Trust in Sharing Resources in Logistics Collaboration

Vom Fachbereich Produktionstechnik

der

UNIVERSITÄT BREMEN

zur Erlangung des Grades eines

Doktors der Ingenieurwissenschaften

– Dr.-Ing. –

genehmigte

Dissertation

von

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Tag der mündlichen Prüfung: 09.05.2018

Acknowledgment

This dissertation might have been difficult to achieve without support from many people and organizations. For this reason, the author of this of this dissertation takes this opportunity to express his appreciations to advisors, financial supporters, the Graduate School for Dynamics in Logistics (IGS), and colleagues.

At first hand, the author appreciates the principal advisor, Prof. Dr.-Ing. habil. Klaus-Dieter Thoben for accepting the author to join the IKAP research division as a doctoral candidate. His encouragement and advice, especially on a topic of resource sharing in logistics, in which trust plays a profound role, was and remains invaluable. Through many discussions held after that, the principal advisor was committed to challenge constructively, and accordingly advise on further improvements to this research work. Secondly, the author's sincere gratitude goes to the assistant advisor, Prof. Dr.-Ing. Jannicke Baalsrud Hauge. She was helpful, from constructing unstructured (early) ideas to successful publications. Her tireless mentorship included advice on academic authorship as well as comments to improve further this dissertation. Thirdly, the author cannot forget to thank Prof. Dr. Otthein Herzog, the second examiner in the first-year oral examination, for his advice on the topic of this research.

Without the financial support, this research might have been impossible. Therefore, the author would like to thank the Ministry of Education, Science, and Technology (MoEST) and DAAD for the joint doctoral scholarship they awarded to the author. The MoEST and DAAD awarded the scholarship under the Tanzania-Germany Postgraduate Training Program.

During this research, the author enrolled as the doctoral candidate in the IGS. Therefore, the author thanks Dr.-Ing. Ingrid Rügge, the managing director of the IGS, for her commitment to organizing various courses under the IGS training program. Dr.-Ing. Ingrid Rügge is also the mother of the internationals, as she excellently handles international culture, and; she blends such diverse values under one peaceful roof of understanding and experience.

Finally, the author would like to thank colleagues and doctoral candidates, Ms. Molin Wang, Ms. Elaheh Nabati, Ms. Samaneh Beheshti-Kashi, and Mr. Christoph Greulich for discussions, encouragements, but also jokes they had during the research and stay in Bremen, Germany.

Abstract

Collaboration on resource sharing advocates a joint usage of resources by multiple parties (actors) to attain mutual benefits. Resource sharing becomes vital when resources under consideration are scarce, challenging, and expensive to attain; as well when they are idle or underutilized. In collaborative logistics, resource sharing entails the joint usage of the physical and non-physical assets. Shared assets include the transportation vehicles (trucks), warehouses, distribution centers, information, on-demand staffing, and logistics services offered under cloud computing. Through sharing, collaborating partners in logistics can reduce costs and harms to the environment, but also improve the efficiency of logistical functions. Although collaborative sharing is beneficial, still many difficulties impede its uptake. The difficulties include how to choose partners, establish and maintain trust among partners involved. Indeed, in both academia and industry, low-level trust inhibits the collaboration critically on sharing logistics resources. To this end, the present dissertation addresses the trust problem encountered by collaborating partners when they are sharing logistics resources. It deals with the trust problem by developing the *Trust Mech*anism (*TrustMech*) concept. The primary role of the TrustMech is to help logistics stakeholders acquire the far-reaching understanding about the trustworthiness of prospective networks of sharing they configure, before advancing them to an implementation stage.

The TrustMech stands on a mitigation approach that focuses on estimating outcomes of trust uncertainties – rather than – their sources. Henceforth, this dissertation advances on estimating outcomes of trust uncertainties to answer the following central Research Question (RQ): how can collaborating partners acquire the far-reaching understanding about the trustworthiness of prospective networks of sharing they configure? An approach to the research problem, which as well answers the RQ proceeds as follows. The first steps involve establishing behavioral factors and parameters, which influence trust in collaborative sharing of logistics resources. The second stage entails establishing a conceptual framework that depicts and guides trust-based interaction of collaborating partners. The third step comprises developing the TrustMech concept, validating it in both the conceptual and operational aspects, and demonstrating its application by carrying out controlled (simulation) experiments in Multi-Agent Systems. In particular, the proposed TrustMech concept characterizes fundamental logical processes that account for trusting decisions, actions, and reactions of collaborating partners to reinforce emergent trusting outcomes.

The core contributions of this dissertation are the general-purpose TrustMech and the operational TrustMech. The operational TrustMech is customary for collaborative sharing of logistics resources. Regarding its application, the operational TrustMech provides logistics managers and stakeholders the ability to

forecast how a configured network of sharing may, in respect of trustworthiness, function upon its implementation. To clarify further, the operational TrustMech scrutinizes many issues. For example, it scrutinizes trustworthiness of the configured network regarding possible strengths and pitfalls and provides pathway explanations underlying such foreseen strengths and pitfalls. Secondly, the operational TrustMech scrutinizes effects which such strengths and pitfalls can generate. Moreover, the operational TrustMech estimates an extent to which behavioral factors influence the trustworthiness of the individual partner and entire resource sharing network. Future research works include extending the TrustMech and replicating the study using system data. Additional future work consists of adjusting the design and settings used, as well as incorporating additional predictor and response variables into the operational TrustMech.

Abstract in German

Das Teilen d.h. das gemeinsame Nutzen von Ressourcen ist vor allem dann vielversprechend, wenn die aktuell betrachteten Ressourcen knapp und teuer sind, nur aufwändig zu beschaffen sind, oder wenn diese nicht ausreichend genutzt werden. In einer durch Kollaboration geprägten Logistik (*collaborative logistics*) führt Ressourcenteilung zur gemeinsamen Nutzung der materiellen und nicht materiellen Vermögenswerte. Zu den gemeinsam genutzten Vermögenswerten zählen u.a. Transportfahrzeuge (LKWs), Warenlager, Vertriebszentren, Informationen, aber auch das zur Verfügung stehende Personal und IT-basierte Logistikdienstleistungen, die im Rahmen von Cloud Computing angeboten werden. Durch das gemeinsame Nutzen von Ressourcen können in der Logistik sowohl Kosten und Umweltschäden reduziert, als auch die Effizienz von logistischen Aufgaben verbessert werden. Auch wenn das gemeinsame Nutzen von Logistikressourcen viele Vorteile verspricht, bestehen noch immer viele Herausforderungen, die der Umsetzung einer kooperativen Nutzung von Ressourcen entgegenstehen. Zu diesen Herausforderungen zählen sowohl die Identifikation und die Auswahl geeigneter Partner als auch der Aufbau und die Erhaltung von Vertrauen unter den beteiligten Partnern. Ein zu geringes Maß an Vertrauen verhindert letztendlich die Zusammenarbeit der beteiligten Partner und so auch das Teilen von logistischen Ressourcen.

Die vorliegende Dissertation befasst sich mit den verschiedenen Dimensionen von Vertrauen, das bei Kooperationspartnern auftritt, wenn diese logistische Ressourcen teilen. Die Arbeit behandelt das Thema Vertrauen durch die Entwicklung des Konzepts *Trust Mech*anism (*TrustMech*). Die Hauptaufgabe von TrustMech besteht darin, den Akteuren in der Logistik dabei zu helfen, ein weitreichendes Verständnis über die Vertrauenswürdigkeit in den künftigen Netzwerken zu erwerben, die von ihnen konfiguriert und gemeinsam genutzt werden, bevor diese Netzwerke in die Implementierungsphase wechseln. Das Konzept TrustMech basiert auf einem sogenannten Abschwächungsansatz (*mitigation approach*), der darauf fokussiert, die Folgen von fehlendem Vertrauen (d.h. die Vertrauensunsicherheit) zu bewerten.

Die zentrale Forschungsfrage der Arbeit lautet: Wie können die in einem logistischen Netzwerk kooperierenden Unternehmen ein angemessenes Verständnis über die Vertrauenswürdigkeit des Netzwerkes entwickeln. Der Aufbau der Arbeit ist wie folgt: Im ersten Schritt werden verhaltensbezogene Faktoren und Parameter identifiziert, die einen Einfluss auf das Vertrauen bei der gemeinsamen Nutzung von logistischen Ressourcen haben. Im zweiten Schritt wird ein Rahmenkonzept entwickelt, welches eine vertrauensbasierte Interaktion von Kooperationspartnern beschreibt und erklärt. Darauf aufbauend wird im dritten Schritt das TrustMech-Konzept entwickelt und anschließend mit Hilfe eines Multi-Agenten –Systems implementiert.

Die Hauptbeiträge dieser Dissertation sind einerseits das allgemeingültige TrustMech Konzept (General-Purpose TrustMech) und andererseits dessen Umsetzung (Instanziierung) im Kontext der gemeinsamen Nutzung logistischer Ressourcen (Operational TrustMech to Logistical Functions). Vor allem beschreibt das TrustMech-Konzept fundamentale logistische Prozesse, die vertrauensvolle Entscheidungen, Aktionen und Reaktionen von Kooperationspartnern bedingen, um das Entstehen von vertrauensvollen Ergebnissen zu fördern. Aus Anwendungsperspektive bietet das TrustMech Konzept den verschiedenen Akteuren aus der Logistik die Möglichkeit zu prognostizieren, wie sich ein konfiguriertes (bzw. zu konfigurierendes) Netzwerk bei der gemeinsamen Nutzung in Bezug auf den Aspekt der Vertrauenswürdigkeit verhalten wird. Das TrustMech-Konzept wird sowohl hinsichtlich seiner konzeptionellen als auch operationellen Aspekte mit Hilfe eines Multi-Agenten-Systems implementiert und experimentell bewertet (simuliert). Im Rahmen der Anwendung des TrustMech Konzeptes werden verschiedene Aspekte genauer betrachtet. Zum Beispiel untersucht das Konzept die Vertrauenswürdigkeit des konfigurierten Netzwerks mit Blick auf das Entstehen und das Wirken möglicher Stärken und Hindernisse. Schließlich schätzt der operationelle TrustMech, inwieweit verhaltensbezogene Faktoren die Vertrauenswürdigkeit von individuellen Partnern und des gesamten Netzwerks die gemeinsame Nutzung von Ressourcen beeinflussen.

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1 Introduction

Traditionally, sharing as well as collaboration existed since ancient times. In that period, ancestors shared various works such as the hunting, gathering, creating tools, and even looking after babies (Buczynski, 2013) in their family. Those shared works mostly spanned on small geographic areas and were supposed to satisfy joint needs of nearby local communities. Parallel to the traditional era, communities of today realize potentials of sharing the physical and non-physical resources. This sharing is gaining popularity because of benefits it provides to participants who share resources. Owing to realizable benefits, both the individuals and companies have started to adapt resource sharing into business models. Foundationally, the adapted business models stand primarily on a collaboration strategy to enable parties involved to share the idle and underutilized assets and physical spaces. Such shareable resources range from homes (Gorenflo, 2010), transportation vehicles (trucks), warehouses, distribution centers (Gci & Capgemini, 2008; Gorenflo, 2010; Weinelt, 2016), machinery and manufacturing facilities (Kück, Becker, & Freitag, 2016).

Many drivers accelerate and promote the re-birth of today's collaboration in sharing resources. These drivers are mainly notable in the dimensions of technology, economy, ecology, and societal issues (Figure 1). In view of technological perspective, emerging advances in Information and Communication Technologies (ICTs) play a crucial part to promote the collaborative sharing. The ICTs provide global scale and pervasive connectedness to the individuals, companies, and other objects (things) (Goudin, 2016) to facilitate resource sharing.

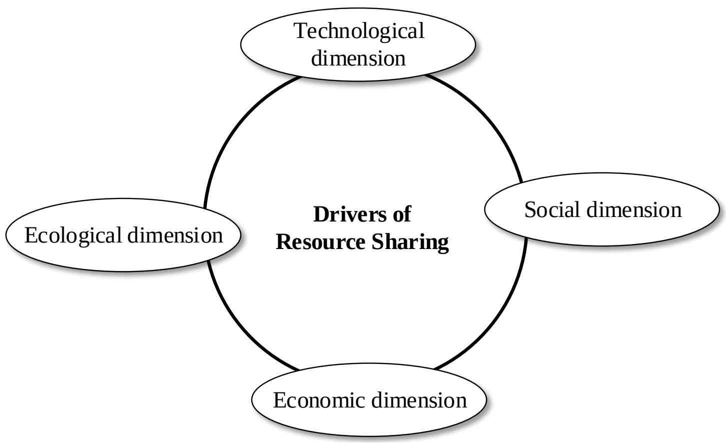


Figure 1: Drivers of resource sharing

The world has seen resource sharing undergoing four phases of revolution in a perspective of connectedness. The connectedness has progressed in the sequence of connect to share information; connect people to each other; connect to share daily thoughts and media, to; connect to access and share assets (Mastercard & The Future Agenda, 2016), such as the physical assets and spaces. Correspondingly, the power of the ICTs has reduced many difficulty's underlying transactions that are essential to support the functioning of resource sharing. To exemplify this, barriers, which were previously inhibiting the: search for information with a trading partner; bargaining towards agreements, and; enforcing agreements reached, are in no small extent reduced. These achievements, backup from emerging digital platforms (see, for example, in Telles (2016)), and play a profound role to bring together (matchmaking) and manage stakeholders who are motivated to go sharing.

The economic, ecological, and social dimensions drive today's collaborative sharing (Figure 1). These drivers are synonymous with what Goudin (2016) discusses as drivers of the sharing economy. One can emphasize further these drivers as follows. That, the increasing production costs, benign environmental regulations, dynamic market needs (European Commission, 2013; Koh & Wang, 2010), and scarcity of energy resources constitutes issues, which drive individuals and companies to go sharing. Such sharing, particularly in logistics, offers many benefits to both individuals and companies. For example, through sharing resources, companies can reduce logistics costs, improve the quality of service offered, gain a position on the market, minimize investments, and reduce harmful emissions (Xu, 2013).

Societal factors elevate a need to share resources. Today, many of us consume more than ever before (Buczynski, 2013). Equally, there appears to emerge a paradigm shift in the alternative use of resources. People are shifting from actual ownership towards temporary access to goods and services (Gesing, 2017). According to Gesig, consumer behavior appears shifting towards preferring experiences over possessions. Such shift in behavior implies that individuals and companies are becoming aware that owning a resource may be more expensive compared to access the same resource when it is needed. Besides such shift, the concentration of people in urban locations has created new needs such as mobility, to find that demand for means of transport increases (Goudin, 2016) than before. Similarly, an increase in population has resulted in a generation of more wastes, which have nowhere to go (Buczynski, 2013). Moreover, in terms of demand for energy resources, transportation's share of overall final oil consumption, from 1990 to 2010, has increased by 7 percent (Dobbs, Oppenheim, Thompson, Brinkman, & Zornes, 2011). Despite this increasing demand, yet most of the fossil fuels used especially in transportation logistics are finite. In this respect, sharing transportation vehicles (trucks), for example, may leverage number of vehicle trucks deployed on the road while also reducing the amount of fuel usage, and CO_2 emissions.

Upon considering the outlined challenges, collaboration in sharing logistics resources remains not only imperative but also beneficial. For example, in less-than-truckload, collaborative sharing provides opportunities to exploit synergies in excess capacity and increase asset utilization (Hernández & Peeta, 2014). As well, collaborative sharing can help to mitigate logistics inefficiencies, which Kayikci and Stix (2014) identify them as poor capacity utilization; empty backhaul; low-profit margins, and; harsh impacts to environments. Furthermore, collaborative logistics helps small and medium-sized companies to reduce costs and increase operational efficiency (Wang & Kopfer, 2014). In the overall, collaborative sharing seeks to leverage excess capacities in resource ownership (possession) against demands by other consumers (users).

Despite realizable benefits, there are many challenges, which hinder collaboration in sharing logistics resources. Many sources attribute to such challenges, especially those sources, which stem from governance mechanism of the sharing network. Under the governance mechanism, one issue to deal with is relational governance. The relational governance mechanism entails relational controls that rely heavily on the management of the trust. In the light of trust management, most of the literature, including (Buczynski, 2013; Dillahunt & Malone, 2015; Gesing, 2017; Gorenflo, 2010; Goudin, 2016; Telles, 2016) identify trust as one of the leading factors inhibiting collaborative sharing. It is for this reason that the present dissertation addresses the trust problem within the context of collaboration in sharing logistics resources.

In essence, collaborative sharing in logistics and other areas rests on the existence of mutual trust among parties involved. Literature (Mastercard & The Future Agenda, 2016; Wosskow, 2014) support this affirmation and see that trust remains a critical enabler of the collaborative sharing. In this case, efforts geared towards resource sharing may be successful when collaborating partners have trust in each other. Contrary to this, lack of trust (low trust) turns out to be a potential barrier to many collaborative partnerships (Pomponi, Fratocchi, & Tafuri, 2015) including those in logistics. Graham (2011) emphasizes further that the lack of trust make collaboration a hard proposition for many companies. This difficulty arises from many sources, such as the supporting environments, partner behavior, as well as collaborative processes that facilitate resource sharing itself. In the overall, the behavior exhibited by partners under the influence of collaborative logistics processes account primarily for indeterminate trusting situations, and reservations of partners to collaborate.

1.1 Trust as a Necessary Ingredient in Sharing Logistics Resources

In collaborative logistics, both the individuals and companies share resources to reduce costs, increase responsiveness, and improve utilization of assets and physical spaces. Statistically, potentials of sharing logistics resources carry implications. According to the World Economic Forum (2009): transportation logistics sector contributes 5.5% of the annual greenhouse-gas emissions; 24% of goods vehicle kms in the EU run empty, and; when carrying a load, trucks are typically only 57% loaded as a percentage of maximum gross weight. In both US and EU, almost 1 in every four trucks along the road runs empty; while within the trucks that are not empty, the utilization rates are 56% and 54% in US and EU, respectively (Srinivasan &

Leveque, 2016). Additionally, according to a survey conducted by (FLEXE, 2015): 70% of supply chain professionals report situations where a warehouse capacity significantly exceeds inventory, and; 70% of warehouse managers with extra capacity do not have a solution; instead, they accept the unused space as sunk costs. These statistics imply that collaborative sharing remains a crucial strategy to mitigate the already outlined logistics inefficiencies. For example, whereas some trucks run empty while others are partially loaded, sharing of trucks can reduce the number of trucks dispatched on a particular route. Consequently, sharing of trucks can enable collaborating partners to: reduce costs; reduce emissions of harmful gases; improve utilization of physical assets and spaces, and; improve customer service.

Collaboration in sharing resources faces many impediments, although it remains imperative. Among the most prominent unresolved challenges encountered in sharing resources are maintaining trust, transparency, liability, and insurance (Gesing, 2017). The effective collaborative sharing requires support involving high levels of trust among manufacturers, retailers, and logistics service providers (Bajorinas et al., 2008; Islam & Olsen, 2014). Fawcett, McCarter, Fawcett, Webb, and Magnan (2015) elaborate theoretically reasons about why collaboration strategies fail. Those authors emphasize that collaborations fail due to information hoarding and imbalanced power, among other reasons. Similarly, the difference in power and control among partners over collaboration processes, prevalence of low trust, and suspicion are also challenges of getting to collaboration table (World Economic Forum, 2011). Furthermore, literature (Fawcett, Magnan, & McCarter, 2008; The Economist Intelligence Unit, 2008) has emphasized that partner (actor) behavior constitute root barriers to collaboration. Since partner behavior get influenced by collaborative processes, then Fawcett et al. (2008) consider the incentive alignment, conflicting decisions, procedures, and information sharing to be among the collaborative processes that impede trust.

To put all together, partner behavior and collaborative processes constitute what this dissertation refers to as behavioral factors. They are factors, which influence (enable and inhibit) trust in collaborative sharing of logistics resources. On the one hand, these factors are considered core in exploiting benefits to collaborative sharing, especially when they are constructive and fairly practiced (enablers). On the other hand, such factors can also be unfair and destructive (inhibitors) to the extent of generating trust uncertainties that harm collaborative efforts directed towards resource sharing.

The brief discussion about trust uncertainties which stem from the outlined factors advances as follows (*for detailed discussion, see sections 2.4 and 4.1*). Firstly, collaboration in sharing logistics resources depends on information visibility. Increased visibility in sales, inventory, and forecast information between a customer and supplier allows partners to improve performance (VICS, 2007). To attain this visibility, collaborating partners have to exchange more information than before. While aspiring to ensure this visibility, partners can encounter real and suspected risks. Through information exchange, partners may indirectly expose their business models to competitors. Other partners may manipulate information before exchanging it, which in turn, may lead into additional uncertainties and low trust. Secondly, the fairness and trustworthiness of methods applicable to divide costs and expected gains remain not addressed to a considerable acceptance. The lack of significant acceptance can instigate logistics partners to suspect whether methods used will benefit all partners to the extent of efforts each has contributed. Thirdly, consortia in logistics are mostly dynamic, heterogeneous, and decentralized. These features introduce complexity and difficulties in managing and synchronizing decisions made by different partners, especially when such decisions are incompatible. The complexity arises, for example, when some partners make uncompromising decisions while remaining inflexible to adjust their decision rights. Finally, some partners may act opportunistically thereby taking advantages on costs of others. In the overall, these impediments cause the uptake of collaboration in sharing logistics resources to remain challenging.

1.2 Trust Problem in Sharing Logistics Resources

Mitigation of the trust problem underlying collaborative logistics and resource sharing can build on the perspective of sources of trust uncertainties or outcomes (consequences) of trust uncertainties. These perspectives appear equivalent to that of Rice (2016) who suggests that mitigations to disruptions can focus either on the source or outcome of a risk. There are plentiful mitigations that focus on the sources of trust uncertainties in the literature (refer Table 2 for details). However, most of such results, according to what Jonsson and Holmström (2016) affirm, are in the least form that is actionable for practitioners. Rice (2016) further stresses to refine the use of mitigation and incline it on mitigation approach that focuses on a predictable set of limited outcomes. Correspondingly, Spekman and Davis (2004) add that trust depends on foreseeable behavior and fair dealing. Henceforth, standing on these arguments, this work focuses on the perspective that refers to outcomes (consequences) of trust uncertainties than their sources. A fundamental basis of this focus is to provide the actionable and practical oriented viewpoint, exploration, and contribution to the trust problem in logistics. Additionally, this perspective aligns with what Fawcett, Fawcett, Watson, and Magnan (2012) emphasize, that managers fail to grasp the dynamism and intricacies that delimit the processes within the collaboration box. Such focus extends to the provision of more valuable insights about trustworthiness of prospective networks configured to facilitate resource sharing, on the one hand.

On the other hand, the focus differs significantly from most of the contributions in literature. Literature contributions have put more emphasis on sources of trust uncertainties (see Table 2). For example, approaches to mitigate trust uncertainties in a perspective of sources of risks are extensively studied. There is a plethora of literature addressing: role, antecedents, and dimensions of trust; approaches to search and select partners, as well as; the measurement and assessment of trust. Section 2.5 presents a detailed discussion of such literature. Moreover, except for studies which operationalize supply chain resilience (Aqlan & Lam, 2015; Cardoso, Paula Barbosa-Póvoa, Relvas, & Novais, 2015; Munoz & Dunbar, 2015), trust approaches resulting from consequences of the risk-worthy relationships in collaborative logistics remain least studied. Such trust approaches have to take a form of supply chain resilience within a context of the trusting outcome. The trusting outcome has a role to cater for insufficiency of sources of uncertainties. Jonsson and Holmström (2016) argue that research has mainly developed analytical models or empirically identified enablers and antecedents for outcomes; without referring to implementable practices and practical contexts. Although authors' argumentation focuses in the supply chain planning, yet it applies also to collaboration in logistics.

For that reason, and by referring, in particular, to the standpoint of the resilience, trusting outcomes, and actionable practices involving collaboration in sharing logistics resources, trust problems potential to address include:

- Difficulties in understanding a degree to which partner behavior under the influence of collaborative logistics processes reinforce trust;

- Difficulties in estimating forthcoming trusting situations, and;

- Insufficiency of pathway explanations (forecasting) about specific character-behavior that can strengthen or weaken needed trusting outcome.

In uncovering outlined trust problems, this dissertation establishes a far-reaching understanding of how behavior and processes reinforce trusting outcomes. This establishment concentrates mainly on estimating and providing a better understanding of how partner (actor) behavior under the influence of collaborative logistics processes, reinforce trusting outcomes. Such understanding plays crucial roles to support logistics stakeholders to figure out, manage, and mitigate possible strengths and vulnerabilities underlying trustworthiness of prospective networks of sharing. However, one critical issue is about how to realize required reinforcement.

Realizing reinforcement of trusting outcomes from partner behavior and collaborative logistics processes requires establishing an appropriate mechanism. The mechanism has to take a form of a logical process, which accounts for trusting actions, decisions, and reactions, which are to be undertaken by collaborating partners. This mechanism may appear in two perspectives. In the first perspective, an ideal desire is to achieve the mechanism that enables logistics managers and other stakeholders to predict the trusting outcomes rationally. However, in practice, achieving rational prediction seems the uneasy task. The second perspective entails a practical reality of the world in which trusting outcomes undergo estimation. Henceforth, a desire that is practical to unveil is the mechanism that helps logistics managers to understand and develop confidence and reliability in the future, trusting decision and actions they undertake. The mechanism has to produce the intended and unintended (Jonsson & Holmström, 2016) trusting outcomes. One can accomplish this need by building a novel trust mechanism that accepts behavioral and process variations, and correspondingly, generates trusting outcomes. It has to stand upon a foundation of appropriate principles whose conceptualization mimics a representation of the human trusting process in the socio-cognitive domain.

In summary, the central argument of this dissertation is as follows: *Effective sharing of logistics resources requires the trust to support and encourage partners to collaborate. However, trust uncertainties resulting from the partner behavior and collaborative processes in logistics impede needed sharing. Such trust uncertainties hinder collaborative efforts, such as efforts to reduce: logistics costs; physical asset underutilization; harms to the environment, and; other logistics inefficiencies. The present dissertation addresses this problem by developing a mechanism that helps collaborating partners to forecast trustworthiness of a prospective (configured) consortium before its implementation. The development focuses mainly on the operational level of collaborative logistics. Such mechanism is set to unveil how partner behavior under the influence of collaborative logistics processes reinforce trusting outcomes, and accordingly advise stakeholders. To realize this objective, firstly, the **Trust Mech**anism (**TrustMech**) concept that stands on a conceptual paradigm of socio-cognition is developed. Secondly, the TrustMech concept is conceptually and operationally validated, and its potential application demonstrated by carrying out controlled experiments in Multi-Agent Systems (MAS).*

1.3 Research Objective, Research Question, and Hypotheses

The primary objective of this dissertation is to develop a trust mechanism that helps logistics stakeholders to understand trustworthiness of prospective networks of sharing they configure. In particular, this mechanism supports collaborating partners to gain a far-reaching understanding (forecasting), and; develop confidence as well as reliability in forthcoming, trusting situations they undertake thereof.

This primary objective is realized by identifying key factors, which influence trust; establishing necessary trust-based interactions of partners; developing a trust mechanism concept, and; carrying out controlled experiments in a virtual world. Development of the trust mechanism is twofold: *the general-purpose trust mechanism*, and; *the operational trust mechanism* that addresses collaborative functions in sharing logistics resources.

Besides this primary objective, specific objectives this dissertation achieves are twofold:

- To determine an extent to which both the combinatorial and singleton behavioral-process[1] reinforce trust, and;

- To provide pathways explanations for trusting outcomes that may potentially lead to strengthening (successes) or undermining (pitfalls) efforts on sharing resources.

Apart from the stated objectives, this dissertation answers the following central research question: *How can collaborating partners acquire a far-reaching understanding about the trustworthiness of prospective networks of sharing they configure?* In answering this central research question, four specific Research Questions (RQ) involved are:

- *RQ1:* What are potential factors and parameters, which affect trust in collaborative sharing of logistics resources?

- *RQ2:* How do collaborating partners in logistics interact, and what conceptual framework can adequately depict trust-based interactions undertaken by such partners?

- *RQ3:* How can a trust mechanism responsible for reinforcing trust from partner behavior under the influence of collaborative logistics processes, be devised efficiently and validated?

- *RQ4:* To what extent do partner behavior and collaborative logistics processes influence trust?

The behavioral factors, trust-based framework of partners' interactions, and trust mechanism constitute deliverables for the first, second, and third research questions, respectively. Such composition excludes the demonstrative application of the trust mechanism concept.

Henceforth, the fourth research question (RQ4) has been set to demonstrate potential applications of the trust mechanism. Its primary goal is to exemplify how partner behavior under the influence of collaborative logistics processes reinforces trusting outcomes. Moreover, the RQ4 is set to investigate relationships between behavioral-process factors and trust to deepen the understanding. Achieving this understanding involves predicting system behavior (expected outcomes), which concern the trustworthiness of the sharing network (as whole) and individual partners. In a viewpoint of system behavior, there are many predictions to perform on a configured network of resource sharing. Even though, to fulfill the demonstrative purposes, the present prediction builds on hypotheses concerning: distortion of information

[1] Behavioral-process comprises of partner behaviors (actions and decisions) under influence of collaborative logistics processes

accuracy; fairness of the sharing methods; conflicting preferences (dilemmas) among collaborating partners; comparative effects of the persuaded and rejected dilemmas, and; highly ranked influential predictor variable. Section 5.3 presents the detailed derivation of the outlined hypotheses.

1.4 Research Contributions

This dissertation provides two core contributions in the form of trust mechanism. The first contribution is the ***general-purpose trust mechanism*** (presented in section 5.1). It is the crucial (fundamental) contribution to a body of knowledge in computing and engineering sciences. It is also the reusable contribution, customizable with little effort to suit specific application domains. The second contribution is the ***operational trust mechanism*** (presented in section 5.2). The operational trust mechanism is drawn (derived) from the general-purpose trust mechanism. It is set to address specifically the trust problem in collaborative sharing of logistics resources. Its operationalization stands mainly on defining predictor and response variables that are necessary to validate and demonstrate the application of the trust mechanism concept. In demonstrating its application, among others, the operational trust mechanism scrutinizes (as a result of reinforcement) trust discontents underlying scenarios related to sharing logistics resources.

Besides these contributions, this dissertation provides other useful contributions in many ways. Resulting from research foundation and techniques, research objective and methodology, and analysis of simulation results, this dissertation also contributes through:

i. Analysis of existing multidisciplinary foundations to trust in collaborative sharing;

ii. Identification of limitations of numerical-based trust approach and proposition of socio-cognitive one to complement;

iii. Identification of factors as well as parameters (criteria) which influence trust in collaborative logistics and resource sharing;

iv. Analysis and comparison of existing models of trust and reputations, as well as their respective techniques;

v. Establishment of a trust framework that depicts (guides) partners' interactions in the collaborative sharing of logistics resources, and;

vi. Provision of pathway explanations (forecasting) against emerging trust phenomena by building on the bottom-up instead of classical top-down interactions of partner's character-behavior.

1.5 Research Approach: An Overview

To achieve the stated research objectives, answer the research question, and contribute accordingly, the research problem is approached by:

i. Conducting a literature review to analyze and synthesize key factors and parameters influencing trust in collaborative logistics;

ii. Analyzing trust modeling approaches, models of trust and reputation to reveal strengths and limitations of existing contributions;

iii. Analyzing approaches suitable to model conflicting decisions, information uncertainty, and negotiation protocols;

iv. Establishing a conceptual framework that depicts partners' trust-based interactions in collaborative logistics. This framework is established based on (partly) the PASSI technique under the Agent-Based Modeling (ABM);

v. Developing the trust mechanism concept by building from the socio-cognitive paradigm, which also incorporates the analogy of human trusting process and socio-economic principles;

vi. Designing and implementing a simulation prototype based on the Multi-Agent Systems (MAS);

vii. Establishing the conceptual and operational validity of the proposed trust mechanism concept, and;

viii. Conducting demonstrative application of the TrustMech under resource sharing scenario in logistics.

Currently, this section presents only an overview of the research methodology. Chapter 3 presents the research methodology in a broad-view.

1.6 Structure of the Dissertation

The present dissertation follows a logical structure as per the stream indicated in Figure 2. Chapter 1 contextualizes the sharing of logistics resources, and trust problem, and justifies rationality of this research. Also, it outlines the problem statement, research objectives, and research questions, as well as research contributions. Chapters 2, 3, and 4 lay a foundation on which this research stands on. In particular, chapter 2 describes basic concepts, terms, and definitions, but also, provides an in-depth (extended) analysis and discussions of the research motivation and problem. Chapter 3 presents the research methodology. Chapter 4 presents state of the art on trust mechanism. This state of the art enriches a fundamental research gap addressed in this dissertation.

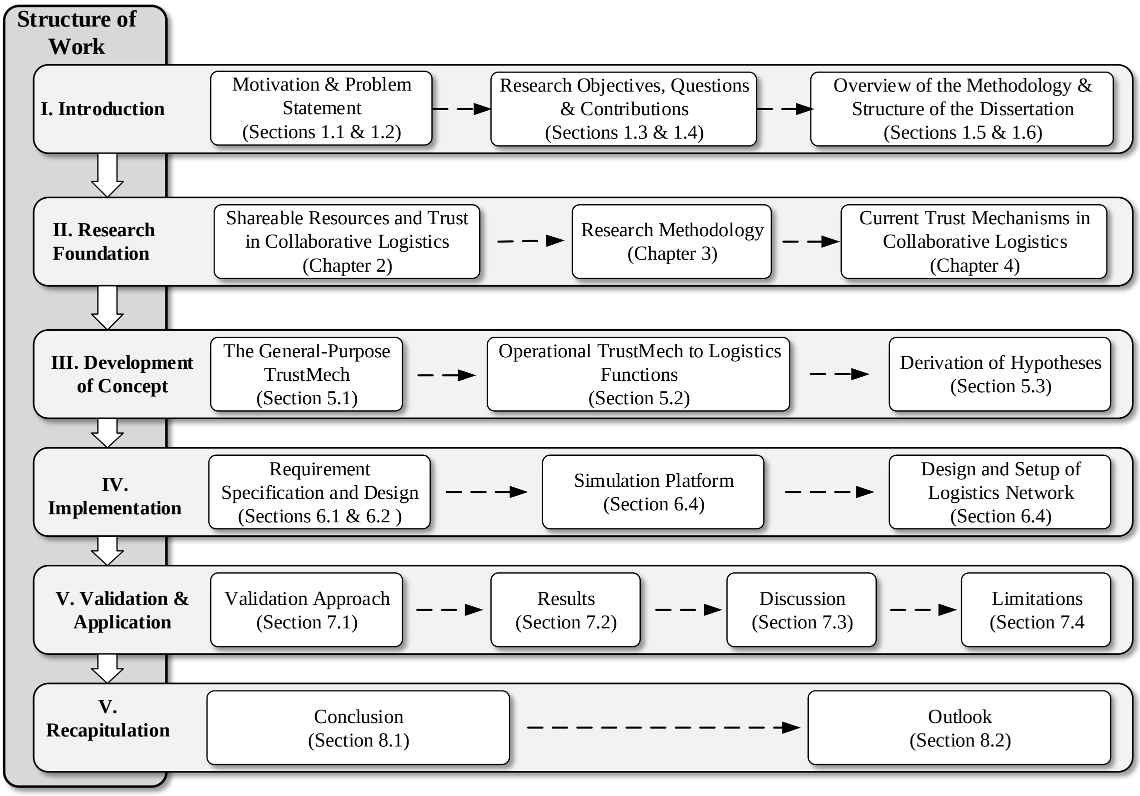


Figure 2: Structure of the dissertation

Upon laying out the research foundation, this work proceeds to develop a trust mechanism concept in chapter 5. In particular, section 5.1 presents the development of a general-purpose trust mechanism. Section 5.2 presents the development of an operational trust mechanism that is customary to collaborative sharing of logistics resources. This operational trust mechanism draws from the general-purpose trust mechanism.

Chapter 6 deals with an implementation that transforms conceptual trust mechanism into the computerized instance. This implementation stands on the MAS to transform the socio-cognitive interactions of collaborating partners in computer controlled-environments using the PlaSMA[2] platform. Moreover, chapter 6 addresses the design and setups of logistics network. Chapter 1 deals with the validation and application, and it presents results, discussions as well as limitations to this study. Finally, this work ends with the recapitulation in chapter 8, by providing the conclusion and outlook.

[2] PlaSMA is an event-driven simulation system which has been designed to solve and evaluate scenarios of the logistics domain (http://plasma.informatik.uni-bremen.de)

2 Shareable Resources and Trust in Collaborative Logistics

During the research parts of the contents have been published in (Daudi, 2015; Daudi, Baalsrud Hauge, & Thoben, 2016a, 2016c).

Trust continues to receive significant attention due to critical roles it plays in collaborative logistics. Following this significance, already there are literary works, which have contributed in this area. Building from such literature works, the present chapter lays fundamental foundations of the research, and it broadens discussions on research motivation and research problem explicitly. Moreover, the chapter provides the descriptive and discursive avenue for basic terms, concepts, and definitions related to shareable resources, trust, and collaborative logistics, on the one hand. On the other hand, it discusses resource sharing in logistics, enterprise collaboration, nature of trust, and determinants of trust in collaborative logistics. The chapter ends by summarizing main addressed issues, but also the concluding remarks. On the overall, the descriptions and discussions throughout this chapter form a crucial clarity of the analysis and discussions of the entire dissertation.

2.1 Shareable Resources in Logistics

In recent years the concept of sharing has grown from a community-based practice into a profitable business model (Böckmann, 2013). This sharing features in the models of Business-to-Business (B2B), Business-to-Consumer (B2C), and Consumer-to-Consumer (C2C). The B2B involves sharing among enterprises while the B2C comprises of companies providing, for example, logistics assets or services to individual consumers. The C2C comprises peers who share assets or services such as the warehouses, accommodation, and vehicles (trucks). In their entirety, these profitable business models enjoy emerged digital platforms, which facilitate matchmaking and coordination. The use of digital platforms reduces the scale for viable hiring transactions or participation in consumer hiring markets (Goudin, 2016), among others.

Various areas such as the consumption, manufacturing, and logistics seem to characterize the re-emerged sharing of resources. As well, the literature appears to use various terms to describe and discuss resource sharing. The terms include the collaborative sharing (Gonzalez-Feliu & Morana, 2011), sharing economy (Goudin, 2016), and collaborative consumption (Buczynski, 2013). The latter two are popular because they mostly involve sharing through renting idle or underutilized resources. Moreover, according to Gesing (2017), resource sharing in logistics emerges under the multi-customer and discreet urban warehouses, community goods on-demand, transport capacity, on-demand staffing, and data. In manufacturing, every production resource such as the specialized machine, or a whole production line can constitute a shared resource (Kück et al., 2016). As far as this dissertation is inclined to shareable resources in logistics, the subsection 2.1.1 presents an overview of such resources, benefits of sharing, and associated trust challenges.

2.1.1 Overview

Logistics sector faces obvious problems of resource scarcity and underutilization, for example, in semi-filled trucks (Schönberger, Kopfer, & Kotzab, 2016). Basically, one can encounter the underutilization of resources when individuals and companies utilize only part of resource capacities they own while incurring same costs as if such resource has undergone utilization fully. There are many reasons accounting for scarcity and underutilization of resources, especially in logistics. According to Schönberger et al. (2016), three trends that have led to the scarcity and underutilization of resources are: continued deregulation of markets; increasing prices for energy consumption and emission, but also; increasing pressure to internalize external costs. The need to share the scarce or underutilized logistics resources seems to be fueled by other causes such as the globalization and population growth. According to Delfmann and Jaekel (2012), the globalization has caused multi-staged logistics systems, whereas the growth of world population has increased demand for more logistics services. Similarly, today's logistics systems are characterized by many logistics objects and their manifold parameters (Schuldt, Hribernik, Gehrke, Thoben, & Herzog, 2011); transient customer demands and changes within the environment, and; globally and individualized distribution in small shipments (Hribernik, Warden, Thoben, & Otthein, 2010; Schuldt et al., 2011). Furthermore, the population has increased, it consumes more than ever before while waste it produces has nowhere to go (Buczynski, 2013).

Therefore, in this context, collaboration in sharing logistics resources remains a very significant agenda that is expected to play a useful role to reduce resulting impacts on logistics systems. When parties go sharing: individualized products/services may be less expensive to deliver, while; improving planning of delivery route and synchronization of variant information sources. Transient demands (especially in small shipments) may need intelligent facilities to support customary sorting in warehouses. Instead of meeting such expensive needs on an individual basis, companies may opt to share warehouse and sorting facilities to reduce operational and investment costs. Equally, combining distinct delivery routes can help to serve energy consumption, and consequently, decrease waste resulting from engine combustion.

The efficient collaboration in sharing logistics resources encounters several challenges. Challenges involve issues such as the safety, complexity, and uncertainty. According to Buczynski (2013), stepping outside a familiar framework of usage of resources makes people feel uncomfortable, but also; people have fear about possible adverse outcomes such as the theft, strangers, and intrusion of privacy. As well, shareable logistics resources are challenged to increasing complexity in planning and less freedom in decision-making, and; a need to process and analyze more data from collaborative partners compared to use same resources within a company (Baalsrud Hauge et al., 2014). Equally, there are uncertainties concerning the shrinking time-windows for deliveries, customized order bookings, and many packaging types (Nilsson, 2006). Other uncertainties Nilsson emphasizes are such as the variations in many products per pallet and per order, increased frequency of deliveries, increased product variants, and less volume per order.

In due of all outlined challenges, the primary challenge is the lack of trust. This primary challenge aligns to what Goudin (2016) emphasizes, that the critical challenge to the growth of the sharing economy is the need to establish trust. In view of this, Goudin maintains that consumers need to trust that: delivery of services will be according to normal standards; they will receive adequate compensation in case of unmet expectation, and; maintenance to their safety and security is a priority.

2.1.2 Types

There are many types of shareable resources in logistics. One can derive typical shareable resources by considering the areas (parts) of a logistics system. The logistics system comprises of six parts: transportation, information systems, customer service, warehousing, inventory, and material management. Out of those parts, resource sharing is most feasible in transportation, information systems, warehousing, and on-demand staffing (an emerging area). Other areas such as material management have potentials to offer when partners go for shareable packaging. In the overall, sharing in logistics entails the physical, non-physical, and human resources. The sharing of physical resources involves a joint usage of tangible assets such as the vehicles (trucks), warehouses, distribution centers, and machinery equipment (Gci & Capgemini, 2008; Gorenflo, 2010; Weinelt, 2016) (Figure 3). By sharing warehouses, for example, firms can benefit from cost synergies and greater flexibility (Weinelt, 2016). Other shareable tangible assets include containers, machinery, and sorting and packaging infrastructures. Given those tangible resources, firms may share logistics infrastructures to sort and combine various products (goods) before shipping to customers and retailers. Such infrastructures are potentially shareable because their deployment, especially on the individual basis is difficult and expensive.

The non-physical assets are intangible assets such as the data, information, supporting processes (Pomponi, Fratocchi, & Tafuri, 2015), as well as logistics services (Figure 3). Information is a non-physical shareable resource (Gci & Capgemini, 2008; Gorenflo, 2010) that drives and makes logistics systems functional. It is the core resource that has to be shared among collaborating parties to accomplish planning, management, and implementation of logistics functions.

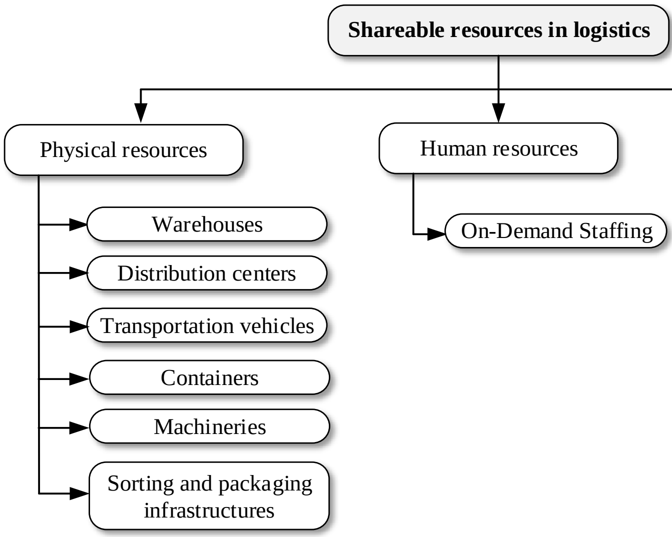


Figure 3: Shareable resources in logistics

Moreover, partners may share logistics services offered under cloud computing (Figure 3). These services include the Platform as a Service (PaaS), Software as a Service (SaaS), and Logistics Business Process as a Service (BPaaS). The PaaS is a layer in clouds that provide essential services in the form of the platform (framework) (Schuldt, Hribernik, Gehrke, Thoben, & Herzog, 2010) that can be used to simulate various logistics scenarios and simplify their deployment. The SaaS may, for example, provide shareable digital platforms to facilitate matchmaking among suppliers and consumers of shareable assets. The BPaaS facilitates a bundling of several logistics cloud services from different vendors and providers, to produce a directly useable logistics turnkey application (ALICE, 2014). As well, sharing is seen to emerge in human resources. In recent years, human-beings have started to offer skills and personal time through shareable modes, facilitated by digital platforms (Gesing, 2017). In the US, according to Gesig, about 34% of the workforce work as freelancers, revealing that there is a fundamental shift in attitudes about flexibility in workforces. Although a wide range of shareable resources exists, this dissertation, in its present form, concentrate much on resource sharing that involves warehouses (and distribution centers), vehicles (trucks), and information (Figure 3). These resources are also classified in (Pomponi, Fratocchi, Tafuri, & Palumbo, 2013) as logistics shareable assets at the operational and tactical level of collaborative logistics.

