business-to-business markets is to understand these multiform interactions. In recent years, the academic interest in business studies has emphasized the manager’s ability to operate in the network environment. In addressing one aspect of this issue, research examining the role of managerial cognition has shown that understanding managers’ cognitive mental structures is focal in studying successful network operations (Simon, 1991; Henneberg, Naudé and Mouzas, 2010; Gary and Wood, 2011). Research on a person’s cognitive mental structures is not a novel area. The prior research offers several disciplines in which to study a person’s mental model, such as managerial and organizational cognition (Huff, 1992; Huff and Eden, 2009), the sense-making literature (Louis, 1980; Weick, 1995), psychology including social psychology (Markus and Zajonc, 1985; Markus, 2005), and cognitive psychology (Eysenck and Keane, 2010; Manktelow, 2008). These disciplines offer concepts, such as cognitive maps (Ring and Rands, 1989; Fiol and Huff, 1992), schemas (Markus and Zajonc, 1985; Harris, 1994), mental models (Hodgkinson and Johnson, 1994; Osborne, Stubbart and Ramaprasad, 2001), heuristics (Eysenck and Keane, 2010), dominant logic (Bettis and Prahalad, 1995), and belief systems (Rokeach, 1968; Grube, Mayton and Ball-Rokeach, 1994). Generally, the mental structures can be understood as a person’s simplified knowledge structures or cognitive representation of how the business environment works. The focus in these concepts typically lies in the entire business environment, including for example human resource policies, earning logics, and existing business relationships. However, the IMP research group’s focus remains trained on the interaction of the parties in the network. In addition, dissimilar ontological assumptions or alternative viewpoints to sense-making differentiate the IMP perspective from that of the existing literature (Henneberg, Naudé and Mouzas, 2010). Thus, a dissenting stream of discussion concerning cognitive mental structures has evolved among the IMP research group.

Building on the concept of network theories, a notion has developed that all persons in the network have their own different, subjective “picture” of the network (Johanson and Mattson, 1992; Ford, Gadde, Håkansson, and Snehota, 2003). These pictures are based on the person’s perceptions, experiences and presumptions. Nevertheless, these mental structures are the foundation for managers’ understanding of relationships, interaction and interdependencies, and thus are also fundamental to the actor’s decision making process (Henneberg, Mouzas, and Naudé, 2006). Therefore, these subjective mental representations of the surrounding network are a central concept to managing in networks, and thus a relevant issue for study. IMP group research has proposed that the network picture concept describes “the different understanding that players have of the business network in which their focal company is operating.” (Henneberg, Mouzas, and Naudé, 2009, p. 95). These network pictures are argued to be the result of the “subjective, idiosyncratic sense-making with regard to the main constituting characteristics of the network in which their company is operating.” (Henneberg, Mouzas, and Naudé, 2006, p. 409). Thus, the network pictures are retrospective in nature, constructed of past events. However, the pictures form a basis for prospective decisions and thus shape organizations’ future options (Weick, 1979).

The network pictures are an individual's interpretation of the surrounding network, and thus the foundation for decision making (Ford, Gadde, Håkansson, and Snehota, 2003; Henneberg, Mouzas, and Naudé, 2006; Colville and Pye, 2010). The relation between network pictures and operations in the network is therefore evident. Ford, Gadde, Håkansson, and Snehota (2003) have suggested a model that grasps the composition, one of managing in networks. The model comprises the interconnected elements of network pictures, networking, and network outcomes. The networking element comprises all the interactions of a company or an individual. Networking is an ongoing process in which all actors are networking simultaneously. The essential feature is that networking is affected by the network pictures (Ford, Gadde, Håkansson, and Snehota, 2003; Corsaro, Ramos, Henneberg, and Naudé, 2011). This linkage of managerial cognition and managerial behavior is found also in other research streams (Thomas, Clark, and Gioia, 1993; Gioia and Chittipeddi, 1991). Ultimately, the network pictures impact the network outcomes (Ford, Gadde, Håkansson, and Snehota, 2003). Conversely, the network outcomes affect the actor's network pictures and thus also networking. If the network outcomes are in line with the present network picture, the outcomes validate the picture. On the other hand, if the outcomes are not in line with the network picture, it will most likely be revised (Ford, Gadde, Håkansson, and Snehota, 2003). Thus, these three elements are at the heart of an ongoing process, in which an actor's network picture is revised by the network outcomes as well as by networking itself.

