# Trust, Information Technology, and Cooperation in Supply Chains

**John D. Lee and Ji Gao**
Department of Mechanical
and Industrial Engineering
The University of Iowa
jdlee@engineering.uiowa.edu
jgao@engineering.uiowa.edu

The decentralized control of supply chains enables them to adapt to unforeseen circumstances. However, local decisions can lead to suboptimal outcomes at the global level, as with the bullwhip effect and vicious cycles, if cooperation between supply chain members gives way to competition. Forecasting systems and other forms of information technology promise to alleviate the bullwhip effect and vicious cycles but may actually exacerbate these problems if used inappropriately. Inappropriate trust in the forecasting technology can lead to erroneous decisions, and supply chain members may misinterpret these technology-induced errors as the intent of other supply chain members to compete. This paper reviews literature regarding trust in technology and presents a framework for information sharing that can help to promote appropriate trust in supply chain technology and in other supply chain members. Explicitly considering trust in technology may lead to improved supply chain performance and may protect against loss of trust between supply chain members. Overall, this paper identifies human interaction with forecasting systems and other types of technology as an important contributor to cooperation and performance in supply chains.

## Introduction

Companies have moved away from vertical integration, in which a single company converts raw materials into products for end users, to an increasing reliance on supply chains. A typical U.S. company purchases 55% of the value of its products from other companies (Dyer & Singh, 1998). The promise of greater efficiency and the ability to adapt to increasingly volatile market dynamics have prompted this shift from centralized control to decentralized control.

Trust and cooperation between supply chain members are critical for the overall chain performance (Handfield & Bechtel, 2002), but have proved difficult to foster (Cachon & Lariviere, 2001). The increasing prevalence of information technology in supply chains introduces several challenges that can influence trust and cooperation. First, inappropriate use of supply chain technology, such as forecasting systems, can lead to behavior that other members interpret as competitive and thus cause them to respond by competing. Second, inappropriate use of information technology can lead to poor decisions that may induce inventory fluctuations that undermine supply chain efficiency. Reliance on information technology depends, in part, on users' trust in the technology. For these reasons, inappropriate use of information technology may be a critical factor affecting cooperation and supply chain performance.

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This paper considers the role of trust between supply chain members and how this trust depends on the appropriate use of information technology in supply chains, which in turn depends on members' trust in the information technology. The following section describes the role of trust in technology in other domains and relates those findings to information technology for supply chains. Next, the role of inappropriate trust in technology is related to two common breakdowns in supply chains—the bullwhip effect and vicious cycles. The paper concludes with a conceptual framework that suggests novel types of information sharing that may promote appropriate trust in supply chain technology, appropriate trust in supply chain members, and greater cooperation.

## Trust and Reliance on Technology

Supply chains consist of a network of individuals and companies making decisions at a local level that can have surprisingly important implications for global supply chain performance (Chen, 1999; Helbing & Kuhnert, 2003). Increasingly, these decisions are supported by information technology that may have profound effects on these local decisions and, by extension, the overall supply chain performance. Such information technology includes computer systems for production scheduling, demand forecasting, and—more generally—advanced planning systems (APS) and enterprise resource planning (ERP). Other examples include procurement and content cataloging, transportation planning systems, demand planning and revenue management, customer relationship management, and sales force management (Chopra & Meindl, 2003). This information technology promises to alleviate persistent problems that confront supply chains; however, research considering how individuals adapt to information technology in other domains suggests some emerging problems for supply chain management.

Sophisticated information technology is becoming ubiquitous, appearing in work environments as diverse as aviation, maritime operations, process control, and information retrieval (Lee, in press; Parasuraman, Sheridan, & Wickens, 2000). Such technology exhibits tremendous potential to extend human performance and improve system efficiency; however, recent disasters indicate that it is not uniformly beneficial. Users may rely on technology even when it is not appropriate. Pilots, trusting the ability of the autopilot, failed to intervene and take manual control even as the autopilot crashed an Airbus A320 (Sparaco, 1995). In another instance, an automated navigation system malfunctioned and the crew failed to intervene, allowing the Royal Majesty cruise ship to drift off course for 24 hours before it ran aground (Lee & Sanquist, 2000). A similar situation occurred when Cisco inappropriately relied on its forecasting system.