There are many approaches needed to support resource sharing in logistics. On account of the decision-making processes and hierarchical structures, approaches to supporting resource sharing in logistics may consist of (Gonzalez-Feliu & Morana, 2011):

- *Collaborative sharing with hierarchical decision making* –where usually, users assume responsibilities on managing shared resources. A hierarchy has to be established to help in managing and guiding the collaborative sharing.

As well, the hierarchy supports central decisions which a manager or a small group of stakeholders undertakes;

- *Collaborative sharing with non-hierarchical decision making* –is a more co-operative approach where all users take part in the decision processes. The management can be given to a third party, for example, the broker, but all stakeholders are directly and equally involved in decisions.

Thus, drawing from types of sharing approaches, a distinction may be established between "*sharing*" and "*collaborative sharing*." Sharing means permitting someone to use what belongs to others. Collaboration means merely two or more entities work together to achieve a common goal. Accordingly, whereas the sharing may involve allowing a party to use a resource without mutual benefits, collaborative sharing draws on the joint usage of a resource that mutually benefits all parties involved. Therefore, in this respect, collaborative sharing can be referred to as an act that involves parties to use a resource jointly in a form that mutually benefits all those parties involved.

2.2 Integrated Partnerships in Logistics and Supply Chain

Since the era of the open-market transaction, a degree of integration of production factors has been increasing. The present era has witnessed such integration in the form of cooperation as well as collaboration, particularly in logistics and supply chain. Following this, the current section describes an evolutionary change of such integration towards collaboration (subsection 2.2.1). It subsequently introduces in short features of integrated partnerships (subsection 2.2.2) that are necessary to characterize the role trust plays in collaborative sharing of logistics resources (subsection 2.2.3).

2.2.1 Transition towards Collaboration

The objects of integration such as the coordination, cooperation, collaboration, extended and virtual enterprises resulted from a transition on a continuum in production factors. This transition dates back to the era of market transactions. Looking back on the nature of the firms (Coase, 1937) and economics of firms (Williamson, 1981); orchestration of transactions has shifted from markets' transactions to authority. Under the authority orchestrated transactions, different production factors were integrated to achieve delivery of intended goods and services. However, because of the economic, environmental, and social pressures, there has been an increase in the level of integration of production factors. In manufacturing, for example, some of the pressures placed on enterprise emerge from reality that (Browne et al., 1995): manufacturing now takes place in a global economy; with manufacturing systems obliged to develop environmentally benign products and processes, and; where business and organizational structures are under increasing stresses. Due to this, and in the appeal of levels of integration and interaction of production factors, the orchestration of transactions has evolved from the open-market negotiations to coordination, cooperation, and finally to collaboration (Figure 4).

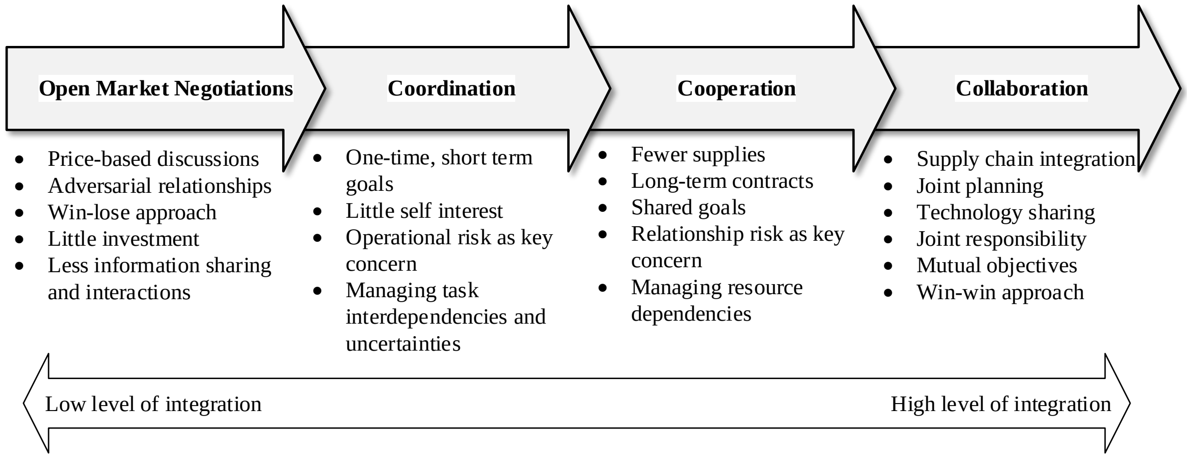


Figure 4: Transition towards collaboration[3]

The first stage, open-market negotiations, was featured with adversarial (arm's length) relationships and least information sharing. Succeeding the open-market negotiations is the coordination and cooperation. Whereas as the former refers to a deliberate and orderly alignment of partners' actions to achieve jointly determined goals; the latter refers to a joint pursuit of an agreed-on goal in a manner corresponding to a shared understanding about contributions and payoffs (Gulati, Wohlgezogen, & Zhelyazkov, 2012). Unlike the preceding two objects, a recent evolutionary stage (collaboration) has taken various forms, including the supply chain collaboration, collaborative logistics, but also the extended and virtual enterprises. In itself, collaboration is understood as the exchange of information, altering activities, and enhancing the capacity of another to attain mutual benefit on a common purpose (Himmelman, 2001). Kozar (2010) differentiates between cooperation and collaboration. She emphasizes that under cooperation, partners can perform their assigned responsibilities separately and bring their results to the table, while; under the collaboration, partners are involved in the direct interaction among each other to achieve common goals thereby negotiating and accommodating others' perspectives.

In the supply chain, collaboration refers to a partnership process involving two or more independent firms that work closely in planning and executing supply chain operations to achieve common goals and mutual benefits (Cao & Zhang, 2011). In logistics, collaboration seeks to increase information visibility, but also synchronize

[3] It is has to be noted that Figure 4 is partly adapted from (Gulati, Wohlgezogen, & Zhelyazkov, 2012; Spekman, Kamauff, & Myhr, 1998; The Economist Intelligence Unit, 2008).

the planning and coordination of workflows. A critical concern is why collaboration is vital to companies?

Collaboration is vital because no company can individually be competitive and provide the spectrum of products, and services around products to satisfy today's customer demands (Sitek, Seifert, & Klaus-Dieter, 2010). In due of this, collaboration has become a core trading mechanism, and its establishment has adopted many evolutionary initiatives (Cheng, Chen, & Mao, 2010). This evolution has particularly blurred enterprise boundaries to the extent that partnerships with suppliers, clients, and even competitors have become commonplace (Browne et al., 1995). Some of those partnerships can emerge in the form of the extended and virtual enterprises, which appear to differ slightly with those of logistics and supply chain collaboration. For example, in the extended enterprise's relationships, firms are linked as learning organizations (Spekman & Davis, 2016), which is somehow different from collaboration in logistics and supply chain. In a context of similarity, enterprise networks occur when two or more participating enterprises are involved in the supply and receipt of goods or services on a regular and on-going basis (Jagdev & Thoben, 2001). Typical extended enterprises are characterized (Braziotis, Tannock, & Bourlakis, 2016): as the advanced form of the supply chain; with a focus on the product value chain for the entire product lifecycle; with an enhanced competitive capability, and; with an approach that focuses on exchanging information and knowledge. Supply network is another form of integration that is closely related to supply chain. In their distinctive features, supply networks consist of non-linear and dynamic structures, and their integration is more ad hoc (Braziotis, Bourlakis, Rogers, & Tannock, 2013) than those of the supply chain.

2.2.2 Features of Integrated Partnerships and a Need for Trust

Integration involves cross-functional interactions, which can result in intense relationships internal to the company and external to other companies (Chen, Daugherty, & Roath, 2009). The critical components of integration include the interaction, and information flow and business process linkage (Wong & Boon-Itt, 2008). According to Kwon and Suh (2005), supply chain integration links all participating players throughout the chain, and its success depends on shared information and trust. It incorporates customers and suppliers into a cohesive supply network, characterized by information sharing, and interdependence (Huang, Yen, & Liu, 2014).

Basically, integration occurs in three dimensions: supplier integration, customer integration, and internal integration (Schoenherr & Swink, 2012; Srinivasan & Swink, 2015). Supplier integration refers, to a degree, to which a company incorporates information about its supplier's capabilities into its planning and execution (Srinivasan & Swink, 2015). This integration represents a change in attitude away from one of the adversaries to one of the collaborations (Wong &

Boon-Itt, 2008). The customer integration is the extent to which organization incorporates customer requirements into its planning and execution; and it involves information sharing on production planning, inventory levels, and deliveries, and demand (Srinivasan & Swink, 2015). The internal integration requires full system visibility from the point of purchasing to distribution within an organization to achieve customer satisfaction (Wong & Boon-Itt, 2008). Benefits of integrating chain activities are such as the ability to reduce costs and inventories, alignment of customer requirements, and improving competitiveness and responsiveness.

The chain integration has been implemented using many initiatives. It has been implemented using various models such as the: Vendor-Managed Inventory (VMI), Continuous Replenishment Programs (CRP), and Collaborative Planning, Forecasting, and Replenishment (CFPR). Fundamentally, these models stand on information integration, which is highly supported by ICTs to update manufacturers and retailers, and even other 3PL members. Under the VMI, the manufacturer has an authority to manage inventory of the retailer, while; under the CRP buyers and suppliers share inventory status to increase replenishment frequencies and reduce inventory (Yao & Dresner, 2008).

The outlined features of integrated partnerships depend on the existence of mutual commitment and trust. One of the reasons for this dependency is that such partnership relationships, especially those on customer and supplier (external integration) span beyond the organizational boundaries. This span occurs because one organization can hardly accomplish its goals without relying on others in the chain. In realizing inter-organizational integration, participant organizations have to share their information with one another, while expecting to gain relative benefits out of it. However, integration may impose uncertainties (risks). Particularly in logistics, integration imposes many uncertainties. It may remain unclear, for example, that: all participant organizations (partners) will play a game trustworthily; shared information will be used as intended, and; partners will gain benefits they expected. In a viewpoint of these dilemmas, the success of integration has to stand upon a foundation of trust. It is for this reason that the next subsection presents a discussion on role trust plays in collaborative logistics and resource sharing.

2.2.3 Role of Trust in Resource Sharing and Collaborative Logistics

Compared to a formal mechanism, relational governance mechanism characterizes mostly the collaboration in sharing logistics resources. The relational mechanism comprises of the social mechanics of commitment, reputation, and trust. On account of this, models that support and facilitate the integration of logistics activities depend much on trust. Trust plays a crucial role in bonding together suppliers and customers. This role is even more vital, especially when customers and suppliers exchange information beyond their internal boundaries. Exchanged information has to be reliable and bear integrity required to facilitate production planning, management of inventory, deliveries, and demand.

However, a dilemma surrounding any collaborative relationship is that with close interactions comes a fear of opportunism where some partners may acts in their self-interest to the detriment of others (Spekman & Davis, 2003). In this context, Spekman and Davis assert that if partners are to share sensitive information, they need an assurance that use of such information will be as intended. Additionally, there can arise a possibility that partners can share modified data that denies visibility and reality. The modification of data may occur when partners attempt to avoid disclosure of their business model through reporting slightly modified information. There are other uncertainties encountered when partners share logistics resources collaboratively. The uncertainties include fairness of methods used dividing costs and gains, as well as synchronizing distributed processes and decisions. In addition, Chopra and Meindl (2010) emphasize that some partners may have local focus and decision, and engage in information processing that leads to a distortion of demand information. In essence, the existence of mutual trust mitigates many of these challenges, and consequently, may motivate and strengthen initiatives geared towards collaborative sharing.

2.3 Nature of Trust

The role and significance of trust backups from a context of dependence that is commonly prevalent in relational exchanges. Typically, this dependence occurs in a situation where one party experiences difficulties in achieving its goals without relying on another party. This reliance is beneficial in case execution to transaction goes in a manner the trustor expects. If execution of the transaction proceeds unexpectedly, the prior established reliance turns out to be a risk. In some transactions, risks are recoverable while in others, restoration is entirely impossible. In due of this, trust makes sense in situations of dependence and where the execution of transaction seems risk-worthy. By risk-worthy, it means that the transaction bears possibilities of both the certainty and risks.

Two conditions, namely: *risk* and *interdependence* (Rousseau, Sitkin, Burt, & Camerer, 1998; Williamson, 1993) characterize trust in relationships. The first condition, risk, originates from the uncertain intention of the other party (Rousseau et al. 1998). This uncertainty arises because the trustor has incomplete information on the subject it desires to trust, at a moment of undertaking trusting decisions. The second condition, interdependence, implies that interests of one party can difficultly be achieved without relying upon another party (Rousseau et al. 1998). Strengthening the value of the outlined trust conditions depends on possible vulnerabilities that arise in trusting situations. Li (2012) emphasizes that trust tend to matter the most when uncertainty, vulnerability, and long-term interdependence are high. Likewise, according to Nguyen and Liem (2013), trust is characterized by risk, vulnerability, expectation, and confidence in the belief that trustee will perform in the manner predicted. Comprehending on arguments in (Li, 2012; Nguyen & Liem, 2013; Rousseau et al., 1998; Williamson, 1993), the risk, interdependence, expectations, and vulnerabilities situate (qualify) trust in interpersonal and inter-firm relationships.

Towards realizing these trust conditions in their entirety, a critical requirement is to formalize in which object (actor of conception) is a notion of trust embedded within (Figure 5). Ideally, trust exists as embedded within the *trustor* and *trustee* objects. The trustor object is an actor who desires to assume trust (rely on another actor). Conversely, the trustee object is the actor who is to be trusted (be relied upon). Conceptualizing on these two opponent contexts, when trust is embedded within the trustor, its meaning differs significantly to when trust is embedded within the trustee. Trust as embedded within trustor is conceptualized as feelings and emotions; while trust, as embedded within the trustee, may mainly be conceptualized as competence, ability, and expertise (Laeequddin, Sahay, Sahay, & Waheed, 2012) (Figure 5).

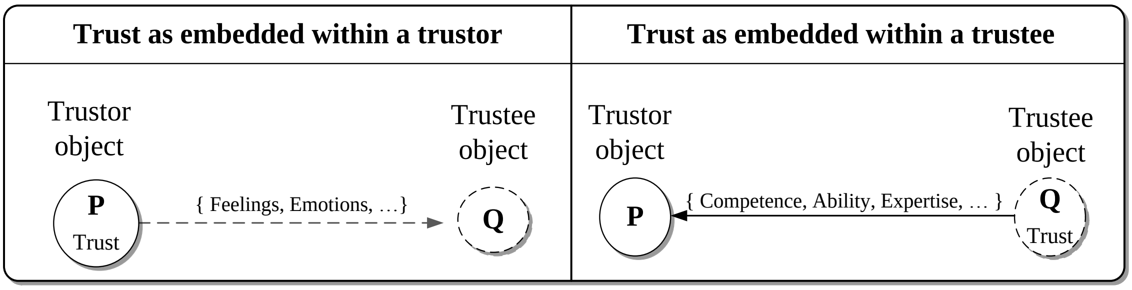


Figure 5: Trust embeddedness within actors

Conceptualizing and operationalizing trust as embedded within the trustor, especially in engineering sciences, remains uneasy, due to operational difficulties faced in measuring and assessing constructs like feelings and emotions. In due to this claim, Li (2012) maintains that the notion of trust as mental attitude is insufficient. He instead proposes to understand trust-as-choice or decision about trusting behavior. The trust-as-choice requires embedding trust within the trustee. This embeddedness appears similar to what (Möllering, 2006) describes as trust manifestation between the trusting attitude and trustful behavior.

To this end, the present dissertation proposes and advances on the notion of trust as embedded within the trustee. Alongside this orientation, trust is conceptualized to result from trustworthy behavior and involves idealized rational decisions and choices than attitudes. This proposition is concordant with that of Li (2012) who affirm that trust-as-choice: involves behavior in trust-related exchanges; extends beyond a propensity to trust, and; captures dynamic nature of trust. This understanding is partly consistent with a layered notion of trust in Figure 6.

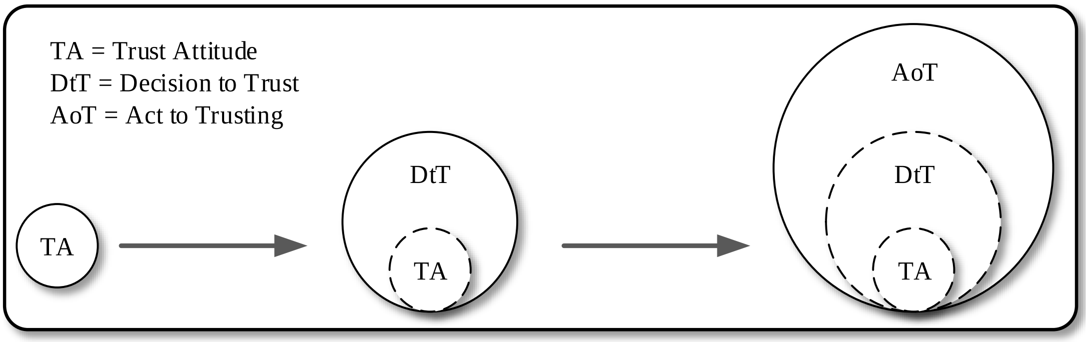


Figure 6: Trust stages and layers (Source: Castelfranchi & Falcone, 2010)

With the layered notion of trust, Castelfranchi and Falcone (2010) theorize that trust:

a) In its basic sense to be just a mental, cognitive attitude and disposition;

b) In its richer use, to be a decision and intention based on that disposition;

c) To be the act of relying upon other's expected behavior, and;

d) To be the consequent overt social interaction and relation to other parties.

The first proposition is too psychological and thus challenging to unveil under computational settings. Due to this difficulty, it is prominent to substantiate that trust-as-decision or choice remains vividly feasible in the remaining principles. Due to this feasibility, in its characterization, trust consists of intention, decision, reliance, and behavioral expectation occurring in interactions such those featured in the socio-economic arena.

Furthermore, to accomplish discussions of this subsection the following terms/concepts: trustor, trustee, and trust are defined as follows. Trustor is an entity that develops a degree of reliance on another object and accepts to be vulnerable to possible actions of that other object. Similarly, the trustee is the party in whom the trust resides, who has the opportunity to take advantage of the trustor's vulnerabilities (Laeequddin et al., 2012). Moreover, trust is a multidisciplinary construct that is critical to human's many and daily interactions. Due to this multidisciplinary nature of trust, until recently, a generalized theory of trust is still not reached. On account of this, there are diverse definitions of trust in literature. Despite this diversity, a particular consensus is somehow getting to a table. In general, the trust may refer, to a degree (level of confidence or expectation) to which the trustee will perform in a manner the trustor expects. To be more specific, this dissertation adapts the definition of trust in (Mayer, Davis, & Schoorman, 1995). According to authors' definition, trust is a level of confidence a trustor–party develops in a trustee–party based on the expectation that the trustee–party will perform a particular action necessary to the trustor–party, irrespective of the ability to monitor or control the trustee–party.

2.4 Trust Determinants in Collaborative Sharing of Logistics Resources

Determinants of trust are elements, behavior, criteria, or factors, which characterize trust in relationships. These determinants vary depending on a domain in which trusting relationships befall. Determinants of hard-trust in computer-network relationships (interactions) are such as the confidentiality, integrity, availability, and privacy. Unlike the trusting relationships in computer-network interactions, trust determinants in collaborative logistics (and supply chain) are different.

There are many determinants of trust in literature, which account for trusting relationships to collaboration in sharing logistics resources. In analyzing such determinants, a preliminary classification needs to be carried out. The goal of this classification is to figure out whether a particular determinant of trust contains a large part of the behavioral elements or not. On account of the present context, behavior implies a set of actions and decisions, which collaborating partners can undertake in collaboration. The ruling to behavioral and non-behavioral elements backs up from the problem statement already presented in section 1.2. That, the present work concentrates on investigating trust uncertainties that result from partner behavior under the influence of collaborative logistics processes. To this effect and in a standpoint of determinants of trust, two streams emerge. The first stream refers to trust determinants, which focus more on partner behavior (behavioral-oriented). The second stream refers to trust determinants, which contain least elements of partner behavior (non-behavioral). In enriching this further, the behavioral-oriented stream depicts trust determinants, which involve various sets of partner's actions, interactions, and decisions, whereas; non-behavioral stream depicts determinants, which lack this requirement.

A survey of the literature was conducted to establish determinants of trust (factors) which influence collaboration and resource sharing in logistics[4]. Apart from collaborative logistics, the survey involved other areas such as the supply chain, manufacturing, and business. For this reason, factors synthesized from literature do not only apply to collaborative logistics. Furthermore, specifications were provided to screen factors between behavioral and non-behavioral oriented streams, and; establish preliminarily how each behavioral factor can influence partner trust. In the end, results from the survey on the literature unveiled a total of nine (9) factors. The factors are commitment, capability, information sharing, communication, asset specificity, joint knowledge creation, incentive alignment, bargaining power, and

[4] Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2016a). Behavioral factors influencing partner trust in logistics collaboration: a review. *Logistics Research*, *9*(1), 19.

opportunism (Table 1). Each trust determinant is briefly discussed and deliberated on whether it constitutes the behavioral or non-behavioral stream.

Commitment

Commitment constitutes crucial elements in social exchanges among collaborating partners. It refers to an exchange partner who believes that an ongoing relationship is worth working on to ensure that it endures indefinitely (Morgan & Hunt, 1994). In a context of collaborative paradigm, commitment appears to be a form of a belief, which may drive a trustee-partner to fulfill tasks delegated to it, in a way that conforms to expectations of a trustor-partner. However, a fundamental question is whether commitment influence trust or trust influences commitment. According to Asawasakulsorn (2009) and Kwon and Suh (2004), there is a definite relationship between trust level and degree of commitment, whereby trust influences commitment. According to Seppänen, Blomqvist, and Sundqvist (2007) trust is potentially a reciprocal construct because it is both, a cause and partly an effect. Therefore, on the one hand, the presence of trust causes entities to develop more commitment. On the other hand, when entities perceive that commitment exists they relatively develop more trust. Henceforth, in a context of collaborative logistics, and in concordance to Asawasakulsorn (2009) and Kwon and Suh (2004), it may be posited that trust influences commitment. This argument rests upon a fact that, usually entities have to trust before they develop commitment. With this establishment, commitment is least considered a factor that can influence collaborating behavior and subsequently trust.

Table 1: Determinants of trust (factors) to collaboration in logistics

Determinant	Literature
Commitment	(Jones, Fawcett, Fawcett, & Wallin, 2010; Ouzrout, Chaze, Lavastre, Dominguez, & Akhter, 2013; Skandrani, Triki, & Baratli, 2011; Wu, Chuang, & Hsu, 2014)
Capability	(Laeequddin et al., 2012; Skandrani et al., 2011; Tejpal, Garg, & Sachdeva, 2013)
Information sharing	(Chen, Yen, Rajkumar, & Tomochko, 2011; Kwon & Suh, 2004; Skandrani et al., 2011; Wu et al., 2014; Yin & Zhao, 2008)
Communication	(Cao & Zhang, 2011, 2013; Su, Song, Li, & Dang, 2008)
Asset specificity	(Jeng & Mortel, 2010; Kwon & Suh, 2004)
Joint knowledge creation	(Cao & Zhang, 2011, 2013)
Incentive alignment	(Cao & Zhang, 2011; Cruijssen, 2006; Wang & Kopfer, 2011; Xu, 2013)
Bargaining power	(Cruijssen, 2006; Jones et al., 2010; Kwon & Suh, 2004; Xu, 2013)
Opportunism	(Hudnurkar, Jakhar, & Rathod, 2014; Ouzrout et al., 2013; Tejpal et al., 2013; Wang & Kopfer, 2011)

Capability

Capability in collaboration is mainly applied when searching and selecting partners. It refers to competence or work standard, skill, knowledge, and ability to fulfill a promise, agreement or obligation (Tejpal et al., 2013). Partner’s capability applicable during the search and selection is unassociated with partner's behavior, but mainly the competence of the partner. To this end, arguably, the capability in collaboration can characterize (describe and represent) behavior of collaborating partners in the least satisfactory manner.

Information Sharing and Communication

Information sharing and communication appear well-known issues concerning collaboration and trust. According to Kumar and Nath Banerjee (2014), information sharing is an act of capturing and disseminating timely and relevant information for decision-makers to plan and control supply chain operations. In similar understanding, Cao and Zhang (2011) define communication as contact and message transmission process among supply chain partners, which concerns issue related to the frequency, direction, mode, and influence strategy. Subject to requirements of collaboration and resource sharing, a critical question is whether information sharing and communication influence collaboration and trust. According to Kottila and Rönni (2008), high frequency of communication is not an indication of collaboration and is less significant than the quality of communication in the creation of the trust. With this view in mind, information sharing can better characterize the behavior of the partner compared to communication. Meaning that partner's actions and decisions associated with the information sharing are worthy to reveal useful insights related to trusting than those associated with the frequency of communication.

Asset Specificity and Joint Knowledge

The asset specificity and joint knowledge creation constitute fundamental issues in supply chain and collaborative logistics. Asset specificity is a transaction-specific investment involving physical or human assets that are dedicated to a particular relationship, and which cannot be redeployed easily (Heide, 1994). Level of asset specificity may imply partners' commitment and trustworthy in sharing resources especially when underlying resources are uneasy to redeploy. Moreover, joint knowledge creation is the extent to which supply chain partners develop a better understanding of and response in the market and competitive environment by working together (Cao & Zhang, 2011; Malhotra, Gosain, & El Sawy, 2005). Upon examining further these issue, asset specificity is least related to the behavior of partners but an investment. Correspondingly, there may exist significant limitations about how to represent partner behavior in a perspective of investment. In reference to joint knowledge, partner behavior is highly recognized at the operational level; whereas joint knowledge creation focuses primarily on the strategic level. To this end, it is thus insufficient to qualify joint knowledge creation as the behavioral factor in the operational level of collaborative logistics.

Incentive Alignment, Bargaining Power, and Opportunism

Literature considers the incentive alignment, bargaining power, and opportunism as significant concerns that impede collaboration and trust. The incentive alignment is understood as a process of sharing costs, risks, and benefits (savings) among partners (Hudnurkar et al., 2014). Equally, bargaining power is an ability of a person, group, or organization to exert influence over another party to impress outcome of the negotiation and achieve a favorable deal (Xu, 2013). Moreover, Ouzrout, Chaze, Lavastre, Dominguez, and Akhter (2010) refer to opportunism as a particular form of the inconsistency of purpose; involving disclosure of incomplete/misleading information, especially calculated efforts to mislead, distort, disguise, or cause confusion. In a viewpoint of opportunism, Spekman and Davis (2004) emphasize that a dilemma surrounding any collaborative relationship is a fear that one partner will act in its self-interest to the detriment of others.

In summary, four determinants are deliberately formalized and qualified to constitute the stream of behavioral factors that influence trust. The behavioral factors are information sharing, incentive scheme, bargaining power (decision synchronization), and opportunism. Section 4.1 presents further discussion on how each factor influences trust.

2.5 Research Problem in a Broader-Spectrum

The current section presents in a broad-view a discussion on challenges of trust to collaboration in sharing logistics resources. The discussion focuses on considering how existing literature has dealt with this problem. Furthermore, the discussion furnishes an understanding of the context, motivation, and problem statement in a wider-view. It is also worthy to note that the discussion in this section carries a multidisciplinary perspective. The multidisciplinary perspective arises due to a fact that, literature contributions that address trust problems originate from many areas. The discussion continues by considering the following. The first consideration entails extents to which current approaches and mechanisms can address the trust problem. Second, a degree to which literature contributions cannot solve the outlined research problem constitutes a research gap. Such research gap formalizes a core basis of the research problem on which this dissertation contributes. Moreover, before analyzing and discussing literature contributions, a reference is made to behavioral factors influencing trust in collaborative sharing of logistics resources.

As highlighted previously, trust uncertainties impede the collaboration in sharing logistics resources. Collaborating partners encounter mostly such uncertainties when: searching for a partner; bargaining towards agreements, and; enforcing collaborative agreements. Trust uncertainties encountered during the bargaining and enforcement stem, mainly from partner behavior and underlying collaborative logistics processes. Explaining this in short, first, collaborative logistics demands information visibility across an entire chain. In due to this demand, the quality of data uses in the process, and possible misuse procreates trust uncertainties. Second, trust uncertainties arise in respect of an extent to which methods (mechanisms) to divide costs and gains may reasonably be accepted. Third, the act of synchronizing complex group-wise decision-making to a compromise, especially when partners establish individual preferences, which are incompatible, pose additional complexity and trust uncertainties. Fourth, opportunism becomes high because of fear that some partners might be involved with hidden and incongruent purposes (extended discussions in section 4.1).

It is noteworthy to recognize contributions from the literature that has dealt with trust the problem. This recognition goes in parallel with the identification of underlying limitations. The recognition may be looked on from perspectives of contributions, which originate from collaborative logistics; supply chain collaboration, and; other related areas. An overall goal is to explore solutions proposed from all possible angles. Henceforth, literature which addresses trust issues, mostly in logistics, supply chain, and other areas were surveyed and analyzed. In the final analysis, Table 2 presents the: literature analyzed; focus on that literature; methods used to study the trust and related problem, as well as; results or findings and recommendations.

On the overall, the literature on trust in collaboration has mostly focused on:

- Addressing the the nature, roles, antecedents, and determinants of trust aimed to overcome the opportunism, alliance failure, and subsequently build trust (Cao & Zhang, 2013; Chen et al., 2011; Day, Fawcett, Fawcett, & Magnan, 2013; Jones et al., 2010; Jones, Fawcett, Wallin, Fawcett, & Brewer, 2014; Madlberger, 2008; Skandrani et al., 2011; Wu et al., 2014);

- Proposing approaches for measuring trust (Ha, Park, & Cho, 2011; Laeequddin et al., 2010) and select collaborating partners in a formation stage (Asawasakulsorn, 2009; Seifert, 2009).

- Investigating the impact of trust on collaborative processes (Ha et al., 2011; Hossain & Ouzrout, 2012; Jeng & Mortel, 2010; Madlberger, 2008; Wu et al., 2014) and managerial ties (Wang, Ye, & Tan, 2014).

- Studying dynamics underlying trusting attitudes and trusting actions (Huang & Wilkinson, 2014), as well as the influence and relationships between trust and other collaborative dimensions (Asawasakulsorn, 2015; Chen et al., 2011; Ha et al., 2011; Jeng & Mortel, 2010; Kwon & Suh, 2004; Mlaker Kač, Gorenak, & Potočan, 2015).

Table 2: Literature addressing trust problem and related areas

Article	Focus	Method	Results / Findings / Recommendations
(Huang & Wilkinson, 2014)	Dynamics in trusting attitudes and trusting actions	A case study using the interview	Trust is really useful when trusting actions occur
			Recommending on the outcome of trust uncertainties
(Jeng & Mortel,	Impact of trust on the	Survey using	Trust affect the level of collaborative processes

Article	Focus	Method	Results / Findings / Recommendations
2010)	level of collaborative processes	questionnaire	practiced by firms with their suppliers Trust is positively related to asset specificity and collaborative processes
(Madlberger, 2008)	Antecedents of inter-organizational information sharing	Survey using questionnaire	Trust in the trading partners do not positively impact the strategic and operational information sharing behavior
(Kwon & Suh, 2004)	Testing a relationship between trust and commitment empirically	Survey using questionnaire	Behavioral uncertainty decreases the level of trust Information sharing lowers the degree of behavioral uncertainty and indirectly improve the level of trust A model that can span interactions regarding trust is indeed required for a complete understanding of trust in supply chain partnerships
(Chen et al., 2011)	Role of information sharing, quality, and availability of trust in collaboration	Survey using questionnaire	Levels of the information quality and availability are positively related to a trust level Information sharing is positively related to commitment Information quality and availability play a positive role in building trust
(Skandrani et al., 2011)	Determinant and manifestations of trust in supply chains	Survey using interview	Trust manifests in risk-taking, demonstrating a preference for a partner, and confidential information sharing
(Jones et al., 2010)	Facets of supply chain trust and its multi-faceted measure	A survey using interview and literature review	Most companies lack the know-how and ability to develop high levels of trust The necessity of trust cycle within the context of an exchange cycle
(Hossain & Ouzrout, 2012)	Modeling trust in supply chain management	MAS simulation	Level of trust impact directly level and quality of information sharing
(Jones et al., 2014)	Role, influence, and measurement of trust in supply chain alliances	Survey using interview and questionnaire	Performance can be improved when partners pursue trust-based collaboration and demonstrate trustworthiness Role of trustworthiness signaling as a proactive means of developing trust
(Ha et al., 2011)	Measure trust and investigate the effect of trust on supply chain collaboration and logistics efficiency	Survey using questionnaire	Affective trust influence collaboration in information sharing and benefit/risk sharing Trust in competency affects collaboration in joint decision making and benefit/risk sharing Detecting insignificant relationships: between trust in a competency and information sharing, and; between benefit/risk sharing and logistics efficiency
(Laeequddin et al., 2010)	Develop an instrument to measure trust	Theorization	The critical perspectives of trust in a supply chain relationship are: characteristics trust, rational trust, and institutional trust/security system
(Asawasakulsorn , 2015)	Partner selection criteria during the formation stage	Survey using questionnaire	Direct prior alliance experience is positively related to some elements of trust Commitment is positively related to trusting the intention
(Seifert, 2009)	Measuring performance	Laboratory experiment	Approach to select partners during collaboration formation
(Cao & Zhang, 2013)	Nature, antecedents characteristics, and consequences of	Survey using questionnaire	Supply chain collaboration stand on elements: information sharing, goal congruence, decision synchronization, incentive alignment,

Article	Focus	Method	Results / Findings / Recommendations
	supply chain collaboration		resource sharing, collaborative communication, and joint knowledge creation
(Mlaker Kač et al., 2015)	Influence of commitment to collaborative behavior	Survey using questionnaire	Trust has a semi-strong/strong influence on relationship commitment
			Relationship commitment and trust have a strong influence on collaborative behavior
(Wang et al., 2014)	Impact of trust on information sharing and opportunism	Survey using questionnaire	Quality of the information shared – rather than the extent of information sharing – should be seen as the primary leverage in reducing supplier opportunism
(Wu et al., 2014)	Trust as antecedents of information sharing and collaboration	Survey using questionnaire	Trust is vital to determine information sharing and collaboration
			Information sharing and collaboration indicate partial mediation effect on supply chain performance
(Day et al., 2013)	Role of trust as an enabler and constraint between buyers and suppliers	A case study using the interview	Buyer behavior on not fulfilling promises and share information diminish trust
			Buyer behavior on performing to promise and sharing necessary information promotes trust
(Moramarco, Stevens, & Pontrandolfo, 2013)	Role of pre-existing trust for the successful buyer-supplier relationships	A laboratory experiment using human as subjects	Face-to-face and e-mail negotiations may be used as trust-building or trust-repairing strategies
(Capaldo & Giannoccaro, 2015)	The positive relationship between trust and performance in supply chain	Simulation using a mathematical model	Trust has a positive effect on supply chain performance
(Abdullah & Musa, 2014)	Impact of trust and information sharing on relationship commitment	Survey using questionnaire	There is a definite relationship between trust and relationship commitment, and; information sharing and relationship commitment

To put it together, contributions from existing literature appears primarily in five areas. First, literature has contributed on roles, meaning, characteristics, antecedents, and dimensions of trust. The second contribution features under approaches used to search and select appropriate partners. Approaches to measure and assess trust constitute the third contribution; whereas influence/impact of trust marks the fourth contibution. Finally, the literature has contibuted on establishing relationships (correlations) between trust and the antecedents, determinants, and collaborative processes.

However, literature in Table 2 carries many limitations as follows. Firstly, some of the approaches proposed remain theoretical, for example, in (Laeequddin et al., 2010), because they lack empirical evaluation. Secondly, for studies which involve the empirical evaluation, yet such studies lack an exact nature of the collaborative realm. Most literature (see in Table 2) has advanced a survey method using the questionnaire and interview techniques. One drawback of survey method is that it hardly incorporates *process* and *time* during data collection. As a consequence, most of the empirical trust research consists of the static, cross-sectional, survey-based studies designed to develop and test variable-based correlation models in which process and time are least considered (Huang & Wilkinson, 2014; Lewicki, Tomlinson, & Gillespie, 2006). The tiniest consideration of time and process is against a longitudinal property of a trust that requires the trust to build over time through repetitive interactions (Spekman & Davis, 2004). Moreover, measuring trust at one point in time, according to Delbufalo (2012) inflates an actual effect size of the trusting outcome compared to longitudinally designed research. Thirdly, most studies establish influential relationships between trust and its determinants and collaborative processes without unveiling the extent of this influence. Fourthly, some of the results and findings in the literature lead to controversies. For example, results and findings in (Madlberger, 2008) contradict with most of the other results (see, in Table 2). Fifthly, except for a study in (Hossain & Ouzrout, 2012), the analysis in most of the studies is based mainly on the top-down than the bottom-up analytical approach. The bottom-up analytical approach envisions a micro-level analysis of interactions of collaborating partners. This approach enriches multiple partners' interactions, which in the end; aggregate, to sum up, a whole effect, thus providing more valuable insights on the trust problem.

Therefore, towards enriching the problem statement, the outlined limitations (challenges) may be summarized in categories as follows:

- *Knowledge gap* –there is a lack of explicit establishment about an extent to which partner behavior under the influence of collaborative logistics processes reinforces trusting outcomes. In a context of this study, processes being referred are the information sharing, incentive alignment, decision synchronization, and opportunism;

- *Controversies* –some results and findings contradict, while others seem to focus more only on correlations among variables. There is a need to unfold arising contradictions, and at the same time, extend the investigation beyond correlative establishments;

- *Mitigation approach* –compared to the trusting outcome, most studies advance on the mitigation approach that focuses on sources of trust uncertainties. Unlike the sources of trust uncertainties, a mitigation approach that focuses on the limited prediction of trusting outcomes (consequences) remains imperative, and;

- *Methodological flaws* –there is a lack of collaborative realm and nature of trusting due to: absence of time (cross-sectional than longitudinal) and process; usage of top-down than bottom-up analysis, and; simple causality of trust.

To this end, set to overcome the outlined limitations, the present dissertation builds on the resilience of systems, which among others, requires estimating outcomes of trust uncertainties. Meaning that practitioners need to estimate and understand trusting outcomes resulting, for example, from manipulation (distortion) of exchanged information; various methods used to distribute savings, as well as; compromised and uncompromised decisions among logistics partners. Barroso, Machado, Carvalho, and Machado (2015) conclude ideation to estimate outcomes. Barroso et al. empathize that to adopt the most suitable mitigation strategies (proactive or reactive); it is necessary to identify in advance risks (uncertainties) that may potentially occur and estimate their potential effect(s). This assertion compares to that of Huang and Wilkinson (2014) who recommend investigating the outcome of trust uncertainties. In a similar context, Kwon and Suh (2004) propose a need for a model that can span trust-based interactions and provide a complete understanding of trust in supply chain partnerships. Henceforth, as suggested in (Rice, 2016), the focus has to shift from mitigating sources of trust uncertainties to predicting (forecasting) outcomes of trust uncertainties. Accordingly, development of a particular trust mechanism has to stand on the perspective of estimating trusting outcomes (consequences) that result from reinforcement of behavior and collaborative processes.

With reference to provisions outlined in an earlier paragraph, this study advances on risky-worth relationships prevalent in collaborative sharing of logistics resources. Respective sources of risk and uncertainties are already established in section 2.4, although section 4.1 presents detailed discussion. In particular, the information sharing, incentive scheme, decision synchronization, and opportunism are main behavioral sources that account for risks, uncertainties, and finally the low level of trust to collaboration in sharing logistics resources.

Also, the present research conducts longitudinal investigation on influence of behavioral factors on trust. The investigation takes into account mechanisms by which partner behavior and underlying logistics processes reinforce trust in the sharing of logistics resources. By drawing also from the social ability of partners, this research integrates feedback loop to trust. Finally, purported to suit real-world settings the MAS simulation experiments are conducted to provide virtual but yet realistic logistics scenarios.

2.6 Summary and Conclusion

The present chapter has described and defined basic concepts related to a topic addressed in this dissertation. It has discussed reasons as to why resource sharing in logistics is imperative, and correspondingly specified logistics resources, which are feasible to share. The chapter has argued on various forms of collaborations as strategic alliances that facilitate the sharing of resources. Role and nature of trust have been discussed extensively to establish how collaborative relationships depend on mutual trust. Additionally, drawing from the logistics and supply chain integration, the chapter has unveiled how trustworthy relationships matter in sharing logistics resources. Towards broadening an understanding of the research problem, the chapter has also addressed recent challenges of trust in collaborative sharing of logistics resources and related areas.

Primarily, individuals and companies are motivated to go sharing because of the scarcity and underutilization of resources. Many factors such as the turbulence of markets, costs, energy consumptions, environmental concerns, globalization, urbanization, and population growth drive a need to share resources. In logistics, feasible resources to share are such as the warehouses, distribution centers, vehicles (trucks); as well as information and information systems. However, collaborative sharing depends on mutual trust among partners involved. Concordant to this, trust is a relational factor necessary to maintain collaborative relationships. In its nature, trust becomes meaningful when embedded within the trustee. Conceptualization of trust as embedded within the trustee requires that trust manifests in behavior than attitudes. In a viewpoint of this embeddedness, the subsequent conceptualization has to consider trust-as-choice that entails decision-making and respective actions. In collaborative sharing of logistics resources, trust, as manifested in behavior, is profoundly influenced by the information sharing, sharing scheme, decision synchronization, and opportunism.

Recent challenges of trust range from controversies in findings, flaws in the research methodology, to unanswered questions. In particular, an extent to which partner behavior and logistics processes reinforce trusting outcomes remains mostly not addressed. Equally, some results and findings seem to contradict. Furthermore, a mitigation approach that focuses on the trusting outcome appears ignored in the literature. Moreover, most of the previous studies do not incorporate process and time and advances in the linear analysis while employing simple causality of trust. The successful resource sharing in logistics requires, among others, to address most of the previously outlined recent challenges. Beyond understanding sources of trust uncertainties, logistics managers and other stakeholders have to understand also a degree of the impact such uncertainties may generate. In addition, collaborating parties willing to share logistics resources need the ability to forecast (anticipate) possible strengths and weaknesses of their network before implementing it.

In its entirety, the chapter has discussed the motivation and research problem in the broad-spectrum. In order to address the identified research problem, the subsequent task is to establish an appropriate research methodology. For this reason, the next chapter discusses in a broad view the research methodology employed by this study.

3 Research Methodology

The overall goal of this chapter is to present the methodology used to study the trust problem and mainly address the research problem specified in section 1.2. For this reason, this chapter extends the previous overview of research methodology presented already in section 1.5. The methodology appears structurally in four sections, which are: background (section 3.1); environmental factors, partner interactions, and causal relationships (section 3.2); specification and implementation (section 3.3), as well as; summary and conclusion (section 3.4).

This research, among others, is guided by an interdisciplinary theoretical foundation presented in section 4.4. This foundation comprises principles drawn from transaction cost economics; social exchange, and; social dilemma. It stands on simulation of collaborative sharing scenarios under a framework of Multi-Agent Systems (MAS). In a context of MAS, a laboratory (controlled) experiment is employed as the primary method. Accordingly, principles of the Agent-Based Modeling (ABM) are used to guide the development of the conceptual modeling of partners' interactions as well as causal mechanics. The ABM principles provide a closer linkage to the MAS simulation experiments in the domain of Artificial Intelligence (AI). In relation to the MAS, reasons mentioned in section 3.3, justify advantages the ABM in AI has over other comparable approaches such as the system dynamics, mathematical modeling, and stochastic differential equations. The ABM permits agents to adapt experience in both proactive and reactive situations. Alongside the advantages of the ABM , Axelrod and Tesfatsion (2006) emphasize that when past experiences determine agents' interactions, and; especially when the agents continually adapt to that experience, mathematical analysis becomes very limited in deriving resulting dynamic consequences.

This research has also followed a longitudinal time horizon. A preference to follow the longitudinal time horizon arises from a fact that trust builds over time. This preference enables collaborating agents to learn, adapt, and accordingly, react to emerging trustworthiness issues. In collecting data obtained from experiments, the text files and relational database tables are used as tools for capturing needed data. Moreover, analysis of data collected advances on both the dedicated (such as Minitab[5]) and general statistical software (such as Excel) tools.

3.1 Background

In the light of the overview already presented, this dissertation adapts the model-centered methodologies of the AI as well as heuristics of empirical works on trust. The model-centered approach, as proposed by Cohen (1991) requires advancing on

[5] https://www.minitab.com/en-us/products/minitab/

the Modeling, Analysis, and Design (MAD) methodology for supporting the design and analysis of AI systems. However, the MAD, in its current form, is more appropriate for model-centered than system-centered research[6]. The present work, however, is mostly system-centered than model-centered. It is for this reason that the MAD methodology is preferably adapted to suiting context of the present work.