As a person's mental structures have various bases in the literature, change in a mental structure has been an object of interest in various research streams. Since network pictures are found to be a result of the ongoing sense-making process (Henneberg, Mouzas, and Naudé, 2006), the change of a network picture is closely related to the process of cognitive sense-making. According to Weick, Sutcliffe, and Obstfeld (2005), sense-making involves the ongoing retrospective development of plausible images that rationalize what people are doing. The organizational learning literature based on organizational theory has also focused on the change of mental models through individual learning (Kim, 1993; Bontis, Crossan, and Hulland, 2002). The literature explains the nature of learning ability through the concept of absorptive capacity, which refers to the "ability to recognize the value of new information, assimilate it, and apply it to commercial ends." (Cohen and Levinthal, 1990, p. 128). Zahra and George (2002, p. 186) redefine the concepts at the firm level as "a set of organizational routines and processes by which firms acquire, assimilate, transforms and exploit knowledge to produce a dynamic organizational capability." The nature of absorptive capacity is found to be cumulative, meaning that prior related knowledge confers an ability to recognize the value of new information (Cohen and Levinthal, 1990). Dyer and Singh (1998) and Lane and Lubatkin (1998) further develop the conception of absorptive capacity by finding that the ability to learn is jointly determined by the relative characteristics of the parties. Furthermore, Peters and Johnston (2009) extends the research on absorptive capacity from dyadic level to network level.

The existing literature on the network picture concept focuses on defining the dimensions of the network picture (e.g. Henneberg, Mouzas, and Naudé, 2006; Leek and Mason, 2010), discussing its nature (e.g. Colville and Pye, 2010; Geiger and Finch 2010), and creating a model to study network pictures from both the academic and managerial perspectives (Leek and Mason, 2009; Leek and Mason, 2010; Ramos and Ford, 2011). The network picture discussion has thus far addressed the development of the concept at the theoretical level, offering some empirical evidence (Henneberg, Mouzas and Naudé, 2006; Öberg, Henneberg, and Mouzas, 2007; Kragh and Andersen, 2009; Leek and Mason, 2009;

Leek and Mason, 2010). Meanwhile, Henneberg, Naudé and Mouzas (2010) note that research on the relation between networking and revising network pictures remains sparse, although the impact on the outcomes and positioning in the network has been recognized (Ford, Gadde, Håkansson, and Snehota, 2003; Corsaro, Ramos, Henneberg, and Naudé, 2011). In addition, there still seems to be a dearth of longitudinal studies on network picture changes, with some exceptions adopting a well framed perspective (e.g. Ford and Redwood, 2005; Öberg, Henneberg, and Mouzas, 2007). However, the constantly changing network emphasizes an actor's ability to make sense of changes and revise the network picture. Thus, understanding the dynamic nature of network pictures is essential in constructing theory around it (Colville and Pye, 2010). The present study aims to address these gaps in the network pictures research.

## **SIMULATION MODEL**

Simulation has been put forward as a suitable tool for management research (Warren, 2005; Gary, 2005), B2B marketing research (Watkins and Hill, 2009), and to model industrial networks (Folgesvold and Prenekert, 2009). In addition, simulation has attracted growing interest from the IMP group (Wilkinson and Young, 2011). Its particular strength is that simple models can be used to support research on abstract topics that are hard to study quantitatively using traditional research methods, especially when a longitudinal research approach is needed. Both of these elements are central to the research focus here, given our interest in the effect of revising network pictures on decision making quality. The network picture concept is inherently abstract so its measurement is empirically challenging, and research on the change process requires a longitudinal view as change happens over time. Simulation was therefore selected as the research approach for this paper.

More specifically we selected agent based modeling, which utilizes a bottom-up approach where the behavior of the system emerges through the interaction of the agents (North and Macal 2007). Agents have the same basic properties. According to Wooldridge and Jennings (1995) these are: autonomy, social ability, reactivity, and pro-activeness. The agents are located in an environment where they collect local information and make decisions, which impacts other agents or modifies the environment (Wooldridge and Jennings 1995). Usually the models contain stochastic elements (North and Macal 2007). Agent based modeling is an especially powerful tool in the simulation of different types of network, as all models based on this method are essentially a network built on agents. Although agent based models allow for the dynamic restructuring of the network (e.g. in this case the addition or removal of firms in the business environment), we decided to simplify the model and simulate a structurally static business environment.

## **MODEL STRUCTURE**

The objective for the agent based model is to simulate two distinctively different tasks. First, to create the simulated business network environment and the necessary dynamism in the relationships between the firms operating in the network. Second, the managerial perspective that aims to model how different managers can cope in this environment.

The objective for the simulation model is to create a life-like business environment. The model is constructed to represent a situation where a company is selecting the appropriate partners from the firm's external environment with whom to co-operate. Thus,

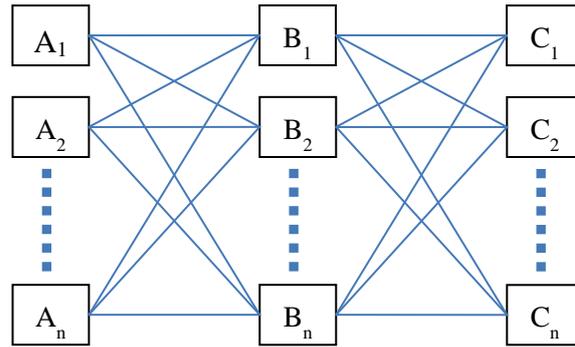
the model needs to simulate an environment describing different types of firm and their relationships. The simulation is then used to simulate the dynamic relationships between firms, which emulates a dynamic and constantly changing dynamic business environment in the model.