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**Cisco's Forecasting Failure**

In the third quarter of 2001Cisco's unquestioning trust in their highly touted forecasting systems prevented the company from seeing the impending downturn that was clear to others with far less sophisticated forecasting technology (Berinato, 2001; Kaihla, 2002). Companies that saw the downturn started downgrading forecasts and reducing their inventories months earlier than Cisco. As a result, Cisco had to write off inventory worth $2.2 billion and lay of 8,500 people.

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Conversely, users are not always willing to rely on technology when it is appropriate. In the context of supply chain management, there is a long history of decision makers who have neglected potentially beneficial decision aids (Davis & Kottemann, 1995; Kottemann & Davis, 1991). As an example, the usefulness of a production planning aid was substantially underestimated, even though it outperformed those judging it (Davis & Kottemann, 1995). However, feedback regarding performance of the aid relative to unaided performance did increase perceived usefulness, reliance on the decision aid, and overall performance (Davis & Kottemann, 1995).

Although many factors (such as self-confidence and time pressure) influence the use of technology, substantial research suggests that how much a person trusts the technology strongly influences reliance (Lee & See, 2004). Although trust has long been used to describe why humans rely on each other and cooperate (Deutsch, 1958; Deutsch, 1960; Rempel, Holmes, & Zanna, 1985; Ross & LaCroix, 1996; Rotter, 1967), trust has also been used to describe why users rely on technology. Just as trust mediates human relationships, trust may also mediate human-technology relationships (Sheridan, 1975; Sheridan & Hennessy, 1984). This is particularly true when technology is relatively complex and goes beyond simple tools with clearly defined and easily understood behaviors. Many studies show that users respond socially to technology, and reactions to computers can be surprisingly similar to reactions to human collaborators (Reeves & Nass, 1996). Trust is one example of the tendency to respond to technology socially.

Trust in the technology can be viewed as the attitude that technology will help to achieve one's goals in a situation characterized by uncertainty and vulnerability (Lee & See, 2004). This definition is quite similar to that developed by Mayer, Davis, and Schoorman (1995), who described trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the truster, irrespective of the ability to monitor or control that other party" (p. 712). An important difference in these definitions, however, is that the first explicitly defines trust as an attitude and identifies both uncertainty and vulnerability as situational variables—both relevant to the question of trust in technology—whereas the second defines trust in terms of intent and does not mention uncertainty.

Many studies have demonstrated that trust is a meaningful concept to describe human-technology interaction, both in naturalistic settings (Zuboff, 1988) and laboratory settings (Lee & Moray, 1992; Lewandowsky, Mundy, & Tan, 2000; Muir & Moray, 1996).

Trust has helped to explain reliance on systems as diverse as augmented vision systems for target identification (Conejo & Wickens, 1997; Dzindolet, Pierce, Beck, Dawe, & Anderson, 2001) and pilots' perception of cockpit automation (Tenney, Rogers, & Pew, 1998). Recently, trust has also emerged as a useful concept to describe interaction with Internet-based applications, such as Internet shopping (Corritore, Kracher, & Wiedenbeck, 2001; Lee & Turban, 2001) and Internet banking (Kim & Moon, 1998). Some argue that trust will become increasingly important as the metaphor for computers moves from inanimate tools to animate software agents (Castelfranchi & Falcone, 1998, 2000; Lewis, 1998; Milewski & Lewis, 1997) and as computer-supported cooperative work becomes more commonplace (Van House, Butler, & Schiff, 1998).

The dimensions of purpose, process, and performance describe the information that influences trust in technology (Lee & Moray, 1992; Lee & See, 2004):

- *Purpose* defines the designers' intended use of the technology
- *Process* defines the algorithms that guide the technology
- *Performance* defines the historical reliability of the technology.

These three dimensions identify goal-oriented information needed to support appropriate trust. However, availability of information alone does not ensure appropriate trust. Trust depends on the inferences drawn by comparing information associated with performance, process, and purpose (Lee & See, 2004). If inferences between levels are inconsistent, trust will likely diminish. For example, inconsistency between the intentions conveyed by the manager (purpose basis of trust) and the manager's actions (performance basis of trust) have a particularly negative effect on trust (Gabarro, 1978). The dimensions describing the information needed to support appropriate trust provide initial guidance to mitigate two major supply chain problems described in the following section.