The second consideration entails the heuristic of empirical works on trust. In a viewpoint of this heuristic, Möllering (2006) stipulates the methodology that advances on establishing: causal chain; the level of analysis; the aim of investigation; the viewpoint of operationalization, and; method of field work. For the causal chain, the trust and dependency are preconditions whose antecedents comprise of factors influencing trust in collaborative sharing of logistics resources. Such preconditions manifest in partners' behavior, and; their consequences are observed using logistics performance metrics. Additionally, analysis of trust centers at a micro-level to serve predictive purposes. The operationalization of trust uses the trustor and trustee agents, although their coordination depends on the third-party (broker or administrator). Concerning the method, preference goes to the quantitative method, although the final trust values exist in both the quantitative and qualitative expression. However, the present work focuses on controlled experiments, instead of field works.

Therefore, following the clarification and specification provided, this dissertation pursues prominently the methodology presented in Table 3. This methodology comprises six stages.

Table 3: A broad-view of the research methodology

Goal	Activity	Approach/Method/ Technique	Data Sources & Tools	Deliverables
1. Establishing environmental factors	a) Establish factors and parameters influencing trust	Literature review	Literature	Factors and parameters
	b) Establish partners' trust-based interactions	Analysis & Synthesis	Literature	Conceptual framework
2. Modeling causal relationships	a) Establish an appropriate modeling approach	Analysis & Comparison	Literature	Modeling approach
	b) Identify strengths and limitations of existing models	Analysis & Comparison	Literature	Strengths & limitations
	c) Develop a TrustMech concept	ABM	Inputs from 1, 2a & 2b	TrustMech concept
3. Predicting behavior	Derive hypothesis	N/A	Inputs from 1 & 2	Hypotheses
4. Implementing a prototype	a) Specify requirements and design	ABM design & modeling	Inputs from 1, 2, & UML	SRS
	b) Computerize the	MAS guided by spiral	PlaSMA, JADE &	Simulation

[6] A distinction of the two is clarified in (Cohen, 1991)

Goal	Activity	Approach/Method/ Technique	Data Sources & Tools	Deliverables
	TrustMech	model	PostgreSQL	prototype
5. Validating TrustMech	a) Establish conceptual validity	Statistical test & GD	Results from simulation	Conceptual credibility
	b) Establish operational validity	Comparison to other models	Results from simulation	Operational credibility
6. Demonstrating application	Test hypotheses derived from 3	Statistical tests and GD	Results from simulation	Applicability of TrustMech

The first stage entails establishing environmental factors, whose deliverables supports the modeling of causal relationships in the second stage. The third and fourth stages involve predicting system's behavior and transforming TrustMech concept into a computerized instance, respectively. Remaining stages seek to establish validity (stage five) and demonstrate application (stage six) of the TrustMech concept.

3.2 Influencing Factors, Partner Interactions, and Causal Relationships

The first goal (in Table 3) entails establishing environmental factors based on the literature survey/review. This review is meant to identify critical factors and parameters, which influence trust in collaborative sharing of logistics resources. Besides such factors, significant interactions partners undertake during collaboration are also established. This establishment takes into account identification of the following aspects: key partners and their roles; tasks performed by partners, and; information exchanged among such partners. In the end, all identified aspects are loosely linked together to form a conceptual trust-based framework.

The second goal (Table 3) focuses on modeling causal relationships. The accomplishment of the causal relationships is threefolds. At first hand, standard approaches used to model, trust, and reputation are analyzed and afterward compared to conclude the most appropriate one. Secondly, strengths and limitations of existing models of trust and reputation, as well as underlying techniques are also analyzed and compared. Resulting strengths are thoughtfully adapted while unfolding limitations. The third step incorporates the development of the Trust Mechanism (TrustMech) concept. The development begins with a general-purpose TrustMech, and afterward, deriving the operational TrustMech from the general-purpose TrustMech. As highlighted previously, this development rests on principles of transaction cost economics, social exchange and learning, and dilemma analysis. Concordant to this, the TrustMech is conceptually modeled based upon the ABM method, as described and discussed in subsequent sections.

The third goal (Table 3) is set to predict how a system may behave, and subsequently demonstrate the application to the TrustMech concept. In a present context, the prediction has to depend on hypotheses. A purpose of the hypotheses is to investigate how the TrustMech helps logistics stakeholders to understand phenomena that may emerge in prospective resource sharing networks.

3.3 Specification and Implementation

Implementation of the prototype (fourth goal) involves: specifying requirements and design, as well as; transforming the conceptual TrustMech into the computerized instance. Among others, this transformation applies the ABM method, “PASSI” (Cossentino & Potts, 2002) technique as well as the Unified Modeling Language (UML). Why choosing to apply the ABM? According to Axelrod and Tesfatsion (2006), ABM is a method for studying systems which: are composed of interacting agents, and; exhibit properties arising from the interactions of the agents that cannot be deduced by merely aggregating the properties of the agents. Axelrod and Tesfatsion further maintain that the ABM uses concepts and tools from social and computer science to represent a methodological approach that permits a deeper understanding of fundamental causal mechanisms in social systems. Given these points, the ABM is more suitable, especially upon considering the context of the research problem that also originates from social systems. In due to this, modeling TrustMech using system dynamics, may contradict the reality of world on representation of trusting situations.

In addition, models built on the ABM conceptual paradigms are used to simulate and elaborate complicated scenario in socio-economic systems (Bandini, Manzoni, & Vizzari, 2009). It is far from other approaches such as the mathematical modeling, stochastic differential equations, and system dynamics. For example, the latter modeling approach seems unable to provide sufficient features of an agent such as learning, adaptability, and social ability. Furthermore, compared with other modeling approaches, the ABM (Bonabeau, 2002): captures emergent phenomena; provides a natural description of a system, and; is flexible. Bonabeau emphasizes further that the ability of the ABM to deal with emergent phenomena drives the other benefits.

Besides the ABM, the UML technique sequenced in steps proposed by Cardellini et al. (2007) provides a guide in specifying requirements and designs. The specifications and designs take into account the UML extensions proposed in (Bersini, 2012; Cardellini et al., 2007; Cossentino & Potts, 2002; Odell, Parunak, & Bauer, 2000). The UML unifies and formalizes methods of many approaches to the object-oriented software lifecycle and supports modeling of (Odell et al., 2000):

- Use cases for specifying actions performed;
- Dynamic models, in the form of sequence diagrams, and;

- Static models, in the form of class diagrams, which describe the unchanged semantics of data and messages.

Transformation of the conceptual TrustMech into a computerized instance succeeds the specification of the requirements and design. This transformation builds on the MAS that consists of computerized intelligent agents. Intelligent agents are known as agents who are capable of flexible autonomous actions, social ability, reactivity, and pro-activity to meet their objectives (Wooldridge & Jennings, 1995). It might be interesting to know why MAS is applied. Application of the MAS comes when a phenomenon under investigation seems complicated, and mainly when handling such a phenomenon using other forms of experiments is difficult. On account of this, it becomes hard to deal with the outlined research problem using experiments that are founded, for example, on the systems dynamics, micro-simulation, and stochastic differential equations. Moreover, the case study, field study, and action research methods are less appropriate compared the MAS approach. This appropriateness is raised by existing difficulties to obtain real-world platform to validate and demonstrate how useful the proposed TrustMech concept is. In developing (building) a prototype, it is preferred that the respective transformation use the PlaSMA framework to provide logistics infrastructure, the organizational, and individual agents in their roles as decision-makers (Warden et al., 2010). The final goal is concerned with formalizing approaches to be used to validate the TrustMech. The validation employs two validation objects, namely: conceptual and operational validity. Establishment of the operational validity rests on comparing the TrustMech to other rival models. Establishment of both validities employs the Graphical Displays (GD) and statistical techniques. Since further elaborations on validation also depend on output from subsequent chapters, then section 7.1 presents a detailed discussion on validation approach.

3.4 Summary and Conclusion

The current chapter has presented the research methodology employed to study the trust problem in collaborative sharing of logistics resources. The proposed research methodology supposes to:

1) Identify environmental factors by reviewing the literature;

2) Establish trust-based interactions undertaken by collaborating partners in logistics, based on the ABM;

3) Develop the TrustMech concept based on the ABM;

4) Carry out laboratory (controlled) experiment using the MAS as the primary method;

5) Establish the conceptual and operational validity by relying on the internal consistency and model to model comparison techniques, respectively and;

6) Demonstrate the application of the TrustMech concept by simulating resource sharing scenario(s) in logistics.

The first purpose of controlled experiments is to enrich a virtual realism in the respect of process and time. The second purpose is to provide an alternative to a lack of a real-world platform needed to carry out industrial testing. Moreover, the methodology pursued overcomes many methodological flaws identified previously in section 2.5. Expectedly, the controlled experiments generate enough amounts of output data to draw patterns (trends) of trust behavior. The simulation platform provides also flexibility, for example, on an ability to add or reduce the number of participating partners.

A closure to this chapter marks an opening of a next chapter. To this effect, the next chapter (chapter 4) presents state of the art on trust mechanism in collaborative logistics. Among others, it presents discussion regarding behavioral factors influencing trust, trust modeling approaches, and models of trust and reputation. Accordingly, the chapter reveals strengths and limitations of existing models of trust and reputation. Revealed strengths and limitations refer to an extent to which existing models of trust and reputation can suitably be applied to solve the trust problem. In the end, the chapter specifies contributions this dissertation provides to a body of knowledge.

4 Current Trust Mechanisms in Collaborative Logistics

During the research parts of the contents have been published in (Daudi, Baalsrud Hauge, & Thoben, 2016b; Daudi et al., 2016a; Daudi, Baalsrud Hauge, & Thoben, 2017a, 2017b).

The chapter presents, among others, the most-recent requirements and developments (aspects) that address mechanisms of trust in collaboration and related areas. Much attention pursues on aspects, which can add value to a proposed concept in chapter 5. The first aspect focuses on addressing the analysis and synthesis of critical behavioral factors and parameters that account for promotion and detriment of trust in collaborative sharing of logistics resources. This aspect extends previous establishments in subsection 2.4 to unveil further how such behavioral factors influence trust. The second aspect involves discussion on means by which collaborating partners interact, negotiate, and get coordinated. Such discussion results further into establishing the conceptual framework that depicts and guides trust-based interactions of partners engaging in sharing logistics resources collaboratively. The third aspect addresses suitable means to model information uncertainty and decision-making in the decentralized, complex, and predicament environments. Realization of this suitability encompasses comparing the qualitative and quantitative streams that address information sharing; while also identifying incompatible decisions.

The other most-recent aspects addressed in this chapter include theoretical foundation, trust modeling approaches, and models of trust and reputation. To this effect, the fourth aspect is set to formalize an interdisciplinary theoretical foundation that guides this research. The interdisciplinary foundation builds on principles of social exchange and transaction cost economics. Furthermore, since trust is a multi-context construct, it can then be modeled from various perspectives. As such and in concordance to the research problem, the fifth aspect focuses on identifying an approach that is most suitable to model trust mechanism. Towards this suitability, three approaches for modeling trust are analyzed and compared to conclude the most appropriate one. The sixth aspect concerns the analysis and comparison of well-known models of trust and reputation. Its goal is to unveil a degree to which such models are appropriate as well as limited to addressing the outlined research problem. The chapter ends by summarizing key findings, but also by providing concluding remarks.

As general remarks in this chapter, it is worth taking note about an interchangeable usage of words, as well presentation of the interdisciplinary and multidisciplinary discussions (contents). Firstly, the terms *partner* and *agent* are used interchangeably to link the organizational systems, Agent-Based Modeling (ABM), and Multi-Agent Systems (MAS). Secondly, contents of section 4.1 and subsection 4.2.2 present the interdisciplinary issues. Section 4.1 addresses the integration of trust and its influencing behavioral factors, while; subsection 4.2.2 deals with trust and interactions among collaborating partners in logistics. Section 4.4 is also presented in an interdisciplinary manner because it integrates the theoretical foundation from principles of transaction cost economics and social exchange. Thirdly, the remaining sections present multidisciplinary issues because they separately address the topical points in question from other domains, including computing, engineering, and management sciences. These domains provide a solution approach to trust problem in the collaborative sharing of logistics resources.

4.1 Behavioral Factors and Parameters Influencing Trust

The section provides discussions on behavioral elements, which characterize trust in sharing resources in collaborative logistics (Figure *7*). It establishes how behavioral factors influence trust and articulate parameters (criteria) which constitute each factor. In particular, an assumption exists that under current settings the fourth factor, opportunism, remains intrinsic in the other factors. Those other factors are the information sharing, sharing scheme, and decision synchronization. The outlined behavioral factors are two-sided in a sense that they can deteriorate or promote trust. To clarify this, when partners behave in a way that imposes positive or negative influence then trust can be promoted or deteriorated, respectively. The latter refers to behavioral uncertainties. According to literature, behavioral uncertainties refer to potentials inherent in a situation for difficulty anticipating and understanding actions (Krishnan, Martin, & Noorderhaven, 2006) of partners with whom one is collaborating or interacting.

4.1.1 Information sharing

Collaborating partners share information among themselves to facilitate planning and operation of logistics functions. Partners share information concerning various logistics elements such as the capacity, lead time, demand, production schedules, inventory, and cost. These elements, according to Flynn, Koufteros, and Lu (2016), are task characteristics whose uncontrolled variability imposes a micro-level uncertainty. In connection to this, Wu et al. (2014) stipulate that one can treat information sharing as a behavioral intention of partners that leads to actual behavior in collaboration. As such, challenges associated with information sharing are such as: coping with demand uncertainty; coping with logistics decision-making complexity, and; dealing with the vulnerability of opportunistic behavior to protect the individual interest (Simatupang & Sridharan, 2002). Such challenges may difficultly be determined in advance, while their effects remain a bottleneck to partners' motives to collaborate. Despite these challenges, still, other partners may behave fairly, while minimizing the demand and decision-making uncertainties.

Under such circumstances, collaboration becomes featured with a mix of both certainty and uncertainty.

Accordingly, while exchanging information, collaborating partners exhibit information-sharing behavior, which may be beneficial or detrimental. Beneficial behavior entails the action and decision of partners in a context of exchanging information that conforms to required standards of the collaborative consortia. On the contrary, actions and decisions which lack this conformity remain considerably damaging. The categories (dimensions) of Information Quality (InfQ) can characterize both, the beneficial and detrimental information behavior. This characterization employs a viewpoint of the information exchange rituals exhibited by partners during collaboration. The four dimensions of InfQ are system support, inherent (context examination), representation, and purpose-dependent (*data use in processes*) (Rohweder, Kasten, Malzahn, Piro, & Schmid, 2011). As per the methodological approach followed by this research, the former three dimensions are difficult to characterize in computational settings. For this reason, this dissertation builds on the dimension of purpose-dependent because it depicts data to use in the collaborative logistics processes.

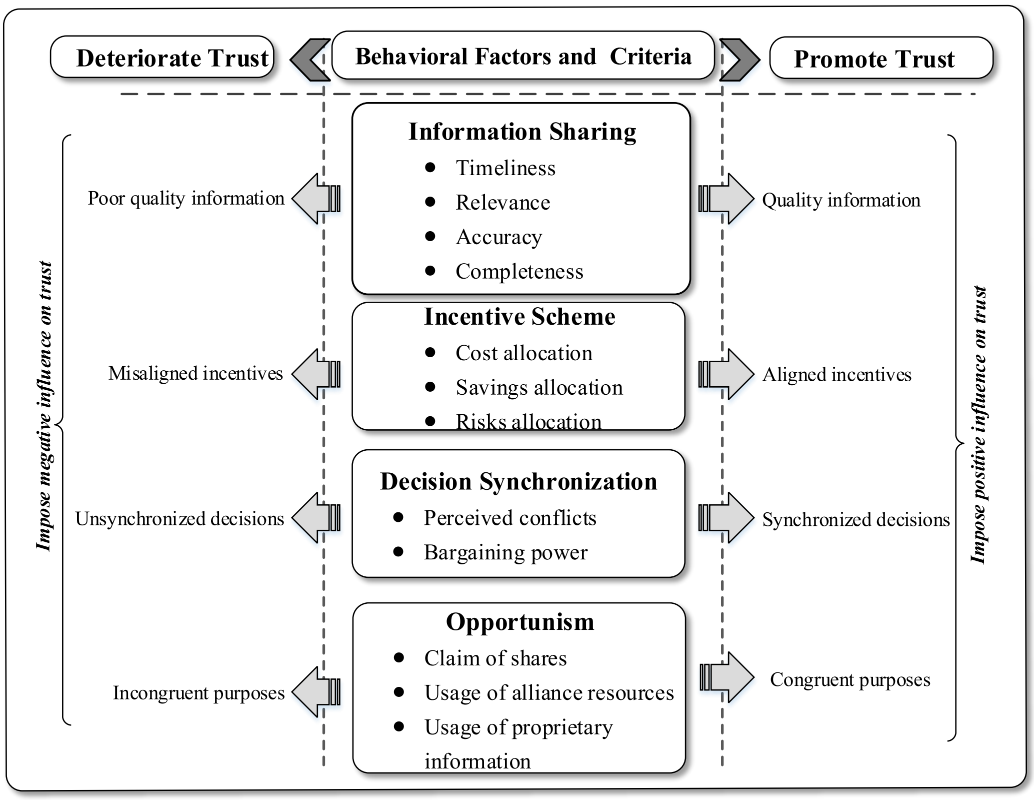


Figure 7: Factors and parameters influencing trust

A critical analysis of the literature on collaborative logistics has unveiled that characterization of data uses in processes may consist of many criteria (Figure 7), including:

- Timeliness (Cao & Zhang, 2011; Chen et al., 2011; Yin & Zhao, 2008);
- Relevance (Cao & Zhang, 2011; Chen et al., 2011);
- Accuracy (Cao & Zhang, 2011; Chen et al., 2011; Yin & Zhao, 2008), and;
- Completeness (Cao & Zhang, 2011; Chen et al., 2011; Yin & Zhao, 2008).

These criteria, together, emphasize the on-time availability of reliable data, abundant enough to meet consumer's needs. In addition, such data has to represent a fact on business reality and provide adequate interpretation within an intended context. Under the present settings, such context is the collaboration in sharing logistics resources.

Information sharing (exchange) behavior can influence trust in both negative and positive ways. For example, the untimely, irrelevant, inaccurate and incomplete information (information asymmetry) may escalate uncertainty and low level of trust. This uncertainty signals not only a situation of deviation from the prior agreement but also inconformity. In contrast, the act of exchanging the timely, relevant, accurate and complete information (quality information) signals a situation of compliance and high level of trust to previously established collaborative agreements. The exchange of quality information by partners appears to grant and promote trustworthiness. Conversely, the exchange of poor quality information by partners can deteriorate trust. Even though, a choice to exchange quality or poor information remains a partners' innate ability that is guided further by prevailing situations.

4.1.2 Incentive Scheme

According to Simatupang and Sridharan (2005), proper incentives motivate partners to align individual decision-making more closely with an overall goal of collaborating. Even though, it is hard to identify contributions of each partner in the coalition (Wang & Kopfer, 2011). This difficulty relates to means or methods, which collaborating partners can use to divide costs and saving resulting from coalitions. Towards mitigating this problem, Xu (2013) and D'Amours and Rönnqvist (2010) have emphasized on simple rules of thumb that distribute savings proportionally. In similar manner, Tseng, Yan, and Cruijssen (2013) propose a general framework for designing a compensation rule. Despite these initiatives, one issue that seems unveiled yet is about an extent to which such methods are trustworthy and fair.

The literature has discussed trust challenges associated with sharing scheme methods. For example, arguments exist that it is difficult to determine potential cost savings (Cruijssen, 2006; Wang & Kopfer, 2011) as well as ensuring a fair allocation of the shared workload in advance (Graham, 2011). In support of this, one open question is, to what extents are rules or methods (proposed in literature) reasonably acceptable and thus trustworthy? In the light of this open question, Cruijssen (2007) claims that many collaborative logistics initiatives disintegrate because of trust uncertainties concerning the fairness of these rules.

In relation to behavioral uncertainty, one critical requirement is to synthesize how incentive alignment influence partner trust in sharing logistics resources. The influence depends on a degree of fairness, which partners perceive upon distribution of costs and gains. For example, unfair allocation of incentives may increase trust uncertainties because of suspiciousness and rivalry in unseen returns. Conversely, upon realizing fairness in the sharing of pains and gains using evenhanded negotiations (Jones et al., 2010; Sutherland, 2006), trust can be promoted. To this end and in viewpoint of the incentive scheme, allocation of costs (Cruijssen, 2006; Jones et al., 2010; Xu, 2013), allocation of savings (Jones et al., 2010); Wang & Kopfer, 2011), and risks allocation (Cao & Zhang, 2011; Jones et al., 2010) constitute formal criteria, which can affect trust in collaborative sharing of logistics resources (Figure *7*).

4.1.3 Decision Synchronization

Decision synchronization refers to a process by which partners orchestrate decisions in planning and operations to optimize chain benefits (Simatupang & Sridharan, 2002). It is joint decision-making that plays a vital role to resolve many issues such as the costs, forecasting, ordering, and replenishment of logistics orders. Decision synchronization becomes crucial to situations where decisions made by one partner(s) create uncompensated costs or benefits to others (Cruijssen, 2006).

The joint decision-making involves synchronizing decisions among partners who are not only distributed but also who possess distinct preferences. Such preferences center on a particular domain of decision to the extent that positions taken in decision rights by different partners result in conflicts due to arising incompatibilities. To avoid such conflicts, one has to synchronize decision positions of individual partners to a compromise. This decision synchronization involves a joint exercising and redesigning of decision rights (Simatupang & Sridharan, 2005) to help resolve conflicts or disagreements (Kwon & Suh, 2004) that arise. In the supply chain, for example, disagreements may occur when companies attempt to optimize their performance while disregarding benefits of the supply chain as a whole (Trkman, Stemberger, Jaklic, & Groznik, 2007). Effects of such disregards may also affect partners on an individual basis. In their entirety, such self-interested decisions seem to generate consequences that may either strengthen or weaken trust in sharing logistics resources.

To mitigate a problem of incompatible preferences, an owner of a specific decision right has to reconsider effects of its decision rights and position on other partners and entire consortium. This consideration requires parties concerned to resolve arising differences (conflicting preferences). This dissertation refers to unresolved conflicting preferences as unsynchronized decisions. The unsynchronized decision appears in two behavioral discontents: rivalry and compromise (Simatupang & Sridharan, 2005). Simatupang and Sridharan describe such behavioral discontents as follows:

- With rivalry behavior, a party has a high concern for its interest coupled with low concern for the other parties' interests;

- With compromise behavior, a party emphasizes on give-and-take bargaining during the relationship.

Towards building trust, partners have to moderate their decision rights to the compromise style which appears satisfactory and acceptable. In contrast, the rivalry style may largely contribute to low level of trust. As concluding remarks, perceived conflict (Cruijssen, 2006; Kwon & Suh, 2004) and bargaining power (Cruijssen, 2006) are criteria constituting decision synchronization (Figure *7*) and are considered to yield a significant influence on trust.

4.2 Collaborative Controls, Interactions, and Negotiations

The section presents discussion set to accomplish three main issues: control approaches for mediating interactions of collaborating agents; trust-based interactions of collaborating agents (partners), as well as; negotiation protocols. In accomplishing the first issue, concepts of the institutional and social control approaches are discussed and subsequently adapted in subsequent sections and chapters. The goal of this adaptation is to regulate interactions of agents in collaborative sharing of logistics resources. The second issue entails trust-based interactions of collaborating agents. This dissertation characterizes such interactions in the form of a conceptual framework that specifies, among others, typical agents, their roles and tasks, as well as information to be exchanged. Regarding the third issue, out of three protocols of interactions, one protocol appears most suitable to the context of the outlined research problem.

4.2.1 Institutional and Social Control Approach

Agents reside and interact in both the physical and virtual world. A large part of such a world is dynamic and heterogeneous. The world comprises human-agents, hardware-agents (robots), software-agents (programs), and organizations; which altogether appear beginning co-interact but also co-evolve. Most of the interactions undertaken by agents, whether formal or informal, are mediated. On the one hand, this mediation seeks to control or regulate agent behavior about norms articulated by a community in which such agents reside. On the other hand, a degree of trustworthiness attributed to each agent, constitutes determinants of interactions such agent undertakes. The mediation and trustworthiness depend on principles, which can be drawn from various norms. A norm is an (ideal) behavior which agents are expected to exhibit (Grizard, Vercouter, Stratulat, & Muller, 2007). Norms are also understood as social attitudes of approval and disapproval, specifying what ought to be done and not (Sunstein, 1996). Tuomela (1995) categorizes social norms into rules (r-norms) and proper social norms (s-norms). The r-norms are created and regulated by authorities such as formal institutions. Unlike the r-norms, the s-norms represent the conventions or the mutual beliefs about the right thing to do in a community (Grizard et al., 2007; Tuomela, 1995). By drawing on the r-norms and s-norms, the subsequent paragraphs present a discussion on the institutional and social control approaches for mediating collaborative interactions in logistics.

The institutional approach assumes a central authority that observes or enforces agents' actions, and punishes them, in case they exhibit undesirable behavior (Pinyol & Sabater-Mir, 2013). There are many institutional activities, which monitor and verify agents' conformity (Lianos, 2003) to r-norms. Under the institutional approach, control encircles structural aspects of the interactions of the form: *allowed*, *forbidden*, and *obliged actions* (Pinyol & Sabater-Mir, 2013). The formal rules comprise articulated and written norms with formal sanctions, reinforced by properly established authorities (Tuomela, 1995). In e-commerce, for example, institutional enforcement is implemented using reputation systems. In general, reputation refers to something said or believed about a people or thing's character or standing (Josang, Ismail, & Boyd, 2007). On employing the reputation, for example, an entity can be trusted standing on the degree of reputation ratings a respective community has provided to it. In e-commerce, reputation systems are implemented in digital forms to provide buyers a reputation of the seller (service providers) of goods and services. It is from this reputation where the buyers can derive and establish trust in service providers. Next to institutional control is the social control approach.

The social control approach is a way for the population to avoid unwanted agents (Rasmussen & Jansson, 1996) in a community. It mainly applies s-norms to regulate interactions of agents thereby sanctioning misbehaving agents. The s-norms sanction is only a social approval or disapproval, which is hard to decide in advance (Grizard et al., 2007). The social sanctions create a range of unfriendly feelings, which are intense, and may lead to substantial consequences (Sunstein, 1996) to the misbehaving agent. Moreover, the authority point of view distinguishes the institutional approach from the social approach. Unlike the institutional approach, which is centrally coordinated, the social approach is decentralized. In the light of this decentralization, each agent is obliged to enforce s-norms to other agents surrounding it.

When applied to solve the trust problem, each control approach bears strengths as well as limitations. The institutional control approach suits collaborative settings, which are coordinated by a central authority. Example of central authority is a usage of the broker to administer a network of collaborative sharing. This central authority (broker) has to be a neutral agent (body). Furthermore, consortia designed to last for a medium or long-term duration usually are controlled based on the institutional approach. Those designed to last for short-term may only provide essential information to the authority and be coordinated based on the social approach. This study builds on the institutional control that fulfills longitudinal observations.

4.2.2 Partners' Trust-based Interactions to Collaboration in Logistics

The primary goal of this subsection is to establish a conceptual trust-based framework that depicts and guide interactions of collaborating partners in sharing logistics resources. The conception of this framework considers: how collaborating partners (agents) can interact when engaged in the sharing of resources, and; what particular trusting processes they are engaged. This conception draws from many angles, including early collaborative models in supply chain integration such as the VMI, CRP, and CPFR.

This establishment involves identifying and specifying the following main aspects: key partner entities; partner' trust-based characteristics; propagation of trusting processes; essential roles and tasks performed by partners; information exchanged by partners, and; emerging preferences in decision rights that may be incompatible. Furthermore, in developing the trust-based framework, it is worthy to note that the term "*agent*" is more formal in place of the term "*partner*." A goal of this interchangeability is to link subsequent chapters that address the development of TrustMech concept and its subsequent implementation. Establishment of the framework consists of three main stages: *selection and front-end agreement* (Figure 8); *engagement and order forecast* (Figure 9), and; *transaction execution* (Figure 10).

Towards examining trust uncertainties, which underlie collaboration in sharing logistics resources, three categories of agents: *shipper*, *carrier*, and *receiver* constitute crucial and formal partnering entities (Figure 8). Additional to defined categories of agents is a *warehouse manager* whose interactions are less frequent than those of the other agents. Other stakeholders are currently not included in the framework because they do not play primary roles. The leading role of the shipper is to produce goods, while that of the receiver is to receive (consume) produced goods. The primary role carrier is to move goods between the shipper and the receiver. The warehouse manager is responsible for storing goods in a shared warehouse. Notably, each agent category may consist of more than one actor who still serves similar roles. The ABM and MAS allow to adjust the number of actors befalling in each category.

Selection and Front-End Agreement

In the first stage (Figure 8), agents have a responsibility to undertake a decision of disposing of their willingness to participate in risk-worthy relationships. In respect of this, the shipper, receiver, and carrier develop an intention to trusting by taking on strategic agreements in a context of the planning of logistics functions. According to Mayer et al. (1995), assessment of the propensity to trusting by the trustor-agent depends on two aspects: a relationship it has with the trustee-agent, and; other factors outside of the relationships which lead into uncertain decisions. The uncertain decision (or decision-making uncertainty) means an inability to predict partner behavior or changes in the external environment (Joshi & Stump, 1999). In a context of sharing logistics resources, the decision uncertainty is attributed to, for example, production capacity, warehouse capacity, carriage capacity, and consumption capacity. Moreover, this relationship between the trustor-agent and trustee-agent depends on previous experiences and future expectations.

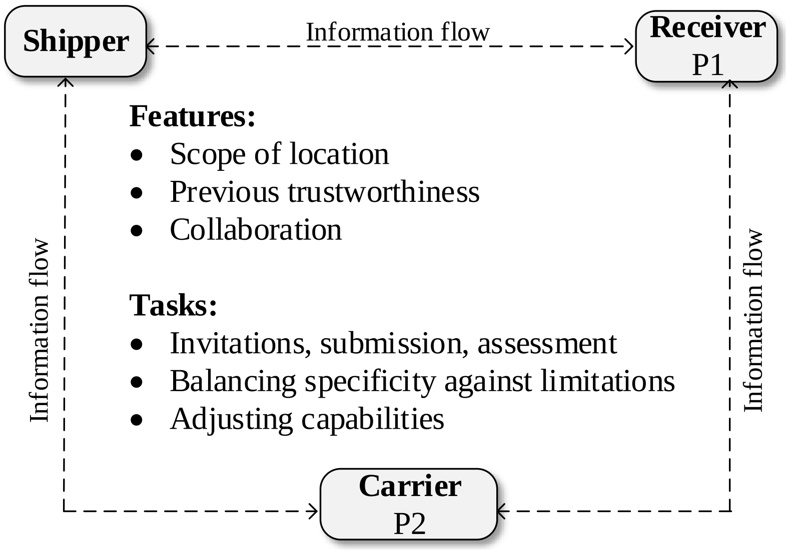


Figure 8: Collaborative interactions in developing a propensity to trusting

In developing a propensity to trusting, each trustor-agent determines if characteristics of the trustee-agents meet (satisfy) its needs to establish an intention to trust. Given such needs, the decision may become satisfactory or unsatisfactory. If characteristics of the trustee-agent's are unsatisfactory, the trustor-agent terminates its intention to trust. Otherwise, the trustee-agent commits its intention to trust.

Besides the defined procedures, tasks performed in this stage include: setting up specificity of a consortium; inviting partners; submission (exchange) of necessary information; assessing submitted capacities, and; synchronizing conflicting preferences (P_1 and P_2). A short description of outlined tasks, as adapted in part from VICS (2004) is as follows:

- *Setup of specificity:* It is a setup or configurations of a collaborative consortium to execute logistical functions. More precisely, a leader of the consortium (also known as a *broker*) sets out specific requirements for the prospective consortium. In this setup, the broker, for example, specifies the length of collaboration period, number of participants, as well as entry and exit rules. The broker also specifies the planning capacities of prospective partners in the aspect of production, warehousing, carriage, and demand. Such planning includes daily, weekly, and monthly sizes of the production, warehousing, carriage, and demand capacity.

- *Invitation:* The broker agent invites prospective partners by sending specificities it has configured to potential partners residing in a community, and who desire to go sharing. Afterwards, the broker waits for responses from the community.

- *Submission:* Upon receiving this invitation, interested prospective partners respond by applying for a collaboration opportunity thereby submitting needed information. Those who might not be interested, ignore the call. Besides submissions to this call, the broker uses beliefs it possesses as well as those it can enquire from the related community to obtain partners' previous trustworthy. The two forms of beliefs, together, serve to extend confidence about prospective partners with whom one is going to share logistics resources collaboratively. Moreover, partners may also acquire experience (beliefs) of one another, among themselves.

- *Assessment and adjustment:* Once interested prospective partners have submitted their proposals; the broker begins to assess them. The goal of this assessment is to figure out whether proposed capabilities can satisfy specificity of the consortium set. The results of the assessment may be satisfactory or unsatisfactory. At this level, the configuration of the consortium is halfway successful if results are satisfactory. If unsatisfactory, the broker recommends adjustments. In either case, the broker publicizes results to applicant members. On receipt of results, applicant members can: accept the proposal, suggest further adjustments or otherwise reject them. If the proposal is rejected or suggested to adjustments, broker adjusts strategic structures (capabilities and capacities) again until when they are acceptable or terminates them otherwise. Alike to previous roles of beliefs, again, each prospective partner makes a decision depending on beliefs it possesses.

- *Synchronization of preferences:* Alongside the defined protocols, before passing the strategic agreement, two conflicting preferences (P_1 and P_2) which can result in conflicts must be compromised. Even though, detailed open choices to each agent, their consequences like rewards and penalties are established in Table 4 and Appendix *I*.

Engagement and Order Forecast

In the second stage (Figure 9), trustor-agents are engaged to forecast orders and establish their actions to trusting. The action to trusting require trustor-agents' to delegate their tasks to the trustee-agents. Since risks are inherent in the behavioral manifestation of the desire to be vulnerable (Mayer et al., 1995), trustor-agents have to develop a degree of expectation. This expectation relates to the performance of the trustee-agent in executing the task delegated to it. Such expectations can be developed using standard deviation method or common benchmark underlying logistics functions.

Specific tasks undertaken at this stage include: extending order forecasts into shipping forecasts; building initial loads and assign a carrier; deciding on which methods to use in diving costs and savings, and; synchronizing conflicting preferences (P_3, P_4, and P_5). The preferences P_3, P_4, and P_5 are defined in Table 4 and Appendix *I*.

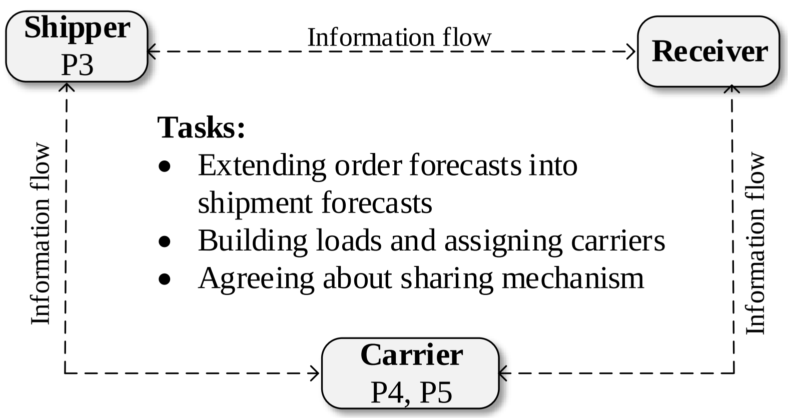


Figure 9: Collaborative interactions in the development of expectation

This stage involves mainly three activities, whose description is adapted in part from VICS (2004) and presented as follows:

- *Extending orders:* At this level, collaborating partners are expected to have more accurate information than it was in the strategic and front-end agreement stage. For example, different from previously, planned capacities, shipper, warehouse manager, carrier, and receiver may at present be having more accurate information. Such information reflects how much is possible to produce, store, transport, and demand. In this task, the primary activity is to extend order forecasts into shipment forecasts.

- *Initial load building:* This task focuses on the preliminary building of small loads from shippers onto full trucks for delivery and storage. It helps the carrier to forecast under or over truck capacities as well as a warehouse manager to forecast storage capacity.

- *Sharing scheme method:* Departing from proportional sharing methods, partners have to deliberate which one to advance on. As far as proportional sharing method bears many options, partners have to deliberate further, which specific option to apply.

- *Synchronization of preferences:* Upon successful executions of the previous tasks, partners negotiate to compromise conflicting preferences (P_3, P_4, and P_5).

Physical Distribution

The last stage (Figure 10) involves carrying out the physical distribution (move goods from shipper to receiver) as well as storage of goods in a warehouse. It is the stage in which realization of benefits to collaboration can occur. Additionally, context to the trusting process, this is a moment where comparison of previously, developed expectation against a score realized (actual score) takes place. The actual score realized becomes crucial feedback that signals back to a respective agent, about the extent of the performance of the task, it delegated. This feedback can be below, within or above the previously established expectation.

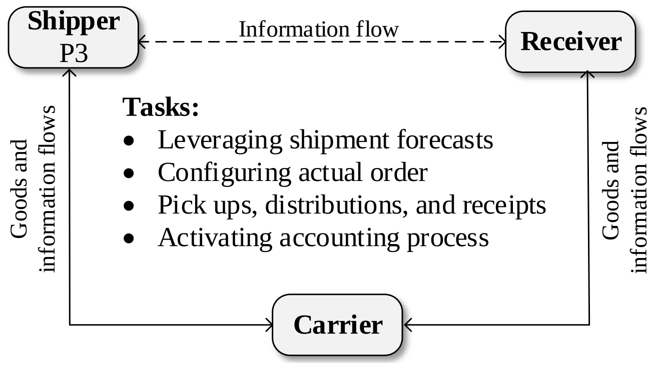


Figure 10: Collaborative interactions during transaction execution

Furthermore, tasks performed in this stage include leveraging shipment forecasts, configuring actual orders, and activating accounting process. Description of these tasks, as adapted in part from VICS (2004), is as follows:

- *Leverage shipment forecasts:* This is a final adjustment in quantities to be shipped and ordered. In a similar context, it is a final adjustment to carrier's capacity and storage space in a warehouse. At this moment, the shipper, warehouse manager, receiver, and carrier are expected to provide real information about their transactions.

- *The configuration of actual orders:* The broker configures an actual order, and execution begins by entailing a virtual movement and storage of goods. The carrier pickups the small loads and move them to receivers. Furthermore, there can occur temporary storage of some goods, if a need arises.

- *Activation of the accounting process:* Finally, the broker activates the accounting process to reward partner. Hereafter, each partner acquires records about operating performance resulting from the executed collaboration that it compares with its prior expectations. Moreover, partners may have further preferences such as the visibility information, lead time, responsiveness and on-time delivery. On these preferences, fortunately, all partners appear to have compatible positions. The exception is seen on the on-time delivery preference, by which the carrier perceives a possible delay. Even though, on-time delivery preference has been excluded to reduce complexities, which may appear in the MAS simulation platform.

4.2.3 Negotiation Protocols

Collaborating agents in logistics act autonomously so do their negotiations. In automating agent's negotiation processes, an appropriate negotiation protocol has to be developed, adapted, or adopted. Since this study does not intend to develop negotiation protocols, then the latter two options are considered in a subsequent analysis. Short explanations about automation of negotiations precede an analysis of the protocols. To this end, and according to Jennings et al. (2001), the automation of negotiation deals with:

- *Negotiation protocols*: a set of rules that govern the interactions such as the legitimate types of participants, negotiation states, events that change negotiation states, and valid actions of the participants in particular states;

- *Negotiation objects*: range of issues over which agreement must be reached, such as the price and quality, and;

- Agents' decision-making models: the decision-making apparatus employed by participants in acting alongside with the negotiation protocol.

This section is instead set to discuss the negotiation protocols in a broad view, and it formalizes the appropriate one. Thus, remaining issues such as the negotiation objects and agent decisions making model remain addressed in subsequent sections and chapters.

Three types of agents' negotiation protocol, namely: auction-based, bargaining-based, and Argumentation-Based Negotiations (ABN) can be distinguished. The former two negotiation protocols are preferred than the ABN because they are less complicated, and are easy to understand and follow. According to Rahwan et al. (2003), the ABN negotiation protocol is more complicated compared with the rest because it involves many locutions and rules. For this reason, subsequent comparison involves only the auction-based and bargaining-based negotiation protocols. A goal of this comparison is to figure out the negotiation protocol that suits better to needs of the research problem at hand.

Descriptive workability of the auction-based and bargaining-based protocols proceeds as follows. Under the auction-based negotiation protocol, an auctioneer calls out prices (negotiation objects, with a single attribute, for example). Meaning that one partner exclusively proposes potential agreements while others only accept or reject them (like the Dutch auction) (Berndt & Herzog, 2016). When other partners reject proposals in the auction, an auctioneer makes a new offer which it believes will be more acceptable (Jennings et al., 2001). The auction-based protocol appears equivalent to a single-tier (1: N) interaction protocol proposed in (Warden, Wagner, Langer, & Herzog, 2012) to facilitate knowledge transfer among agents. According to this interaction proposition, an advisee may place a same advisory request from multiple advisors. Unlike the auction-based negotiation protocol, the bargaining-based negotiation protocol requires that partners bilaterally exchange offers and counter-offers (Berndt & Herzog, 2016).

Concerning control approaches, the auction-based negotiation protocol suits centralized (institutional control) exchanges, while the bargaining-based negotiation protocol suits the decentralized (social control) exchange. Together with this, in a viewpoint of the complexity, the auction-based negotiation is less complicated compared to bargaining-based negotiation. It is because the bargaining-based negotiation advances on the bilateral exchanges that complicate more the agreements.

In reference to a topological structure of sharing networks in collaborative logistics, this dissertation adopts the auction-based negotiation. It is the negotiation protocol whose mechanism matches the centralized exchange. The centralized exchange requires that the broker-agent coordinates exchanges among collaborating agents (shippers, warehouse managers, receivers, and carriers). Furthermore, as emphasized in (Berndt & Herzog, 2016), the auction-based negotiations correspond to the FIPA iterated contract net interaction protocol (Figure 11).

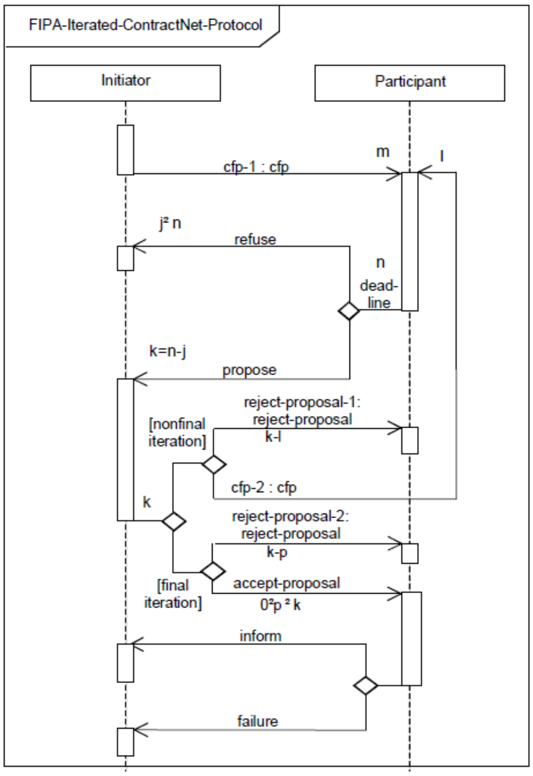


Figure 11: Iterated Contract Net interaction protocol (Source: FIPA, 2002)

A brief description of the negotiation protocol in Figure 11 can proceed as follows. The initiator (broker) sends a call for a proposal to multiple participants (collaborating agents). Upon receiving the proposal, collaborating agents either agree (propose) or refuse to collaborate, and accordingly, respond to the broker. After that, the broker assesses agents' proposals to the extent that it accepts them or suggests further adjustments. It then sends back the revised proposal to collaborating agents who finally accept or reject the proposal. Subsection 6.1.2 provides further details about an algorithm that corresponds to the iterated contract net interaction protocol.

4.3 Uncertainty and Complexity of Logistical Functions

The analysis and discussion under this section formalize method and derive relevant techniques for modeling a purpose-dependent InfQ dimension (for the selected attribute). It also establishes an appropriate approach for modeling incompatible preferences.

4.3.1 Information Uncertainty

When partners (agents) exchange the precise information, then planning, implementation, and control of logistics functions become relatively more straightforward. Opposed to this, agents may exchange uncertain information, thus leading to inconsistent behavior as well as trust uncertainties. The four attributes that constitute the InfQ on the dimension of data use in the process can describe better the uncertain information. These attributes depict the dimensions of data quality measurement process as follows (Bobrowski, Marré, & Yankelevich, 1999):

- *Timeliness*: data is as up to date as needed;
- *Relevance*: every piece of information is essential to get a representation of the real world;
- *Accuracy:* every set of data represents a real-world situation, and;
- *Completeness:* every fact of the real-world is represented, and its value is present at the real time.

Presently, this dissertation employs one attribute, the information accuracy because other attributes are currently uneasy to quantify in computational settings. Additionally, employing all attributes at once may complicate the model and impose difficulties in observing resulting outcomes.