The model's second purpose is to simulate decision making executed by managers with different attributes. These managers collect local information and make decisions of their own based on that information, and thus are the agents in the model. Each manager is assumed to be identical in every other dimension, but their initial network picture is different and each possesses different abilities to revise their network picture. As the focus of our research is on network pictures, we focus the simulation at the managerial level on each manager's individual network picture. The network picture represents a single manager's understanding of the network formed by the external companies. This picture changes over time as the manager makes sense of the business environment. The model highlights the disparity between the simulated business environment and the manager's network picture.

The performance of each manager is assessed through the quality of their decisions, which is determined by the manager's ability to find the most efficient combination of firms as calculated from the business environment simulation. The managers will always make the best possible decision facilitated by their network picture. However, decision quality is likely to differ just as the manager's network picture differs in the simulated status of the network. This kind of structure leads to a situation where the manager with the best network picture, in this case the minimum of error in the picture at any given time, will make the best decisions. As the network is assumed to be dynamic, the manager's ability to learn, or revise their network picture, becomes significant. Decision quality is also affected by changing costs, which are realized when a manager decides to reselect the combination of firms. The changing costs are realized as the diminishing performance of that new combination of firms. In the model changing costs are implemented with diminished performance to 75% from previous. After the change the performance increases with linear manner and achieves the full performance in 10 simulation rounds. In practice the changing costs occur, for example, when new partners have to learn to work with each other. The following section provides a more thorough description of how the parts of the model were executed and combined.

### *Business environment*

The business environment is simulated as a network comprising three different types of company (A, B, C). Each company describes a layer in a supply chain and all three layers are needed in order to produce a service. The simulated network describes how effectively firms from one level of the supply chain are able to work those from another, simplified so that only connections between companies on levels A to B and on levels B to C are simulated (Figure 1). The structure of the simulated network is presumed to be static, but the value of each link is dynamic. In practice, this means that the number of firms at different levels does not change, but a firm's ability to work with other companies in different supply chain levels in a network changes over time.



**Figure 1.** Structure of the network.

The dynamics of the companies' co-operation linkages are controlled for by a set of variables which describe environmental dynamism (Dess and Beard, 1984) that refers to the rate of change, instability, absence of pattern and unpredictability (Dess and Beard, 1984; Priem, Rasheed, and Kotulic, 1995; Hough and White, 2004; Street, Street, and Lamont, 2010). In the present study, we operationalize three variables; interval time, amplitude, and trend. The first, interval time of changes, refers to the instability of the environment (Street, Street, and Lamont, 2010). The network change is implemented as a discrete event causing the co-operation connections to change between static intervals. The control for the length of this interval is interval time. The second variable is amplitude, which refers to the rate of change (Dess and Beard, 1984; Priem, Rasheed, and Kotulic, 1995) and controls the average size of a change in the co-operation network, but the actual size is implemented randomly. The final variable of change is trend, referring to the unpredictability and absence of patterns of environmental change (Dess and Beard, 1984; Hough and White, 2004; Street, Street, and Lamont, 2010). The trend variable controls for the randomness of change. When the trend is high, the co-operation change is more likely to develop in a similar direction to that during previous change. If the trend is low, both the change and the development of the network are more random.

The actual change in the model is implemented with random functions that define how much each of the firm linkages will change. The values of the random functions are dependent on the model parameters. The amplitude parameter controls for the size of change. The interval time describes how often the random change occurs in the model. The third variable, trend, controls for the likelihood of the change continuing in the same direction as during previous change. A high trend value implies that the change of linkages between firms becomes more predictable.

### *Manager's network picture*

The manager's network picture is implemented as a simple system dynamic model. The model contains system dynamic stocks that describe the manager's current vision of the quality of connections between different companies. When the manager's view is compared to the simulated network, a gap can be calculated which represents the discrepancy in the manager's network picture. The gap also represents how much more accurate the manager's network picture could be. Revision is implemented as a continuous change for which the control is the size of the gap, the manager's absorptive capacity, and the manager's ability to revise the network picture; this is used to separate the revisers with different capabilities for revision; the faster reviser will revise a higher relational share of the gap than the slow

reviser. The cumulative nature of the absorptive capacity (Cohen and Levinthal, 1990) dimension implies that if the manager’s view is highly erroneous, it is challenging for them to revise their network picture. Once the manager’s knowledge and understanding of the situation improves, the change becomes easier. The selected implementation method results that the numerical behavior of manager’s network picture closes asymptomatic the simulated network, but it can never be exactly right.

The manager’s network decision is also implemented using the system dynamic model, the selection enacted through brute force. The function travels through the whole network in each simulation round, searching for the best possible connections between the firms. This kind of approach provides an accurate optimization algorithm, but from a technical perspective makes the model difficult to simulate. The presupposition is that if the network picture corresponds broadly to the network conditions at a certain point in time, decision quality is high, and vice versa. High quality decisions are supposed to lead to positive network outcomes. The presupposition is supported by the extant literature which claims that an appropriate network picture helps actors achieve desired outcomes, especially when the specific occasion demonstrates high ambiguity and uncertainty (Weick, 1995; Henneberg, Mouzas and Naudé, 2006). In addition, it is presupposed that the revision of the network picture is always enacted towards the existing network conditions at a certain point in time.