## Supply Chain Problems and the Role of Information Technology

One important problem with supply chains is the *bullwhip effect*, which is the large oscillation in orders caused by small variations in product demand. This oscillation creates swings between excessive and insufficient inventories, which can burden companies with high inventory costs and undermine customer satisfaction. To combat this problem, each link of the supply chain sometimes stockpiles inventory to accommodate the oscillating demand. In the grocery store supply chain alone, this excess inventory represents an estimated $30 billion cost (Lee, Padmanabhan, & Whang, 1997). The bullwhip effect severely compromises the potential benefits of supply chains.

One contributor to the bullwhip effect is the cognitive bias that causes individuals to underweight supply chain inventory (Croson & Donohue, 2002). Information technology such as demand-forecasting technology is not prone to such biases and can substantially reduce the bullwhip effect (Zhang, 2004). Moreover, sharing information such as point-of-sale information and centralizing demand information can further reduce the bullwhip effect (Chen, Drezner, Ryan, & Simchi-Levi, 2000; Croson & Donohue, 2003). Replacing human players with automated forecasting and ordering algorithms reduced supply chain costs by 86%, demonstrating the potential for information technology to reduce the bullwhip effect (Croson, Donohue, Katok, & Sterman, 2003).

Forecasting systems have great promise because accurate forecasts can moderate inventory oscillations (Lee & Whang, 2000; Zhao & Xie, 2002), but these systems can also magnify the bullwhip effect if the forecasts are inaccurate. An in-depth, multiyear survey of 32 companies shows that forecasting technology is imperfect and that forecasting inaccuracy is a common problem—companies in their survey reported an average forecast error of 55% (Fisher, Raman, & McClelland, 2000). Forecasting errors can diminish the promised cost savings associated with information technology (Zhao & Xie, 2002).

With such imperfect technology, its ability to reduce the bullwhip effect depends on decision makers trusting it appropriately. If the technology is not trusted, the users may neglect its input. In contrast, trusting the technology when it generates inaccurate forecasts could exacerbate the bullwhip effect. Providing information associated with the dimensions of purpose, process, and performance that underlie trust could support more appropriate reliance on the technology and reduce the bullwhip effect. Feedback regarding the historical performance of forecasting technology could diminish the influence of cognitive biases that lead to inaccurate forecasts. Information regarding the purpose and process of the forecasting automation could help users understand when the application of a forecasting algorithm is consistent with the designers' intent and the assumptions of the forecasting algorithms. Because technology is imperfect, feedback is needed to assess whether the information technology has helped or hindered.

A second important problem in supply chains is the vicious cycles phenomenon, in which cooperation breaks down and the interactions between supply chain members degenerate into an escalating series of conflicts (Akkermans & van Helden, 2002). Although decentralized control (typical of many supply chains) is more flexible and adaptable than centralized control, decentralized control is also prone to individuals' pursuit of local optima and competing rather than cooperating. Such competitive behavior can be triggered by supply chain disruptions, such as those associated with the bullwhip effect (Akkermans, Bogerd, & Vos, 1999). In this way, inappropriate trust in information technology can trigger vicious cycles.

The vicious cycles and associated competitive behavior can have dramatic negative consequences for a supply chain. For example, a strategic alliance between OfficeMax and Ryder International Logistics degenerated into a legal fight in which OfficeMax sued Ryder for $21.4 million, followed by Ryder's suing Office Max for $75 million (Handfield & Bechtel, 2002). Such behavior is typical of vicious cycles, in which failures to cooperate undermine trust and make cooperation less likely in the future, degenerating to a point where distrust dominates. Even if such vicious cycles do not result in lawsuits, they can diminish information sharing, which can exacerbate the bullwhip effect. Because informal agreements between individuals and information sharing are increasingly important for supply chain management, trust has emerged as a critical factor in shaping the cooperative dynamics in supply chains (Akkermans, Bogerd, & van Doremalen, 2004; Handfield & Bechtel, 2002).