Literature in logistics and supply chain models the information sharing and information accuracy in two standpoints. The first standpoint concerns a qualitative stream defined by constructs such as the "*no information sharing*," "*limited information sharing*," and "*full information sharing*." This stream has been commonly used in (Chan & Chan, 2009; Strader, Lin, & Shaw, 1998; Zhang & Zhang, 2007; Zhao & Xie, 2002; Zhou & Lee, 2014) to study how information sharing impacts various performances of the chain. The second standpoint concerns a quantitative stream which builds on a continuum of the information certainty and uncertainty. The certainty and uncertainty usually are defined by a coefficient which ranges between the lower and upper bounds. The lower and upper bounds are formulated depending on a context of the problem at hand. Firouzi, Jaber, and Baglieri (2015) use this stream to investigate the role of trust in a shared forecast between the supplier and manufacturer. In their model, Firouzi et al. (2015):

- Assume that the supplier's shipment quantity is affected by the coefficient (θ) multiplied by the manufacturer's order quantity (q), such that θ times q is the shipment quantity;
- The coefficient θ is the supplier's uncertainty on which the manufacturer has a belief θ';
- The probability distribution of random yield uncertainty (θ) and manufacturer's belief (θ') is from the same distribution family; although this may not occur at the same time.

This dissertation uses information accuracy, which is the attribute of the InfQ to study trust uncertainties underlying information sharing behavior of partners. This information accuracy is modeled using the quantitative stream. Concordant to (Firouzi et al., 2015), logistics elements such as the production capacity, market demand, and forecasts are modeled to be affected by a specific factor. Through this factor, collaborating agents can manipulate (modify/distort) or retain true beliefs (actual information) before exchanging that information to others.

The influential situations that surround partners, such as previous trustworthiness, determine a degree to which partners distort the actual information. Therefore, upon considering such situations, three categories of factors (affection) can affect a degree of information accuracy:

- Negative distortion (or negative information accuracy) that is denoted by a symbol "**γ**." This category of distortion implies that partner chooses to exchange information, which is below an exact value;

- No distortion (or neutral information accuracy) that is denoted by the symbol "**α**." This category of distortion implies that partner chooses to exchange information that is equal to the exact value. As well, partners may exchange information whose distortion is small and tolerable, and;

- Positive distortion (or positive information accuracy) that is denoted by the symbol "**ß**." This category of distortion implies that partner chooses to exchange information that is above the exact value.

It is crucial to note that each factor comprise a set, from which partners select elements to use in affecting the accuracy of information. The affection materializes by multiplying the chosen factor with a real-world situation data. For example, let q_0 denote the real-world data, and q_n denote the value of affection. Then the affection is of the form: $q_n = q_0 + q_0 * factor$. To illustrate, if q_0 is 100 units and *factor* is -0.15 then the value after affection is 85 units ($q_n = 100 + 100 * -0.15$). The factor is a coefficient whose value may be negative, zero, or positive.

4.3.2 Synchronization of Complex Decisions

Many collaboration scenarios assume that partners' preferences in decision rights are compatible. However, such assumption seems to contradict because there are incidences when decision positions taken by collaborating agents may be incompatible. By incompatible, it means that agents can take positions in decision rights that differ. Incompatible preferences in collaboration are distasteful, henceforth, a need to compromise (synchronize). In collaborative logistics, one can encounter major incompatible preferences on issues such as the production, distribution, and demand for goods (refer to Okdinawati, Simatupang, and

Sunitiyoso (2014) for detailed discussions). The synchronization hinges on calibrating individual agents' position to an agreement. Since the synchronization process involves complex decision-making, it has to be guided by an appropriate resolution approach. For this reason, employing a confrontation analysis approach helps to study and model conflicting preferences.

A methodological approach to confrontation analysis is grounded in drama theory, although it has its background in mathematics. The approach involves the characters as players (agents). Such characters may consist of individuals, groups or organizations that deal with each other (Azar, Khosravani, & Jalali, 2012). Typically, the approach and method, together, emphasize that characters have options to their decisions and interact through particular episodes. The four blocks that builds this episodic frames (Bennett & Howard, 1996; Howard, Bennett, Bryant, & Bradley, 1993): *who are the relevant agent types; choices open to each agent type; consequences (outcomes) of various choice combinations,* and*; agents' preferences for outcomes*.

Built on this framework, open choices in preferences may contain a point in a decision which becomes a last and uncongenial (also called dilemma). Agents face dilemmas at a point when each of the participating agents has taken a position that it considers as final (*a moment of truth*), which may be compatible or incompatible (Murray-Jones & Howard, 2001). If positions are found to be compatible, collaboration continues to subsequent stages. If positions are incompatible agents have to negotiate by synchronizing (calibrating) positions in their conflicting preferences. Although agents get into negotiation, it is not mandatory that always they will end up in a compromised state.

To any occurring dilemma, according to (Bryant, 2007), a character may respond by changing its position; amending its preferences for the possible outcomes; denying that the dilemmas exist, or; taking irreversible unilateral action. There exist six dilemmas in total. They are the dilemma of cooperation, the dilemma of trust, the dilemma of persuasion, the dilemma of rejection, the dilemma of positioning, and the dilemma of a threat (Bennett, 2004; Bryant, 2007; Hermawan, Kobayashi, & Kijima, 2008; Murray-Jones & Howard, 2001). The first two dilemmas are referred to as dilemmas of *collaboration mode*, while the remaining are dilemmas of *conflict mode*. Presently, this dissertation draws on dilemmas of conflict mode and advances specifically on dilemmas of persuasion and rejection.

To compromise conflicting preferences, agents engage in negotiation whereby some agents convince others to accept their positions or follow them otherwise. Although there may exist many principles to guide the negotiation process, this study employs a negotiation process that rests on anchoring and adjustment principles. Proposed in (Bazerman, 1998), the anchoring and adjustment principles require that agents take decisions by starting from an initial value and adjusting to the final decision.

This dissertation employs five conflicting preferences to investigate an impact they generate on trust. These conflicting preferences (Table 4) are adapted from Okdinawati et al. (2014).

Table 4: A matrix of conflicting preferences and threatened future

Agent	**Options**	**Agent's Position**			**Threatened Future**
		Shipper	Receiver	Carrier	
Receiver	Demand mode (P_1)	Certain demand	Uncertain demand	Certain demand	Uncertain demand
Carrier	Profit mode (P_2)	Reduce transport costs	Reduce transport costs	Reduce transport costs or increase transport rates	Increase transport rates
Shipper	Production quantities (P_3)	Fixed quantities	Consistent with demand	Both options	Fixed quantities
Carrier	Delivery quantities (P_4)	Consistent with demand	Consistent with demand	Fix delivery quantities	Fix delivery quantities
	Full capacity or not (P_5)	Both options	Both options	Full capacity	Full capacity

The definition of each preference is as follows:

- *Demand mode (P_1):* Receiver prefers fluctuated demand of goods due to uncertain market demand;
- *Profit mode (P_2):* Carrier prefers increasing profit by increasing transportation rates;
- *Production quantities (P_3):* Shipper prefers producing goods in fixed quantities;
- *Delivery quantities (P_4):* Carrier prefers delivering goods in fixed quantities, and;
- *Full capacity or not (P_5):* Carrier prefers to deliver goods in full capacity of its carriage.

For example, looking from Table 4 and preference (P_1), receiver prefers uncertain demand while the shipper and carrier prefer the absolute demand. In this case, the threatened future is an uncertain demand which is the receiver's position. The receiver has to persuade the shipper and carrier or reject the existence of this threat.

4.4 Interdisciplinary Collaborative Systems

The economic and social theoretical foundations inspire the proposed trust mechanism concept in chapter 5. These foundations also link to control approaches, agents' interactions, and negotiation protocols. This interdisciplinary loop in foundation backups from Nooteboom (2003) who concludes that trusting processes among people and organizations need to take into account the economic and social phenomena. For this reason, the transaction cost economics, social exchange, and social dilemma foundations are mainly applied to guide the development of trust mechanism concept (Figure 12).

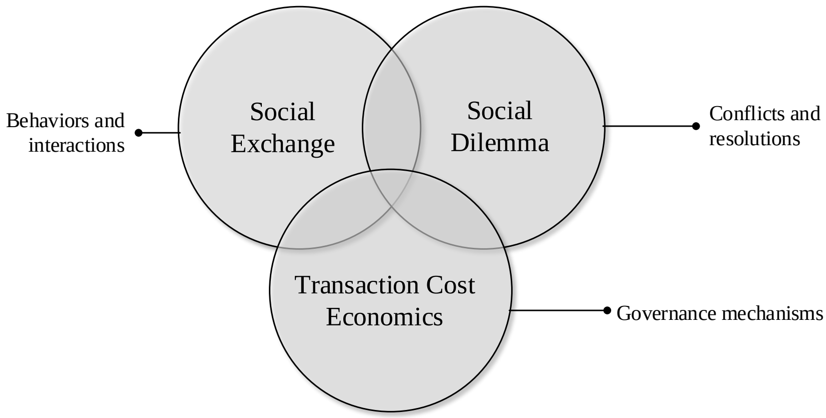


Figure 12: An interdisciplinary theoretical foundation to trust mechanism

Firstly, principles of transaction cost economics, which address on the firm existence (Coase, 1937; Williamson, 1985) are used to establish collaborative logistics as a form of firms. This establishment employs, for example, the principles of information search, bargaining, and reinforcement. Secondly, self-reinforcing principles in relational or social exchanges are used to guide characterization (description and representation) of behavior exhibited by partners during collaborative interactions. In particular, principles of learning, social-ability (Bandura, 1977, 1986), and propositions of value and rationality (Homans, 1974) are employed. Thirdly, it is prominent that partners can exhibit behavior, which procreates not only misunderstandings but also dilemmas. To synchronize (manage and resolve) resulting dilemmas (conflicting preferences), a confrontation analysis method proposed in (Bennett, 1998, 2004; Hermawan et al., 2008; Murray-Jones & Howard, 2001) is applied. Furthermore, development of the trust mechanism in chapter 5 pursues a common framework of a causal chain proposed in Möllering (2006).

Finally, it is worthy to note that this dissertation seeks not to describe and discuss in details of each concept and principle underlying the three theoretical foundations. It is for this reason that readers are referred to sources for further details.

4.5 Trust Modeling Approaches

The focus of this section is to present an establishment that answers a question: *in the context of the outlined research problem, which approach can appropriately be used to model trust?* This question is answered by analyzing and discussing the three modeling approaches, namely: reputation, game-theory, and cognition. The analysis and discussion partly draw from other related works in (Adams, Flear, Taylor, Hall, & Karthaus, 2010; Artz & Gil, 2007; Pinyol & Sabater-Mir, 2013; Sherchan, Nepal, & Paris, 2013).

4.5.1 Reputation Approach

Trust generated using a reputation system is commonly referred to as reputation-based trust. Reputation-based trust is established from past interactions or performance of an entity to assess agent's future behavior (Artz & Gil, 2007). For example, the e-markets (such as the eBay and Amazon) and digital match platforms (such as the Uber, Bla Blar Car, and Airbnb) establish and manage trust by mainly relying on online reputation systems.

The reputation systems (whether traditional or online ones) carry strengths and limitations. On the one hand, the reputation approach appears richer in third-party information, obtainable from non-direct interactions or observations. This richness provides supplementary understanding that is relevant to help trustor-agent undertake trusting-decisions. On the other hand, firstly, the reputation systems may be biased due to unfair ratings or change of identity. Secondly, reputation systems lack a direct involvement of the trustor-agent, which as a result, hinders direct interactions and observations. Therefore, in itself, reputation approach to trust modeling in collaborative logistics is insufficient. It may instead become a constituent element in other trust modeling approaches.

4.5.2 Game-theory Approach

The second consideration is inclined to a game-theory approach. The game-theory is a mathematical system to analyze and predict (prognosticate) how humans behave in strategic situations (Camerer, Ho, & Chong, 2002). The game-theory involves strategic decision-making by participants in contexts where characters do not communicate. According to this approach, before its decision-making, the trustor-agent attempts to predict an outcome of its decision thereby trying to refer to what the trustee-agent will do as a reaction. This approach offers a wide range of choices and associated pay-offs, upon which engaged agents have to go for (for example, in the prisoner's dilemma).

There exists underlying assumption in the analysis of games. In particular, the assumption to a standard equilibrium analysis of the game is that all agents think strategically, optimize their choices, and adjust their responses to an equilibrium (Camerer et al., 2002). Still, this assumption holds only to an entirely rational agent, who is capable of unlimited information sensing. The agent has to be a mythical hero who knows a solution of all mathematical problems and able to perform all needed computations (Selten, 1999). Be that it may, these propositions to the rational agent seem contradicted. People tend to do only a few steps of iterated reasoning and then stop because the reasoning is too complicated (Robinson, 2004). Moreover, while not every player behaves rationally in complex situations (Camerer et al., 2002), human-agents find it extremely hard to define their preferences consistently over outcomes (Jennings et al., 2001). In practice, game-theory models have given good results in scenarios involving the least complex interactions, in e-markets, for example (Sabater & Sierra, 2005). Given these points, the game-theoretical approach may be appropriate to problem domains other than the trust in sharing logistics resources.

In the viewpoint of trust requirements in collaborative logistics, the game-theory approach is limited as follows. According to Bachmann (2011), game-theoretical models: reduce trust to an utterly calculative decision, and; tend to focus on relationships between two agents, without showing much interest in the broader context in individualized decisions. In addition to the complexity of the trust scenarios, under game-theory approach: decision-making appears a guess, and; when players are human beings, a generalization of results can be challenging. Following this limitation, Sabater and Sierra (2005) propose to explore other possibilities such as combining game-theory with the cognitive approach.

4.5.3 Cognitive Approach

Cognitive modeling approach employs cognitive aspects of human agency into computational settings. It stands on coherent beliefs about different trustee's characteristics and reasoning about these beliefs to make trusting-decisions (Ramchurn, Huynh, & Jennings, 2004). Clancey, Sierhuis, Damer, and Brodsky, (2005) propose to integrate cognitive models with social studies. Clancey et al. further suggest shifting from modeling not only goals and tasks (*why people do what they do*) but also behavioral patterns *(what people do when they are engaged in purposeful activities*). In a standpoint of this proposition, trust modeling that employs integrated socio-cognition has its first initiation in (Castelfranchi & Falcone, 2001, 2005; Falcone, Pezzulo, & Castelfranchi, 2003).

One the one hand, the integrated socio-cognitive approach is more suitable for modeling trust within the context of the outlined research problem than its counterparts. This suitability grounds on reasons that the socio-cognitive modeling is closer to the artificial modeling of mind, and theory of delegation; is non-reducible to a pure probability or risk index; it links beliefs and decisions, and; it is analytically powerful on the dynamic property of trust (Castelfranchi & Falcone, 2001). Such modeling distinguishes itself from models that are focused only on cognitive aspect, which in the end impose limitations, as follows. Firstly, cognitive models lack explanations on how they bootstrap and they focus on the internal components while ignoring how such components are built (Pinyol & Sabater-Mir, 2013). Secondly, forming beliefs comprising the cognitive models is not a trivial matter (Burnett, 2006). Thirdly, cognitive models seem to lack explicit details on the calculus of their evaluations. Therefore, to uncover these limitations, the concept of trust mechanism proposed in chapter 5 rests on the integration of social and cognitive aspects. These aspects mimic representation of human being. Subsections 4.6.2 and 4.6.3 provide further clarification on such aspects.

4.6 Models of Trust and Reputation

The current section presents the analysis and comparison of existing models of trust and reputation. The analysis and comparison are meant to reveal an extent to which existing models, in their current forms, can suitably address the research problem defined already. Accomplishment of this task centers on establishing whether the already existing models are adequate to apply in developing needed trust mechanism or; have limitations to uncover through extending such models.

A plethora of trust and reputation models exist within the literature. It may even be tough to survey, analyze, and compare them, as well as deliberating for their strengths and limitations. Efforts to overcome this challenge and spot well-known models, relied on an alternative technique. Such technique involved analysis of literary works, which had reviewed (surveyed) models of trust and reputation. The analysis of literary works was preferred because, usually review articles provide, among others, a summary of literature concerning most models of trust and reputations, but also their preliminary strengths and limitations.

In particular, this analysis builds on the previous survey works carried out in (Artz & Gil, 2007; Audun, Roslan, & Boyd, 2007; Pinyol & Sabater-Mir, 2013; Sabater & Sierra, 2005; Sherchan et al., 2013). Afterward, models that seem to be suitable are selected. The selection updates a list of other models, considered on the merit of researcher's experience. The extent to which a particular model is well-known and highly cited throughout the literature also constitutes a guide in the selection.

Finally, a purposeful selection ended up by concluding four models, namely: ***SPORAS*** (Zacharia & Maes, 2000), ***FIRE*** (Huynh, Jennings, & Shadbolt, 2006), ***Castelfranchi & Falcone* –C&F** (Castelfranchi & Falcone, 2010), and ***BDI+Repage*** (Pinyol, Sabater-Mir, Dellunde, & Paolucci, 2012). These models are well-known for their attempts to address trust and reputation challenges in various domains other than collaboration in sharing logistics resources. It is worthy to note that the C&F and SPORAS models address trust and reputation, respectively, whereas; the FIRE and BDI+Repage address both trust and reputation.

4.6.1 Analysis

The outlined models are analyzed based on the benchmark criteria used in (Artz & Gil, 2007; Audun et al., 2007; Pinyol & Sabater-Mir, 2013; Sabater & Sierra, 2005;

Sherchan et al., 2013) for surveying/reviewing the literature and classify trust and reputation mechanisms/models. Guided by this benchmark, seven criteria to analyze the models are specified. They are information sources, model's granularity, agent-oriented approach, paradigm type, procedural dimensions, visibility, and model's conceptuality. There are sub-criteria supplementing each criterion.

- ***Information sources***: It refers to origins, from which information needed to generate trust or reputation get collected. Information required can be collected as direct experiences (Pinyol & Sabater-Mir, 2013; Sabater & Sierra, 2005; Sherchan et al., 2013), sociological information, and witness information (Pinyol & Sabater-Mir, 2013; Sabater & Sierra, 2005). As considered one of the most valuable sources of information, the direct experience can result from direct interactions or direct observations (Pinyol & Sabater-Mir, 2013). Sabater and Sierra (2005) distinguish the two experiences as follows. The former, as used by many trust and reputation models, is the experience that stands on the direct interaction with the partner-agent(s). The latter, uncommon and restricted to specific scenarios, is the experience that stands on the observed interaction with other members of the community.

  The second source, sociological information, depends on social relations between agents and the role that these agents play (Sabater & Sierra, 2005). The third source, witness information, is an information source obtainable through third-parties. Such third-parties, in most cases, are expected to have previously interacted with a target agent. Pinyol and Sabater-Mir (2013) also refer to such information as the information gathered from other agents. Another source of information is the certified reputation. It comprises ratings presented by the rated agent about itself, as obtained from its partners based on past interactions (Pinyol & Sabater-Mir, 2013).

- ***Model's granularity:*** This criterion clarifies whether a trust or reputation model is context specific or multi-context one. Identifying the right context for a piece of information or using the same information in several contexts is two examples of the capabilities defining a real multi-context model (Sabater & Sierra, 2005). Pinyol and Sabater-Mir (2013) refer to the granularity as the context-dependence of trust/reputation information.

- ***Agent-Oriented Approach:*** An agent may apply the social or solitary approach to assess trust and reputation. Under the solitary approach, a calculation of potential cooperation partners is solely conducted by the individual agent by relying on its past experiences (ERep, 2006). Contrastingly, under the social approach, the assessment is mostly conducted by the individual agent, although it can also employ third-party information.

- ***Paradigm Type:*** Building on Sabater and Sierra (2005) as well as Pinyol and Sabater-Mir (2013), the trust and reputation models can be classified cognitive or numeric (mathematical). A model is cognitive if its notion of trust or reputation builds on beliefs and their degrees, and; numeric if an explicit representation of cognitive notions is lacking (Pinyol & Sabater-Mir, 2013). In analyzing models of trust and reputation, this dissertation reflects the paradigm type criterion in the form of "**Evaluation**". Meaning that the analysis of the model focuses on establishing whether the evaluation follows a numeric or cognitive approach.

- ***Procedural dimension:*** It describes an extent to which evaluation procedures or calculus of a given model is detailed (implicit or explicit). Implicit representation is standard in some cognitive models, although some non-cognitive models also lack explicit details on the calculus of their evaluations (Pinyol & Sabater-Mir, 2013). Moreover, concerning the assessment of trust and reputation, many models use Likert scaling to rate trust and reputation by employing various levels. The typical levels are 3 and 5, although some studies use 10.

- ***Visibility:*** It distinguishes between the global and subjective properties of agent's trust or reputation information. The agent information can be considered a: global property if all other agents can observe it; or private and subjective property that each agent builds (Pinyol & Sabater-Mir, 2013). Under the subjective property, each agent assigns a personalized trust/reputation value to each member of the community (Sabater & Sierra, 2005).

- ***Model's conceptuality:*** This criterion is used to classify whether a model of trust or reputation is conceptualized as cognitive or game-theoretical.

A short description of each model precedes the classification and comparison. Notably, for a detailed description of models, readers can refer to sources.

The SPORAS Model

SPORAS (Zacharia & Maes, 2000) is a reputation mechanism for building trust in online marketplace community where users rate each other. Its algorithm stands on four principles:

- New users start with a minimum reputation value;

- The reputation value of a user never falls below the reputation of a new user;

- After each transaction, user's reputation value becomes updated;

- Two users may rate each other only once, and;
- Highly rated users experience much smaller rating changes.

The FIRE Model

FIRE is an integrated trust and reputation model for open multi-agent systems (Huynh et al., 2006). It integrates trust and reputation based on many information sources to produce a comprehensive assessment of an agent's likely performance. Specifically, the FIRE integrates four different types of trust and reputation:

- Interaction trust resulting from experience;
- Role-based trust defined by various role-based relationships;
- Witness reputation built from reports of witnesses, and;
- A certified reputation built from third-party references.

The C & F Model

The C&F is a socio-cognitive model of trust founded on agents' belief. According to this model, agents act by the degree of reliability and certainty they attribute to their beliefs (Castelfranchi & Falcone, 2010). Such beliefs are to be evaluated based on (Castelfranchi & Falcone, 2010):

- The value of the content of that belief;
- Sources of that belief (whether it is another agent, own inference process, a perceptive sense of mine);
- How the source evaluates the belief (the subjective certainty of the source itself);
- How the trustor evaluates this source (about this belief).

The outlined beliefs are essential ingredients to the mental state of a trustor to have a goal that it achieves by delegating a task to the trustee (Castelfranchi & Falcone, 2000).

The BDI + Repage Model:

The BDI + Repage (Pinyol et al., 2012) model is a result of integration of logic-based cognition in Repage (Sabater, Paolucci, & Conte, 2006) model. This integration employs human cognitive reasoning defined by a Belief-Desire-Intention logic. This belief logic relates closely to those stated in (Wooldridge, 2009), although there are additional contexts. Pinyol et al. (2012) conceive these logics as

Belief Context (BC), Desire context (DC), and Intention Context (IC). On top of these contexts, there are other four contexts: Planner Context (PC), Communication Context (CC), Repage Context (RC), and the Grounding (GrC).

After providing the brief description that underlies each model, a next task is to analyze the models based on criteria, which are already specified. Results of this analysis are provided in a tabular form (Table 5) to simplify an overall presentation.

Table 5: Analysis of the models of trust and reputation

Criteria	Sub-criteria	SPORAS	FIRE	C&F	BDI+ Repage
Information sources	Direct experience	√	√	√	√
	Witness information	√	√	x	√
	Certified reference	x	√	x	x
	Categorization	x	x	√	x
	Reasoning	x	x	√	~
Model's granularity	Context dependent	x	√	√	√
	Non-context dependent	√	x	x	x
Agent-Oriented Approaches	Social	√	√	√	√
	Solitary	x	x	√	x
Evaluation	Numeric	√	√	x	√
	Cognitive	x	x	√	√
Procedural dimension	Explicit	√	√	x	√
	Implicit	x	x	√	x
	Likert scale size	5	5	~	5
Visibility	Subjective	x	√	√	√
	Global	√	x	x	x
Model's conceptuality	Game-theoretical	√	√	x	x
	Cognitive	x	x	√	√

"√" means supported | "~"means partly supported | "x" means not supported

Subsection 4.6.2 provides a detailed discussion on comparing the four models. It also identifies limitations and suitability of the models.

4.6.2 Comparison of Models: Limitations and Suitability

The two streams, suitability and limitations (in Table 6) lead this comparison. Firstly, regarding limitations, each model is assessed by scrutinizing its inability to address the outlined research problem. Secondly, regarding suitability, each model is again assessed to determine an extent to which it can suitably address the defined research problem. In the end, as the input to chapter 5, a course of action proposed for developing the TrustMech concept is recommended. Considerations towards assessing the models proceed as follows.

The first consideration hinges upon the SPORAS model. About its limitations, this model stands on mechanisms, which do not incorporate formal logics of reasoning. Notably, its calculus of on trust evaluation is purely numeric. The numerical evaluation, usually, denies a reflection of the human reasoning mechanics and notion of belief. However, in view of its suitability, the Likert scale size and direct experience (information source) used by SPORAS are worth to draw on. Following these limitations, the SPORAS model, in its current form is assessed to be unsuitable. Furthermore, even upon considering extending the SPORAS, yet it remains hard to fulfill requirements of the TrustMech concept.

Table 6: Suitability and limitations of the trust and reputation models

Model	Suitability	Limitations
SPORAS	• Can control agents with a bad reputation • Can reduce biases resulting from multiple submissions • Incorporates agents' social-ability	• Lacks the formal logics of reasoning • Susceptible to rating noise due to treating all ratings equally (Huynh et al., 2006) • Penalizes newcomers and may discourage them from participating in the community (Huynh et al., 2006)
FIRE	• Integrates many information sources to produce agent's likely performance • Incorporates agents' social-ability	• Less feasible to agent's ability to evaluate trust for itself, especially in highly dynamic interactions • Assumes agents report their trust information truthfully (Huynh et al., 2006) • Lack cognitive reasoning
C & F	• Modeling approach follows human mental, cognitive ability • It incorporates agents' social-ability	• It remains unspecified how agents obtain information to build their beliefs (Sabater & Sierra, 2005) • Implicit establishment of weight assigned to sources of belief • Trust evaluation is unclear
BDI+ Repage	• Incorporates agents' social-ability • Modeling approach follows human mental cognition ability	A mechanism on how to obtain realistic probabilities to be assigned to each belief is unclearly established and difficult to attain practically

The second consideration involves the FIRE model. Conceptually, the FIRE model rests on the game-theory approach. Since the game-theory approach is already conclusively inappropriate, the FIRE model seems unsuitable to extend. Even though, similar to the SPORAS, proposed mechanism in chapter 5 applies the Likert scale size of 5 that the FIRE model has also employed.

The final consideration builds on comparing the C&F and BDI+Repage models. While both models rest on a conceptual paradigm of the socio-cognition, they carry differences in the evaluation and procedural dimension criteria. First, unlike the BDI+Repage which employs the numeric and cognitive evaluations, the C&F employs only the cognitive evaluation. Second, whereas the procedural dimension of the C&F seems implicit, that of the BDI+Repage model is rather explicit. Third, compared to the C&F model whose evaluation scale appears unclear, the

BDI+Repage model uses the Likert scale whose size is 5. As well, the C&F model incorporates solitary agent-orientation. Therefore, resulting from outlined suitability and limitations, this dissertation builds (extends) on strengths of the C & F and BDI+Repage models, while uncovering their underlying limitations. Strengths of the SPORAS and FIRE models are as well incorporated.

4.6.3 Main Contributions

The goal of this subsection is to derive (specify) main contributions, which the proposed trust mechanism concept in chapter 5 provides. These contributions result from limitations unveiled in the C & F and BDI+Repage models and are threefold. In particular, analyzed models lack to address adequately critical issues about *belief weight mechanism, explicit evaluation,* and *learning enforcement*.

Belief Mechanism

Both models almost attempt to assign weights on each of the generated sources of beliefs. Assigning weights on beliefs raise open challenges about the viability of an underlying mechanism responsible for generating needed weights (especially in virtual reality). Even when it is claimed to be there, such mechanism appears to assign weights implicitly and thus imposing consequent difficulties to obtain needed (assumed) realism. There are backup reasons as to why the assignment of weight is seen to be difficult. First, a human trusting process is a mix of two notions (component): cognition and emotion. A question thrown up is to whether assigned weight takes into account their mix or is inclined to one component. Second, quantifying such beliefs in real-life trust problem is not a trivial matter. Third, such weighted beliefs seem to correspond to an intention of trusting where the trustor develops only a willingness to assume the risk but not to take the risk. This means that beliefs are only used to develop a propensity for trusting where a party can still withdraw its intention to trust. In overcoming this limitation, the proposed trust mechanism puts no weight on beliefs. Instead, the trustor-agent processes received beliefs and decide on whether it proceeds to trusting action or abort.

Explicit Evaluation of Trust in a Perspective of Expectation

Evaluation of trust and reputation in the C&F model is implicit. The C&F model evaluates trust based on fuzzy cognitive maps whose representations are even more implicit. Although evaluation of trust in the BDI+Repage models is explicit, still it seems that it needs further improvement. The BDI+Repage evaluate trust and reputation based on beliefs whose weight assignments appear impractical to unveil. Additionally, the BDI+Repage evaluate trust by using both the numeric and cognitive approaches. Thus, on account of these limitations, proposed TrustMech evaluates trust based upon an analogy of a human trusting process that propagates in three primary stages. In particular, the TrustMech evaluates trust by comparing an expectation developed during an action to trusting against a score realized after execution of a transaction. This evaluation approach goes in parallel with what Vangen and Huxham (2008) propose that each time partners act together; they take a risk and form expectations concerning intended outcomes. According to authors, trusting behavior becomes reinforced when the outcome meets expectations.

Learning Reinforcement

The proposed TrustMech incorporates learning enforcement to make the mechanism more cognitive in a socio-able context. This enforcement builds on principles of social behavior and learning. The learning enforcement improves the proposed TrustMech in comparison with its counterparts, on the one hand. On the other hand, it marks trust dynamics in view of a reciprocal property of trust.

4.7 Summary and Conclusion

The current chapter has presented state of the art on keys issues related to the research problem outlined in chapter 1 and broadly discussed in chapter 2. It has presented the analysis, discussion, and in other sections, the assessment of the behavioral factors influencing trust in collaborative logistics, and; trust-based interactions. The chapter has also addressed issues about uncertainty in information sharing; complexity in decision-making; modeling approaches, as well as; existing models of trust and reputations. In particular, contents of this chapter are both interdisciplinary and multidisciplinary.

Concluding remarks in this chapter comprises the following statements. First, partner behavior under the influence of collaborative logistics processes reinforces trusting outcomes. In a current form, this reinforcement relies on three collaborative processes, which are the information sharing, sharing scheme, and decision synchronization. To highlight this, the exchange of poor quality information, use of unfair sharing methods, and exercising power and decisions in a manner that excludes consideration of other partners; together, can procreate trust uncertainties. Second, in regard to trust modeling approaches, out of the reputation, game-theoretical, and cognitive approaches, the socio-cognitive approach appeals the best approach that suits the context to the research problem. Third, shippers, carriers, receivers, and warehouse manager constitute main categories of collaborating partners in logistics. They assume distinct roles, tasks, and exchange a wide range of information. As well, collaboration in sharing logistics resources undergoes three stages: selection and front-end agreement; engagement and forecast, to; physical distribution. Fourthly, out of four well-known models of trust and reputation, no model can sufficiently address the outlined research problem. For this reason, the TrustMech proposed in chapter 5 stands on strengths of existing models while fulfilling limitations of such models.

The current chapter, among others, has identified strengths and limitations of existing works. In view of this, the next chapter (chapter 5) develops the TrustMech concept. The development adapts identified strengths. The main contribution of the proposed TrustMech is on the evaluation of trust. The TrustMech follows an explicit procedural evaluation, which advances on comparing previously developed expectation against a score realized after executing a delegated task.

5 The TrustMech Concept

During the research parts of the contents have been published in (Daudi et al., 2016a, 2016b, 2017b).

The present chapter is set to detail the development of the Trust Mechanism (TrustMech) concept. The development rests on principles, which have been introduced in chapter 2 and discussed in chapters 3 and 4. The development also concentrates on trust analysis that focuses on the micro-level than macro-level, to provide a bottom-up predictive investigation. Additionally, this development inclines towards an experimental measurement of trust that grasps trusting behavior than attitudes. At first hand, section 5.1 presents the development of the general-purpose TrustMech concept. As highlighted before, the general-purpose TrustMech is a reusable contribution, customizable with little effort to suit domain-specific needs. Furthermore, the general-purpose TrustMech is principled to the interdisciplinary foundation specified already in section 4.4. Second, the general-purpose TrustMech is customized to derive the operational TrustMech to logistical functions. The customization incorporates measurement variables, derived with respect to the functioning of logistics activities (section 5.2). In particular, the operational TrustMech is set to investigate the trust problem in the collaborative sharing of logistics resources. Succeeding the operational TrustMech is the derivation of hypotheses in section 5.3. Test results to these hypotheses constitute answers to the fourth research question (RQ4). The chapter ends by providing summary and conclusion (section 5.4).

5.1 The General-Purpose TrustMech

Development of the general-purpose TrustMech builds on an analogy of the human trusting process (Figure 13). This process propagates in three basic stages: "*propensity to trusting*; *action to trusting*" (Laeequddin et al., 2012), and; *task execution* (observable outcome). Succeeding the task execution is an *evaluation stage* that is twofold: *measuring trust*, and; *assessing trust*.

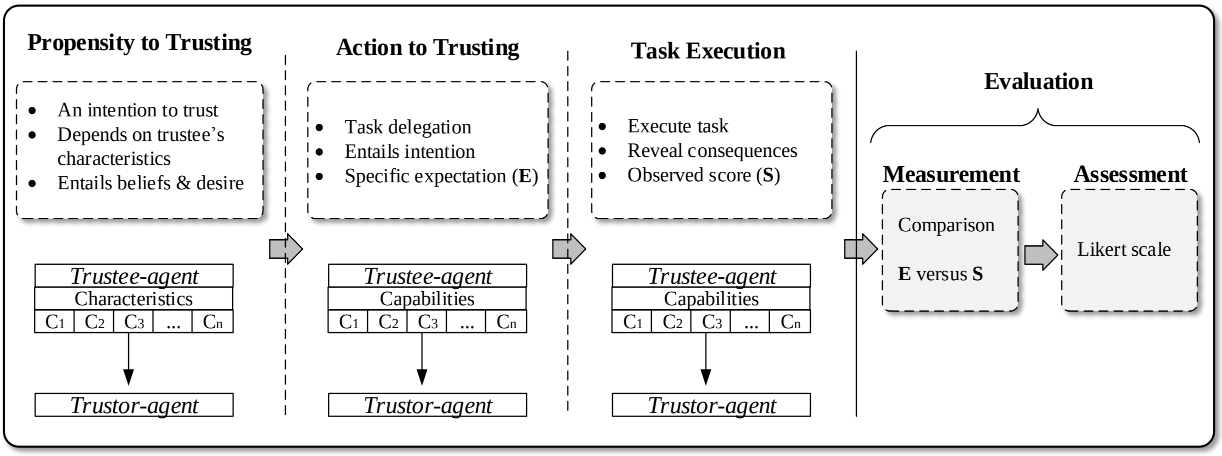


Figure 13: Generic TrustMech: analogy of the human trusting process

In a measurement stage, a quantitative measurement of trust involves comparing an established expectation against an observed score (outcome). In an assessment stage, there is a mapping between the quantitative and qualitative values. On the whole, this human trusting process also corresponds to a *Belief-Desire-Intention (BDI)* model of human practical reasoning. In its current form, this propagation is conceived generic because it applies to most trusting situations, including those in logistical functions.

5.1.1 Propensity to Trusting

The propensity to trusting concerns a willingness of a trustor-agent to delegate its task in risk-worthy dependencies (an intention to trust). It is a preliminary means to figure out whether benefits to task delegation outweigh perceived risks. The propensity to trusting is a preliminary evaluation of the trustee set to assess an extent to which the trustee-agent can be useful. Usually, assessment of this usefulness depends on a goal which the trustor-agent desires to achieve upon delegating its task.

To achieve this preliminary assessment, the trustor uses beliefs which it possesses, or it can acquire from community surroundings it. Usually, beliefs of agents comprise of states, facts, knowledge, and or data about the trustee. These beliefs may be within agent's memory itself and other neighborhood territories. If beliefs are outside of the agent's memory, trustor-agent has to inquire them from the third-party community (Figure 14).

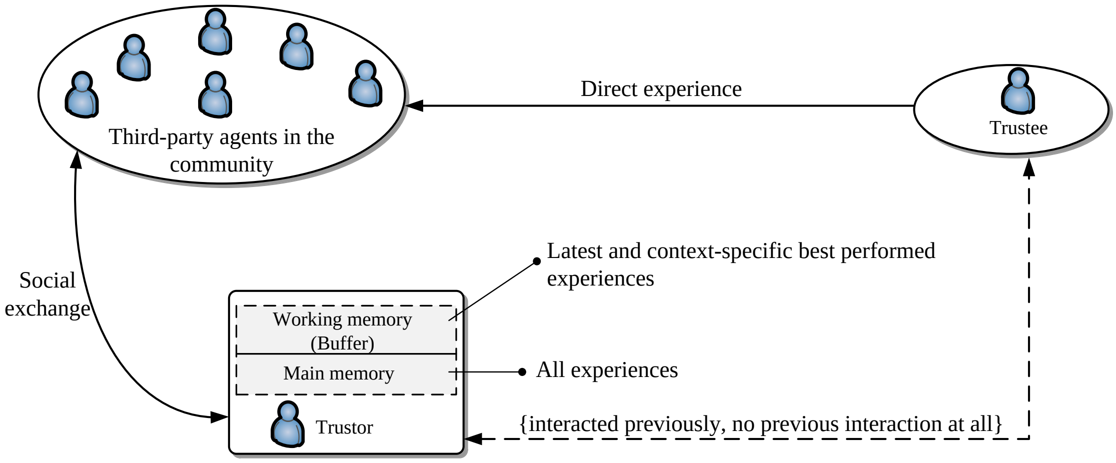


Figure 14: Agent's learning and social ability in the trusting process

Towards acquiring external beliefs, the trustor agent ought to possess two core features: learning-ability, and; social-ability. An agent who possesses these features is conceptually capable of learning from experiences and acts socially through repetitive interactions. By repetitive interactions, it means that the trustor-agent learns from previous experience and uses acquired beliefs to decide issues regarding its next engagement. The learning can be internal or both the internal and external. The external learning requires that the trustor-agent acquire new beliefs from third-parties. Learning from third-parties requires the trustor-agent to communicate with third-party agents. This requirement also furnishes a reciprocal property to the trust. This property emphasizes that trust is a cause and an effect simultaneously. Correspondingly, the principles of learning-ability and social-ability accentuate that, human-agents: tend to repeat past rewarding actions, and; learns by observing behavior and consequences (outcome) of such behavior. One crucial implication brought about by such principles is that real-world agents accumulate beliefs while observing how costly or rewarding is past actions they were engaged in previously. Moreover, in the preliminary evaluation of the trusting process, humans tend to memorize their experience against a situation they are facing at hand (Figure 15).

It is noteworthy to understand that, the fast memory stores the highest ranking costs and rewards (experiences) separate from the main memory. This storage scheme seeks to facilitate and speed up the process of recalling and comparing. The present dissertation refers to the fast memory as the working or buffer memory (Figure 14 and Figure 15). Regarding newly acquired beliefs, the memory of agents is normally updated at a rate of newly incoming trust experiences (beliefs).

Scenario No.	Trustee	Contextual Characteristics					Rewards or Costs
		C_1	C_2	C_3	C....	C_n	
1	Agent1	.	.	.	.	.	Reward 1
2	Agent2	.	.	.	.	.	Cost 1
.	.	.	.	.	.	.	Cost 2
.	.	.	.	.	.	.	Reward 2
.	.	.	.	.	.	.	.
							.

Figure 15: Memory structure of the trustor

The process to recall and compare costs and rewards of past experiences proceeds as follows. The trustor-agent retrieves many experiences that are context-specific to its intention of trusting. Each retrieved experience match a situation at hand in an attempt to figure out possible similarities. Upon finding the matches, the trustor-agent goes one-step further. This further step is meant to determine extents to which matched similarities were costly or rewarding. In a standpoint of social exchange: costs comprise of elements, which carry negative values (outcomes), while; rewards comprise of elements, which carry positive values (outcomes). Since past experiences generate many rewards and costs, among the retrievals, the trustor-agent checks for the experience that generated best rewards or worst costs. As far as the decision mechanism to costs and rewards are similar, to limit duplicates, discussion in subsequent paragraphs advances in a generalized form. Notably, this form of generalization advances on the rewards.

Henceforth, if the best rewarding experience exists and contextual characteristics of this reward resemble a situation at hand, the trustor-agent makes decisions. The undertaken decision is a replication of the past decision that is expected to reward accordingly. At this moment, the trustor may appraise the trustee by preliminarily agree to collaborate.

There are cases when the direct experience may be missing, or the trustor-agent may prefer to inquire additional experiences from the third-party community. In this situation, the trustor-agent has to socially interact with potential third-parties who have had prior interactions with the targeted trustee-agent. Such experiences add value to confidence in developing a propensity to trusting. In the end, depending on selected characteristics and a degree of their fulfillment, the trustor-agent can commit its propensity to trust. After passing this stage, the trustor-agent proceeds to a subsequent stage, the action to trusting.

5.1.2 Action to Trusting

In general, trust deals with a problem of predicting (forecasting) another actor's future behavior. Towards this prediction, a fundamental role of action in trusting is to anticipate an extent to which the trustee-agent may behave. Establishment of this anticipation depends upon a context of a task the trustor-agent delegates to the trustee-agent. This dissertation refers to this anticipation as an *expectation*. It is a degree of confidence the trustor-agent develops in the trustee-agent. Development of expectation is a forecast process set to figure out what the trustee can perform vis-à-vis to task delegated to it. It is also a fundamental cognitive reasoning process undertaken by humans before executing the transaction to trusting. This transaction to trusting occurs only when perceived benefits outweigh possible risks (uncertainties).

The action to trusting is carried out (assessed) by the cognitive agent to predict future state and resulting consequences (outcomes). The assessment of results takes one of the following global states: *withdrawal* or *acceptance*. Withdrawal occurs when the trustor-agent is confident that the task it delegates will not be performed as expected and respective payoffs will likely be unsatisfactory. In contrast, the acceptance occurs when the trustor is confident that the trustee-agent will execute the delegated task in a manner it expects and that payoffs will be satisfactory. Once the trustor-agent delegates its task, it subsequently subjects itself to vulnerabilities that may result from the trustee-agent's actions. The interesting question is, "*how do human-agents develop expectations?*"

Human-agents develop an expectation by building on the rule-norms (r-norms) and social-norms (s-norms) of a target community. Here are few examples of such norms. Starting with r-norms, in the banking sector, for example, people make fixed deposits while expecting interest rate, say of R%. Drivers expect a car to accelerate to a speed equivalent to a magnitude to which the driver presses an accelerator pedal. Equally, a partner can count that the collaboration is worthy if it gains benefits that it was expecting. Examples related to the s-norms are such as an honest person is expectedly faithful; expectedly, children below the age of 18 years should not take alcoholic drinks, and; users on social media should expectedly not use abusive language. In their entirety, expectations can vary from one community to another, as well as from one individual to another. Although both r-norms and s-norms prevail, the present development on expectation draws on the r-norms. This drawing is parallel to the problem statement stated already in chapter 1, which requires advancing on the r-norms.

The mechanism to develop expectation may be generic or context-specific. The context-specific mechanism employs benchmark values that are known in a community. Such benchmark values may consist of industrial best-in-class or averagely known values. For example, a specific value for a given performance indicator (say **E**) may formally become an average score. Thus, every scored value (**S**) that, obtained after executing the transaction to trusting is compared against the value **E**. The outcome of this comparison yields three main possibilities (see in Figure 17). One way to develop expectation is to rely on standard (benchmark) values, which the community regards as normal or typical practices. In a viewpoint of this, section 6.4 provides a broad discussion on the context-specific mechanism of expectation that employs benchmark values. The context-specific mechanism can potentially be applied to develop expectations in situations where benchmark values are obtainable. If, however, obtaining such benchmark values is difficult, then a need to employ a general mechanism to development of expectation arises.

Unlike the context-specific mechanism, the present provision is set to devise a general mechanism of expectation. This expectation may consist of scenarios that involve single or multi-trustor agents. Since establishing an expectation for a single-trustor agent is relatively more straightforward, then the current general mechanism focuses on the multi-trustor agents. Foundationally, the general mechanism of expectation draws from principles, which can better explain phenomena of expectations in human interaction systems. In recalling back, human-agents build expectations by looking at past experiences undertaken by themselves or related third-parties. In choosing from the multiple past experiences, human-agents tend to choose an alternative which by forecasting appear the most rewarding in subsequent engagements. Therefore, it is deducible that upon offering the trustor-agent with multiple options, the trustor-agent will choose those options it perceives (expects) to generate high payoffs (rewards) than low payoffs (cost).

On account of the outlined establishments, the general mechanism of expectation draws from Bandura's (1977, 1986) principle of outcome expectation. According to this principle, one determinant of human’s behavior is the expectation of consequences of its actions. A subsequent implication of this principle is that developed expectation has to correspond to a level of performance, forecasted in respect of the trustee’s ability to execute task delegated to it. Within a context of collaboration, expectations have to be realistic and set within acceptable limits. Meaning that agents have to develop neither lowest nor highest rated expectations. One technique that can be applied to set neither lowest nor highest expectation is the standard deviation technique.