### SETTING UP THE SIMULATION

The simulation model was tested with parameter variation. Table 1 below shows each variable and the range of values used in the simulation. As the model is based on random functions, the results were also analyzed using Monte Carlo methodology. The Monte Carlo Method was first presented to analyze physical problems (Metropolis and Ulam 1949), but it is also frequently used with simulation models. Monte Carlo random variables are assigned different values according to predefined probability distributions, and the results are expressed as a set of probability distributions (North and Macal 2007). Effectively, the employment of Monte Carlo analysis leads to many simulation rounds with the same parameter settings, which we analyzed in our results by taking the average value from each repetition. The selected number of repetitions in the Monte Carlo analysis was 100. The simulation time step was one week and total simulation time 520 rounds, implying that the simulation time represents 10 years. Anylogic software is applied for the simulation.

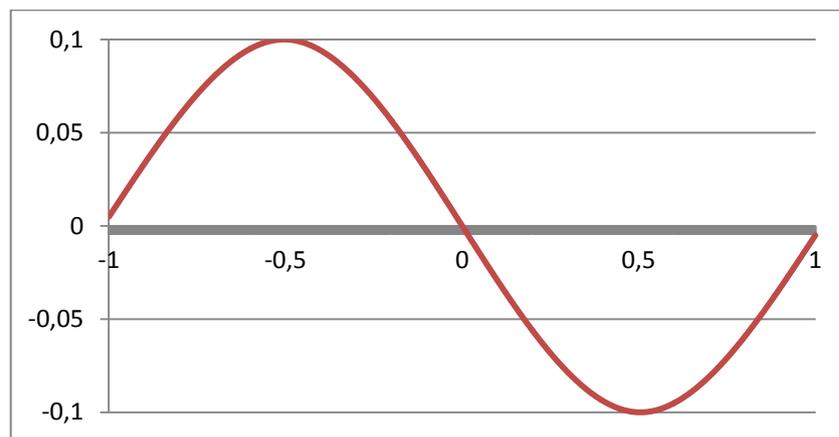
**Table 1.** Parameter variation in the simulation model.

Variable	Description	Values	Increment
Interval time	Interval time of changes	10 – 100	10
Amplitude	Average size of change in the real network	0 – 0.2	0 – 0.04
Trend	Trend dependency in development	0 – 100	10

The true link values change according to interval time, amplitude, and trend. Interval time represents the change interval; the lower the value, the more frequent the changes. At an interval time of ten, the true link values change every tenth time step. Amplitude indicates the maximum size of change, uniformly distributed with a minimum value of 0% and a maximum amplitude value. If amplitude is 0.1, the largest possible change is 10%. Trend represents the impact of previous change on current change; with the value set to 0, each change has a 50% chance of increasing or decreasing, while at 1 the change depends totally

on the previous value. The only exception is when the link has reached a value of 0 or 1, at which point trend has no impact on chance.

The individual managers revise their network picture according to their own, specific revision efficiency. Learning speed depends on the relative correctness of the network picture. If the picture is nearly complete, learning is very slow. On the other hand, if the view is totally erroneous, learning is also slow. As such, learning is fastest in the “middle ground”. Figure 2 represents the learning curve utilized in the study.