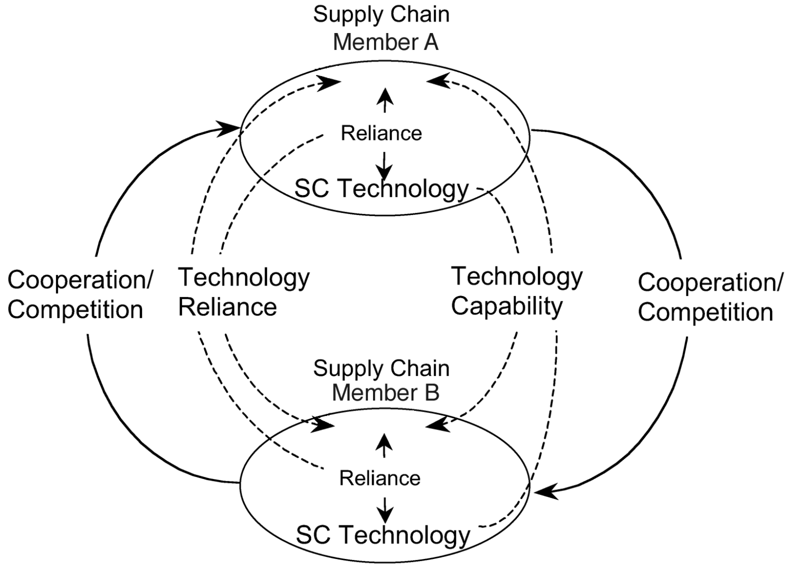
Sharing information associated with the dimensions of purpose, process, and performance that underlie trust could help avoid vicious cycles. Specifically, feedback regarding the historical performance of forecasting technology of supply chain partners could help partners identify unintentionally competitive behavior that results from erroneous forecasts. Likewise, sharing information regarding the forecasting process could help partners identify technology-induced errors. This information could promote trust in supply chain partners and avoid vicious cycles.

## Trust in Technology and Its Influence on Trust between Individuals

Figure 1 shows how technology may influence the dynamic interactions that underlie cooperation and competition between supply chain members. Each of the two supply chain members in Figure 1 faces the decision to rely on technology and the decision to cooperate with the other operator. Both decisions depend on trust. Supply chain members will tend to rely on technology they trust and cooperate with members they trust.

The interactions within the ovals at the top and bottom of Figure 1 show that the output of any link in the supply chain depends on the joint behavior of the person and the supply chain technology. The person's reliance determines the degree to which the supply chain technology accounts for the joint behavior. To the extent that a person has appropriate trust in the technology, the joint behavior will reflect the person's intent to cooperate or compete. For example, if demand dramatically drops in a way that is not predicted by the forecasting system, then the forecasting system will suggest an order that will produce excessive inventory. If supply chain member A trusts the forecast too much and acts on the erroneous information, an excess inventory will accumulate. This excess inventory may undermine the payoff of both supply chain members and may be viewed by supply chain member B as an intention to compete rather than cooperate. Such unintentional competition undermines the trust and could trigger further competition, initiating a vicious cycle. In this way, inappropriate trust in technology can undermine trust between supply chain members. This simple framework shows the feedback loops that contribute to vicious cycles that undermine cooperation by diminishing the trust between individuals (Kumar & vanDissel, 1996).

*Figure 1*
**The Influence of Supply chain Technology on Cooperation between Supply Chain Members.**




The dotted lines indicate technology-related information that could be shared to promote appropriate trust in supply chain technology and appropriate trust in other supply chain members. The solid lines represent trust-dependent decisions.

*Table 1*
**Information to Promote Appropriate Trust**

| Basis of trust | Conditions leading to inappropriate trust | Strategy to support appropriate trust |
|---|---|---|
| Purpose | The purpose of information technology is sometimes misunderstood. As an example, inventory-planning software for products with long life cycles is not intended for products with short life cycles. More generally, complex algorithms make it difficult to determine if the system is being used in a manner consistent with the designers' intents (Fisher, Raman, & McClelland, 2000). | Provide users with information that describes the purpose and intended use of the technology. |
| Process | The algorithms of information technology are often difficult to understand and contain assumptions contrary to the intuitions of the users. This problem stems from a tendency of developers of information technology to misinterpret information from merchants. As an example, developers may interpret *always* as meaning 100% of the time when merchants actually mean 75% of the time (Fisher et al., 2000). In another case, developers assumed no lag between order and delivery, when the actual lag was three weeks. This mismatch caused a 60% sales shortfall relative to model prediction because stockouts diminished sales (Fisher et al., 2000). | Provide users with information that describes the process used by the information technology and the underlying assumptions of the algorithms. |
| Performance | Feedback regarding the performance of forecasting technology can promote more appropriate reliance (Davis & Kottemann, 1995). Only 9 of 32 retailers surveyed tracked forecast errors and only 13 of the 32 tracked stockouts. Failing to collect and distribute such data makes it difficult to identify when forecasting technology is being used inappropriately. | Provide users with feedback regarding the past performance of the information technology, such as the history of forecast errors. |