The standard deviation is the statistical technique applied to establish acceptable limits. Mechanics of this technique go as follows. Assume a collaboration consortium to consist of *n* number of partners (equation 1).

$$Partners = \{P_1, P_2, P_3, \dots, P_n\} \dots eqn\ 1$$

Each partner draws from its past experiences a highly ranked reward that it previously encountered, and, which also matches better with an underlying context. Let such past reward, as denoted by *Exp*, represents the expectation of that particular partner. For all available partners, there shall be a total of *n* individually estimated expectations. In a second step, mean expectation (Exp_{mean}) is obtained from individually estimated expectation (Exp_{ind}) (equation 2).

$$Exp_{mean} = \frac{\sum_{i=1}^{n}(Exp_{ind}\ of P_i)}{\text{n}} \dots eqn\ 2$$

In a third step, one can obtain the standard deviation to individually established expectations (Exp_{sd}) as illustrated in equation 3.

$$Exp_{sd} = \pm \sqrt[2]{\frac{\sum_{i=1}^{n}(Exp_{mean} - Exp_{ind}\ of\ P_i)^2}{n}} \dots eqn\ 3$$

A global range of expectation whose size is two times that of the Exp_{sd} (Figure 16) is consequently, attainable (equation 3). One peculiar feature of global expectation is that its range is devised to be customary ($CustomExp_{range}$). The range is customary because each collaborating agent set own expectation. As the expectation of different agents is anticipated to differ, then upon applying the Exp_{sd}, resulting range will consequently, differ (in most incidences).

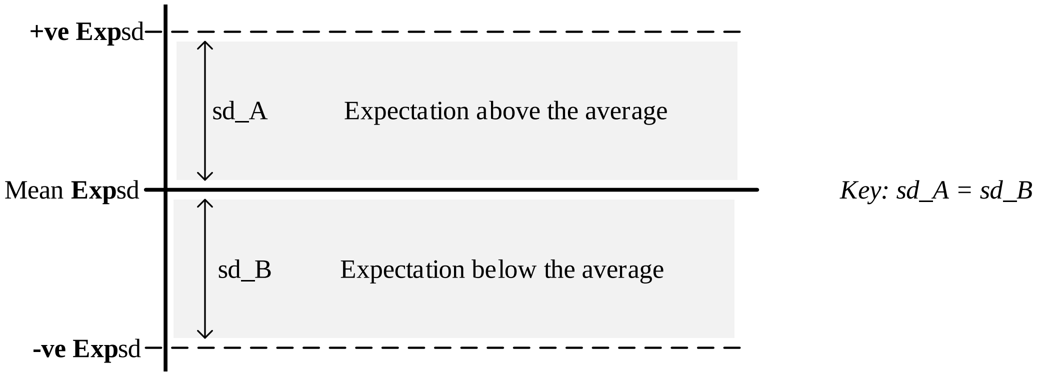


Figure 16: Range of expectation

Furthermore, since each trustor-agent estimates its expectation, then the mechanism checks if such expectation is within acceptable limits. If not, the trustor-agent redefines its expectation to ensure that it is within an acceptable range (limits).

5.1.3 Executing a Transaction to Trusting

Execution of the transaction is a final stage in which the trustee-agent performs the delegated task. This execution also entails a shift of control power, from the trustor-agent to the trustee-agent. The shift means that when the transaction is under execution, the trustor-agent passes (loses) its control at the hands of the trustee-agent and waits or observes for resulting outcomes. Such outcome on task delegation forms feedback in reference to the already developed expectation. The feedback results from comparison of the observed outcome against a corresponding expectation. Owing to these provisions, the subsequent subsection presents a detailed discussion about this comparison (measurement and assessment of trust).

5.1.4 Evaluation of Trust

The evaluation of trust is twofold: measurement of trust, and; assessment of trust. Measurement of trust centers on comparing a degree of expectation developed by the trustor-agent when it delegates a task against a real score observed after execution of the task. Within a perspective of the human trusting process, this comparison is simple to follow and understand but yet sounding logical. Moreover, resulting from the comparison of the expectation against the realized score, an outcome may comprise of three primary states: *below expectation, within expectation*, and *above expectation* (Figure 17).

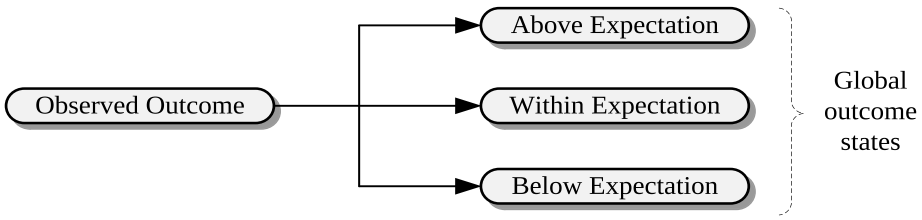


Figure 17: Global outcome states of the trusting process

These global states, in their present forms, are operationalized a macro. Due to this, refining further those macro levels, for example, can result in the meso level or even micro level. The refinement will still depend on the contextual needs and level of modeling. In their present form, such states may correspond to a Likert scale of size 3. After measuring trust, a next task is to assess trust.

Assessment of trust is meant to interpret quantitative values into qualitative ones. In its natural form, trust is a qualitative construct, which is richly understandable in the form of attitudinal cues. Owing to this, and in a context where the present study investigates trust problem using the experimental method, obtained results have to exist (interpreted) into attitudinal values. Interpretation of attitudinal cues requires deciding in advance, which a Likert scale size to use. As previously established, this dissertation uses the Likert scale of size 5. Assessing trust based on this scale can stand on the: *standard deviation technique* or *benchmark values*. The standard deviation technique requires that the range of expectation indicated in Figure 16 be divided into 5 (scale size) equal segments. From left to right, interpretation of the segments into attitudinal values is as follows: *least trustworthy, less trustworthy, trustworthy, more trustworthy*, and *most trustworthy* (Figure 18).

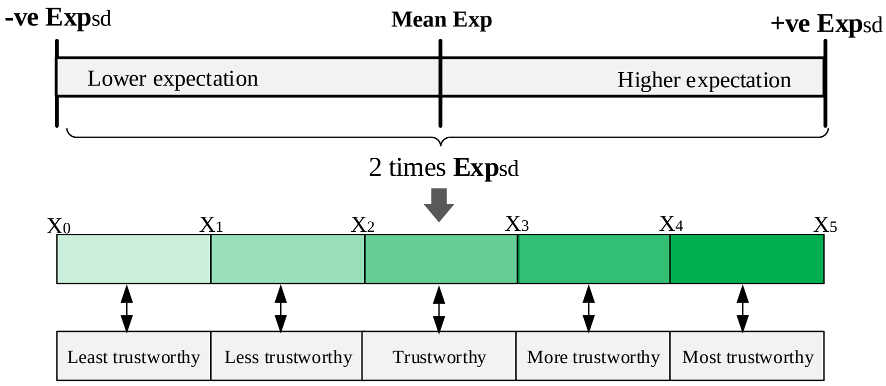


Figure 18: Trust meter to measure and assess trust

To exemplify this, assume that the mean expectation of partner "$\mathbf{P_1}$" is seven units, and the standard deviation for all collaborating partners is ±3units. Then the range of expectation for "$\mathbf{P_1}$" will be six units (two times the standard deviation). This range expectation lies between 4 (7-3) and 10 (7+3) units. Upon dividing the range by Likert scale size (5), it yields an interval of 1.2 units. Let a value observed after execution of the transaction to trusting by "$\mathbf{P_1}$" be denoted by "*score*." Then interpretation of resulting trust level into attitudinal value is as follows:

- Least trustworthy if observed value is in the interval: *{4.0 <= score < 5.2}*;
- Less trustworthy if observed value is in the interval: *{5.2 <= score < 6.4};*
- Trustworthy if observed value is in the interval: *{6.4 <= score < 7.6}*;
- More trustworthy if observed value is in the interval: *{7.6 <= score < 8.8}*, and;
- Most trustworthy if observed value is in the interval: *{8.8 <= score < 10.0}*.

If another partner, say, "$\mathbf{P_2}$" had a mean of expectation of 5 units while the standard deviation remains common to all, the range of expectation will lie between 2 units (5-3) to 8 units (5+3).

Unlike the standard deviation technique, the benchmark value technique follows the following procedures. Definition of the expectation value has to depend on industry practice. Let this value denoted by "*scoreInd*." Then values below the scoreInd constitute lower expectation while those values above scoreInd constitute upper expectation. The range of expectation spans from the lower to upper expectations. However, precisely defined range relies usually on prevailing practices of the industry as well as the experience of the logistics manager. It is for this reason that subsection 6.4.3 presents an example of trust evaluation based on the benchmark values, which this dissertation has used to validate the TrustMech, and demonstrate its application. It is also worthy to note that under the benchmark value technique, all partners use similar interval.

5.2 The Operational TrustMech to Logistical Functions

Section 5.1 has detailed the development of the TrustMech concept within a generalized context. Towards investigating (forecasting) trust uncertainties underlying collaborative sharing of logistics resources, the general-purpose TrustMech needs refinement. This refinement is unveiled by customizing the TrustMech into logistical functions. The customization includes formalizing the predictor (independent) and response (dependent) variables, as well as linking them to causal mechanics. Further operationalization entails specifying settings, especially benchmark values for response variables (section 6.4). Such values are separated from the current operationalization because they are adjustable. Moreover, in this operationalization, the behavioral factors and parameters influencing trust are set as predictor variables. Equally, performances metrics adapted from logistics and supply chain are used to define response variables.

On the whole, the operationalization supposes that parametric variations (input) are set into the TrustMech to produce (output) a corresponding reflection in response variables (results). In the end, evaluation of trust uses generated results with an assumption that distinct parametric variations will generate distinct and similar effects on performance metrics, and subsequently, the trust.

5.2.1 Predictor Variables

Three primary predictor variables procreate trust pains to the collaboration in sharing logistics resources. The predictor variables are the information sharing, incentive scheme, and decision synchronization (Table 7).

Table 7: The predictor variables and their sub-variables[7]

Main predictor variables	Sub-predictor variables
Information sharing (Information accuracy)	Positive accuracy; neutral accuracy, and; negative accuracy
Incentive Scheme	Distance traveled; the number of customers served; total load shipped, and; general
Decision synchronization	Demand mode –P_1; profit mode –P_2; production quantities –P_3; delivery quantities –P_4, and; full capacity or not –P_5

Each main variable comprises sub-variables. This modeling supposes that variations in sub-variables either in isolation or combination will yield the distinct trusting

[7] Note: These predictor variables are not meant to be exhaustive

outcomes. In reference to this, sections 4.1 and 4.3 have already presented discussion regarding details about the principal and sub-predictor variables.

5.2.2 Response Variables

Response variables used in the operational TrustMech are at first hand derived from the Supply Chain Operations Reference (SCOR) model (Supply Chain Council, 2012). Subsequently, related works which have adopted and adapted metrics of the SCOR model constitute a basis for deriving response variables. Such works are unlimited to logistics metrics affected by collaborative transportation management (VICS, 2004); logistics performance measurement systems (Gunasekaran, Patel, & Tirtiroglu, 2001), and; a framework for measuring performance in a supply chain (Gunasekaran et al., 2001). This derivation is meant to serve the validation and application purposes. For this reason, selected, response variables do not constitute a complete list (unmeant to be exhausted). They are instead used to validate the TrustMech as well as demonstrating how useful and applicable the TrustMech is. Accordingly, the response variables may be changed to fit contextual needs of a respective logistics manager but also a business domain.

The employed response variables (metrics) can be explained in perspective proposed by Audy et al. (2012). Such perspective distinguishes between qualitative and quantitative benefits of collaborative logistics. Although two streams of benefits are notable, this study concentrates on the quantitative benefits of collaborative logistics, constituted by shareable and non-shareable benefits.

There are five performance perspectives set to serve measurement and analysis of processes underlying the supply chain. These perspectives emphasize (Supply Chain Council, 2012):

- *Reliability* –an ability to perform tasks as expected by focusing on the predictability of the outcome of a process;

- *Responsiveness* –a speed at which entities perform tasks for providing products or services to the customer;

- *Agility* –an ability to respond to external influences such as the marketplace changes;

- Cost –the cost of operating the supply chain processes such as the management and transportation costs, and;

- Asset management efficiency (asset) –an ability to efficiently utilize assets.

The present operationalization employs some metrics from three attributes, which are the reliability, cost, and asset. Currently, other attributes such as the responsiveness and agility are unconsidered because it is much difficult to accommodate them in a prototype that implement the operational TrustMech. A reason behind is that the prototype to operational TrustMech does not incorporate time functions due to technical constraints, but also to reduce resulting complexities. To this end, Key Performance Indicators (KPI) defined under the attributes of the reliability, cost, and asset (Table 8) are purposely selected out multiple KPIs defined in SCOR model.

Table 8: Purposely selected response variables[8]

Orientation	Performance attribute	Response variables
Customer-oriented perspective	Reliability	Forecast accuracy
		Order fill rate
		Backorders as a percent of total orders
Internal-oriented perspective	Cost	Distribution cost as percent of sales
		Cost saving
	Asset utilization	Vehicle fill
		Full truck load

The selected KPIs provide partners the potential chances to behave in both deceitful and trustworthy manner concurrently. Other KPIs such as the item location accuracy, delivery quantity accuracy, and delivery location accuracy provide insignificant chances for partner exhibit deceitful and trustworthy behavior concurrently. Additionally, although this selection is unexhausted, yet it remains relevant to serve the purpose of validation and application. The response variables presented in Table 8 are defined as follows:

- *Forecast accuracy* defined as the difference between the forecasted value (F) and the actual value (A) (Armstrong, 2001);

- *Order fill rate* defined as the number of order lines/cases/SKUs delivered in full divided by the total number of lines/cases/SKUs ordered (VICS, 2004);

- *Backorders as a percent of total orders* defined as the portion of total orders that held and shipped late due to lack of availability of stock (Manrodt, Vitasek, & Tillman, 2011);

- *Distribution cost as a percent of sales* defined as the cost to run distribution relative to total sales (Manrodt et al., 2011);

[8] Note: These response variables are not intended to be exhaustive. They are rather selected for demonstrating the application to the operational TrustMech.

- *Cost saving* defined as the potential financial collaboration benefit evaluated based on freight cost per pallet (Audy et al., 2012);

- *Vehicle fill* defined as the average volume of vehicles used divided by the total volume of vehicles (VICS, 2004);

- *Full Truck Load (FTL)* defined as the number of trucks with over 95% of volume full divided by the total number of trucks shipped (VICS, 2004).

Succeeding a specification of predictor and response variables is a logic underlying a causal chain of trust. To fulfill this, the present operationalization follows a fundamental logic of trust causal chain, adapted in part from Möllering (2006). Essentially, the logic of trust propagation exhibits the following sequence. That, (a) partner behavior under the influence of collaborative logistics processes procreates an impact in; (b) the operational TrustMech that generates corresponding reactions; (c) whose manifestation is observed using logistics performance metrics; (d) to determine underlying trustworthiness, and; (e) other emergent trustworthy behavior (Figure 19).

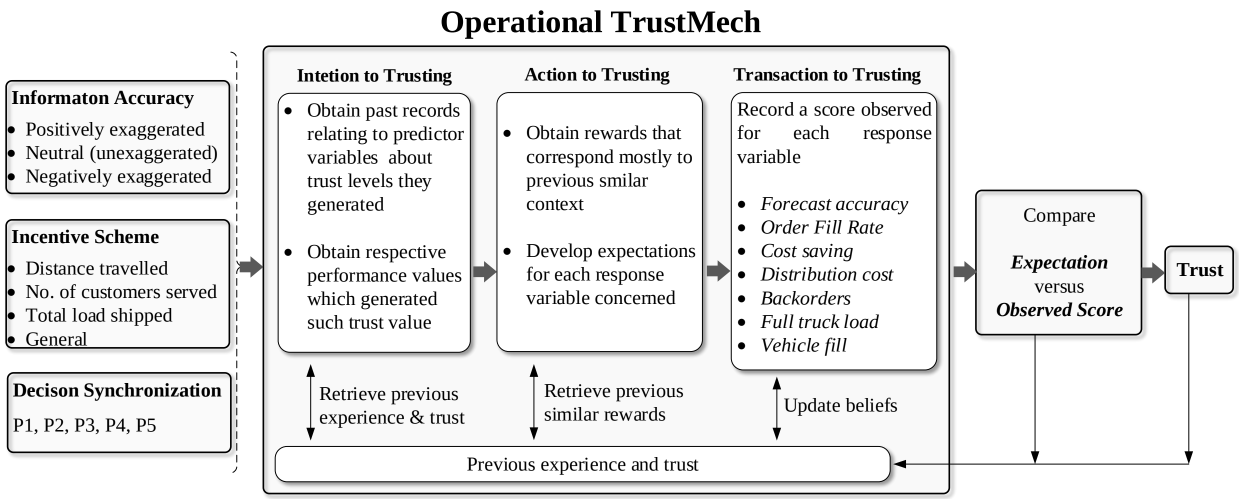


Figure 19: The operational TrustMech to logistical functions

For a sake of enriching the causal chain, this propagation implies that variations in partner behavior under the influence of logistics collaborative processes have to feed back into the TrustMech. Correspondingly, the TrustMech act predictively, by scrutinizing interactions among the trustor-agents and trustee-agents. In the end, the TrustMech generates trust levels that reflect interactions and reactions which partners have undertaken.

5.3 Derivation of Hypotheses

Prediction is one of a constituent criterion that helps to understand a system and its underlying aspects such as behavior (Cohen, 1991). According to Cohen, one can claim this understanding if he can predict to some degree of success how changes to the design of a system or environmental conditions will affect behavior. In relation to the designed logistics network and settings presented in section 6.4; this dissertation seeks to predict how partner behavior and collaborative logistics processes reinforce trust. Beyond this prediction, the purpose is to additionally explore and uncover behavior (emerging phenomena or unforeseen events), which are helpful in lessening the trust problem. To realize these goals, a total of five hypotheses are derived in the subsequent paragraphs.

First Hypothesis

During the collaboration, partners exchange necessary information among themselves. A degree to which the exchanged information is accurate or inaccurate (manipulated) information remains the choice and decision of the individual partner. The exchange of accurate (non-manipulated) information signifies a realistic collaborative situation that carries needed trustworthy and congruence than opportunism, on the one hand. On the other hand, exchanging incorrect (manipulated) information signifies incongruence to goals of collaborating. The manipulated information may imply partner's deceitful efforts to win individual payoff on the cost of others. Deceitful efforts may occur when partner exaggerates real information, either positively or negatively. It also occurs when the partner is unwilling to be entirely honest thereby deviating from exchanging information that reflects reality. For example, a shipper may provide forecasts that are above (positive exaggeration) or below (negative exaggeration) of what it can produce. To this end, in order to understand how different levels of information accuracy affect trust, the corresponding hypothesis states as follows:

> **Hypothesis 1:** (Information accuracy)
> *The negatively exaggerated, neutral (unexaggerated), and positively exaggerated information accuracies generate distinct levels of trust.*

Second Hypothesis

There is an open question on how partners can divide collaborative costs and gains. Similarly, an extent to which methods for dividing costs and gains are fair, trustworthy, and thus acceptable appears unclearly established. It is also doubtful whether it is possible to decide in advance about incentive schemes to use. To this end, and under the present configurations, this dissertation establishes the fairness and trustworthiness of the three proportional sharing methods, namely: distance traveled; number of customers served, and; total load shipped. One main goal is to establish if one method is more valuable and trustworthy than the rest. In realizing this, the corresponding statement of the hypothesis is:

> **Hypotheses 2:** (Fairness of the sharing methods)
> *The proportional sharing methods: distance traveled, number of customers served, and total load shipped rank equivalently in levels of trust they generate.*

Third Hypothesis

The logistics network under simulation consists of five conflicting preferences (P_1 to P_5). Ability to compromise these preferences depends either on the state of persuasion or rejection. Despite the state to which they are compromised, conflicting preferences may affect the level of trust of the network with similar or different magnitudes. With this idea in mind, it is helpful to know whether one preference generates trust impact in a large magnitude than others. Achievement of this goal hinges on setting up the following hypothesis:

> **Hypothesis 3:** (Impact of conflicting preferences on trust)
> *All conflicting preferences generate an equivalent effect on levels of trust.*

Fourth Hypothesis

Collaboration on sharing logistics resources is assumed to proceed in the absence of dilemmas other than dilemmas of a collaboration mode. This assumption does not hold for all moments. Instead, the collaborative sharing may face dilemmas of conflict mode such as the persuasion and rejection. Such dilemmas are part of complex decision-making in logistics and have to undergo compromise before advancing to subsequent stages. Expectedly, the persuaded dilemma will yield better trust levels than the rejected one. Ability to figure out whether the compromised and uncompromised dilemmas differ about the effect they generate on trust requires setting up the following hypothesis:

> **Hypothesis 4:** (Persuaded and rejected dilemmas)
> *Persuaded dilemma yields higher levels of trust than the rejected dilemma.*

Fifth Hypothesis

The configured logistics network has three main predictor variables: information sharing, sharing scheme, and decision synchronization. In a viewpoint of influences, it may be interesting to determine how they are ranked. Towards achieving this goal, a corresponding statement of the hypothesis is:

> **Hypothesis 5:** (The most influential main predictor variable)
> *Information sharing ranks higher on the effect it generates on levels of trust compared with the sharing scheme and conflicting preferences.*

Moreover, an overall goal (also stated in section 1.2) is to deeply investigate how partner behavior and collaborative logistics processes (behavioral-processes) reinforce trustworthiness of the logistics network. This goal is further purported to understand unforeseen (emergent) events, which are interesting and valuable for improving trust in an entire network of sharing. It is unfortunately hard to unveil this reinforcement by relying only on hypotheses set already. As an alternative, it is possible to rely on the unspecific (unstated) hypothesis. To this effect, analysis of output behavior in the experiments 1 to 9 helps to realize this goal.

5.4 Summary and Conclusion

The current chapter has focused primarily on developing the TrustMech concept. The central purpose of the TrustMech concept is to provide a predictable set of trusting outcomes in collaborative logistics. The TrustMech is devised generic, and therefore, it remains a concept to apply in various domains. The TrustMech stands on artificial modeling of human's minds that mimics workability of the human trusting process. Such trusting process consists of three stages: intention to trusting; action to trusting, and; execution of a task delegated. It requires that an agent (individual and firms) make trusting decisions by building on past rewarding actions, while; avoiding those costly ones. In its operationalization, the TrustMech draws on collaborative functions set to share logistics resources. The operationalization comprises plugging in both the predictor and response variables. In addition, the operationalization also involves the design and setups related to the trust meter, benchmark values, conflicting preferences, and logistics network. In order to demonstrate the application of the TrustMech, section 5.3 has provided predictions on trustworthy behavior of the logistics network. The goal of this prediction is to provide a deeper understanding that underlies the simulated logistics network.

The proposed TrustMech differs from other related models (mechanisms) in literature. The most distinguishing feature of the TrustMech is its mechanism to evaluate trust. In evaluating trust, the TrustMech compares expectation of the trustor-agent against a score realized after the trustee-agent has executed the delegated task. Such feature reflects daily trusting processes undertaken by human-beings as well as organizations. Additionally, the general-purpose TrustMech is worthy to adapt in various domains, other than resource sharing in collaborative logistics. Its conception, which foundationally stands on socio-cognition, enriches further a phenomenon of real-world in which agents reside. The TrustMech exhibits a form of representation that is not only easy to follow but also simple to understand.

The next task after developing the TrustMech concept is to transform it into a computerized instance. Thus, chapter 6 presents an implementation of a vehicle (prototype) for proving the proposed concept.

6 Prototypical Implementation

During the research parts of the contents have been published in (Daudi et al., 2016b, 2017b).

The present chapter provides an implementation (transformation) of the TrustMech concept into a computerized form. The implementation begins by specifying functional requirements, negotiation algorithm, and subsequently, interactions which occur among collaborating agents (section 6.1). Succeeding this specification is a description of roles and knowledge ascribed to collaborating agents as well as other entities. The description of roles and knowledge is conceived and accomplished by using a class diagram (section 6.2). Section 6.3 presents a platform that transforms the design and specifications of the TrustMech. This platform exists within a virtual realism, facilitated by Multi-Agent Systems (MAS) to simulate trust scenarios. Considering that the platform is flexible to accept varied inputs; then section 6.4 specifies the design and setups, which are particularly used to carry out the simulation. The chapter ends in section 6.5 by providing the summary and concluding remarks.

6.1 Specification of Requirements

The goal of this section is to furnish specification of requirements relating to agency and purpose. First, descriptive domain and agent identification are presented to provide functions of the TrustMech. Realization of this purpose counts on employing the use-case diagram. Second, sequence diagrams are subsequently used to specify roles and tasks performed by collaborating agents (partners).

6.1.1 Problem Situation

A simplified view in Figure 20 helps to describe the problem situation to trusting in the collaborative sharing of logistics resources. Similar to what Okdinawati et al. (2014) describe, the shipper produces goods, which get moved to the receiver (also known as a consumer). The warehouse manager stores goods before they move them to the consumer. In this context, a corresponding logistical function is to plan, implement, and control movement of resources (especially goods) from the point of origin to the point of consumption.

Ability to achieve such logistical function hinges on collaborative sharing of information, warehouse, and vehicles (trucks). In this regard, the shipper, carrier, receiver, and warehouse manager are key agents involved in the sharing. All these partners exhibit a range of behavior under the influence of collaborative logistics processes, whose outcome generates a corresponding effect on trust.

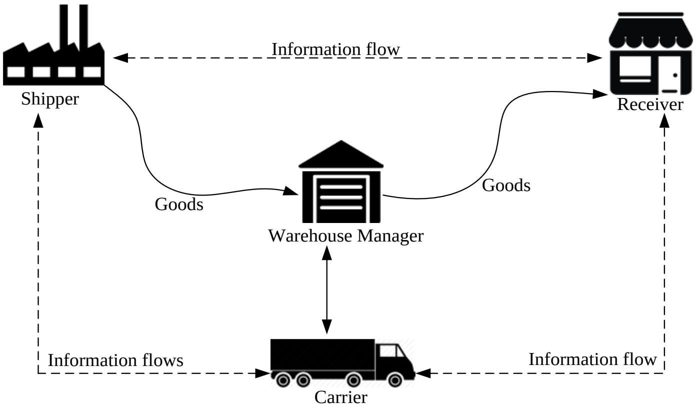


Figure 20: Problem situation on shareable logistics resources –a simplified view

Realizing resource sharing in logistics involves many tasks. Such tasks are described as functional requirements and modeled by using use-case diagram. In particular, to recall, the purpose of the second specific research question (RQ2 in section 1.3) was to provide answers relating to trust-based interactions undertaken by collaborating partners. For this reason, the output of RQ2 constitutes key inputs to a use-case diagram in Figure 21. Equally, the use-cases and their extensions, actors involved, and description of each use-case draw from section 4.2.

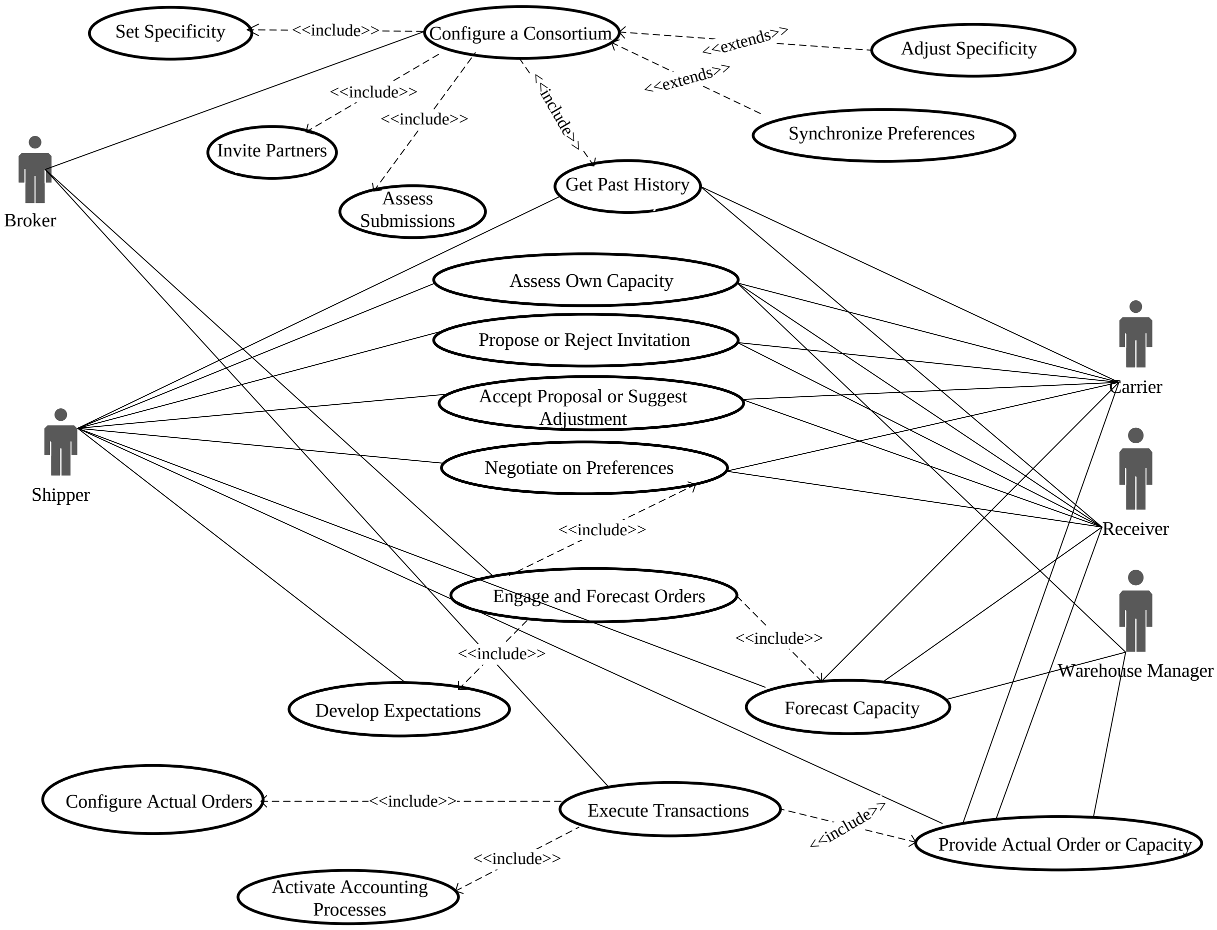


Figure 21: A use-case diagram to describe functional requirements

The use-case diagram comprises of main use cases as well as various extensions and inclusions. It also comprises of four actors, who correspond to categories of agents participating in the resource sharing scenarios. The subsection 4.2.2 presents other details on the use case diagram presented in Figure 21. A short description of each main use case proceeds as follows:

- *Configure a consortium*: Broker-agent set a prospective consortium whose realization extends to other use cases. This use case depends also on other extensions and inclusions;

- *Set specificities*: The broker agent sets up specificities needed for a prospective collaborative consortium. Unless that the network is expected to exhibit a form of the supply network[9], the broker has to specify requirements of the network. These requirements concern, for example, planned capacity relating to production, storage, carriage, and demand (consumption);

- *Invite partners*: Invitation involve sending the already established specificities to prospective partners who inspire to go sharing. Along with this, the broker communicates the specificities to prospective partners who are interested to go sharing;

- *Apply*: Interested prospective partners apply for a collaborative resource sharing opportunity thereby submitting needed information;

- *Accept/reject proposal*: Prospective partners may accept or reject the proposal proposed by the broker;

- *Assess submission*: The broker assesses proposal submitted by prospective partners to figure out if they meet specificities of the consortium. The proposals relate to what each willing partner has suggested as its specificity;

- *Get history*: All agents access existing records to determine the trustworthiness of prospective partners. These beliefs relate to the extents to which a targeted partner is consistent and inconsistent in fulfilling agreements. The trustor-agent derive such beliefs, for example, from forecast accuracy, order fill rate, cost saving, and backorders;

- *Synchronize preferences*: Compromising conflicting preferences which may result in dilemmas. It includes P_1 and P_2 preferences as outlined in Table 4;

- *Adjust specificities*: The broker adjusts its previous specificities (capacities) in the case submitted proposals are unsatisfactory;

[9] Difference between supply chain and supply network is highlighted in section 2.2.1

- *Assess own capacity*: The invited agents assess internal capacity according to the specificities set. The assessment centers on individual capacities subject to the underlying environment;

- *Negotiate on preferences*: Similar to synchronize preferences;

- *Engage and forecast orders*: Collaborating agents are engaged and requested to forecast their orders (also extended to *forecast capacity*);

- *Extend orders*: Communicate more accurate information relating to production, carriage, demand, and warehousing capacities;

- *Build initial load*: A preliminary building of small loads from various shippers for delivery and storage. The broker begins to build possible load and project subsequent possibilities;

- *Develop expectation*: Developing expectation relating to performance metrics used which are forecast accuracy, order fill rate, backorders as a percent of total orders, distribution cost as a percent of sales, cost saving, vehicle fill, and full truckload;

- *Leverage shipments*: A final adjustment in quantities to be shipped and ordered. The final shipments are re-checked against the previous forecast made to adjust excess or deficiency at the individual level;

- *Configure actual orders*: Configuring actual orders, move goods and store goods where necessary. At this level, the broker has actual details of the operation. The additional task of the broker is to configure orders;

- *Activate accounting*: Activating accounting processes to reward partner accordingly. In this activity, the broker retrieves records of each partner involved in the sharing and starts calculating how much gains/costs to pay.

6.1.2 Logistics Functions: Roles and Tasks

The current subsection presents the identification of roles and specification of tasks underlying collaborative functions in logistics. Equally, details relating to these roles and tasks are depicted and presented in an algorithmic form. The algorithm explains negotiations, which occur among collaborating partners, and it rests on the auction-based negotiation protocol. The algorithm adapts the FIPA Contract Net in (FIPA, 2002) (Figure 22).

The following order defines rules of the auction-based negotiation algorithm. That, a broker invites collaborating partners who are shippers, carriers, receivers, and warehouse managers thereby issuing a *Call For Proposal* (CFP). In the CFP, the broker set required specificity, including an estimated planned capacity of each partner. Upon receiving the CFP, each partner conducts own internal assessment about capacity required to fulfill preset requirements. Afterward, each partner replies to the broker by proposing or rejecting the CFP. If rejected, the CFP gets terminated. If proposed, each partner sends a reply proposal to the broker who assesses the proposals against established specificity.

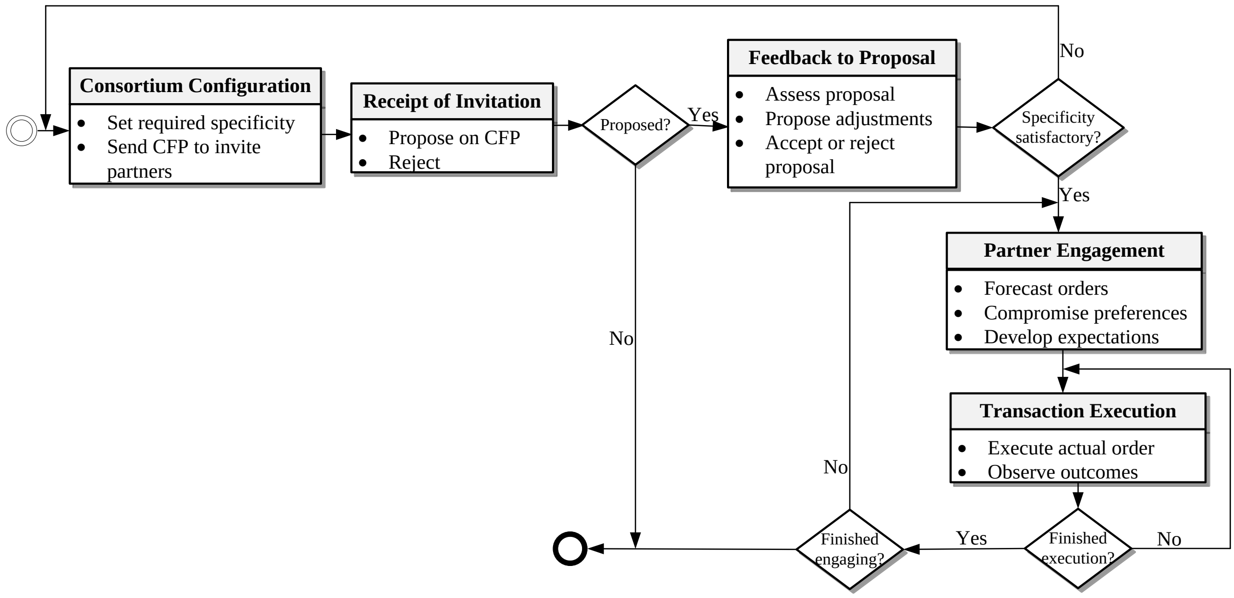


Figure 22: Auction-based negotiation algorithm

Depending on an outcome of the assessment the broker-agent accepts, adjusts or rejects the proposals. If the assessment is satisfactory, the broker-agent engages partners to forecast orders, compromise conflicting preferences, but also to develop expectations. In the end, during the execution, goods are moved and stored (where necessary). In this execution, behavior exhibited by partners is observed and recorded as well.

Further identification of roles and specification of tasks is modeled using sequence diagrams. The sequence diagrams are primarily used to depict sequential interactions of the broker, shippers, carriers, warehouse managers, receivers and other related objects. It is worth noting that it is difficult to present all interactions and dependencies occurring when collaborating agents interact. It is for this reason that the three main-sequence diagrams are devised (modeled) to present macro-level trust-based interactions. These sequence diagrams cover three areas. The first area denotes the configuration of a consortium and corresponds to a *propensity to trusting* (Figure *23*). The second area denotes the engagement and forecasting of orders and corresponds to an *action to trusting* (Figure 24). The third area denotes the execution of the transaction and corresponds to the *transaction to trusting* (Figure 25).

Configuring a Consortium

In order to configure the consortium (setting up specificities), the broker specifies the length of collaboration period and planned capacities, which relate to the production, carriage, warehousing, and demand (consumption) (task 1 in Figure *23*). Afterward, the broker invites prospective partners by sending them established specificities (task 2). Upon receiving this invitation, prospective partners assess their internal capacity before submitting back their proposals to the broker (tasks 3 to 6). This assessment employs records related to previous trust experiences (tasks 7 to 10). Upon retrieving previous trust experiences, each invited member assesses further whether it can participate or not (tasks 11 to 13). Additionally, on completing the assessment of trust, each prospective partner sends back its reply to the broker. Such reply can either be a proposal to agree to collaborate or a rejection that the partner is uninterested (tasks 14).

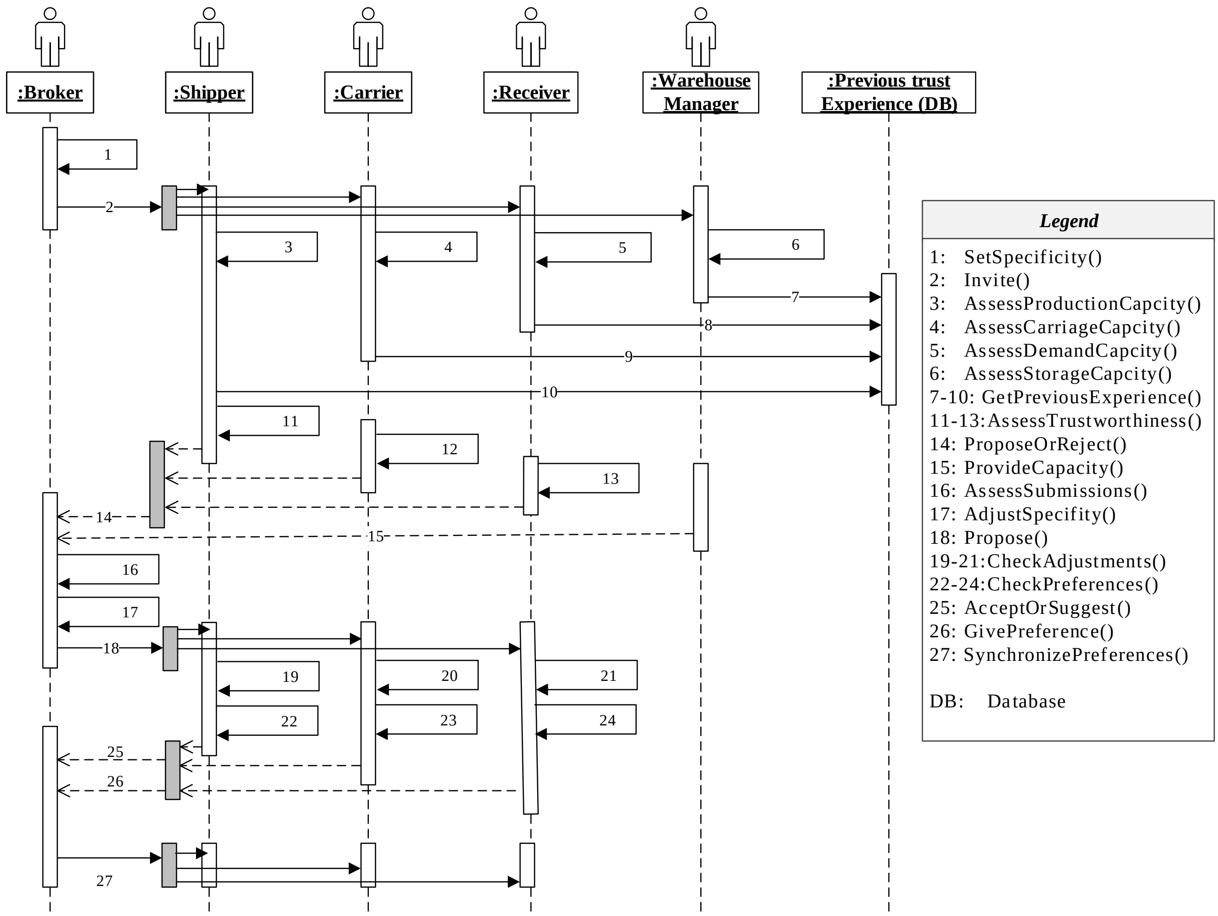


Figure 23: Sequence diagram for configuring a consortium

Upon receiving such replies, the broker assesses the submissions concerning specificities it has set before (task 16). Alongside this, results underlying such assessments are twofold: satisfactory, or; unsatisfactory. If results are unsatisfactory, the broker recommends adjustments (task 17) and brings out another proposal (task 18) which can be accepted, adjusted, or rejected by partners (tasks 19 to 21). About the preferences (P_1, P_2), prospective partners who have agreed to collaborate, choose their preferred positions (task 22 to 24). Afterward, partners send their acceptance or further adjustments (task 25) together with positions they have taken in conflicting preferences (task 26). The broker synchronizes these preferences (task 27). In the end, the consortium is set and ready to begin operate.

Engagement and Forecast of Orders

In the second stage (Figure 24), collaborating partners have more accurate information about production, carriage, consumption, and storage. This information reflects how much is likely to be produced, moved, consumed, and stored. In this stage, the primary activity is to extend order forecasts into shipment forecasts as well as compromising conflicting preferences.

Remaining part of the engagement and forecasting process proceeds as follows. The broker engages partners to begin the forecasting process (task 1) thereby informing collaborating partners to provide their forecasts (tasks 2 to 5). For a partner to accomplish tasks 2 to 5, it has to carry out an internal assessment and provide a corresponding reply to the broker. Alongside the provision of forecasting information, each partner also communicates a position it has taken on a particular preference (P_3, P_4, and P5) (task 6 to 8). Afterward, the generated forecasts, as well as preferred positions, are sent back to the broker. The broker handles the forecast's information and specific positions in preferences (tasks 9 to 10).