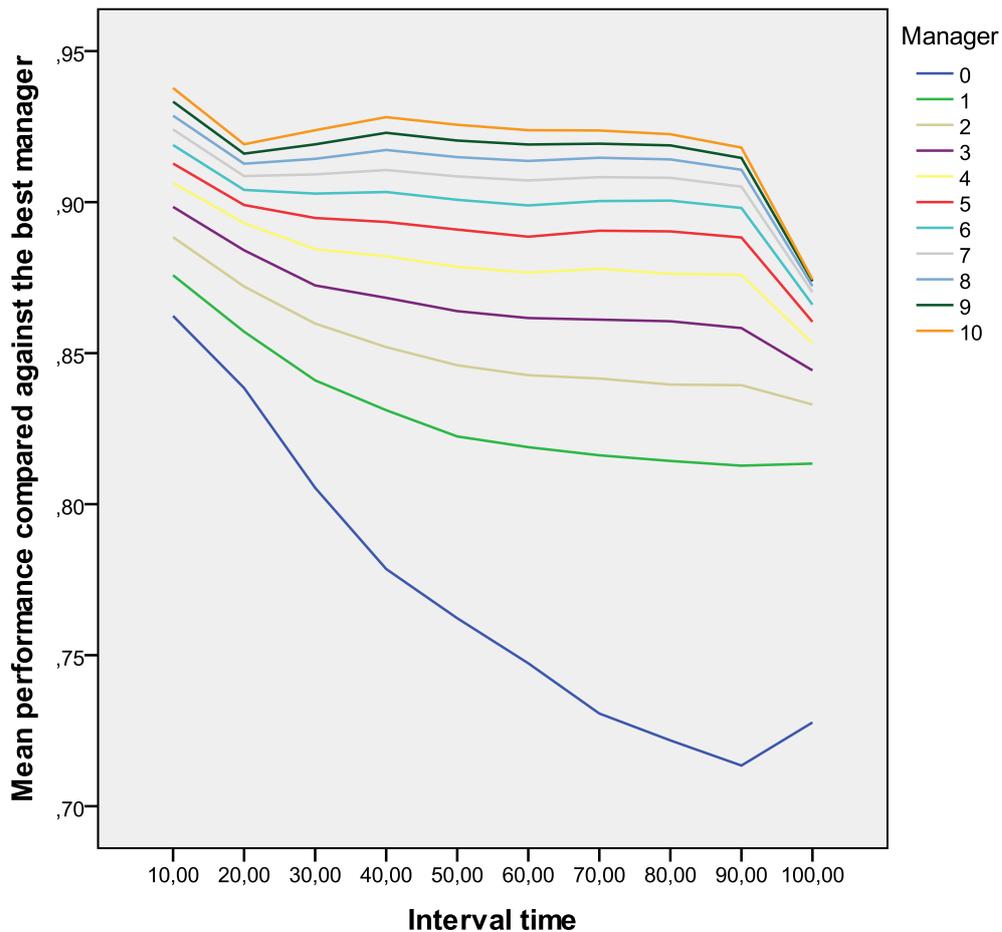


**Figure 2.** Learning curve.

The relative “gap” between the simulated and perceived value is shown on the x-axis. If the value is 0, the perceived value equals the simulated value. If the values are -1 or 1, the perceived value is either 0 or 1, while the simulated value differs from these. As such, if there are no changes in the network, learning follows an S-curve. The actual learning at the coordinator level is the value from the table function multiplied by learning efficiency.

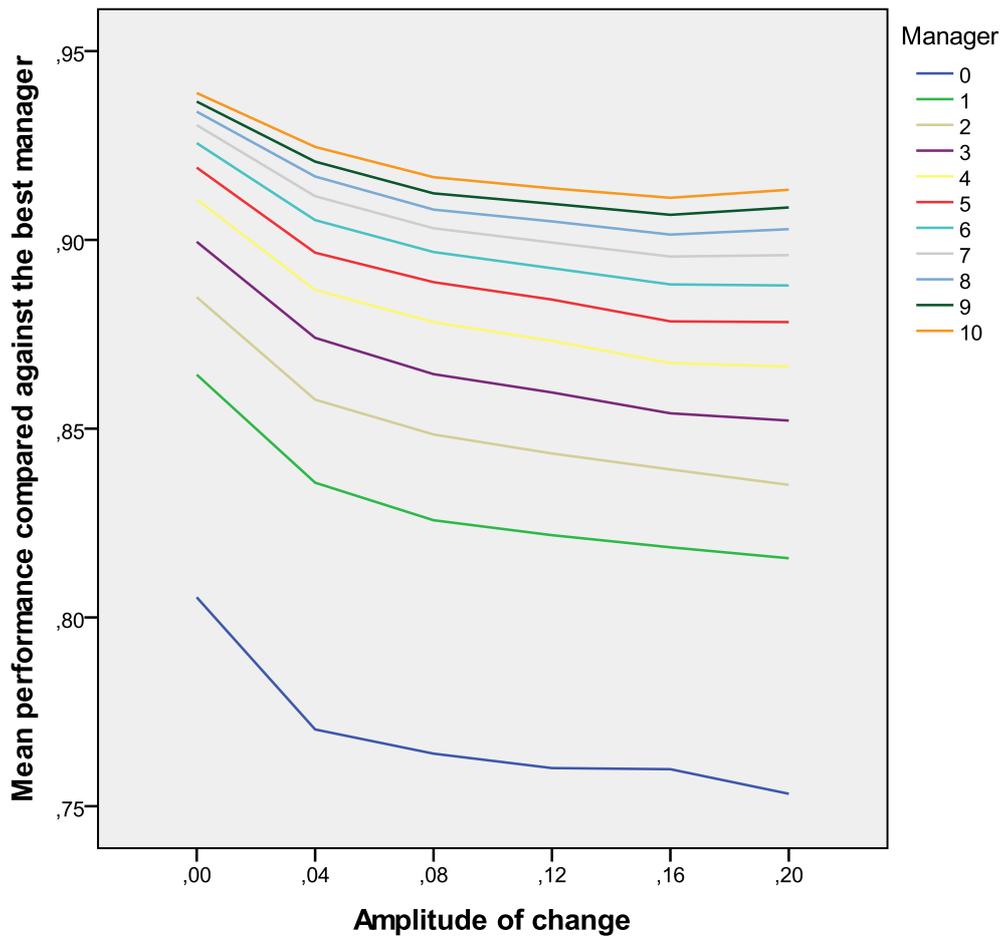
## SIMULATION RESULTS

The simulation model was analyzed both visually and statistically. We first present the visual results, which chart individual coordinators against specific environmental factors. Thereafter we present the regression models, which are used to estimate the impact of the interactions between the environmental factors. The first variable to study is the impact of interval times, presented in Figure 3.