Sharing two types of technology-related information may promote more appropriate trust in the technology and in other supply chain members. Figure 1 shows these two types of information as dotted lines. The lines from the supply chain technology to each supply chain member represent sharing information related to the capability of the technology. The lines from the reliance to the person represent sharing information regarding the influence of the technology on the person's decision. These two types of technology-related information—technology capability and reliance on technology—are qualitatively different from information such as point-of-sale information that is currently shared to support collaborative forecasting.

Sharing the capability of the technology could help operators develop a more appropriate level of trust in supply chain technology. Returning to the example of forecasting technology, sharing information regarding how well the forecasting algorithm performs in different conditions may help operators understand the capability and limits of the particular algorithm so that their trust more precisely reflects the true capability of the technology. Table 1 summarizes information describing the capability of the supply chain technology that is expected to result in more appropriate reliance and avoid unintended competitive behavior caused by inappropriate use of technology.

Sharing information regarding operators' reliance on technology is a second type of technology-related information that could improve supply chain performance. This information describes the extent to which the information technology influenced the person's decision. Knowing only the behavior of the other person makes a precise inference of the other person's intent to compete or cooperate impossible. Sharing information regarding the other person's reliance on the technology can help disambiguate intent by identifying whether competitive behavior was generated by the technology or by the other person. In the example of forecasting technology, knowing that the other's decision was based on flawed technology, even when competitive behavior was observed, would indicate that the other person may have intended to cooperate, but inadvertently competed because of flaws in the forecasting technology. Information concerning reliance on technology can help operators assess the intent of others and this knowledge may sustain trust and promote cooperation.

## Conclusion

Information sharing has been widely recognized as an important mechanism to mitigate the bullwhip effect and vicious cycles. Likewise, previous research has suggested that sharing information such as inventory and sales can improve supply chain performance and cooperation, but little attention has been paid to sharing technology-related information. Sharing such information may improve supply chain performance by promoting more appropriate trust in supply chain technology and by promoting trust in other supply chain members. The dimensions of purpose, process, and performance place these information types in theoretical framework developed to promote appropriate trust in technology (Lee & See, 2004). The importance of sharing such information may grow as supply chain technology becomes more pervasive and complex.

Companies invest millions of dollars in sophisticated information technology in the hope that it will mitigate problems such as the bullwhip effect and vicious cycles. Although such technology has the potential to improve supply chain performance, it can also undermine performance, as seen in the case of Cisco's inappropriate reliance on a sophisticated forecasting system. Sharing technology-related information represents an untested, but promising approach to promote appropriate trust in technology and in other supply chain members. Explicitly considering the trust in technology may lead to improved supply chain performance and may protect against loss of trust between supply chain members.

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## About the authors

**John D. Lee** is Associate Professor of Industrial Engineering at the University of Iowa. He has a background in engineering and psychology, with a Ph.D. in Mechanical Engineering from the University of Illinois at Urbana-Champaign. His research enhances the safety and acceptance of complex human-machine systems by considering how technology mediates attention. He also investigates the role of trust in affecting how people manage imperfect automation.

**Ji Gao** received a B.S. in Mechanical Engineering from Tsinghua University, China, in 1999 and an M.S. in Mechanical Engineering from the University of Iowa in 2002. She also received an M.S. in Computational Engineering from Singapore-MIT Alliance, Singapore, in 2000. Currently, she is a Ph.D. candidate in Industrial Engineering at the University of Iowa. Her research interests include human-automation interaction, modeling human decision making, and cooperation in decentralized systems.