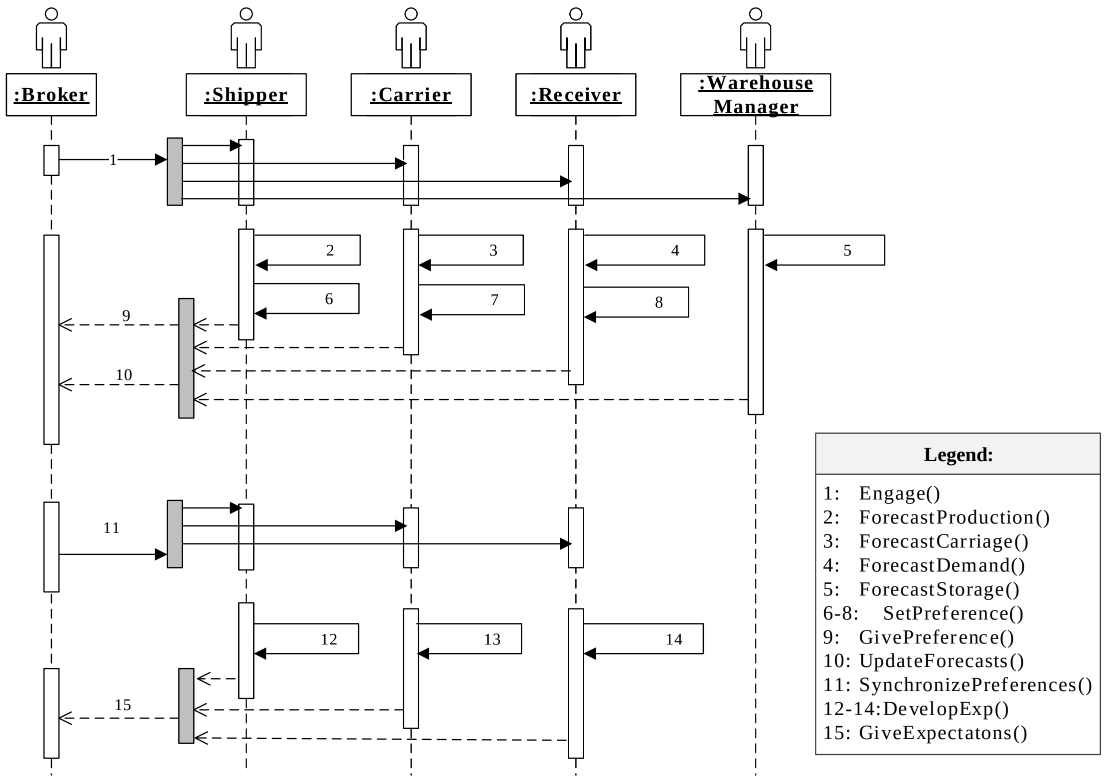
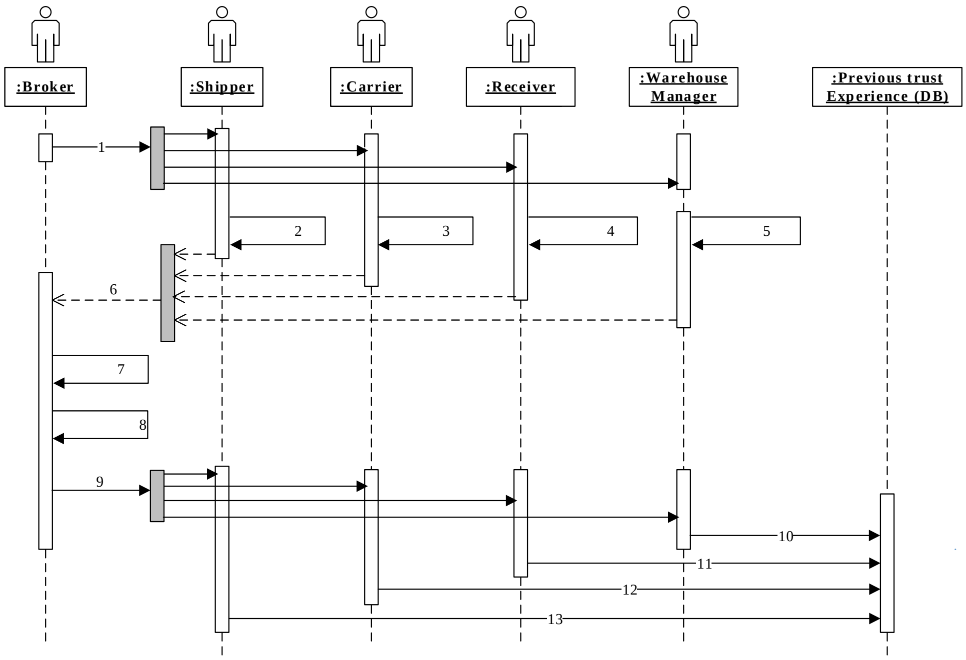


Figure 24: Sequence diagram for engagement and order forecast

The broker attempts to synchronize the conflicting preferences and send back results to respective partners (task 11). Another process known as developing expectations succeeds the synchronization process. Each partner develops its expectation by referring to performance metrics, relevant to that partner (tasks 12 to 14). The established expectations are then communicated to the broker (task 15) to finalize the stage of engagement and forecast.

Execution of Transactions

In the third stage (Figure 25) the assumption is that orders are precisely known. At this moment, the shipper, warehouse manager, receiver, and carrier have approximately exact (real) information about transactions they are going to execute. The shipper provides the exact amount of shipments it has produced or possesses; the carrier provides its actual carriage capacity; the receiver provides actual demand of goods to consume, and; the warehouse manager communicates actual space available at the warehouse (tasks 2 to 5). The information relating to the actual orders from each collaborating partner gets communicated to the broker (task 6). Upon receiving this information, the broker has to configure the actual orders (task 7). At this sub-stage, the broker has a role in coordinating transaction execution (a virtual movement and storage of goods), and after this execution, it activates the accounting process (task 8).



Legend:	
1: ExecuteTrans()	7: ConfigureActualOrder()
2-4: ProvideActualOrder()	8: ActivateAccountingProcesses()
5: ProvideActualSpace()	9: GiveRecords()
6: GiveOrders()	10: UpdateExperience()
	11-13: UpdateTrustAndExperience()

Figure 25: Sequence diagram for transaction execution

In the accounting process, the broker-agent performs three main activities. It evaluates the individual-based trust level as well as system-based trust level. Next, it processes vital records partners may need as well as other necessary records.

Lastly, the trust levels and records are stored in the database as well as sent to respective partners for future reference (tasks 10 to 13).

6.2 Description of Agent Roles and Knowledge

The purpose of this section is to describe roles and knowledge ascribed to collaborating agents and other entities. Such description is realized using a class diagram. Concordant to Cossentino and Potts (2002), the class diagram (Figure *26*) is primarily used to describe involved agents, their knowledge, and their communication relationships. The class diagram has been abstracted not only to reduce details but also simplify an overall presentation.

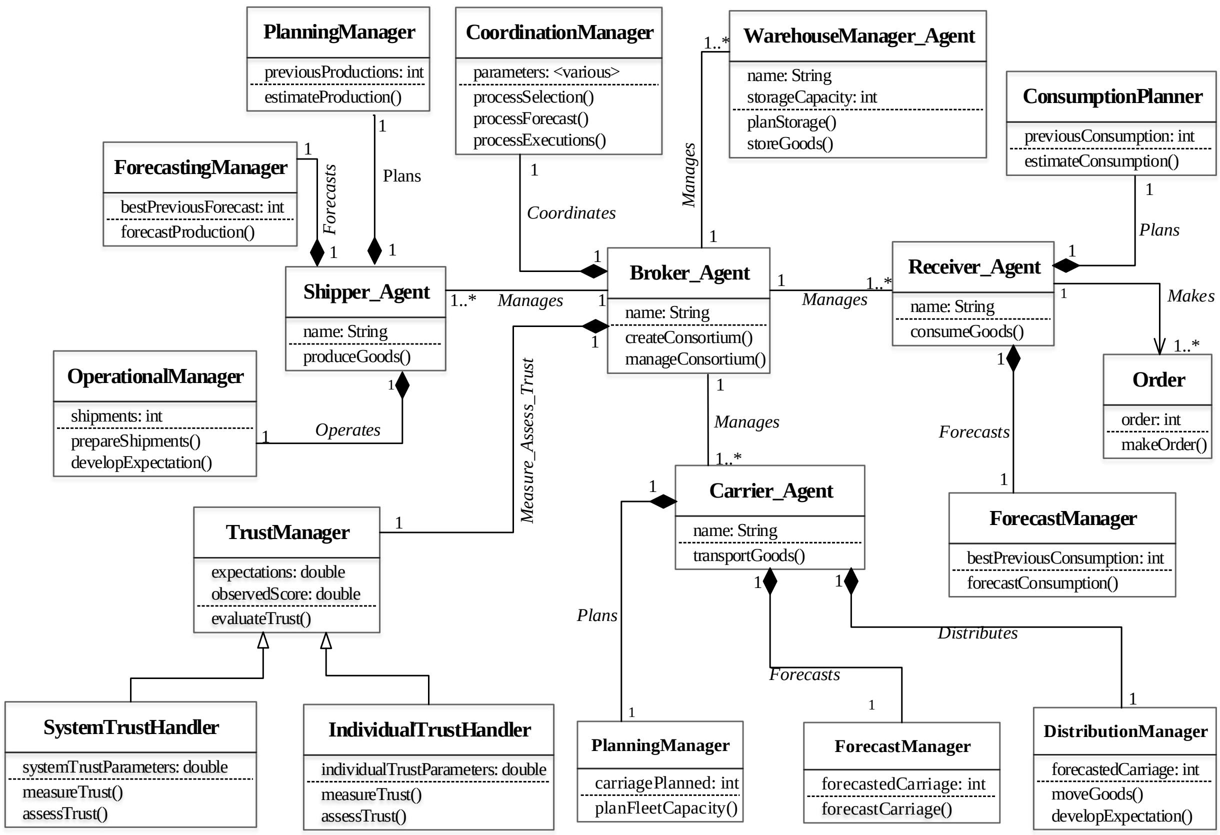


Figure 26: Roles and knowledge in the form of a class diagram[10]

As depicted on the diagram, the chief agent (broker) has a role in managing other agents, namely: shipper, carrier, receiver, and warehouse manager. In its management (coordination) role, the broker requests the shipper, carrier, receiver, and warehouse manager agents to provide their interests and capacities (offers to satisfy specificities of the consortium). Such offers are necessary for carrying out collaboration scenarios aimed to share logistics resources. Specific requests and

[10] It has to be noted that many tasks to be accomplished in a perspective of this class diagram were established previously in subsection 4.2.2, *Figure 23*, *Figure 24*, and *Figure 25*

involved communication exchanges vary depending on requirements of the particular stage during collaborative sharing.

Besides agents, there are other entities whose role is to facilitate functions of agents. Such entities are not agents in themselves. They are ordinary (external) classes, which assume the internal role to serve agents' internal computational processing. The external classes play the role of simplifying the computational task that may have been undertaken by the individual agents themselves. To this effect, in their implementation, such classes are regular object-oriented classes, which do not carry characteristics of agents (functionalities). In due of this and with an exception of the warehouse manager who does not delegate its internal processing to external classes; assessment by remaining agents involves external processing. Even though, the warehouse manager does not use external processing because it does not handle many tasks as compared to remaining agents.

The illustration on how agents delegate their tasks to external classes employs the shipper-agent, as an example. In the selection and front-end agreement stage, the shipper is engaged by the broker to conduct planning. This planning, among others, is concerned with: how much it can produce; what are her choices on conflicting preferences, and; whether it needs adjustments in pre-configured specificities. To accomplish these issues, the shipper agent delegates its respective task to a planning manager. The planning manager scrutinizes its production history (if it exists) or provides necessary assumed plans (in the case of an initial run) and communicates the same to the broker. Equally, in the order forecast and physical distribution stages, the shipper engages forecasting and operational manager, respectively. Remaining agents follow similar arrangements.

Once the broker receives all information, it also delegates its processing tasks to its coordination manager who handles the selection, forecast, and executions tasks. In the end, the broker handles collected information (trust parameters) to its external processing for assessing and evaluating trust. Evaluation of trust takes place at the agent's level as well as system level. The system-level trust measures an extent to which the entire collaboration network of sharing may be trustworthy.

6.3 Simulation Platform

There are many MAS simulation platforms (tools). According to a survey by Kravari and Bassiliades (2015), the majority of these platforms are primarily designed to solve problems whose domains are generic. Kravari and Bassiliades add that fewer of these platforms (like JADE, Jadex, JACK, and EMERALD) comply with the FIPA[11] standards while others are either partially or entirely incompliant. In a context of a research problem at hand, what is needed is a platform whose primary domain

[11] http://www.fipa.org/specifications/index.html

is specific instead of generic one. Besides a long list, Kravari and Bassiliades (2015) provide, PlaSMA remains a popular platform dedicated to the domain of logistics functions, and, which is also FIPA compliant. It is an event-driven simulation system designed to solve and evaluate scenarios of the logistics domain[12] (Figure 27).

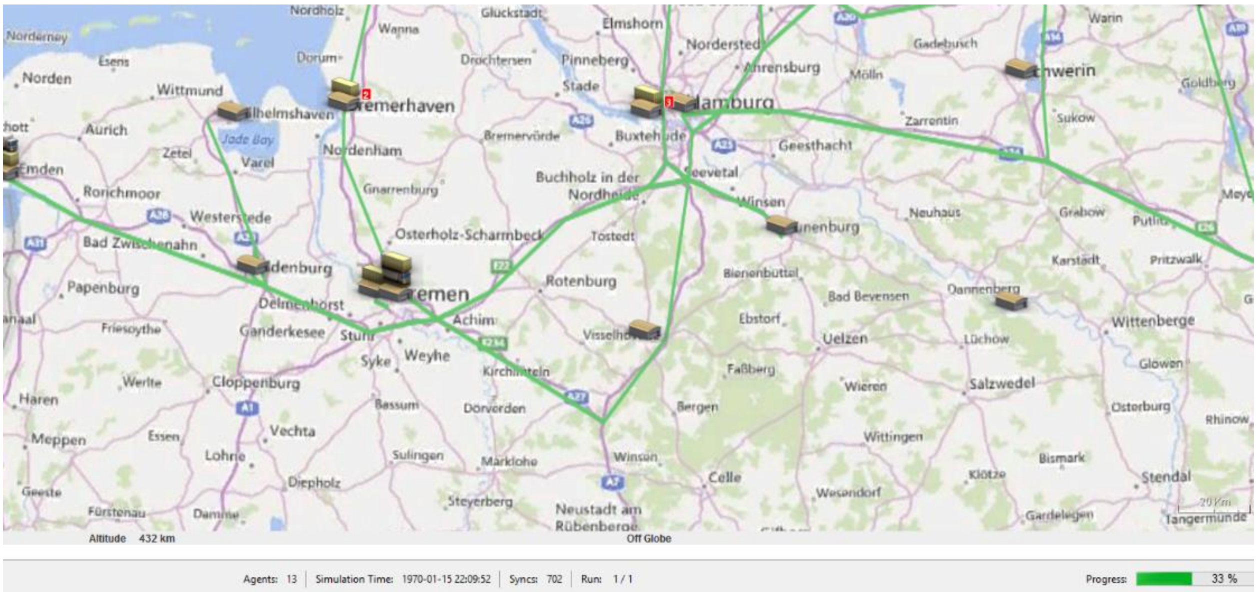


Figure 27: View of the simulation scenario in PlaSMA

In its current form, PlaSMA can hardly be used to simulate the trust mechanism in the collaborative sharing of logistics resources. Due to this limitation, an extension of the PlaSMA platform involves implementing missing classes and functionality. Substantially, this implementation extends existing base classes in PlaSMA, but other classes in JADE[13]. The implementation employs virtual shareable infrastructures like vehicles and warehouses, as well as virtual organizational and individual entities that undertake trusting decisions (Figure *28*).

Specifically, shippers, carriers, receivers, and warehouse managers (agents) gather information, adapt the environment, act autonomously, and care for utility. After acquiring such information, the agents change their behavior depending upon the experience, and undertake decisions using acquired knowledge (beliefs) without continuous user inputs. Furthermore, these agents are programmable as utility-based agents than goal-based ones. In their utility function, agents predict a utility value and compare it with others and select the action associated with that highest value (Matsumoto, Matsumoto, & Abe, 2006). Corresponding to a present context, employed agents develop trust and expectation by selecting the action associated with highest rewarding past experiences.

The operational TrustMech (in Figure *28*) requires specifying (entering) values related to design and setup before initiating the simulation. The purpose of

[12] http://plasma.informatik.uni-bremen.de/
[13] http://jade.tilab.com/

employing adjustable design and settings is to allow flexibility than relying on hard-coded design and settings.

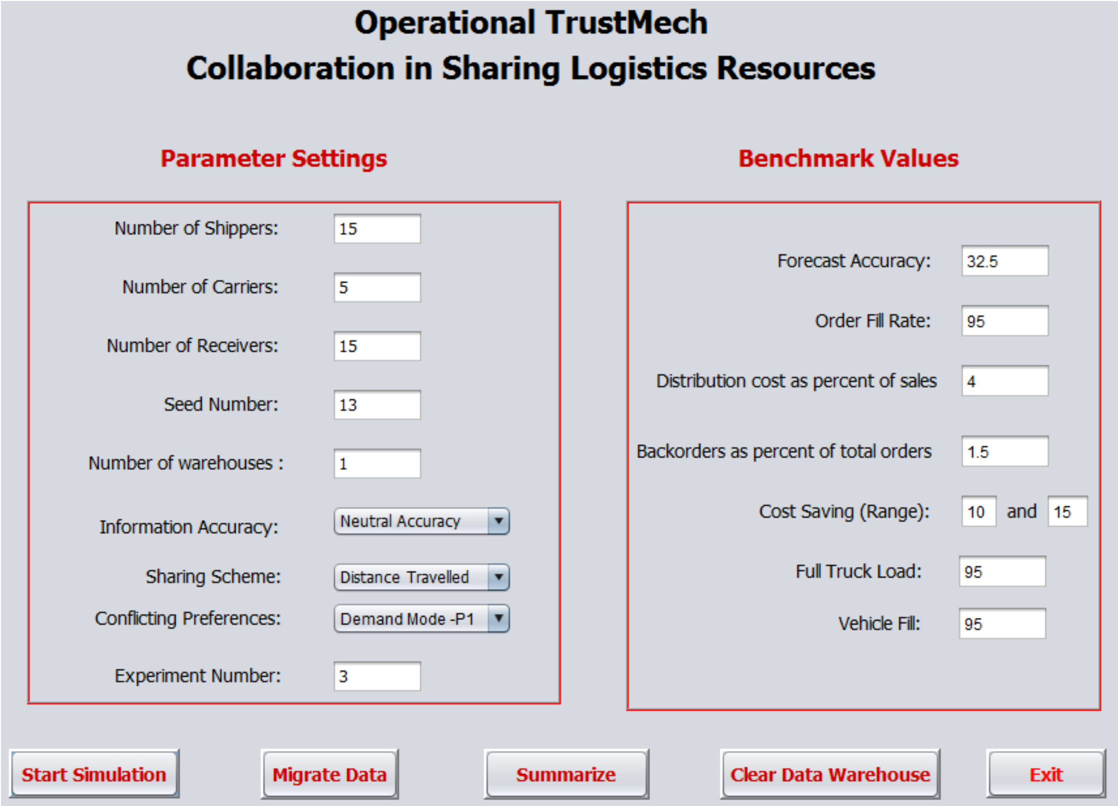


Figure 28: A user interface for setting simulation parameters

In addition, for each cycle of the simulation run, the resulting performance and trust level data for individual entities (agents) and system as a whole is stored. The relational tables managed by PostgreSQL DBMS store such data. However, frequently adjustable data is stored in text files to simplify access by the read and write functions. Moreover, after each experiment, all data (including several replications) is filtered and subsequently migrated to other database tables for further analysis.

6.4 Design and Setup of the Logistics Network

The present section specifies design and setup of a logistics network. It also addresses issues related to replication of experiments, predictor variables and their respective levels (design). Subsequently, the section presents specific settings to use in simulation experiments.

6.4.1 Benchmark Values to Performance Metrics

As previously discussed, trust can be measured and assessed using standard deviation technique or industry benchmark values. Currently, the present work utilizes benchmark technique than the standard deviation. This inclination towards industrial benchmark values is purposely meant to unveil trustworthiness that underlies industrial practices. In achieving this, the benchmark technique requires obtaining industrial benchmark values in prior. These values may be the best-in-class or average ones. Following this requirement, a survey of the literature is conducted to obtain these benchmark values.

The literature survey involves conducting a thorough search of relevant industrial reports that detail industrial benchmark values. After carrying out this survey, it appears that it is difficult to obtain unique standard benchmark values that fit all. Instead, benchmarks values in use differ in some companies, although they correlate in other companies. Despite a challenge that obtaining standard benchmark values is difficult, values discussed in a subsequent paragraph, and later in Table 10 satisfy the present goal and objectives. Additionally, to accommodate this challenge, even the TrustMech is both devised and designed flexibly to accept adjustable benchmark values.

About response variables specified already, subsection 5.2.2 has outlined seven benchmark values. Respective specification proceeds as follows. Firstly, while many techniques to measure forecast accuracy exist, the Supply Chain Consortium (2011) observes that common measures used are the MAPE and percentage error. Many stakeholders prefer the MAPE than the percentage error, and they forecast own sales averagely at an error of 32.5%. Secondly, the order fill rate has two benchmarks values: “95%” (Supply Chain Consortium, 2011) and “93.6%” (Butner & Iglesias, 2010). Since these values are close, this dissertation advances on the 95% to streamline measurement of trust. Thirdly, the cost saving is commonly mentioned to range between 10 to 15% (Tseng et al., 2013). Fourthly, the distribution cost as a percentage of sales and backorders as a percentage of total orders are benchmarked to 4% and 1.5%, respectively (Manrodt et al., 2011). Fifthly, the Full Truck Load (FTL) according to (VICS, 2004) is usually 95%. Finally, one can derive vehicle fill by building from the benchmark value of the FTL. In this situation, the vehicle fill takes the same benchmark value as the FTL (95%).

6.4.2 Design

The adequately designed experiment(s) provides maximum information with the minimum number of experiments (Jain, 1991). Parallel to Jain’s argument, the design of experiments in this work targets to minimize the number of experimental runs thereby considering three issues. The first consideration involves replicating the experiments. A prototype of the TrustMech is implemented in a way that a single run of experiment yields four rounds of outputs. Therefore, to satisfy requirements of statistical tests, each run is replicated two times to yield eight observations using the same seed value. It is worthy to note that each experimental set is performed sequentially using five distinct seeds. Under this design, therefore, in the end, every single experiment is expected to generate a total of 40 samples of observations.

The second consideration entails combining all predictor variables to study their combinatorial effect on trust. This design is complicated because it involves all three predictor variables and their varying levels, at once. The predictor variables: information accuracy, sharing scheme, and decision synchronization have three, four, and five levels, respectively. If a full factorial design is applied, it will yield 45 (3^1 x 3^1 x 5^1) experiments. Recalling that each experiment is set to yield 40 samples of observations then a total of 1800 (40 x 45) samples are expected. This number is too large and may complicate the analysis of recorded results. One can overcome this problem (reduce the number of experiments) by applying a screening technique. This screening is realized using tools for designing experiments (the JPM[14] and Minitab[15]). After this screening, the number of experiments drops from 45 to 9 (experiment number 1 to 9, in Table 9).

Table 9: Design of experiments for combinatorial and singleton effects

Experiment Number	**Information Accuracy**	**Sharing Scheme**	**Conflicting Preference**
		Combinatorial effects	
1	Neutral accuracy	Number of Customers	P2
2	Positive accuracy	Distance Travelled	P3
3	Neutral accuracy	Distance Travelled	P1
4	Positive accuracy	Total Load Shipped	P2
5	Positive accuracy	Number of Customers	P4
6	Negative accuracy	Distance Travelled	P4
7	Negative accuracy	Number of Customers	P1
8	Negative accuracy	Total Load Shipped	P5
9	Neutral accuracy	Total Load Shipped	P3
		Singleton effects	
10	Positive accuracy	General	P3
11	Neutral accuracy	General	P3
12	Negative accuracy	General	P3
13	Neutral accuracy	Distance Travelled	P3
14	Neutral accuracy	Number of Customers	P3
15	Neutral accuracy	Total Load Shipped	P3
16	Neutral accuracy	General	P1
17	Neutral accuracy	General	P2
18	Neutral accuracy	General	P3
19	Neutral accuracy	General	P4
20	Neutral accuracy	General	P5

[14] https://www.jmp.com/en_us/software.html
[15] https://www.minitab.com/en-us/products/minitab/

The screened design yields 360 (9 x 40) samples of observations which generate an effect equivalent to that of the 1800 samples.

The third consideration emphasizes on studying the effect of behavioral-process reinforcement on trust in isolated manner. This design requires manipulating one predictor variable while holding fixed remaining variables. This design is relatively easy as it involves 11 experiments (experiment 10 to 20, in Table 9) and is expected to generate 440 (11 x40) samples of observations. In the overall, the design for all experiments (combined and singleton effects) is expected to generate 800 (360 + 440) samples of observations.

6.4.3 Setups

Parameters used in a simulation scenario require prior settings. There are five categories of settings: (1) benchmark values for measuring and assessing trust; (2) trust meter; (3) awards and penalties on persuasion and rejection of dilemmas; (4) information accuracy, and; (5) structure of a collaborative logistics network.

The first category of parameters refers to response variables used to measure and assess trust. Subsection 6.4.1 presented parameters derived already from benchmark values. The benchmark values are refined and specified under the Likert scale of size 5 (Table 10). Furthermore, four response variables, namely: forecast accuracy, order fill rate, full truck load, and vehicle fill have an interval of two units spanning on both sides of the benchmark value. The backorders as a percent of total orders uses the interval of 0.5 units, which spans on both sides as well. The cost saving and distribution cost as percent of sales use an interval of one unit that spans on both sides of the benchmark value.

Table 10: Measurement and assessment of trust (5 Likert scales)

Response variables	**Benchmark value**	**Lower value (L_v)**	**Upper value (U_v)**	**Width (w)**
Forecast accuracy (sales)	32.5%	*27.5%*	*37.5%*	*2*
Order Fill Rate	95%	*90%*	*100%*	*2*
Cost saving	10 to 15%	*10%*	*15%*	*1*
Distribution cost as percent of sales	4%	*2%*	*6%*	*1*
Backorders as a percent of total orders	1.5%	*0.5%*	*2.5%*	*0.5*
Full Truck Load (FTL)	95%	*90%*	*100%*	*2*
Vehicle fill	95%	*90%*	*100%*	*2*

Note: These parametric values, are derived from subsection 6.4.1

Resulting from the lower and upper specifications of the benchmark values (Table 10), the measurement and assessment of trust proceed as follows. Partner develops own expectation to be compared with the benchmark value after execution. A result from this comparison falls into one of the five scales (even beyond) as defined in the trust meter (Table 11).

It is worthy to note that definition of the trust meter for the forecast accuracy and backorders go in reverse order. A reason to set up the trust meter in the reverse order backups from a fact that, usually, the forecast accuracy and backorders become trustworthy when observed outcomes are smaller. Moreover, the trust meter maps the quantitative value to respective qualitative (attitudinal) values, for both the system and individual levels of trust.

Table 11: The trust meter

Range	Quantitative value	Qualitative value
L_v <= *score* < $(L_v + w)$	1	Least trustworthy[16]
$(L_v + w)$ <= *score* < $(L_v + 2w)$	2	Less trustworthy
$(L_v + 2w)$ <= *score* < $(L_v + 3w)$	3	Trustworthy
$(L_v + 3w)$ <= *score* < $(L_v + 4w)$	4	More trustworthy
$(L_v + 4w)$ <= *score* < U_v	5	Most trustworthy[17]

Succeeding the trust meter is synchronization of conflicting preferences. Settings under decision synchronization are concerned with awards for the preference persuaded or penalties for the preference rejected. Provision of the awards (incentives) occurs in case conflicting preferences are persuaded. Unlike the persuasion, charging of penalty (punishment) occurs in case the particular preference is rejected (*Appendix I*).

Besides providing setups to response variables, settings under information sharing, as the predictor variable, proceeds as follows. First, the preceding provisions in subsection 4.3.1 are adopted. Alongside this adoption, information accuracy gets subjected to manipulation under the negative, neutral, and positive aspects of affection (Table 12). The affection uses a continuum of variables ranging from -0.45 to 0.45. This range also accommodates a parameter of certainty, {0}, although slight deviations, {-0.05, 0.05} have been introduced to allow flexibility. This allowance enriches a reality on the beliefs about the world, that, it is uneasy to predict the world rationally.

[16] If a score is less than L_v the trust level is also assessed as the least trustworthy
[17] If a score is greater than U_v the trust level is also assessed as the most trustworthy

Table 12: Type of affection and elements used to affect information accuracy

Type of affection	Elements used in affection	Description
Negative information accuracy (γ)	{-0.45, -0.40, -0.35, -0.30, -0.25, -0.20, -0.15, -0.10}	A partner who exhibits this behavior is considered untrustworthy and acts in a manner of maximizing individual payoff. Such partner exchanges information that is underestimated but also that affects needed accuracy negatively
Neutral information accuracy (**α**)	{-0.05, 0, 0.05}	A partner who affects logistics elements using this factor is considered honest, congruent, and can certainly be relied upon. In particular, if a chosen factor is zero, then the partner is absolutely honest and reports the true information. Otherwise, it is a normal honest partner
Positive information accuracy (**ß**)	{0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45}	Partner who exhibits this behavior is still considered untrustworthy (similar to the negative information accuracy). He instead exchanges overestimated information

** It has to be noted that this affection extends the previous discussion in subsection 4.3.1*

Final settings are related to a topological structure of the collaborative logistics network. The logistics network employed in this study correlates partly to that used in (Zolfagharinia & Haughton, 2012). In particular, the network comprises 15 shippers and 15 receivers (to simplify interactions), and five carriers. One shipper serves only one receiver but with multiple orders. Each carrier owns one vehicle truck, which constitutes a pool of trucks, and the carrier cannot choose whom the customer to serve. This number of collaborating partners was explicitly set to ensure the prototype executes appropriately. It has to be noted that, previous attempt to increase the number of partners resulted in improper runs (errors and bugs) due to computational capacity of the desktop machine used.

6.4.4 Validity of Data

Data validation is a process of determining that the data used in building and validating the simulation model is sufficiently accurate (Love & Back, 2000). To fulfill requirements of validity of a model (mechanism) and its application, simulation (controlled) experiments have to rely primarily on using historical data. Historical data is the data collected on a system (Sargent, 2013), with the condition that the system is observable, and that it is possible to collect data about it. The system data may originate from an operational system or specific experiments such as laboratory and field experiments (Xiang, Kennedy, & Madey, 2005).

Unlike the historical data, another source of data that may be used to establish validity and demonstrate the application of the model (mechanism) is the model data. The model data get in use when a system under investigation is partially observable or entirely non-observable. Usually, the best data is the historical data, obtained (collected) especially from operational systems such as real functioning logistical systems.

As addressed further in subsection 7.1.2, the system data collected from the industry-based collaborations in sharing logistics resources is insufficient and incomplete. One of the reason is that data used especially in the trucking industry is primarily proprietary due to the potential interest of protecting privacy (Hernández & Peeta, 2014). Secondly, collaborative scenarios in sharing logistics resources, which exhibit realism to nature of this study are limited. To overcome this problem, therefore, the present validation uses model data estimated on account of industry reports and related literature in (Cruijssen, Borm, Fleuren, & Hamers, 2010; Department for Transport statistics, 2017; Hernández & Peeta, 2014; Zolfagharinia & Haughton, 2012). Therefore, generation of model data relies on adapting trends (patterns) of data from the mentioned literature (see subsection 7.1.2 for further details). Upon obtaining such patterns, generation of actual data advances by employing random number (linear-congruential) generators. Afterward, the chi-square test is applied to scrutinize and ensure that generated model data exhibits a uniform distribution.

6.5 Summary and Conclusion

The current chapter has presented details to implement TrustMech's prototype. The prototype plays a primary role as a vehicle, which is very necessary in proving the proposed concept. The implementation consists of transforming the TrustMech concept into a computerized instance. The transformation has employed the UML techniques to specify software requirements, interactions, and design. The coding has involved extending base classes of the PlaSMA and JADE to build a new prototype. The new prototype addresses the trust problem in collaborative sharing of logistics resources. About the design and setups, the chapter has specified a logistics network that comprises an equal number of shippers and receivers, while carriers are one-third of shippers (or receivers). Provided settings also include benchmark values that are used to develop the expectation and trust meter. The simulation experiments advance on the model than system data. The model data is generated based on industrial practices, and its standard distribution is validated using chi-square test. Afterward, simulation experimentation begins as specified, while results obtained are accordingly analyzed, presented, and discussed in chapter 1.

In regard to concluding remarks, the following are stated. Trusting outcomes in resource sharing networks, usually, result from multiple interactions of individual partners. Quantifying such outcomes using the equation-based modeling denies an ability to observe such individual interactions, whose effect aggregates to generate outcomes of a whole system. In this respect, it is more appropriate to prove the TrustMech concept by relying on benefits offered by the ABM and MAS. For this reason, the ABM has guided specifications and designs of the TrustMech concept. Correspondingly, the MAS has provided guidance in coding such specifications and designs. In the end, the realized prototype allows individual and adjustable agents (in categories of shippers, carriers, receivers, and warehouse managers) to interact within computational settings. Such agents generate trusting outcomes, which resembles (ideally) the outcome which human beings may generate.

Chapter 1 succeeds the current chapter. It addresses the validation as well as the application of the TrustMech concept. In addition, it presents results and discussion in a viewpoint of the usefulness of the TrustMech, but also the hypotheses tested.

7 Validation and Application

During the research parts of the contents have been published in (Daudi et al., 2016b, 2017b).

The present chapter deals with two issues concurrently, namely: validation and demonstrative application of the proposed concept. The goal of the former is to assess and establish the usefulness of the TrustMech. The goal of the latter is to demonstrate how the TrustMech can be applied to serve its purpose. This demonstration succeeds the hypotheses' testing, derived already in section 5.3. The validation and demonstrative application appear in the following sequence. An approach to validation is analyzed and discussed by providing the background, validation objects, as well as comparative standard (section 7.1). Whereas section 7.2 presents the analysis of results obtained from simulation experiments, section 7.3 provides a corresponding discussion. The chapter ends by providing limitations (section 7.4) as well as summary and conclusion (section 7.5).

7.1 Validation Approach

Previous chapters addressed issues concerning the environmental factors, causal mechanism, and its computerized instance. Succeeding this establishment is an approach to validate the TrustMech concept. To this effect, this section presents a background on validation approach, and later it presents discussions about a methodology used to establish both the conceptual and operational validity.

7.1.1 Background

There are many categories and criteria to use to figure out how a model is beneficial and valuable. Out of multiple categories proposed by Sargent (1981), this dissertation draws on a validation category that is constituted by the conceptual and operational validity. The conceptual and operational validities are validation objects used throughout this dissertation to establish the credibility and reasonableness of the TrustMech concept. These objects are employed to establish credibility in the MAS models, instead of the ISO 9126 Software Quality Characteristics[18] that are used to evaluate software systems. An interesting question is why putting both validation objects to use? The use of both objects backups from the fact that each validity object furnishes limitations on the other. In elaborating this, Heath, Hill, and Ciarallo (2009) observe that if the model is only conceptually valid, it is unknown if it will produce correct output results. Correspondingly, authors add that if the model

[18] http://www.sqa.net/iso9126.html

is only operationally valid, it is unknown whether that model stands on any appropriate representation of reality.

7.1.2 Conceptual and Operational Validity

In a standpoint of intelligent systems, validation is as a process set to ensure that outputs of the intelligent system are equivalent to those of human experts when given same inputs (Gonzalez & Barr, 2000). The validation of agent-based models involves two aspects: a piece of the simulation model under validation (the conceptual model and simulation output), and; techniques used to validate each piece of the simulation model (statistical and non-statistical) (Heath et al., 2009). The conceptual validity is set to determine that theories and assumptions underlying the conceptual model are correct (Sargent, 2013). Sargent emphasizes that the operational validity is purported to determine that the model's output behavior has a satisfactory range of accuracy for the model's intended purpose.

The decision about which validation techniques to apply depends on whether a simulated system is observable (historical data exist) or not. Collaboration in sharing logistics resources is partially observable. By partial observations, it means that there are few collaborative practices that entail a realm of resource sharing in logistics. In a standpoint of the present situational context, the operational validity may proceed by comparing the simulation (model) to (Sargent, 2013):

a) Other existing models with or without statistical tests, and;

b) A system with or without statistical tests.

By referring to a context of the outlined comparisons, the *simulation model* means a model that undergoes validation. Under the present settings, the TrustMech is the model that gets validated. By *other existing models*, it means models of trust available in the literature which relate to the TrustMech, and which are not only already validated but also well-known. In clarifying further, the *system* refers to a set of real and historical data collected, for example, on a particular entity, which is operationally functional.

Currently, establishing the operational validity on the basis of the system data is difficult. Of course, there is system data (secondary data) collected from the literature. The secondary data originated from few projects such as the "Collaboration Concepts for Co-modality[19] –CO^3". One limitation of secondary data that is obtained from the literature is that it is insufficient and undetailed to suit needs of logistics scenarios being simulated. Another problem is that the literature data is even incomplete because some of the predictor variables have been missing entries. As far as the available system data is insufficient, this dissertation, therefore,

[19] http://www.co3-project.eu/

advances on the other comparison approach. The approach requires establishing the operational validity by comparing the TrustMech to other existing models.

In regard to the conceptual validity, its establishment stands on assessment of the internal consistency of the TrustMech concept. On the whole, Table 13 presents a generalized summary of the methodology used to validate the TrustMech concept.

Table 13: Validation methodology

Context	Goal	Procedures
I. Data validity	To ensure data is factually realistic and unbiased	1. Obtain industrial benchmarks reports 2. Use linear-congruential generators to establish the independence of data 3. Assign each predictor own seed value to avoid wrong correlation 4. Use the chi-square test to ensure data is uniformly distributed
II. Conceptual validity	To establish that theories and assumptions underlying TrustMech are correct and that the TrustMech's representation of the problem entity is reasonable	5. Use Graphical Displays (GD) to show patterns (trends) 6. Apply the CI technique to determine the internal validity
III. Operational validity	To assess whether output behavior to the TrustMech has the accuracy needed	7. Use GD to compare output behavior of the TrustMech and FIRE trust model 8. Use statistical tests to compare output behavior of the TrustMech and FIRE trust model

The discussion on validation methodology continues as follows. Model data is used not only to validate the TrustMech but also demonstrate its potential applications. The model data is generated by specific models to suit and mimic the desired problem situation. Such data has to satisfy statistical requirements (see subsection 6.4.4) and be valid as well. The establishment of the conceptual validity succeeds the data validity. In determining data validity, assessment of the internal stochastic variability of the TrustMech relies on comparing output behavior using the GD and statistical tests. To attain the operational validity the output behavior of the TrustMech is compared to the output behavior of another valid model objectively (using statistical tests) and subjectively (using GD) (Sargent, 2013). As a result, the present context and settings engage comparing the TrustMech to the FIRE model.

Before establishing the operational and conceptual validity, criteria that guide decisions on whether particular output behavior suffices needed validity or not, have to be formalized. In the light of this, Jain (1991) proposes decisive guidelines to compare two alternatives based on a Confidence Interval (CI) technique. According to Jain, if CIs overlap considerably such that the mean of one falls in an interval of the other, then the two alternatives are equal with the desired level of confidence. If the CIs do not overlap considerably, the two alternatives are significantly different.

Besides the statistical tests, the accuracy of the operational validity is also established using GD. The accuracy succeeding this validity is a similarity in patterns of output behavior, which the pairs under comparison generate.

7.1.3 Benchmarking the TrustMech to the FIRE Model

As stated previously, the operational validation of the TrustMech is achievable by comparing output behavior of the TrustMech and FIRE. FIRE is one of the well-known integrated trust and reputation model for open multi-agent systems(Huynh et al., 2006). It uses four types of sources to provide trust-related information (see subsection 4.6.1). Even though, the present validation uses only the direct experience as the source of trust information. The direct experience is preferred because, under the context of the present scenario and settings, attaining other sources of information appears to be difficult. Additionally, although the FIRE model has many components, the present validation employs only one component, known as the *Interaction Trust* (*IT*). This component, the IT, is selected because it corresponds better to features of the TrustMech. The short description of the IT component used to validate the TrustMech is as follows (Huynh et al., 2006):

- Under direct experience as a source of trust information, the evaluator uses its previous experiences in interacting with the target agent to determine its trustworthiness (*Interaction Trust –IT*). The IT is captured by using rating. Rating is the evaluation of an agent's performance given by its partner in an interaction occurring between them. To emphasize this, each agent rates its partner's performance after every transaction and stores its ratings in a local rating database. Ratings appear in a form of tuples such that the rating ***r*** is given by = *(a, b, c, i, v)*, where ***a*** and ***b*** are agents that participate in the interaction ***i***, ***v*** is the rating value agent **a** gives to agent **b** in a context ***c*** (like quality, honesty)
- To calculate the trust value of the target agent the IT component of the FIRE collects relevant ratings about that agent's past behavior. After that, calculation of trust value incorporates the sum of all the available ratings weighted by the rating relevance, and which become normalized afterward.

In accomplishing this comparison, evaluation of trust is carried out using both the TrustMech and FIRE –IT, concurrently. The FIRE –IT requires one category of a partner to evaluate (rate) performance of another category. The evaluation of performance depends on how the evaluator is satisfied with a service provided by service providers. In respect of this, for each interaction, evaluator rates the service provider as its trading partner.

Afterward, a next step is to compare output behavior generated by both the TrustMech and FIRE–IT. Since the TrustMech and FIRE–IT uses distinct evaluation approaches, measurement of resulting output behavior stands on unpaired observations.

7.2 Results

The MAS simulation was carried out to validate the proposed TrustMech concept and confirm or reject derived hypotheses, on the one hand. On the other hand, obtained results were analyzed to enrich the discussion in section 7.3. On account of the simulation experiments carried out, results presented in this section appear in categories of the: conceptual validity; operational validity; hypothesis 1; hypothesis 2; hypothesis 3; hypothesis 4; hypothesis 5, as well as; trustworthiness and general behavior of the network.

Conceptual Validity

The first category of results is related to a conceptual validity of the TrustMech. Realization of the conceptual validity relied on assessing a stochastic degree of internal variability of the TrustMech. A goal of this assessment was to reveal an extent to which the TrustMech is internally consistent or inconsistent. In realizing this, a one-way analysis of means trust level of all 20 experiments was carried out. Each experiment had more than 35 samples of observations. Analysis of results involved comparing 190 ($^{20}C_2$) outputs (see Appendix *II*) using the Tukey comparison method at a 95% CI. Results obtained were twofold: interval plots and statistical tests. Concerning the interval plots, Figure 29 portrays plots that depict the internal variations of the TruchMech, after subjecting the TrustMech to 20 distinct treatments.

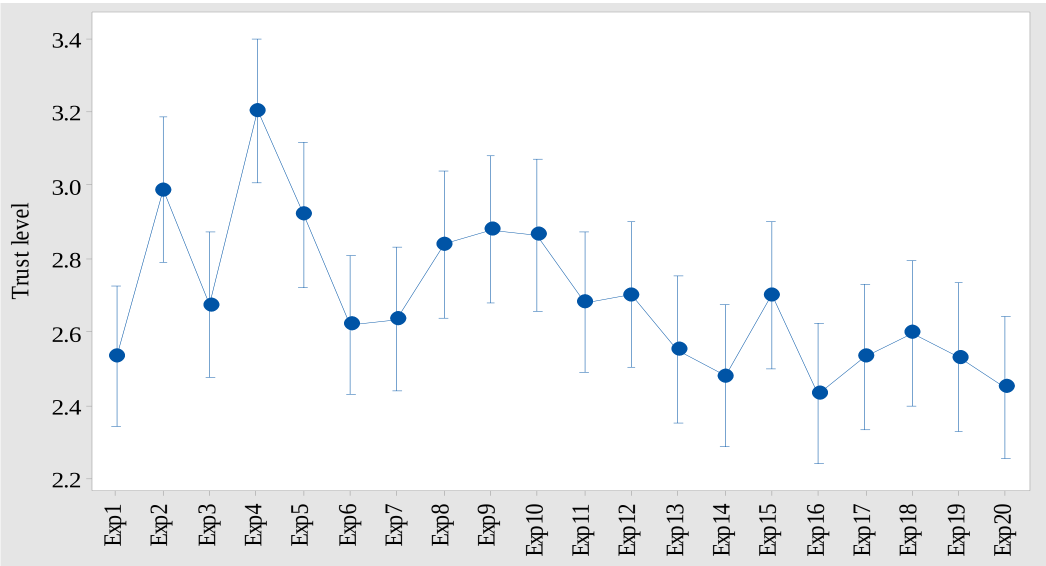


Figure 29: Internal variability of the TrustMech

In regard to the statistical tests, analysis of outputs (*Appendix II*) shows that not all means trust levels were equal. This inequality signifies that the TrustMech carries some variances. In particular, out of 190 comparisons:

- 175 comparisons (92.1%) had an adjusted P-Value that was greater than a significance level ($\alpha = 0.05$) and their 95% CI included a null value, and;

- 15 comparisons (7.9%) had the adjusted P-Value that was less than a significance level ($\alpha = 0.05$) and their 95% CI excluded a null value.

Operational Validity

Establishment of the operational validity involved a comparative analysis of output behavior of both the TrustMech and FIRE. The comparison was carried out in a standpoint of the graphical displays, proportionality, and statistical tests. This analysis employed data recorded under experiments 1 to 20 (see Table 9). Each experiment involved recording an average trust level for every eight consecutive samples. Such recording resulted in five mean trust levels for each experiment. This recording ended up by generating 100 (5 x 20) samples of observations. Figure 30 shows the comparative performances of the TrustMech and FIRE (based on the unpaired observation of samples). In regard to the proportionality, out of 646 recorded samples, the TrustMech outperformed the FIRE by 73.53%, and; performed equally to the FIRE by 26.47%. As well, the statistical test (t-test at 95% CI) that employs unpaired observations was carried out. The statistical test of the FIRE against TrustMech yielded sample means of 3.34 and 3.81 trust levels, respectively (Appendix III). Further t-test yielded a mean difference (FIRE – TrustMech) of -0.4727 trust level, with the 95% CI for the difference in trust levels ranging between -0.6617 and -0.2837.