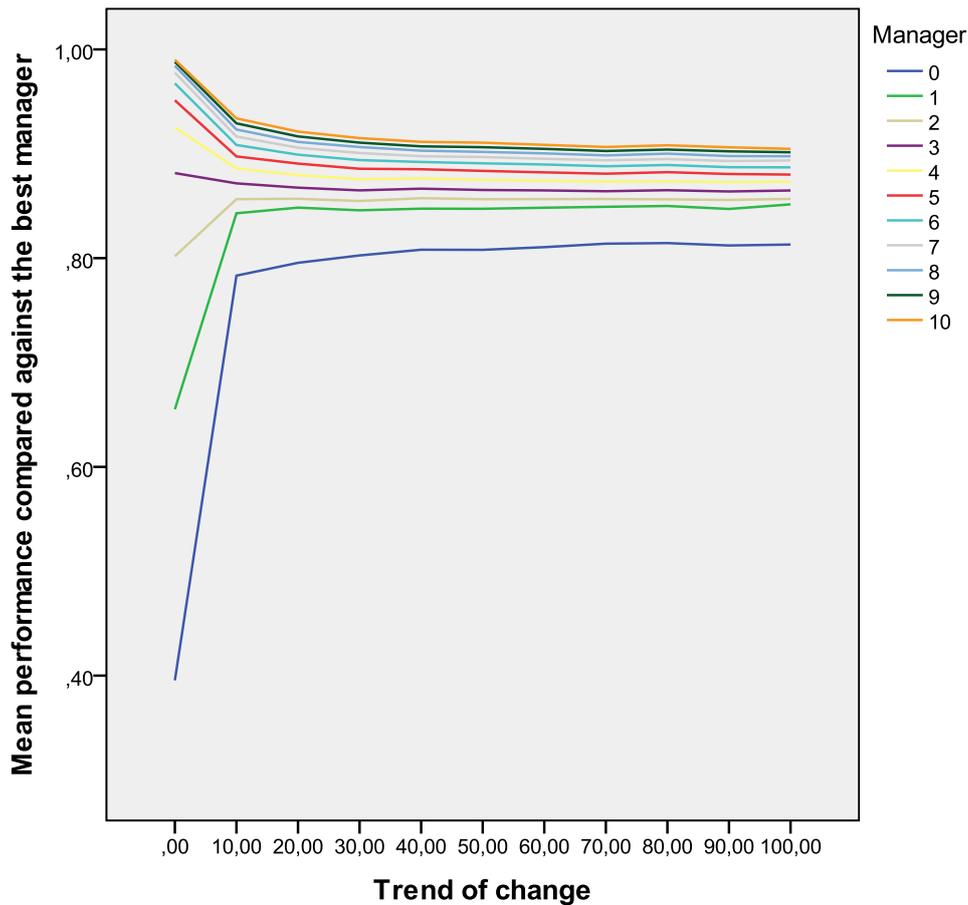
**Figure 3.** Impact of interval time.

As can be seen in Figure 3, the fast reviser always outperforms the slower revisers, no matter what the interval time. There is a sharp drop in the values when interval time is set to 100. This is most likely due to the simulation run time. When the network changes during the 500th time step, the faster revisers change their chosen connection more quickly and thus incur the penalty for the rest of the simulation run. The results reach a relatively stable plateau for the faster than average revisers (coordinators 5 through 10). The slower revisers suffer diminishing returns as the interval time increases. The results are similar to the amplitude of change, presented in Figure 4. The faster revisers achieve better profits than the slower revisers.



**Figure 4.** Impact of amplitude of change.

The final environmental variable, trend of change, has more interesting dynamics, as presented in Figure 5. At most values (all those above 0), there is little impact on the performance of individual revisers. As the trend change value increases, the difference between the coordinators decreases. However, when trend is set to 0, there is a large spread in the results. In a totally chaotic environment, faster learning speed is highly significant. On the other hand, if changes are systematic (trend in the direction of change), a faster learning speed still produces greater benefits, but the relative difference is smaller.



**Figure 5.** Impact of trend of change.

In addition to analyzing the results visually, linear regression analyses were also conducted. The relative performance between the fastest reviser and second slowest was analyzed using the environmental variables and their interactions as the independent variables. For the environmental variables (trend), a square root was used in the calculation to make the interaction between the variables more linear. Also, in order to analyze the interactions, the environmental variables were first standardized to make the comparison between the models more meaningful. The results are presented in Table 2.

**Table 2.** Regression model without interaction. The dependent factor is the relative performance of the slow reviser compared with the fast reviser. All of the independent variables are standardized.