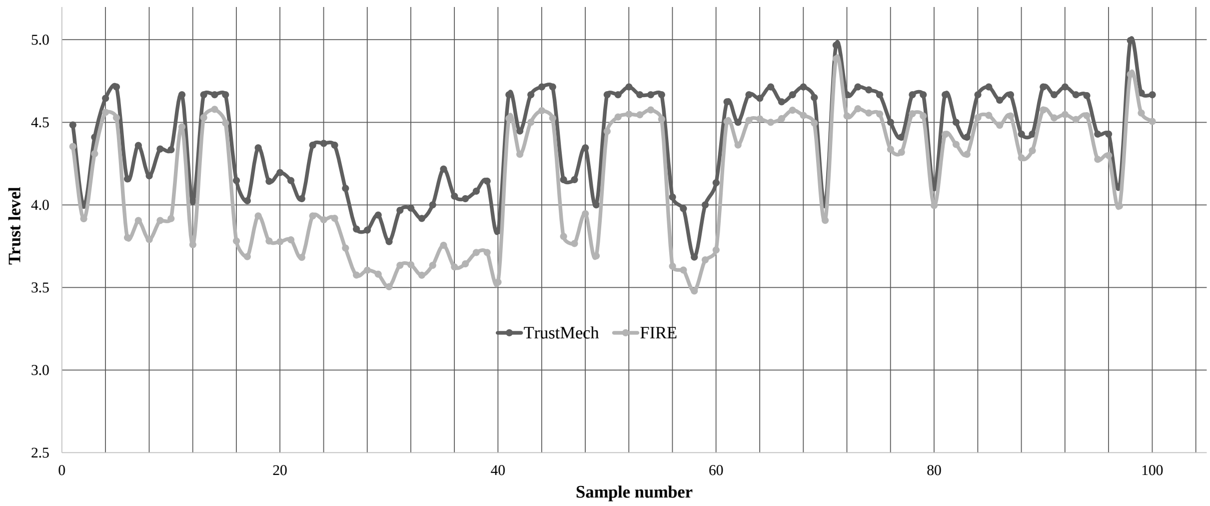


Figure 30: Comparative performances of the TrustMech against FIRE

Hypothesis 1

In regard to the information sharing, the goal behind was to assess whether the negatively exaggerated, neutrally (unexaggerated) and positively exaggerated information accuracies affect trust with distinct magnitudes. To achieve this goal, at first hand, the subjective comparison that employs GD (Figure 31) was used to compare such information accuracies. It presents comparatively the effect of the positively, neutrally, and negatively manipulated information (accuracies) on trust.

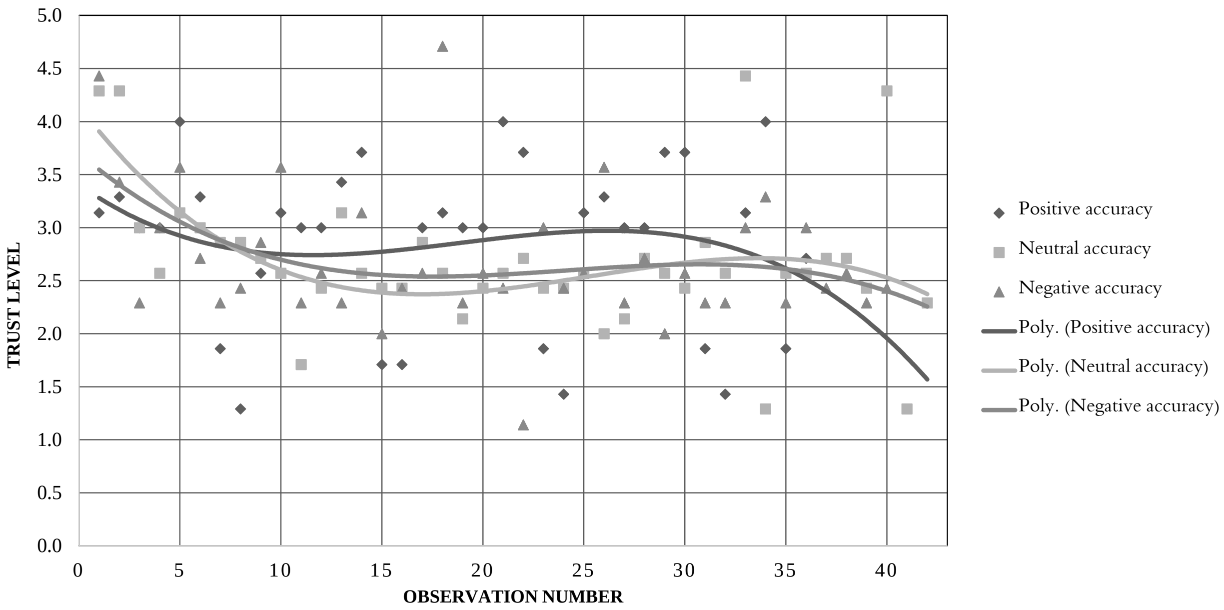


Figure 31: Comparison of information accuracies

The patterns resulting from graphical displays are, however, difficult to distinguish, and subsequently draw a subjective decision. For this reason, the depicted, graphical patterns remain inconclusive to decide whether effects generated are distinct or not. Due to this difficult, the statistical test was carried out to provide alternative evidence. It employed a 95% CI to achieve an objective decision (Table 14). The comparison was three-fold: neutral versus positive information accuracy; negative versus positive information accuracy, and; negative versus neutral information accuracy. The difference between pairs compared appears to range between -0.3 to 0.6 trust level.

Table 14: Comparative effect of information accuracies on trust

Difference of Levels	Mean difference	95% CI	Adjusted P-Value
Positive accuracy - Negative accuracy	0.027	(-0.254, 0.308)	0.590
Neutral accuracy - Positive accuracy	-0.325	(-0.606, 0.000)	0.025
Negative accuracy - Positive accuracy	-0.027	(-0.308, 0.254)	0.590

Hypothesis 2

In regard to the proportional sharing methods, the goal was to assess whether distributing gains based upon the number of customers served, distance traveled, and total load shipped results in distinct trust levels. Figure 32 presents comparatively the graphical patterns of the sharing methods. Similar to the previous results (Figure

31), the graphical displays provide an output which is difficult to subjectively judge (inconclusive).

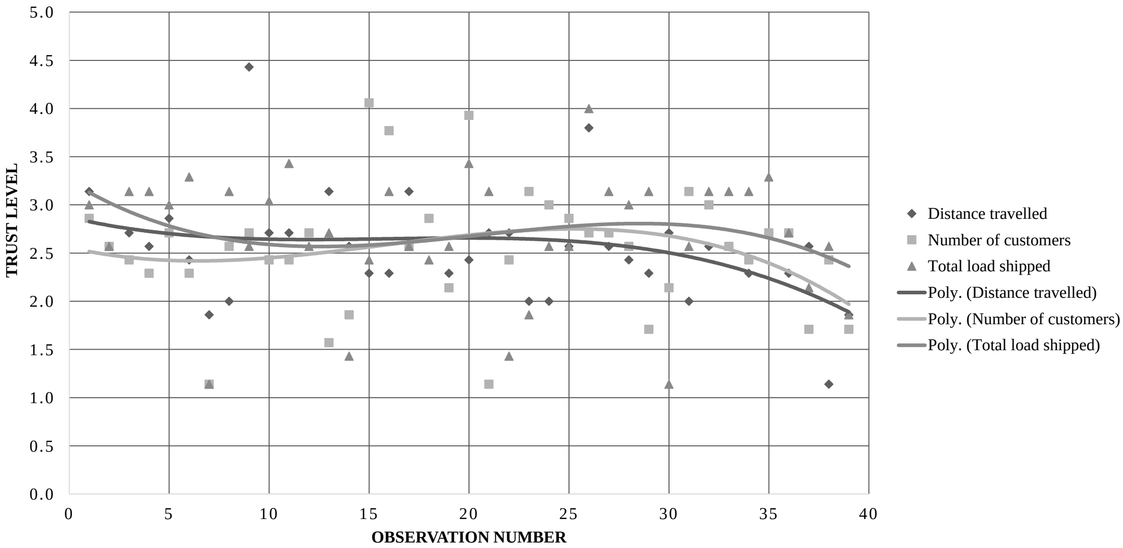


Figure 32: Comparison of proportional sharing methods

In overcoming this challenge, the statistical test at 95% CI was carried out (Table 15). All the three pairs compared had CIs which include a null value. The inclusion or exclusion of the null value provides an objective decision on judging whether pairs compared differ significantly or not. Owing to this, section 7.3 provides the corresponding deliberation to required judgment.

Table 15: Comparative effect of sharing methods on trust

Difference of levels	**Mean difference**	**95% CI**
Number of customers - Distance travelled	-0.072	(-0.396, 0.253)
Total load shipped - Distance travelled	0.148	(-0.182, 0.479)
Total load shipped - Number of customers	0.220	(-0.104, 0.544)

Additional results were concerned with the level of trustworthy each method generates when employed to divide costs and gains. Results analyzed (at 95% CI) indicated that dividing gains based on the:

- Distance traveled yielded 2.55 mean trust level and interval of {2.36, 2.75} trust level;
- Number of customers served yielded 2.48 mean trust level and interval of {2.29, 2.67} trust level, and;
- Total load shipped yielded 2.70 mean trust level and interval of (2.51, 2.89) trust level.

Hypothesis 3

In regard to the conflicting preferences, each preference was compared to other preferences to determine whether effect it generated was distinct. There was a total of 10 ($^{10}C_2$) comparisons. It was, however, difficult to deduce any meaningful correlation or difference in graphical patterns generated, and that is why a corresponding graph has been complicated to present. Following this difficulty, again, the statistical test was conducted to yield results as indicated in Table 16. With a 95% confidence, results showed that each pair compared contained a null value. Furthermore, the CI in difference ranges roughly between -0.4 to 0.4 trust level.

Table 16: Comparative effect of conflicting preferences on trust

Difference of levels	Mean difference	95% CI
P_2 - P_1	0.101	(-0.203, 0.405)
P_3 - P_1	0.165	(-0.140, 0.469)
P_4 - P_1	0.098	(-0.211, 0.406)
P_5 - P_1	0.017	(-0.284, 0.318)
P_3 - P_2	0.064	(-0.245, 0.372)
P_4 - P_2	-0.003	(-0.315, 0.309)
P_5 - P_2	-0.084	(-0.388, 0.220)
P_4 - P_3	-0.067	(-0.379, 0.245)
P_5 - P_3	-0.147	(-0.452, 0.157)
P_5 - P_4	-0.081	(-0.389, 0.228)

Hypothesis 4

Results presented in this paragraph were concerned with a degree to which the persuaded and rejected dilemmas affect trust. One limitation of this comparison is that some pairs carried the potential difference in some samples compared. For example, under the full truck or not (P_5) preference, there were no occurrences by which the respective preference appears persuaded. For this reason, no comparison test was carried out on this preference. Again, as far as graphical displays provided an inconclusive decision, then the statistical test was carried out to yield results indicated in Table 17.

Table 17: Impact of the persuaded and rejected preferences on trust

Preference	N		Mean trust level		95% CI	Adjusted P-value
	Per	Rej	Per	Rej		
P_1	36	6	2.44	2.36	(-0.267, 0.444)	0.338
P_2	16	14	2.63	2.6	(-0.358, 0.404)	0.460
P_3	19	21	2.72	2.48	(-0.066, 0.541)	0.098
P_4	14	24	2.69	2.43	(0.000, 0.498)	0.039

Key: "**Per**" means Persuasion, and "**Rej**" means Rejection

Hypothesis 5

Another test was concerned with how the primary predictor variables, namely: information sharing, proportional sharing scheme, and decision synchronization, rank, in effect they generated on trust. Realization of this ranking relied on applying the one-way analysis of variance using a Hsu MCB method at 95% CI (Figure 33 and Appendix IV).

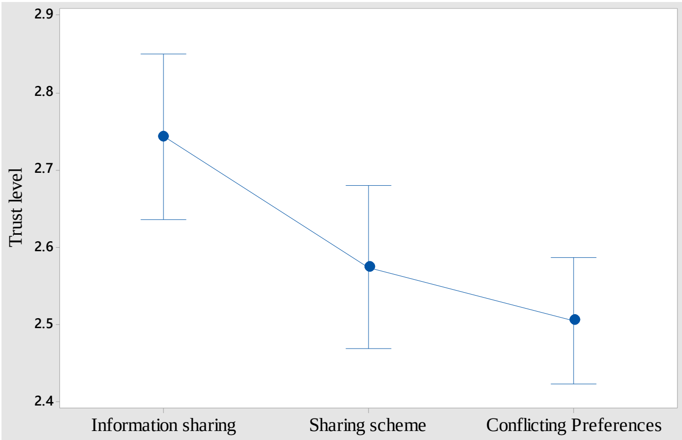


Figure 33: Ranked sensitivity of main response variables

Emergent Trustworthy Behavior

The final set of results was concerned with emergent trustworthy behaviors of the sharing network and collaborating partners. This set comprised of emerging behavior, which was unpredicted. Since there may have been many kinds of this behavior, those analyzed and reported are unexhausted. They are instead used to demonstrate the further application of the TrustMech on hidden events to help logistics managers acquire a far-reaching understanding. In view of this, results on the emergent trustworthy behavior are four-folds: degree of persuasions and rejections; frequency of trust levels; information distortion, and; the trend of trust in operational cycles. Additionally, it is worthy to note that results reported under emerging phenomena were generated from experiments designed to offer combinatorial effect on trust (see Table 9).

The first category of results concerned a degree to which persuaded or rejected dilemmas affect levels of trust. Figure 34 shows results of this behavior. The figure presents also comparatively frequencies of persuasions and rejections at different levels of trust.

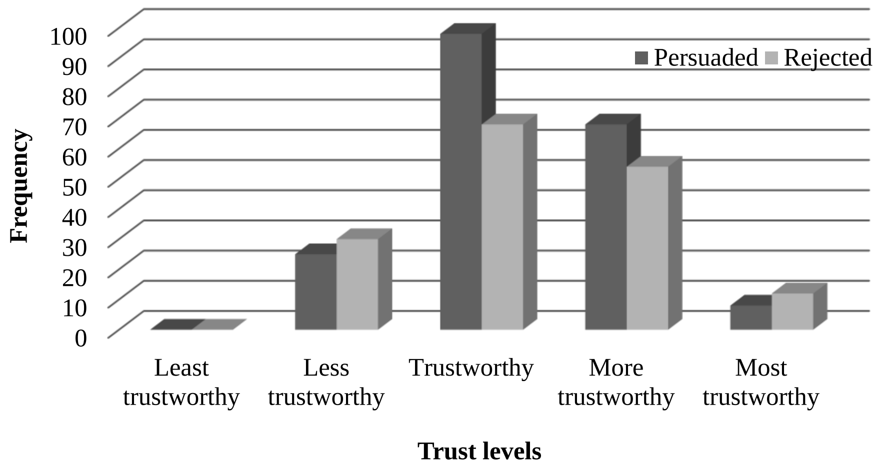


Figure 34: Frequency of persuasion and rejection at different trust levels

The second category concerned frequency to which the four trust levels, namely: *less trustworthy; trustworthy; more trustworthy*, and; *most trustworthy* appeared. Analyzed results indicate that: *less trustworthy* occurred 55 times (15.15%); *trustworthy* occurred 166 times (45.73%); *more trustworthy* occurred 122 times (33.61%), and; *most trustworthy* occurred 20 times (5.51%). In relation to this, another new phenomenon under consideration concerned a trust level, which the simulated logistics network can exhibit once implemented operationally. By using 363 samples, results analyzed indicate that the mean trust level and 95% CI of such network are 2.81 and {2.73, 2.88}, respectively.

The third category concerned a degree to which collaborating partners distort the accuracy of the information they exchange. Such degree of information distortion links further to a trust level in which it occurred. Since there were 19 factors (elements) of information affection, results presented in Appendix V include only top five factors. By top factors, it means factors of information accuracy, which were mostly used by partners to affect information accuracy. The presentation of top five factors of information affection goes in hand with four levels of trust levels in which they featured. The levels of trust are *less trustworthy*, *trustworthy*, *more trustworthy*, and *most trustworthy*. In regard to which factors were frequently used to distort the accuracy of shared information, results analyzed reveal the following. In descending order the frequency of usage was: *{"0.00", "-0.40" , "0.40", "0.45", "-0.45", "0.20", "-0.20", "0.25", "-0.25", "0.30", "-0.35", "-0.30", "0.35", "0.05", "-0.05"}*. The most-used factor is *“0.00”* while the least used factor is *“-0.05”*. Moreover, in reporting information, partners were: exactly honest by 36.36% (exchanging unexaggerated information), and; cheating by distorting (exaggerating) information by 68.64%.

The fourth category was concerned with depicting trends of trust, at a moment when collaborative sharing got repeated before resetting strategic planning (front-end agreement) and forecast (engagement) (Figure *35*).

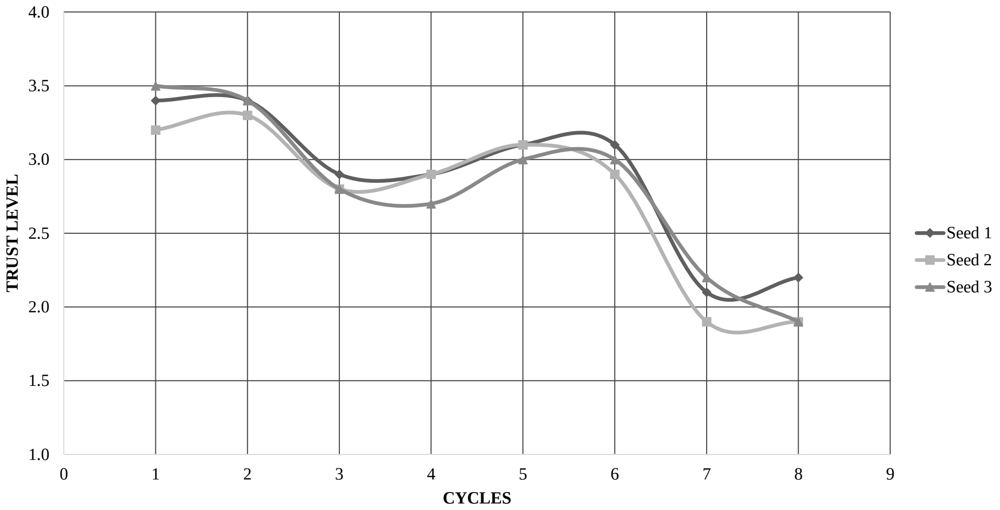


Figure 35: Trend of trust under repetitive cycles

A goal behind this was to understand how trust was being affected as result of reciprocal feedback encountered by partners when they were interacting. There were four cycles (repetitions) that were replicated twice to yield eight cycles. After obtaining eight cycles then the history (previous trust experience) was removed and correspondingly resetting the front-end agreement and engagement.

7.3 Discussion

Discussion in this section succeeds results presented already in section 7.2. The goal of this section is to draw useful meaning from such results and provide corresponding interpretations and implications. This discussion is guided, among others, by criteria to evaluate what the experiments told us, as stipulated by Cohen and Howe (1988) in a sequence (aspect) of:

- How did the TrustMech perform compared to its selected standard such as other programs, people, and normative behavior?

- Did the TrustMech perform differently from predictions of how it supposed to perform?

- Did the TrustMech demonstrate good performance?

- What lesson was learned from the TrustMech and conducted experiments?

- What were limitations of the TrustMech?

While considering the outlined guidelines, the subsequent discussion pursues the following sequence: validity of the TrustMech (subsection 7.3.1); research questions and hypotheses (subsection 7.3.2), and; emergent trustworthy behavior (subsection 7.3.3).

7.3.1 The Validity of the TrustMech

The present work has proposed the TrustMech as a useful concept to estimate (predict/forecast) outcomes (consequences) of trusting process. The TrustMech concept propagates a three stage of the human trusting process. Its development has involved extending well-known models of trust and reputation. In this extension, the limitations identified in previous models have been addressed, while; adapting the appropriate strengths. After developing the TrustMech concept, the next goal was to establish its accuracy (validation). In establishing the validity of the TrustMech, the first task focused on ensuring that fundamental assumptions and theories underlying the TrustMech are correct and reasonable (conceptual validity). This assurance relied on assessing an internal stochastic variability of the TrustMech.

The assessment of the internal stochastic variability was guided by the subjective and objective decision approaches. On account of the former, the subjective decision drawable from the interval plot shows that internal variations among most of the experiments remain bearable. An exceptional case that signifies inconsistent variability appeared under experiment number 4. In this experiment, the mean trust level and confidence interval were relatively higher than the remaining 19 experiments. Following the observed slight variations, and concordant to the subjective decision approach, a concluding remark is that the TrustMech is conceptually valid.

Further revelation can hinge on considering the objective decision. Equally, the statistical results unveil that the TrustMech is internally consistent. This observation is backed up by the internal stochastic variability of the TrustMech in Appendix *II*. The observed variability was not only assessed to be very low (less than eight percent) but also insignificant. Therefore, following the subjective and objective results, it is concluded that the TrustMech is internally consistent and conceptually valid. Consequently, the fundamental assumptions and theories on which the TrustMech stands on are appraised to be reasonably accurate and credible. It is essential also to note that the established accuracy and credibility refer to the purpose to which the TrustMech serves.

Succeeding the conceptual validity is the operational validity. Assessment of the operational validity of the TrustMech relied on comparing its performance against the FIRE trust model. Before discussing this comparison, it is essential to recall how the two evaluate trust briefly:

- *TrustMech*: evaluates trust by comparing developed expectation against a score realized after executing a transaction to a task delegated;
- *FIRE –IT*: evaluate trust by calculating the sum of all the available ratings weighted by their rating relevance.

About the subjective decision, results indicate that the TrustMech performs in a manner that is similar to that of the FIRE, on the one hand. The closeness in performance originates from graphical displays (Figure 30), which reveal some similarity in patterns of output behavior. In this respect, the subjective extent to which output behavior of the TrustMech resembles that of the FIRE signifies credibility of the TrustMech. Thus, on account of the subjective decision, the TrustMech is appraised to be operationally credible and reasonably accurate for purposes it serves.

On the other hand, the proportional comparison (percentage-wise) and statistical tests unveil that performances of the TrustMech and FIRE differ significantly. At a 95% confidence, a range for the difference in performances of the TrustMech and FIRE excludes a null value. Exclusion of the null value conveys one significant implication. That, performances of the TrustMech and FIRE are statistically unequal. Since performances are unequal, one crucial question is: which model/mechanism performs better than the other? Answers to this question can depend on comparing mean trust levels of the two. Alongside this comparison, the model/mechanism with higher mean trust level usually is the better one. Results indicate (Appendix III) that the TrustMech scores higher mean trust level than the FIRE. This difference in score unveils that the TrustMech performs better than the FIRE. To this end, and in a viewpoint of the operational validity, it is sufficient to conclude that the TrustMech: is operationally credible and reasonably accurate to a purpose it was intended for, and; generates an improved evaluation of trust than its rivals.

Moreover, the model to model validation of the TrustMech provides other useful implications. One crucial implication may align with a theoretical perspective that emphasizes to conceive trust on the foundation of human trusting process and notion of belief. Although both the C&F and BDI+Repage models stand on cognitive conception, still the approach to evaluate trust in TrustMech appears better and improved. The approach is simple, easy to describe and represent.

However, one limitation of the current operational validity is that the TrustMech compared only to the FIRE model. The model to model comparison left out other models such as the C&F and BDI+Repage. Attempts to compare the TrustMech against the C&F and BDI+Repage suffered the following difficulties. First, the difficulty in comparing the TrustMech against the C&F arose from two areas: an evaluation approach of the C&F that seems implicit, and; Likert scale size that appears unclearly established. These two limitations might have contradicted the needed comparison. Attempts to unfold these difficulties require establishing additional assumptions beyond those of the original model. Introducing new further assumptions might have again increased uncertainty in previous (base) conception of the C&F model.

Second, the difficulty concerning belief weights appeared when attempting to compare the TrustMech against BDI+Repage. According to mechanics of the BDI+Repage, sources of beliefs have to be weighted. As argued before, realizing belief weights in real-world settings is challenging, and remains an uneasy phenomenon. Additionally, transforming a calculus of the BDI+Repage into computational settings was even more difficult. In the overall, there is a need in future, to rework on the mentioned impediments (detailed discussion in section 4.6). After re-working, comparisons can be carried out to unveil how the TrustMech compares to the C&F and BDI+Repage models.

7.3.2 Reflection on Research Question and Hypotheses

The present work has proposed the TrustMech as a fundamental logical process responsible to account for trusting actions, reactions, and decisions of collaborating partners. The TrustMech helps logistics stakeholders to acquire a far-reaching understanding about the trustworthiness of networks they configure. These networks are configured to achieve benefits of collaboration in sharing logistics resources. The sharing enables partners to reduce costs, increase utilization of assets, and mitigate other logistics inefficiencies. On account of this, subsequent paragraphs present discussion that answers the central and specific research questions. The discussion articulates also about how research objectives have been achieved, as well as outcomes to hypotheses testing.

This dissertation was primarily set to answer the following central research question: *how can collaborating partners acquire a far-reaching understanding about the trustworthiness of prospective networks of sharing they configure?* In responding to this question, the following statements constitute the answers. One way to mitigate trust problem in collaborative logistics and respective resource sharing is to empower collaborating partners; with an ability to understand deeply how trustworthiness of logistics networks may become once those networks are taken to an implementation stage. This understanding is unveiled, among others, by estimating outcomes of the trusting process, as reinforced by partner behavior under the influence of collaborative logistics processes. This estimation stands on: identifying environmental factors; specifying trust-based interactions of partners; building a fundamental causality (apparatus), and; observing resulting outcomes (consequences). On account of this foundation and in reply to this central research question, the present dissertation has proposed the TrustMech concept. The concept facilitates the realization of the needs raised already in sections 1.2 and 2.5. Detailed demonstrative application of the TrustMech features under the RQ4.

First Specific Research Question –RQ1

The first specific research question (answered in section 4.1) was destined to identifying behavioral factors which influence trust in collaborative sharing of logistics resources. Answering this question involved paying more attention to factors (and respective parameters) that characterize partner behavior in collaborative sharing of logistics resources. In the end, results substantiate that four behavioral factors influence trust in collaborative logistics and underlying resource sharing. The four factors are information sharing; sharing scheme; decision synchronization, and; opportunism. The first three factors constitute processes that facilitate accomplishment of collaboration in sharing logistics resources, on the one hand. On the other hand, such factors can become inhibitors, especially when partners act opportunistically thereby exploiting individual benefits on costs of others.

It is vital to note that the validation and demonstrative application of the TrustMech did not employ all parameters, which constitute each behavioral factor. To this end, the simulation experiments included some behavioral parameters while leaving out others. In particular, one parameter of the information sharing, three parameters of the sharing scheme, and five parameters of the decision synchronization were set to manipulate the TrustMech. Supposedly, one can incorporate in future works, the remaining (left out) parameters as well as other parameters that may emerge afterward.

Second Specific Research Question –RQ2

The second most critical inquiry to this research focused on how collaborating partners interact to achieve their goals, especially those related to collaboration in sharing logistics resources. The typical interactions to refer to are those inclined to trust-based scenarios. To this end, answers to RQ2 were grasped and depicted in the form of the conceptual trust-based framework. In particular, this trust-based framework has identified and specified vital partnering entities; partner’ trust-based characteristics; essential roles and tasks performed by such partners; information exchanged by partners, and; emerging preferences in decision rights that are incompatible. In highlighting findings related to crucial partnering entities, three main categories (types) of collaborating partners were identified and formalized. They are shippers, carriers, and receivers. About its role, the trust-based framework guides the development of the TrustMech concept. Additionally, this framework can be used to guide the design of related collaborative interactions in other similar application domains.

Moving further in details of the trust-based framework, interactions of collaborating partners occur at three stages: selection and front-end agreement; engagement and order forecast, and; physical distribution. In all stages, interactions involve an exchange of information among shippers, carriers, managers of the warehouses, and receivers. All those partners negotiate on many issues before advancing to subsequent stages. Additionally, each of the three stages consists of one form of trusting process, set as follows: intention to trusting in the selection and front-end agreement; action to trusting in the engagement and order forecast, and; transaction to trusting in the physical distribution.

Third Specific Research Question –RQ3

The third research question was an inquiry on how to devise the TrustMech concept and validate it. Being the fundamental logical process, TrustMech has to account for interactions as well as reactions of collaborating partners. It has to exhibit bottom-up interactions of individual partners and accordingly provide estimations of trusting outcomes.

In answering this research question, this dissertation has developed the TrustMech concept. Before developing the TrustMech concept, there was a series of general research objectives to achieve. At first hand, standard approaches to model trust were analyzed and compared to conclude the most suitable one. In regard to this, the socio-cognitive modeling approach appeared to be suitable than its rivals such as the reputation and game-theoretical approaches. Secondly, existing models of trust were analyzed and compared to unveil strengths and limitations. Strengths such as the sources of trust information, actor relationships, and Likert scale sizes were adapted. Equally, this dissertation addressed many limitations such as the unclear and implicit evaluations of trust. In referring to this, TrustMech stands on trust evaluation that compares expectation against a score realized after executing a transaction to task delegation. About theoretical foundation, the TrustMech rests on principles of the transaction cost economics, social exchange and learning, and dilemma analysis. Compared with its rivals, the TrustMech exhibits human representation to trusting action and decisions. It is conceived to serve general-purposes and subsequently operationalized to suit contextual needs of collaboration in sharing logistics resources.

Moreover, the devised mechanism fulfills recommendations and findings of previous related works. Huang and Wilkinson (2014) substantiate that trust is beneficial when trusting actions take place. In due to this, the TrustMech allows for trusting actions and decisions to take place among collaborating partners. The trusting process occurs under settings of both certainty and uncertainty environments. Moreover, the TrustMech unfolds the challenge identified in (Jones et al., 2010) that most companies lack the know-how and ability to develop high levels of trust. TrustMech has fulfilled such lack because it provides the needed know-how (far-reaching understanding) as well as ability to forecast trust issues in prior.

Fourth Research Question –RQ4

With reference to the RQ4, the present discussion argues on how an idealized network for sharing logistics resources may behave upon its implementation. The discussion draws from test results of the hypotheses as well as other exciting emergent phenomena, which were unpredicted but still surfaced.

Hypothesis 1

The first hypothesis was set to predict that the positively and negatively exaggerated information accuracy, and neutral (unexaggerated) information accuracy generate distinct impacts on trust. Analyzed results confirm this hypothesis. The trust impact generated by the neutral (unexaggerated) and positively exaggerated information accuracy differ significantly. Further consideration of this difference unveils that the positively exaggerated information accuracy yields a higher level of trust than the unexaggerated information accuracy. However, it has to be noted that not all information accuracies can generate distinct impact on trust. The said exclusion is evidenced by results, which indicate that there are no meaningful differences in trust impact generated by the positively and negatively exaggerated information accuracy. This similarity is substantiated at a 95% confidence to find that the CI for difference includes a null value. These findings may lead to the following conclusion. That, employing the positively exaggerated information accuracy, in networks of sharing whose configurations resemble that of the idealized network, may generate higher/equivalent trustworthiness. Besides confirming the first hypothesis, additional findings reveal other differences and similarity as discussed in subsequent paragraphs.

In regard to theoretical expectation, findings of the first hypothesis are quite different from normal (usual) expectation. Theoretically, the expectation is that neutral (unexaggerated) information accuracy might have generated improved (better) trust levels than the positively or negatively exaggerated information accuracy. Instead, the neutral information accuracy seems to generate a low level of trust than its counterparts. Such unexpected results might have originated from assumptions underlying a definition of neutral information accuracy. This definition employed three factors *{-0.05, 0.00, 0.05}*. In view of this, redefining this information accuracy may provide additional updates. Additionally, it might be necessary to conduct a further study that seeks to investigate response variables, which are most sensitive to information accuracy, for example, by replicating this study.

Furthermore, findings of this hypothesis differ and relate to existing works in literature as follows. About the difference, first, literature has established that level of information quality is positively related to a level of trust (Chen et al., 2011). Second, information sharing reduces a level of behavioral uncertainty, and consequently, improves the level of trust (Kwon & Suh, 2004). Third, the quality of shared information leverages (reduces) supplier's opportunism (Wang et al., 2014). In general, these works seem to focus on relationships and correlations, especially between information sharing and trust. However, unlike such literature contributions, the present dissertation has looked upon distinct levels of the InfQ as well as extents of their impact on trust. The study has gone to a one step further to address on quantification of behavioral discontents which underlie information sharing. By building on the causal mechanism, this study has unfolded the extent to which variations in information accuracy impact system's and partner's level of trust. Moreover, as observed, the sharing of quality information appears to improve trust. This observation is also concordant with the previous establishment in (Chen et al., 2011; Kwon & Suh, 2004; Wang et al., 2014).

Trust is a reciprocal construct that stands in facets of both the *cause* and *effect*. As an effect, trust is feedback whose loops affect subsequent engagements. Under this reciprocal property, previous works provide many establishments. Firstly, Jeng and Mortel (2010) have established that trust is positively related to collaborative processes. Although the present study employed three collaborative processes (incentive scheme, decision synchronization, and information sharing), discussion on the reciprocal property of trust draws only on information sharing. In a standpoint of information sharing, the literature has established that level of trust impacts directly level and quality of information sharing (Hossain & Ouzrout, 2012), and; trust has a strong influence on collaborative behavior (Mlaker Kač et al., 2015). Moreover, in contrast to the outlined literature, Madlberger (2008) views that trust among the trading partners, does not positively impact operational information sharing behavior. This view contradicts with many other works in literature. In the overall consideration of the causal facet to the reciprocal property to the trust, findings of the present study: coincide with many works in literature, although; they differ with that in (Madlberger, 2008). Even though, it is still considered that trust is the cause that drives individuals to establish an intention to trusting as well as developing actions to trusting.

The second facet of a reciprocal property, *trust as the effect*, can be seen after collaborating partners have already acquired previous experience. In substantiating this, the graphical patterns show that, on average, shippers (Appendix VI) and receivers (Appendix VII) distort information more than before as a result of experiencing low-level trust. More distortion of information is evident, especially during the fifth to eighth cycles of collaboration per each block[20] (Figure *35*). In connection with this argument and concordant to (Jeng & Mortel, 2010; Mlaker Kač et al., 2015; Ouzrout et al., 2010), trust appears to impact information sharing mostly. One difference to note, against findings in (Madlberger, 2008), is that higher trust levels unfold under less distorted information compared to more distorted information.

Hypothesis 2

The second hypothesis cares about how fair and trustworthy the proportional sharing methods can be. This study has approached this challenge by deriving a hypothesis that tests this fairness (trustworthy). The goal was to establish what may be the appropriate method out of those tested. Analyzed results, confirm this hypothesis. Results indicate that there are no statistically meaningful differences among pairs

[20] Each block is distinct from another one and represents simulation case where trust as effect is observed.

compared. Additionally, in regard to a degree of fairness and acceptability, it can be deduced that all methods seem trustworthy although they bear slight and insignificant differences. Counting on such differences in a viewpoint of trustworthiness the: total load shipped is ranked the first; distance traveled ranked the second, and; the number of customers served ranked the third. To this end, the total load shipped appears a proportional method that can somehow distribute gains fairly than the remaining.

In reference to previous works, it seems that there is a lack of literature that addresses trust in a perspective of sharing (incentive) scheme. However, related contributions may be noted. D'Amours and Rönnqvist (2010) had derived the Equal Profit Method (EPM) from other sharing principles such as the Shapley value. Upon applying the EPM to the case study, D'Amours and Rönnqvist report that it was still difficult to obtain a stable solution. Also, a general framework to design compensation rule in horizontal collaboration has been proposed in (Tseng et al., 2013).

Hypothesis 3

The purpose of this hypothesis was to disclose how the five conflicting preferences can affect trust. It was explicitly set to test whether one preference affects trust in magnitude that differs from that of others. Analyzed results confirm this hypothesis. The distinct affection of trust substantiates from a confidence interval of each pair that includes a null value and thus signifying that there is no statistically meaningful difference between any pair. These results imply that logistics stakeholders may not need to put distinct care into conflicting preferences. They also signify that, when designing logistics networks, managers may treat effects of different conflicting preferences in equal magnitudes.

Hypothesis 4

The fourth hypothesis was set to address impacts of persuaded and rejected conflicting preferences (dilemmas) on trust. The prediction was that compromising conflicting preferences may be a better strategy that can lead to improved trust levels than uncompromised ones. This hypothesis is neither confirmed nor rejected. Analyzed results show that among the four conflicting preferences tested, three of them reject the hypothesis while a remaining one confirms it. This contradiction originates from a small number of sample sizes (less than 30) used in the statistical tests. For example, the comparison between the persuaded and rejected conflicting preference on the demand model (P_1) is even biased. This bias arises because of a significant difference in sample sizes (36 by 6). Likewise, even for other preferences, the samples sizes do not satisfy statistical requirements ($30 \geq$ samples). This imbalance was out of control of researcher because the TrustMech is designed stochastic and autonomous. Meaning that under the present settings no way number of persuasions and rejections might have been externally influenced. Even though, it seems that persuaded conflicting preferences can generate improved trust levels than those rejected. This suggestion, however, needs further substantiation.

Besides the present simulation scenario, previous work related to this dissertation has already established that irrespective of the degree to which preferences are synchronized, a magnitude of the generated effect on trust also depends on other factors[21]. Such work adds that, under similar conditional settings, the persuaded preferences are better than rejected ones. Such findings relate to literature as follows. Kwon and Suh (2004) report that decision-making uncertainty seems to influence trust in a partner negatively. The decision-making uncertainty may as well be equivalent to the rejected dilemma. As such, under rejected dilemmas collaborating partners are involved in decision-making that may cost others. Advancing on an argument that persuaded dilemmas are better than the rejected ones, results of the present work seem to correlate to that in (Kwon & Suh, 2004).

Hypothesis 5

The purpose of the fifth hypothesis was to determine the most influential predictor variables. The goal is to inform logistics stakeholders and managers about which response variable they have to care more. Results analyzed indicate that this hypothesis is confirmed. That information sharing is ranked the highest compared to the sharing scheme and decision synchronization. In particular, the sharing scheme ranks the second, while the decision synchronization ranks the lowest. Findings of this hypothesis relate mostly to expectation. That, information sharing is a critical factor to collaborations including those aimed at sharing logistics resources. These findings also correlate with many works in literature such as those in (Wu et al., 2014). Generally, the literature has established that information sharing is the most critical factor to collaborative logistics, and supply chain integration.

7.3.3 Emergent Trustworthy Behavior

As previously discussed, the agent-based models and resulting simulation outputs provide a room to capture the emergent behavior of partners. The micro-interactions of individual partners, which aggregate to whole system output enable this capture. Upon analysis, part of such behavior may generate patterns, which provide headlights information about the system being investigated. Some of the emergent behavior may be predicted in advance (as in section 5.3) while remaining one is difficult to predict because it surfaces unexpectedly during experimentation.

Henceforth, the present discussion addresses the unpredicted trustworthy behavior of the logistics networks and categories of collaborating agents. The emergent trustworthy behavior is discussed in viewpoints of the: decision synchronization (degree of persuasion and rejection); frequency of trust levels; information distortion, and; the trend of trust in operational cycles.

In regard to decision synchronization, usually, dilemmas of the conflict model ought

[21] Refer to publications used directly in this dissertation

to be compromised prior advancing to the next stage of collaboration. Due to settings used, this study advanced on two dilemmas of conflict mode (persuasion and rejection). Correspondingly, two terms: *extreme-scores*[22] and *mid-scores*[23] are introduced to support clarification of the present discussion. Results analyzed show that there is a notable difference between the degree of persuasion and rejection under the extreme-scores and mid-scores. Under the extreme-scores, the degree of rejection was relatively higher compared to that under the mid-scores. In contrast, under the mid-score, the degree of persuasion was relatively higher than it was under the extreme-scores. Beyond considering contexts of the extreme-scores and mid-scores, generally, partners prefer to persuade than reject dilemmas.

Although these observations infer many implications, at present, the discussion involves two of them. First, as highlighted before, persuading dilemmas seems to be better strategy compared to rejecting it. This is because mid-scores are mostly achievable when persuasion takes place. Second, compromising dilemmas to the rejection appear to offer the equal probability of success and failure. Meaning that choosing to reject the dilemma may lead to payoffs, although those payoffs are unguaranteed. Although trust effect generated by the persuaded and rejected dilemmas is statistically indifferent, yet persuaded dilemmas to seem to increase the level of trust.

The second emergent behavior concerned the frequency with which trust levels surfaced. Four trust levels were involved and ranked in respect of frequency (from highest to lowest) as follows: *trustworthy* ranked the first; *more trustworthy* ranked the second; *less trustworthy* ranked the third, and; *most trustworthy* ranked the fourth. This ranking may imply that, upon implementing this logistics network, there is a more possibility that the network will behave either *trustworthily* or *more trustworthily*. Narrowing a space further and drawing from the confidence interval already presented, out of two trust levels (*trustworthy* and *more trustworthy*), there is a high possibility that the network exhibits the level "*trustworthy*", which is the highest ranked trust level. However, if managers desire a logistics network that is more or most trustworthy, they may need to redesign the network and adjust parametric settings.

The third emergent behavior is concerned with an unbalanced usage of factors used to affect information accuracy. In general, partners exhibited more opportunistic behavior by reporting exaggerated information. When cheating, partners preferred to impose distortions (uncertainties) in the range of ±0.20 to ±0.45. Furthermore, under three trust levels: *less trustworthy*, *trustworthy*, and *more trustworthy*, receivers imposed more information uncertainties compared to those imposed by shippers. Under the trust level, the *most trustworthy*, receivers and shippers imposed

[22] Composed of trust levels: *less trustworthy* and *most trustworthy*
[23] Composed of trust levels: *trustworthy* and *more trustworthy*

equivalent information uncertainties.

The final emergent behavior was concerned with a trend of trust levels within repetitive cycles of a single experiment. The trend illustrates that when collaborative sharing begins, trust levels are relatively higher. However, trust levels become low in subsequent cycles. Trust levels arise again (at fifth and sixth cycles) although they become slightly lower than it was in the first cycle. In the last two cycles, trust levels drop abruptly. With this behavior, trust in the configured network decreases as partners continue to share logistics resources collaboratively. Such decrease may imply that opportunistic behavior of partners increases as some collaborative engagement increases.

7.4 Limitations

Although the present dissertation has successfully fulfilled its objectives, tested hypotheses, and answered the research question, yet there are limitations to unfold.

The first limitation concerns a negotiation algorithm. Efforts to establish validation and application of the TrustMech stood on the auction-based negotiation protocol. Accordingly, its implementation relied on the contract net negotiation protocol, which requires partners (agents) to negotiate through a third-party, for example, the broker. The broker has to be a neutral trustee to all collaborating partners, and its role is to coordinate activities of the consortium (alliance). In this respect, the TrustMech may extend supposedly to an implementation that employs other negotiation protocols, including the bargaining-based protocol. Such protocol may, for example, permit partners to negotiate among each without central coordination. Networks resulting from the bargaining-based negotiation protocol may exhibit formations and operations which are less formal. As well, such networks may take a form of community ownership (decentralized networks) in which consumer-to-consumer (peer-to-peer) resource sharing befalls.

The second limitation relates to the design and setup of the logistics network, as well as data used. The design and settings used in simulation experiment relied on a theorized logistics network. As well, simulation of resource sharing scenario utilized the model data. A lack of enough historical data collected on the system drove the use of model data. This limitation supposes to carry out a further investigation that can employ system data, obtained from industry logistics networks. The industry logistics networks provide real-world design and settings, which the logistics manager and other stakeholders may desire. To this end, beyond simulating industry-based scenarios, further investigation will expectedly update the validity of the TrustMech.

The third limitation may appear on forecasting trustworthiness of the theorized logistics network. The forecast (prediction) of trustworthiness of the theorized logistics network relied only on five hypotheses. The purpose of such hypotheses was to answer the RQ4, and accordingly, demonstrate the potential application of the TrustMech. This implies, therefore, that tested hypotheses remain unexhausted. For this reason, further hypotheses may be derived to suit context-specific needs.

The final limitation may feature in alternatives underlying the simulation experiments. As per its conception, the TrustMech is flexible to the extent that it allows to adjust the structure, design, and settings of the logistics network. Despite rich flexibility inherent in the TrustMech, current experimentation did not incorporate all of them. Therefore, re-experimenting a current scenario under adjusted settings and design may be useful.

7.5 Summary and Conclusion

The present chapter has established the validity and application of the TrustMech. In the former, two validation objects, the conceptual and operational validity characterize the validity of the TrustMech. The conceptual validity stands on assessing an internal variability (consistency) of the TrustMech. Unlike the conceptual validity, TrustMech's operational validity advances on a model to model comparison technique. Analyzed results show that the TrustMech, as the stochastic mechanism (model) generate outputs, which are to no small extent internally consistent. The low level of inconsistencies observed is statistically insignificant. The operational validity shows that the TrustMech produces a pattern of output behavior that resembles that of the FIRE model. Even though, still there are significant differences in performances of the two.

In a viewpoint of application, the TrustMech has unveiled many insights (headlights) that result from a scenario simulated. For example, at first, compared to neutral (unexaggerated) information accuracy, the positively exaggerated information accuracy appear to yield better levels of trust. Second, there seem to be no significant differences about proportioal methods to use in dividing costs and gains. Third, most incompatible decisions generate levels of trust which are relatively equivalent. Finally, one most interesting headlight is that information sharing affects trust more than the sharing scheme and decision synchronization.

The present chapter has fulfilled its goals. It has presented, in a fruitful manner, the validity as well as application of the TrustMech concept. By drawing from both the proportional-wise performance and statistical tests, the TrustMech performs better than its rival, the FIRE. Such performance leads to a conclusive appraisal, that, the TrustMech is conceptually and operationally credible and reasonable to purposes it serves. The TrustMech has proved its core application in providing a deeper understanding of the trustworthiness of prospective networks of resource sharing, before taking them to an implementation stage.

The summary and conclusion presented in the current chapter open the last chapter. Therefore, the next chapter (chapter 8) presents the recapitulation of this research work.