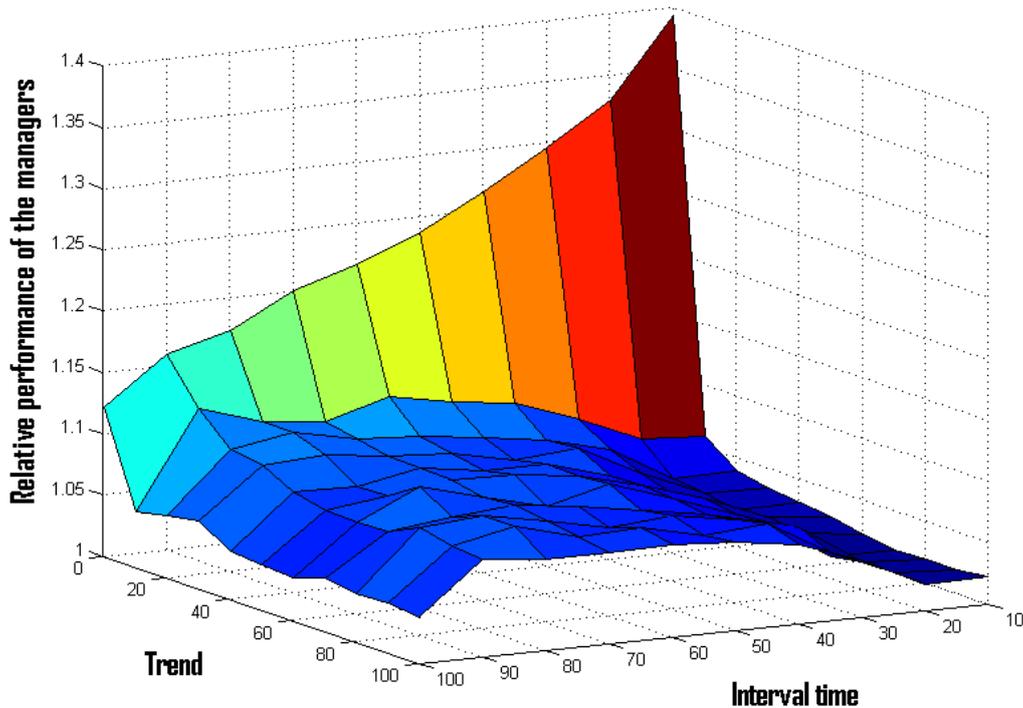
Term	Unstandardized Coefficient	t-value	Significance
Constant	1.082	597.106	0.000
Interval time	0.00472	2,602	0.009
Amplitude	0.00891	4.915	0.000
Square root of trend	-0.0414	-22.819	0.000

All the environmental factors have a statistically significant impact on the results. The R square for the regression model is 45.4%. There is also no multicollinearity between the independent factors and the residuals are relatively normally distributed. In the second regression model, the interactions between the environmental factors were included. These are presented in Table 3.

**Table 3.** Regression model with interaction. The dependent factor is the relative performance of the slow reviser compared with the fast reviser. All of the independent variables are standardized.

Term	Unstandardized Coefficient	t-value	Significance
Constant	1.082	657.714	0.000
Interval time	0.00472	2.866	0.004
Amplitude	0.00891	5.413	0.000
Square root of trend	-0.0414	-25.135	0.000
Interval time and amplitude	0.00262	-1.595	0.111
Interval time and square root of trend	0.0193	11.732	0.000
Amplitude and square root of trend	0.00272	1.654	0.099

The R square of the model increases to 55.0%. However, only the interaction between interval time and trend has a statistically significant value. If that is the only interaction included in the regression, the significance is still 54.8%. The interaction between interval time and trend helps explain the relative difference between different coordinators. The relative performance of the coordinators with different interval times and trend is presented in Figure 6. The only clear interaction can be seen when there is no trend; the line clearly differs from the other possibilities. It could be argued that in the situation where there is constant (interval time is small) and chaotic (no trend) change, the fast reviser performs a lot better than the slower. If even a small trend value is involved, the dynamics between the interacting variables change. The relative performance of the fast reviser decreases significantly when interval time reaches 100.



**Figure 6.** Surface plot between interval time and trend of change in the relative performance of the fast reviser compared to a slower one.

## DISCUSSION

The relative performance of the slow compared to the fast reviser depends on a number of environmental factors (trend, amplitude, and interval time of changes) but, overall, revision efficiency has a greater impact. According to the regression analysis, most of the performance was explained by the constant term. Including the interactions between the environmental factors increases the R square from 45.4% to 55.0%. However, only the interaction between interval time and trend is statistically significant. Including the environmental factors in the analysis nevertheless enables better predictions concerning relative performance.

The general finding from the simulation results is that a manager with the ability to revise the network picture faster will make better decisions than one who can only revise more slowly. The presupposition is that decision quality is high if the network picture corresponds broadly to the network conditions at a given point in time. The extant literature implies that the presupposition is justified, since an appropriate network picture is found to help actors achieve desired outcomes (Weick, 1995; Henneberg, Mouzas and Naudé, 2006).

Scrutinizing the behavior of the employed control variables more thoroughly, some interesting notions can be raised. First, it seems that when the interval time of changes in the network increases, fast revisers benefit even more than slow revisers. Our results do however indicate that as interval time increases, the gap between the performance of fast and slow revisers narrows. In general terms it can be concluded that in business environments with a high interval of changes, for example in new markets and those with a large number of actors, investments in fast learning are lucrative. Second, the amplitude of changes in the network seems to exhibit a similar line of behavior. According to the results, fast revisers benefit even more than slow revisers when the amplitude of changes increases. Thus, in a business environment where radical innovations are likely, investments in fast learning seem to be merited. Third, the trend of changes, exhibits more interesting behavior. The results indicate that in a totally chaotic environment with a low trend of changes, faster learning is of truly great importance. However, once the trend of changes decreases, the relative benefit of being a fast reviser begins to diminish. Thus, in stable business environments, for example the paper, metal, and mining industries, investment in revision capability may not be as lucrative as in other business environments. With regard to external parameters, the trend of changes in the network is the most significant individual variable influencing network picture quality.

These results should not be considered surprising as the ability to revise a network picture swiftly is likely to be valuable in a more dynamic business environment. However, an inspection of the combination effects of variables reveals more interesting findings. Only the interaction between interval time and trend is statistically significant; the significance of the regression is 54.8% if only that interaction is included. The interaction offers two findings. First, when both interval of changes and trend are low, the fast reviser seems to perform substantially better than the slow reviser. However, an increase in the trend of changes in the business environment equalizes the performance differences of fast and slow revisers. In addition, an increase in interval time when trend is at its minimum diminishes the relative performance of the fast reviser. Second, the results indicate that when interval time increases, the fast reviser benefits more than the slow reviser; but where the interval time of changes is extremely high, the benefit to the fast reviser diminishes. This phenomenon seems to occur at almost all trend values, and for the lower trend values the change is even greater (excluding the trend value 0).

The findings of the present study suggest that the manager with the ability to revise the network picture faster will make better decisions, although in certain cases the benefit of being a fast reviser diminishes. Also, prior studies have shown that managers do not necessarily need an accurate understanding of the entire business environment (Gary and Wood, 2011). Denrell, Fang, and Levinthal (2004), and Gavetti and Levinthal (2000), have provided evidence that not all partial knowledge is equally valuable. Managers should focus on identifying the essential knowledge rather than trying to make sense of the entire business network (Gary and Wood, 2011). Besides being able to revise the network picture quickly, a manager should be able to discern the essential information.

## **CONCLUSIONS**

The purpose of this paper is to increase understanding of the dynamic nature of network pictures, and to that end a research question was posed: how does a manager's ability to revise the network picture affect the quality of decisions in a dynamic business environment. To answer that question, we have studied the relation between a manager's ability to revise the network picture and decision quality in a dynamic business environment. In approaching this purpose with agent based modeling, we propose that a manager with the ability to revise the network picture faster benefits more in a dynamic business environment than one who can only revise the picture more slowly. However, in a business environment with a higher trend of changes, the gap between the fast and slow reviser narrows. In addition, the combination effects of the variables of interval time and trend indicate business environments in which a slow network picture reviser gains on the fast reviser, namely where the interval time of changes is either extremely low or high, or when the trend of changes increases.

First, the study contributes to the discussion on the relation between network pictures, networking, and network outcomes (Ford, Gadde, Håkansson, and Snehota, 2003; Henneberg, Naudé and Mouzas, 2010; Corsaro, Ramos, Henneberg, and Naudé, 2011), researching the relation between decision quality and an individual's ability to revise the network picture. The findings extend understanding of which kinds of business environment merit a firm's investment in revision ability, for example by enhancing the communication of information in the business environment. Second, the study offers a dynamic and longitudinal perspective on network pictures research, employing simulation and, to be more precise, agent based modeling (Schelling, 1969; Macal and North, 2006; Gilbert, 2008).

## **LIMITATIONS AND FUTURE DIRECTIONS**

Numerical comparisons between managers with differing network picture revision abilities show that the differences are small. It is not possible to state certainty whether or not this holds, but in analyzing the model some potential justifications can be found. The problematic area in the model is the implementation of network picture revision. No clear way could be found as to how revision should be modeled. Changing the implementation method, and especially how the difference between managers' abilities to revise network pictures is realized, would affect also the actual difference between the scenarios. In addition, approaching the phenomenon through simulation requires some simplifications. In the present research, the network picture revisers are modeled in isolation from the network. Furthermore, the number of actors in the business network is taken to be stable, only the relationships change. However, adding complexity would hamper the results.

Modeling has not previously been applied in network picture research. This opens up a new research stream on the topic, and also explicates the problematic areas in the model, as there are no current models against which to benchmark. Future research should verify the model empirically to improve the validity of the results. In addition, the current state of the model should be developed further to increase its accuracy. Questions considering the implementation of difficult issues, such as revision speed and decision quality, can be improved. In the current model, these issues have been resolved correctly from a relational perspective, where a fast reviser is faster than a slow reviser. The most problematic issues are related to whether this difference should be linear or non-linear. Also, the number of external parameters is currently limited. Additional parameters could be included and tested in the model, if relevant parameters and their implications could be defined. The problem in defining new parameters for the model is that each additional parameter complicates it, and making the model harder to understand decreases its value.

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