8 Recapitulation

The chapter presents concluding remarks and future open streams. Section 8.1 revisits the context to the study, existing challenges, as well as the proposed solution. The section also provides fewer headlights that result from an exemplified network of sharing that has been simulated. The chapter ends with an outlook in section 8.2 by providing open streams that may be researched on.

8.1 Conclusion

In contrast to a sharing in the traditional era, today's sharing of resources is gradually shifting into business models. Particularly in the logistics sector, resource sharing is progressively involving the sharing of information, vehicles, warehouses, and distribution centers, machinery, cloud infrastructures and services in logistics, as well as on-demand staffing. The sharing of logistics resources offers many benefits. The sharing enables participant entities to reduce costs; reduce harms to the environment; increase utilization of assets, and; improve the efficiency of logistics services. Although collaboration in sharing logistics resources is beneficial, its uptake has been relatively slow and challenging.

Many areas attribute to such difficulties. Collaborating entities encounter difficulties concerning how to choose a partner; manage and coordinate a configured consortium; and mitigate risks. Other difficulties are such as unbalanced power, reluctance to change, and low level of trust. The low level of trust is considered a critical inhibitor of collaborative logistics, and; it stems from multiple trust uncertainties. A large part of these trust uncertainties originates from partner behavior under the influence of collaborative logistics processes. To this end, this dissertation has contributed to mitigating the trust problem in collaboration, especially collaboration, which is aimed to share logistics resources.

In addressing the outlined research problem, this dissertation has proposed a Trust Mechanism (TrustMech) concept. The TrustMech concept succeeded an establishment of the conceptual trust-based framework. The goal of this framework was to depict and guide interactions of collaborating partners. The goal of the TrustMech concept is to forecast (estimate) consequences (outcomes) of trusting actions and decisions. This estimation occurs under a hybrid of both the certain and uncertain environments. The estimation helps collaborating partners (and other logistics stakeholders) to acquire the far-reaching understanding about trustworthiness of networks of resource sharing they configure. This understanding is unveiled by forecasting how the network of sharing might behave once it is taken to an implementation stage. In particular, the TrustMech helps stakeholders to understand:

- How trustworthy might a configured network of sharing becomes;
- How trustworthy might the individual collaborating partners become;
- What sort of pitfalls are expected to emerge in the network, and;
- What possible strengths to build on are expected.

Moreover, the proposed TrustMech hinges on the approach of trusting outcomes. This approach differs from many works in literature, which rest on a mitigation approach that entails a perspective of sources of trust uncertainties.

Development of the TrustMech has foundationally stood on the socio-cognitive principles. Unlike its rivals, the TrustMech uses the expectation and score[24] to evaluate the level of trust. Validation of the concept has employed collaborative logistics scenario that entails sharing of logistics resources. The conceptual and operational validity of the TrustMech has relied on carrying out the internal variability and model to model comparison, respectively. Results indicate that the conceptual and operational validities of the TrustMech are credible and reasonable. The credibility and reasonableness are established in reference to the purpose for which the TrustMech is intended. In regard to hypotheses testing, some have been successful while others remain inconclusive.

Furthermore, the following establishments highlight on the part of findings achieved by this dissertation. For example, resulting from an exemplified network of sharing, the trust levels *"less trustworthy"* (extreme lowest trust level) and *"most trustworthy"* (extreme highest trust level) surface when dilemmas get more rejections as compared to when dilemmas get persuaded. As well, out of three behavioral factors which influence trust, information sharing generates a highly ranked effect than the sharing scheme and decision synchronization. Trust appears to decrease continuously as per subsequent collaborative engagements. In the end, this research has thrown up open research streams as presented in the next section.

8.2 Outlook

Although this research has successfully addressed the problem of low trust to collaboration in sharing logistics resources, yet some areas need further improvements. For this reason, this outlook presents limitations outlined previously in section 7.4, as well as other open streams. These limitations and open streams constitute future research works. To this end, proposed future research works fall in categories of extending the TrustMech; replicating the study using system data; replicating the study using another design and settings; comparing the TrustMech to

[24] An outcome realized after a transaction to task delegation is executed

rival models other than the FIRE –IT; incorporating additional predictor and response variables and; investigating trust uncertainties that result from non-behavioral factors.

First, the proposed TrustMech advances on the algorithm that employs auction-based negotiation protocol. Such negotiation protocol uses central coordination under the supervision of the neutral trustee. It might be worthy to examine the performance of the TrustMech under other negotiations protocols, such as the bargaining-based and ABN protocols. Such examination will add value, for example, in exploring if there might occur interesting phenomena that result from peer-to-peer interactions (decentralized coordination).

Second, the validation and application of the TrustMech have relied upon the model data. A decision to employ the model data came out due to lack of the adequate and complete system data. For this reason, the recommendation is, upon obtaining system data, this study be replicated to update results and findings reported in this dissertation.

Third, the operational validity of the TrustMech employed the model to model comparison technique. In this comparison, TrustMech was only compared to the FIRE (IT –component). Subsection 7.3.1 has outlined reasons for why the TrustMech was compared to only one rival model. Therefore, further works may compare the performance of the TrustMech against, for example, the C&F and BDI+Repage. Towards carrying out this comparison, one has to figure out issues concerning the implicit procedural dimensions for the C&F as well as the mechanism for assigning weight to beliefs in the BDI+Repage model.

In regard to the operational TrustMech that depicts collaborative sharing of logistics resources, further study may build on adding variables. The predictor variables (especially for the InfoQ) and response variables used so far are unexhausted. To this end, further works may add more variables to observe effects. The design and settings may be adjusted for observing if distinct outcomes unfold.

Finally, the future work may investigate trust uncertainties resulting from non-behavioral factors which this dissertation did not incorporate. Factors such as the commitment, capacity, asset specificity (see Table 1) once studied may add value to a body of knowledge.

References

Abdullah, Z., & Musa, R. (2014). The Effect of Trust and Information Sharing on Relationship Commitment in Supply Chain Management. *Procedia - Social and Behavioral Sciences*, *130*, 266–272. http://doi.org/10.1016/j.sbspro.2014.04.031

Adams, B. D., Flear, C., Taylor, T. E., Hall, C. D., & Karthaus, C. (2010). Review of interorganizational trust models. *Computer Supported Cooperative Work (CSCW)*, *22*(4–6), 88.

ALICE. (2014). *Information Systems for Interconnected Logistics: Research & Innovation Roadmap*. Retrieved from https://www.etp-logistics.eu/wp-content/uploads/2015/08/W36mayo-kopie.pdf

Aqlan, F., & Lam, S. S. (2015). Supply chain risk modelling and mitigation. *International Journal of Production Research*, *53*(18), 5640–5656. http://doi.org/10.1080/00207543.2015.1047975

Armstrong, J. S. (2001). The Forecasting Dictionary. In J. S. Armstrong (Ed.), *Principles of Forecasting: A Handbook for Researchers and Practitioners* (pp. 761–824). Norwell, MA: Kluwer Academic Publishers.

Artz, D., & Gil, Y. (2007). A survey of trust in computer science and the Semantic Web. *Web Semantics*, *5*(2), 58–71. http://doi.org/10.1016/j.websem.2007.03.002

Asawasakulsorn, A. (2009). Transportation Collaboration: Partner Selection Criteria and Interorganizational System Design Issues for Supporting Trust. *International Journal of Business and Information*, *4*(2), 199–220.

Asawasakulsorn, A. (2015). Transportation Collaboration: Partner Selection Criteria and Interorganizational System Design Issues for Supporting Trust. *International Journal of Business and Information*, *4*(2), 199–220. Retrieved from http://ijbi.org/ijbi/article/view/43

Audun, J., Roslan, I., & Boyd, C. a. (2007). A Survey of Trust and Reputation Systems for Online Service Provision. *Decision Support Systems*, *43*(2), 618–644. http://doi.org/10.1016/j.dss.2005.05.019

Audy, J. F., Lehoux, N., D'Amours, S., & R??nnqvist, M. (2012). A framework for an efficient implementation of logistics collaborations. *International Transactions in Operational Research*, *19*(5), 633–657. http://doi.org/10.1111/j.1475-3995.2010.00799.x

Axelrod, R., & Tesfatsion, L. (2006). A Guide for Newcomers to Agent-Based Modeling in the Social Sciences. In L. Tesfatsion & K. L. Judd (Eds.), *Handbook of Computational Economics* (Vol. 2, pp. 831–880). Amsterdam, the Netherlands: Elsevier/North-Holland. http://doi.org/10.1016/S1574-0021(05)02016-2

Azar, A., Khosravani, F., & Jalali, R. (2012). Drama Theory: A Problem Structuring Method in Soft OR (A Practical Application: Nuclear Negotiations Analysis between Islamic Republic of Iran and the 5+ 1 Group). *The International Journal of Humanities*, *19*(4), 1–14. Retrieved from eijh.modares.ac.ir/article_10520_1218.html

Baalsrud Hauge, J., Kalverkamp, M., Forcolin, M., Westerheim, H., Franke, M., & Thoben, K.-D. (2014). Collaborative Serious Games for Awareness on Shared Resources in Supply Chain Management. In B. Grabot, B. Vallespir, S. Gomes, A. Bouras, & D. Kiritsis (Eds.), *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World* (pp. 491–499). Springer Berlin Heidelberg. http://doi.org/10.1007/978-3-662-44736-9_60

Bachmann, R. (2011). At the crossroads: Future directions in trust research. *Journal of Trust Research*, *1*(2), 203–213. http://doi.org/10.1080/21515581.2011.603513

Bajorinas, A., Borg, T., Boucher, B., Agostino, M., Ambrosio, L. D., Benckiser, R., & Dickson, S. (2008). *2016 Future Supply Chain*. Retrieved from https://www.nl.capgemini.com/resource-file-access/resource/pdf/Future_Supply_Chain_2016_0.pdf

Bandini, S., Manzoni, S., & Vizzari, G. (2009). Agent Based Modeling and Simulation: An Informatics Perspective. *Journal of Artificial Societies and Social Simulation*, *12*(4), 4.

Bandura, A. (1977). *Social learning theory*. *Social Learning Theory*. Englewood Cliffs, NJ: Prentice Hall. http://doi.org/10.1111/j.1460-2466.1978.tb01621.x

Bandura, A. (1986). *Social foundations of thought and action*. Englewood Cliffs, NJ: Prentice Hall.

Barroso, a P., Machado, V. H., Carvalho, H., & Machado, V. C. (2015). Quantifying the Supply Chain Resilience. *Applications of Contemporary Management Aprroaches in Supply Chains*, 13–38. http://doi.org/10.5772/59580

Bazerman, M. H. (1998). *Judgment in Managerial Decision Making* (4th ed.). New York: Wiley.

Bennett, P. (1998). Confrontation analysis as a diagnostic tool. *European Journal of Operational Research*, *109*(2), 465–482. http://doi.org/10.1016/S0377-2217(98)00071-X

Bennett, P. (2004). Confrontation Analysis: Prediction, Interpretation or Diagnosis? In *Proceedings of Analysing Conflict and Its Resolution Conference* (pp. 7–17). Southend-on-Sea: The Institute of Mathematics and Its Applications.

Bennett, P., & Howard, N. (1996). Rationality, emotion and preference change drama-theoretic models of choice. *European Journal of Operational Research*, *92*(3), 603–614. http://doi.org/10.1016/0377-2217(95)00141-7

Berndt, J. O., & Herzog, O. (2016). Anticipatory Behavior of Software Agents in Self-organizing Negotiations. In M. Nadin (Ed.), *Anticipation Across Disciplines* (pp. 231–253). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-22599-9_15

Bersini, H. (2012). UML for ABM. *Journal of Artificial Societies and Social Simulation*, *15*(1), 1–15. http://doi.org/10.18564/jasss.1897

Bobrowski, M., Marré, M., & Yankelevich, D. (1999). A Homogeneous Framework to Measure Data Quality. *Fourth Conference on Information Quality*, (JANUARY 1999), 115–124. http://doi.org/10.2144/000113917

Böckmann, M. (2013). *The Shared Economy: It is time to start caring about sharing; value creating factors in the shared economy*. University of Twente, Faculty of Management and Governance.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, *99*(Supplement 3), 7280–7287. http://doi.org/10.1073_pnas.082080899

Bowersox, D. J., Closs, D. J., & Stank, T. P. (2000). Ten Mega-Trends That Will Revolutionize Supply Chain Logistics. *Journal of Business Logistics*, *21*(2), 1–15.

Braziotis, C., Bourlakis, M., Rogers, H., & Tannock, J. (2013). Supply chains and supply networks: distinctions and overlaps. *Supply Chain Management: An International Journal*, *18*(6), 644–652. http://doi.org/10.1108/SCM-07-2012-0260

Braziotis, C., Tannock, J. D. T., & Bourlakis, M. (2016). Strategic and operational considerations for the Extended Enterprise: insights from the aerospace industry. *Production Planning & Control*, *28*(4), 1–14. http://doi.org/10.1080/09537287.2016.1268274

Browne, J., Sackett, P. ., & Wortmann, J. . (1995). Future manufacturing systems—Towards the extended enterprise. *Computers in Industry*, *25*(3), 235–254. http://doi.org/10.1016/0166-3615(94)00035-O

Bryant, J. (2007). Drama theory: dispelling the myths. *Journal of the Operational Research Society*, *58*(S5), 602–613. http://doi.org/10.1057/palgrave.jors.2602239

Buczynski, B. (2013). *Sharing is Good: How to Save Money, Time and Resources through Collaborative Consumption*. Gabriola Island, BC Canada: New Society Publishers.

Burnett, C. (2006). *Trust Assessment and Decision-Making in Dynamic Multi-Agent Systems*. *PhD Thesis*. University of Aberdeen.

Butner, K., & Iglesias, J. (2010). *The GMA 2010 Logistics Benchmark Report: Performance reaches all-time high during economic depression*. Washington, DC. Retrieved from http://www.gmaonline.org/downloads/research-and-reports/GMA_2010_Logistics_Benchmark_Report.pdf

Camerer, C. F., Ho, T., & Chong, K. (2002). Behavioral Game Theory: Thinking, Learning and Teaching. *Social Science Research Network*, *71*(6), 119–179. http://doi.org/10.2139/ssrn.295585

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, *29*(3), 163–180. http://doi.org/10.1016/j.jom.2010.12.008

Cao, M., & Zhang, Q. (2013). Supply chain collaboration: Roles of interorganizational systems, trust, and collaborative culture. *Supply Chain Collaboration: Roles of Interorganizational Systems, Trust, and Collaborative Culture*, (3), 1–197. http://doi.org/10.1007/978-1-4471-4591-2

Capaldo, A., & Giannoccaro, I. (2015). How does trust affect performance in the supply chain? the moderating role of interdependence. *International Journal of Production Economics*, *166*, 36–49. http://doi.org/10.1016/j.ijpe.2015.04.008

Cardellini, V., Casalicchio, E., & Galli, E. (2007). Agent-based modeling of interdependencies in critical infrastructures through UML. In *Proceedings of the 2007 spring simulation multiconference* (Vol. 2, pp. 119–126). Norfolk, Virginia. Retrieved from http://dl.acm.org/citation.cfm?id=1404699

Cardoso, S. R., Paula Barbosa-Póvoa, A., Relvas, S., & Novais, A. Q. (2015). Resilience metrics in the assessment of complex supply-chains performance operating under demand uncertainty. *Omega*, *56*, 53–73.

http://doi.org/10.1016/j.omega.2015.03.008

Castelfranchi, C., & Falcone, R. (2000). Trust and control: A dialectic link. *Applied Artificial Intelligence*, *14*(8), 799–823. http://doi.org/10.1080/08839510050127560

Castelfranchi, C., & Falcone, R. (2001). Social Trust : A Cognitive Approach. *Trust and Deception in Virtual Societies*, 55–90. http://doi.org/10.1007/978-94-017-3614-5_3

Castelfranchi, C., & Falcone, R. (2005). Socio-cognitive theory of trust. In P. J (Ed.), *Open agent societies: normative specifications in multi-agent systems* (pp. 58–89). London: Wiley.

Castelfranchi, C., & Falcone, R. (2010). *Trust Theory: A Socio-Cognitive and Computational Model*. Chichester, UK: John Wiley & Sons, Ltd. http://doi.org/10.1002/9780470519851

Chan, H., & Chan, F. (2009). Effect of information sharing in supply chains with flexibility. *International Journal of Production Research*, *47*(1), 213–232. http://doi.org/10.1080/00207540600767764

Chen, H., Daugherty, P. J., & Roath, A. S. (2009). DEFINING AND OPERATIONALIZING SUPPLY CHAIN PROCESS INTEGRATION. *Journal of Business Logistics*, *30*(1), 63–84. http://doi.org/10.1002/j.2158-1592.2009.tb00099.x

Chen, J. V., Yen, D. C., Rajkumar, T. M., & Tomochko, N. A. (2011). The antecedent factors on trust and commitment in supply chain relationships. *Computer Standards and Interfaces*, *33*(3), 262–270. http://doi.org/10.1016/j.csi.2010.05.003

Cheng, H.-C., Chen, M.-C., & Mao, C.-K. (2010). The evolutionary process and collaboration in supply chains. *Industrial Management & Data Systems*, *110*(3), 453–474. http://doi.org/http://dx.doi.org/10.1108/02635571011030079

Chopra, S., & Meindl, P. (2010). *Supply Chain Management: Strategy, Planning, and Operation* (4th Global). Upper Saddle River: Pearson/Prentice Hall.

Clancey, W. J., Sierhuis, M., Damer, B., & Brodsky, B. (2005). Cognitive Modeling of Social Behaviors. In R. Sun (Ed.), *Cognition and Multi-Agent Interaction: From Cognitive Modeling to Social Simulation* (pp. 1–29). New York: Cambridge University Press.

Cohen, P. (1991). A survey of the eighth national conference on artificial intelligence: pulling together or pulling apart? *AI Magazine*, *12*(1), 16–41.

Cohen, P. R., & Howe, A. E. (1988). How evaluation guides AI research. *AI Magazine*, *9*(4), 35.

Cossentino, M., & Potts, C. (2002). *PASSI: A process for specifying and implementing multi-agent systems using UML*.

Cruijssen, F. (2006). *Horizontal Cooperation in Transport and Logistics*. *PhD Thesis*. Universiteit van Tilburg.

Cruijssen, F., Borm, P., Fleuren, H., & Hamers, H. (2010). Supplier-initiated outsourcing: A methodology to exploit synergy in transportation. *European Journal of Operational Research*, *207*(2), 763–774. http://doi.org/10.1016/j.ejor.2010.06.009

D'Amours, S., & Rönnqvist, M. (2010). Issues in Collaborative Logistics. In *Energy, Natural Resources and Environmental ...* (Vol. SNF Report, pp. 395–409). http://doi.org/10.1007/978-3-642-12067-1_22

Day, M., Fawcett, S. E., Fawcett, A. M., & Magnan, G. M. (2013). Trust and relational embeddedness: Exploring a paradox of trust pattern development in key supplier relationships. *Industrial Marketing Management*, *42*(2), 152–165. http://doi.org/10.1016/j.indmarman.2012.12.004

Delbufalo, E. (2012). Outcomes of inter-organizational trust in supply chain relationships: a systematic literature review and a meta-analysis of the empirical evidence. *Supply Chain Management*, *17*(4), 377–402. http://doi.org/http://dx.doi.org/10.1108/13598541211246549

Delfmann, W., & Jaekel, F. (2012). The Cloud – Logistics for the Future ? *Discussion Paper*. BVL international- the global Supply Chain network.

Department for Transport statistics. (2017). Statistics at DFT. Department for Transport, Uk. Retrieved from https://www.gov.uk/government/organisations/department-for-transport/about/statistics

Dillahunt, T. R., & Malone, A. R. (2015). The Promise of the Sharing Economy among Disadvantaged Communities. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15* (pp. 2285–2294). New York, New York, USA: ACM Press. http://doi.org/10.1145/2702123.2702189

Dobbs, R., Oppenheim, J., Thompson, F., Brinkman, M., & Zornes, M. (2011).

Resource Revolution : Meeting the world 's energy , materials , food , and water needs. *McKinsey*. Retrieved from http://www.mckinsey.com/Insights/MGI/Research/Natural_Resources/Resource_revolution

ERep. (2006). *Social Knowledge for e-Governance Review of Internet User-oriented Reputation Applications and Application Layer Networks Status*. *Image (Rochester, N.Y.)*.

European Commission. (2013). *Factories of the Future Multi-Annual Roadmap for the Contractual PPP under Horizon 2020*. Luxembourg: European Commission. http://doi.org/10.2777/29815

Falcone, R., Pezzulo, G., & Castelfranchi, C. (2003). A fuzzy approach to a belief-based trust computation. *Trust Reputation and Security*, *2005*(11 July), 1–15. http://doi.org/10.1007/3-540-36609-1_7

Fawcett, S. E., Fawcett, A. M., Watson, B. J., & Magnan, G. M. (2012). Peeking Inside the Black Box: Toward an Understanding of Supply Chain Collaboration Dynamics. *Journal of Supply Chain Management*, *48*(1), 44–72. http://doi.org/10.1111/j.1745-493X.2011.03241.x

Fawcett, S. E., Magnan, G. M., & McCarter, M. W. (2008). Benefits, barriers, and bridges to effective supply chain management. *Supply Chain Management: An International Journal*, *13*(1), 35–48. http://doi.org/10.1108/13598540810850300

Fawcett, S. E., McCarter, M. W., Fawcett, A. M., Webb, G. S., & Magnan, G. M. (2015). Why supply chain collaboration fails: the socio-structural view of resistance to relational strategies. *Supply Chain Management: An International Journal*, *20*(6), 648–663. http://doi.org/10.1108/SCM-08-2015-0331

FIPA. (2002). FIPA Iterated Contract Net Interaction Protocol. Foundation for Intelligent Physical Agents.

Firouzi, F., Jaber, M. Y., & Baglieri, E. (2015). Trust in supply forecast information sharing. *International Journal of Production Research*, *7543*(December), 1–12. http://doi.org/10.1080/00207543.2015.1068961

FLEXE. (2015). *Warehouse Capacity Economics and Trends: On-Demand Warehousing*. Seattle, USA. Retrieved from http://www.3plnews.com/reports/FLEXE-Warehouse-Capacity-White-Paper.pdf

Flynn, B. B., Koufteros, X., & Lu, G. (2016). On Theory in Supply Chain

Uncertainty and its Implications for Supply Chain Integration. *Journal of Supply Chain Management*, *52*(3), 3–27. http://doi.org/10.1111/jscm.12106

Gci, & Capgemini. (2008). *2016 Future Supply Chain. Serving Consumers in a Sustainable Way*. Retrieved from https://www.nl.capgemini.com/resource-file-access/resource/pdf/Future_Supply_Chain_2016_0.pdf

Gesing, B. (2017). *Sharing economy logistics: Rethinking logistics with access over ownership*. Troisdorf, Germany. Retrieved from http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/DHLTrend_Report_Sharing_Economy.pdf

Gonzalez-Feliu, J., & Morana, J. (2011). Collaborative transportation sharing: from theory to practice via a case study from France. In J. Yearwood & A. Stranieri (Eds.), *Technologies for Supporting Reasoning Communities and Collaborative Decision Making* (pp. 252–271). IGI Global. http://doi.org/10.4018/978-1-60960-091-4.ch014

Gonzalez, A. J., & Barr, V. (2000). Validation and verification of intelligent systems - what are they and how are they different? *Journal of Experimental & Theoretical Artificial Intelligence*, *12*(4), 407–420. http://doi.org/10.1080/095281300454793

Gorenflo, N. (2010). The New Sharing Economy. *Shareable Magazine*. Retrieved from https://www.shareable.net/blog/the-new-sharing-economy

Goudin, P. (2016). *The Cost of Non- Europe in the Sharing Economy*. *European Parliamentary Research Service*.

Graham, L. (2011). *Transport Collaboration in Europe*. *ProLogis Research Insights*.

Grizard, A., Vercouter, L., Stratulat, T., & Muller, G. (2007). A peer-to-peer normative system to achieve social order. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *4386 LNAI*, 274–289. http://doi.org/10.1007/978-3-540-74459-7_18

Gulati, R., Wohlgezogen, F., & Zhelyazkov, P. (2012). The Two Facets of Collaboration: Cooperation and Coordination in Strategic Alliances. *The Academy of Management Annals*, *6*(1), 531–583. http://doi.org/10.1080/19416520.2012.691646

Gunasekaran, A., Patel, C., & Tirtiroglu, E. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management*, *21*(1/2), 71–87.

http://doi.org/10.1108/01443570110358468

Ha, B.-C., Park, Y.-K., & Cho, S. (2011). Suppliers' affective trust and trust in competency in buyers: Its effect on collaboration and logistics efficiency. *International Journal of Operations & Production Management*, *31*(1), 56–77. http://doi.org/10.1108/01443571111098744

Heath, B., Hill, R., & Ciarallo, F. (2009). A Survey of Agent-Based Modeling Practices (January 1998 to July 2008). *Journal of Artificial Societies and Social Simulation*, *12*(4 (9)), 1–46. http://doi.org/Artn 9

Heide, J. B. (1994). Interorganizational Governance in Marketing Channels. *Journal of Marketing*, *58*(1), 71. http://doi.org/10.2307/1252252

Hermawan, P., Kobayashi, N., & Kijima, K. (2008). Holistic formal analysis of dilemmas of negotiation. *Systems Research and Behavioral Science*, *25*(5), 637–642. http://doi.org/10.1002/sres.947

Hernández, S., & Peeta, S. (2014). A carrier collaboration problem for less-than-truckload carriers: characteristics and carrier collaboration model. *Transportmetrica A: Transport Science*, *10*(4), 327–349. http://doi.org/10.1080/23249935.2013.766279

Himmelman, A. T. (2001). On Coalitions and the Transformation of Power Relations: Collaborative Betterment and Collaborative Empowerment. *American Journal of Community Psychology*, *29*(2), 277–284. http://doi.org/10.1023/A:1010334831330

Homans, G. C. (1974). *Social Behaviour: Its Elementary Forms* (Rev. ed.). New York: Harcourt Brace Jovanovich, Inc.

Hossain, S. A., & Ouzrout, Y. (2012). Trust model simulation for supply chain management. In *2012 15th International Conference on Computer and Information Technology (ICCIT)* (pp. 376–383). IEEE. http://doi.org/10.1109/ICCITechn.2012.6509744

Howard, N., Bennett, P., Bryant, J., & Bradley, M. (1993). Manifesto for a theory of drama and irrational choice. *Systems Practice*, *6*(4), 429–434. http://doi.org/10.1007/BF01061961

Hribernik, K. A., Warden, T., Thoben, K.-D., & Otthein, H. (2010). Logistics-an Approach To Connecting the Information and Material Flows in Autonomous Cooperating Logistics Processes. *12th International MITIP Conference on Information Technology & Innovation Processes of the Enterprises. 2010*, 54–67. Retrieved from http://www.sfb637.uni-bremen.de/pubdb/repository/SFB637-C2-10-004-IC.pdf

Huang, M.-C., Yen, G.-F., & Liu, T.-C. (2014). Reexamining supply chain integration and the supplier's performance relationships under uncertainty. *Supply Chain Management: An International Journal*, *19*(1), 64–78. http://doi.org/10.1108/SCM-04-2013-0114

Huang, Y., & Wilkinson, I. F. (2014). A Case Study of the Development of Trust in a Business Relation: Implications for a Dynamic Theory of Trust. *Journal of Business Market Management*, *7*(1), 254–279.

Hudnurkar, M., Jakhar, S., & Rathod, U. (2014). Factors Affecting Collaboration in Supply Chain: A Literature Review. *Procedia - Social and Behavioral Sciences*, *133*, 189–202. http://doi.org/10.1016/j.sbspro.2014.04.184

Huynh, T. D., Jennings, N. R., & Shadbolt, N. R. (2006). An integrated trust and reputation model for open multi-agent systems. *Autonomous Agents and Multi-Agent Systems*, *13*(2), 119–154. http://doi.org/10.1007/s10458-005-6825-4

Islam, S., & Olsen, T. (2014). Truck-sharing challenges for hinterland trucking companies. *Business Process Management Journal*, *20*(2), 290–334. http://doi.org/10.1108/BPMJ-03-2013-0042

Jagdev, H. S., & Thoben, K.-D. (2001). Anatomy of enterprise collaborations. *Production Planning & Control*, *12*(5), 437–451. http://doi.org/10.1080/09537280110042675

Jain, R. (1991). *The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling*. Wiley Computer Publishing, John Wiley & Sons.

Jeng, D. J. F., & Mortel, C. H. A. (2010). Impact of trust, asset specificity, and environmental uncertainty on manufacturing collaborative processes. *40th International Conference on Computers and Industrial Engineering: Soft Computing Techniques for Advanced Manufacturing and Service Systems, CIE40 2010*. http://doi.org/10.1109/ICCIE.2010.5668452

Jennings, N. R., Faratin, P., Lomuscio, A. R., Parsons, S., Wooldridge, M., & Sierra, C. (2001). Automated Negotiation: Prospects, Methods and Challenges. *Group Decision and Negotiation*, *10*(2), 199–215. http://doi.org/10.1023/A:1008746126376

Jones, S. L., Fawcett, S. E., Fawcett, A. M., & Wallin, C. (2010). Benchmarking trust signals in supply chain alliances: moving toward a robust measure of trust. *Benchmarking: An International Journal*, *17*(5), 705–727.

http://doi.org/10.1108/14635771011076452

Jones, S. L., Fawcett, S. E., Wallin, C., Fawcett, A. M., & Brewer, B. L. (2014). Can small firms gain relational advantage? Exploring strategic choice and trustworthiness signals in supply chain relationships. *International Journal of Production Research*, *52*(18), 5451–5466. http://doi.org/10.1080/00207543.2014.915068

Jonsson, P., & Holmström, J. (2016). Future of supply chain planning: closing the gaps between practice and promise. *International Journal of Physical Distribution & Logistics Management*, *46*(1), 62–81. http://doi.org/10.1108/IJPDLM-05-2015-0137

Josang, A., Ismail, R., & Boyd, C. (2007). A survey of trust and reputation systems for online service provision. *Decision Support Systems*, *43*(2), 618–644. http://doi.org/10.1016/j.dss.2005.05.019

Joshi, a. W., & Stump, R. L. (1999). The Contingent Effect of Specific Asset Investments on Joint Action in Manufacturer-Supplier Relationships: An Empirical Test of the Moderating Role of Reciprocal Asset Investments, Uncertainty, and Trust. *Journal of the Academy of Marketing Science*, *27*(3), 291–305. http://doi.org/10.1177/0092070399273001

Kayikci, Y., & Stix, V. (2014). Causal mechanism in transport collaboration. *Expert Systems with Applications*, *41*(4 PART 2), 1561–1575. http://doi.org/10.1016/j.eswa.2013.08.053

Koh, S. C. L., & Wang, L. (2010). Overview of Enterprise Networks and Logistics for Agile Manufacturing. In *Enterprise Networks and Logistics for Agile Manufacturing* (pp. 1–10). London: Springer London. http://doi.org/10.1007/978-1-84996-244-5_1

Kottila, M.-R., & Rönni, P. (2008). Collaboration and trust in two organic food chains. *British Food Journal*, *110*(4/5), 376–394. http://doi.org/10.1108/00070700810868915

Kozar, O. (2010). Towards Better Group Work: Seeing the Difference between Cooperation and Collaboration. *English Teaching Forum*, *2*, 16–23. Retrieved from http://americanenglish.state.gov/resources/english-teaching-forum-2010-volume-48-number-2#child-208

Kravari, K., & Bassiliades, N. (2015). A survey of agent platforms. *Jasss*, *18*(1), 1–17. http://doi.org/10.18564/jasss.2661

Krishnan, R., Martin, X., & Noorderhaven, N. G. (2006). When Does Trust Matter

To Alliance Performance? *Academy of Management Journal*, *49*(5), 894–917. http://doi.org/10.5465/AMJ.2006.22798171

Kück, M., Becker, T., & Freitag, M. (2016). Emergence of Non-predictable Dynamics Caused by Shared Resources in Production Networks. *Procedia CIRP*, *41*, 520–525. http://doi.org/10.1016/j.procir.2015.12.017

Kumar, G., & Nath Banerjee, R. (2014). Supply chain collaboration index: an instrument to measure the depth of collaboration. *Benchmarking: An International Journal*, *21*(2), 184–204. http://doi.org/10.1108/BIJ-02-2012-0008

Kwon, I.-W. G., & Suh, T. (2004). Factors Affecting the Level of Trust and Commitment in Supply Chain Relationships. *Journal of Supply Chain Management*, *40*(2), 4–14. http://doi.org/10.1111/j.1745-493X.2004.tb00165.x

Kwon, I. G., & Suh, T. (2005). Trust, commitment and relationships in supply chain management: a path analysis. *Supply Chain Management: An International Journal*, *10*(1), 26–33. http://doi.org/10.1108/13598540510578351

Laeequddin, M., Sahay, B. S., Sahay, V., & Waheed, K. A. (2012). Trust building in supply chain partners relationship: an integrated conceptual model. *Journal of Management Development*, *31*(6), 550–564. http://doi.org/10.1108/02621711211230858

Laeequddin, M., Vinita, B. S. S., Abdul, S. K., Laeequddin, M., Sahay, B. S. S., Sahay, V., & Waheed, K. A. (2010). Measuring trust in supply chain partners' relationships. *Measuring Business Excellence*, *14*(3), 53–69. http://doi.org/10.1108/13683041011074218

Lewicki, R. J., Tomlinson, E. C., & Gillespie, N. (2006). Models of interpersonal trust development: Theoretical approaches, empirical evidence, and future directions. *Journal of Management*, *32*(6), 991–1022. http://doi.org/10.1177/0149206306294405

Li, P. P. (2012). When trust matters the most: The imperatives for contextualising trust research. *Journal of Trust Research*, *2*(2), 101–106. http://doi.org/10.1080/21515581.2012.708494

Lianos, M. (2003). Social control after Foucault. *Surveillance & Society*, *1*(3), 412–430.

Love, G., & Back, G. (2000). Model Verification and Validation for Rapidly Developed Simulation Models : Balancing Cost and Theory. *Proceedings of the 18th International Conference of the System Dynamics Society*, 1–17.

Madlberger, M. (2008). Interorganizational collaboration in supply chain management: What drives firms to share information with their trading partners? *Proceedings of the Annual Hawaii International Conference on System Sciences*, 1–10. http://doi.org/10.1109/HICSS.2008.219

Malhotra, A., Gosain, S., & El Sawy, O. A. (2005). Absorptive capacity configurations in supply chains: gearing for partner-enabled market knowledge creation. *MIS Quarterly*, *29*(1), 145–187. http://doi.org/10.2307/25148671

Manrodt, K. B., Vitasek, K. L., & Tillman, J. M. (2011). *Findings of a survey of benchmarking measures among WERC members and DC Velocity readers*.

Mastercard, & The Future Agenda. (2016). *The Sharing Economy : Understanding the Opportunities for Growth*. Retrieved from https://newsroom.mastercard.com/eu/files/2017/06/Mastercard_Sharing-Economy_v7.compressed2.pdf

Matsumoto, K., Matsumoto, M., & Abe, H. (2006). Goal-based action selection and utility-based action bias. *Neural Networks*, *19*(8), 1315–1320. http://doi.org/10.1016/j.neunet.2006.05.036

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An Integrative Model of Organizational Trust. *The Academy of Management Review*, *20*(3), 709–734. Retrieved from http://www.jstor.org/stable/pdf/258792.pdf

Mlaker Kač, S., Gorenak, I., & Potočan, V. (2015). Influence of Relationship Commitment and Trust on Collaborative Behaviour in Supply Chains. *PROMET - Traffic&Transportation*, *27*(1), 77–84. http://doi.org/10.7307/ptt.v27i1.1575

Möllering, G. (2006). *Trust: Reason, Routine, Reflexivity*. *Knowledge Management Research & Practice* (First edit). Oxford: Elsevier Ltd.

Moramarco, R., Stevens, C. K., & Pontrandolfo, P. (2013). Trust in Face-to-Face and Electronic Negotiation in Buyer–Supplier Relationships: A Laboratory Study BT - Behavioral Issues in Operations Management: New Trends in Design, Management, and Methodologies. In I. Giannoccaro (Ed.), (pp. 49–81). London: Springer London. http://doi.org/10.1007/978-1-4471-4878-4_3

Morgan, R. M., & Hunt, S. D. (1994). Theory of Relationship Marketing. *Journal of Marketing*, *58*(3), 20–38. http://doi.org/10.1177/1356766710391135

Munoz, A., & Dunbar, M. (2015). On the quantification of operational supply chain resilience. *International Journal of Production Research*, *7543*(July), 1–16. http://doi.org/10.1080/00207543.2015.1057296

Murray-Jones, P., & Howard, N. (2001). Co-ordinated Positions in a Drama-theoretic Confrontation : Mathematical Foundations for a PO Decision Support System. In *Proceedings of CCRTS* (pp. 1–25). Retrieved from http://www.dodccrp.org/events/6th_ICCRTS/Tracks/Papers/Track6/076._tr6.pdf

Nguyen, N. P., & Liem, N. T. (2013). Inter-Firm Trust Production: Theoretical Perspectives. *International Journal of Business and Management*, *8*(7). http://doi.org/10.5539/ijbm.v8n7p46

Nilsson, F. (2006). Logistics management in practice – towards theories of complex logistics. *The International Journal of Logistics Management*, *17*(1), 38–54. http://doi.org/10.1108/09574090610663428

Nooteboom, B. (2003). The trust process. In B. Nooteboom & F. Six (Eds.), *The Trust Process in Organizations: Empirical Studies of the Determinants and the Process of Trust Development* (pp. 16–36). Cheltenham, Uk: Edward Elgar Publishing.

Odell, J., Parunak, H. V., & Bauer, B. (2000). Extending UML for Agents. In G. Wagner, Y. Lesperance, & E. Yu (Eds.), *Proceedings of the Agent-Oriented Information Systems Workshop (AOIS)* (pp. 3–17). Austin. Retrieved from http://people.ucalgary.ca/~far/Lectures/SENG697/PDF/Odell-W001.pdf

Okdinawati, L., Simatupang, T. M., & Sunitiyoso, Y. (2014). A Behavioural Multi-agent Model for Collaborative Transportation Management (CTM) (pp. 1–27). Retrieved from https://www.academia.edu/9805860/A_Behavioral_Multi_Agent_Model_for_Collaborative_Transportation_Management_CTM_

Ouzrout, Y., Chaze, L., Lavastre, O., Dominguez, C., & Akhter, S. H. (2010). Supply chain performance: Collaboration, Alignment and Coordination. In V. Botta-Genoulaz, J.-P. Campagne, D. Llerena, & C. Pellegrin (Eds.), (pp. 267–315). London: ISTE.

Ouzrout, Y., Chaze, L., Lavastre, O., Dominguez, C., & Akhter, S. H. (2013). Simulation of Trust in Supply Chains. In *Supply Chain Performance: Collaboration, Alignment and Coordination* (pp. 267–315). Hoboken, NJ, USA: John Wiley & Sons, Inc. http://doi.org/10.1002/9781118558065.ch8

Pinyol, I., & Sabater-Mir, J. (2013). Computational trust and reputation models for open multi-agent systems: a review. *Artificial Intelligence Review*, *40*(1), 1–25. http://doi.org/10.1007/s10462-011-9277-z

Pinyol, I., Sabater-Mir, J., Dellunde, P., & Paolucci, M. (2012). Reputation-based decisions for logic-based cognitive agents. *Autonomous Agents and Multi-Agent Systems*, *24*(1), 175–216. http://doi.org/10.1007/s10458-010-9149-y

Pomponi, F., Fratocchi, L., & Tafuri, S. R. (2015). Trust development and horizontal collaboration in logistics: a theory based evolutionary framework. *Supply Chain Management-an International Journal*, *20*(1), 83–97. http://doi.org/10.1108/SCM-02-2014-0078

Pomponi, F., Fratocchi, L., Tafuri, S. R., & Palumbo, M. (2013). Horizontal collaboration in logistics: a comprehensive framework. *Research in Logistics & Production*, *3*(4), 243–254.

Rahwan, I., Ramchurn, S. D., Jennings, N. R., McBurney, P., Parsons, S., & Sonenberg, L. (2003). Argumentation-based negotiation. *The Knowledge Engineering Review*, *18*(4), 343–375. http://doi.org/10.1017/S0269888904000098

Ramchurn, S. D., Huynh, T. D., & Jennings, N. R. (2004). Trust in Multiagent Systems. *The Knowledge Engineering Review*, *19*(1), 1–25. http://doi.org/10.1017/S0269888904000116

Rasmussen, L., & Jansson, S. (1996). Simulated Social control for Secure Internet Commerce. In C. Meadows (Ed.), *New Security Paradigms Workshop*. ACM.

Rice Jr., J. B. (2016). Quantifying Supply Chain Resilience. *Keynote Speech Presented at 6th ILS Conference: Building a Resilient Future, Bordeaux, France*.

Robinson, B. S. (2004). How Real People Think in Strategic Games. *SIAM News*, *37*(1), 1–3.

Rohweder, J. P., Kasten, G., Malzahn, D., Piro, A., & Schmid, J. (2011). Informationsqualität – Definitionen, Dimensionen und Begriffe. In K. Hildebrand, M. Gebauer, H. Hinrichs, & M. Mielke (Eds.), *Daten- und Informationsqualität* (pp. 25–45). Wiesbaden: Vieweg+Teubner. http://doi.org/10.1007/978-3-8348-9953-8_2

Rousseau, D. M., Sitkin, S. B., Burt, R. S., & Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of Management Review*, *23*(3), 393–404. http://doi.org/10.5465/AMR.1998.926617

Sabater, J., Paolucci, M., & Conte, R. (2006). Repage: REPutation and ImAGE among limited autonomous partners. *Journal of Artificial Societies and Social Simulation*, *9*(2), 117–134.

Sabater, J., & Sierra, C. (2005). Review on computational trust and reputation models. *Artificial Intelligence Review*, *24*(1), 33–60. http://doi.org/10.1007/s10462-004-0041-5

Sargent, R. G. (1981). An assessment procedure and a set of criteria for use in the evaluation of computerized models and computer-based modeling tools. *Final Technical Report RADC-TR-80-409, U. S. Air Force*.

Sargent, R. G. (2013). Verification and validation of simulation models. *Journal of Simulation*, *7*(1), 12–24. http://doi.org/10.1057/jos.2012.20

Schoenherr, T., & Swink, M. (2012). Revisiting the arcs of integration: Cross-validations and extensions. *Journal of Operations Management*, *30*(1–2), 99–115. http://doi.org/10.1016/j.jom.2011.09.001

Schönberger, J., Kopfer, H., & Kotzab, H. (2016). A Micro- and Macroeconomic View on Shared Resources in Logistics. In H. Kotzab, J. Pannek, & K.-D. Thoben (Eds.), *Dynamics in Logistics: Proceedings of the 4th International Conference LDIC, 2014 Bremen, Germany* (pp. 3–12). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-23512-7_1

Schuldt, A., Hribernik, K. A., Gehrke, J. D., Thoben, K.-D., & Herzog, O. (2010). Cloud Computing for Autonomous Control in Logistics. *40th Annual Conference of the German Society for Computer Science (GI 2010). Leipzig, Germany, September 27-October 1, 2010. LNI 175, Gesellschaft Für Informatik*, 305–310.

Schuldt, A., Hribernik, K. A., Gehrke, J. D., Thoben, K. D., & Herzog, O. (2011). Towards Fourth-Party Logistics Providers: A Business Model for Cloud-Based Autonomous Logistics. In *Proceedings of the 1st International Conference on Cloud Computing and Services Science* (pp. 445–451). SciTePress - Science and and Technology Publications. http://doi.org/10.5220/0003392104450451

Seifert, M. (2009). *Collaboration Formation in Virtual Organisations by applying prospective Performance Measurement*. University of Bremen.

Selten, R. (1999). *What is Bounded Rationality? Paper prepared for the Dahlem Conference 1999. Sonderforschungsbereich (SFB) 303*. Retrieved from https://ssrn.com/abstract=182776

Seppänen, R., Blomqvist, K., & Sundqvist, S. (2007). Measuring inter-organizational trust-a critical review of the empirical research in 1990-2003. *Industrial Marketing Management*, *36*(2), 249–265. http://doi.org/10.1016/j.indmarman.2005.09.003

Sherchan, W., Nepal, S., & Paris, C. (2013). A Survey of Trust in Social Networks. *ACM Computing Surveys*, *45*(4), 47–47:33. http://doi.org/10.1145/2501654.2501661

Simatupang, T. M., & Sridharan, R. (2002). The Collaborative Supply Chain. *The International Journal of Logistics Management*, *13*(1), 15–30. http://doi.org/http://dx.doi.org/10.1108/09574090210806333

Simatupang, T. M., & Sridharan, R. (2005). Supply chain discontent. *Business Process Management Journal*, *11*(4), 349–369. http://doi.org/10.1108/14637150510609390

Sitek, P., Seifert, M., & Klaus-Dieter, T. (2010). Towards an inter-organisational perspective for managing quality in virtual organisations. *The International Journal of Quality & Reliability Management*, *27*(2), 231–246. http://doi.org/http://dx.doi.org/10.1108/02656711011014339

Skandrani, H., Triki, A., & Baratli, B. (2011). Trust in supply chains, meanings, determinants and demonstrations. *Qualitative Market Research: An International Journal*, *14*(4), 391–409. http://doi.org/10.1108/13522751111163227

Spekman, R., & Davis, E. W. (2016). The extended enterprise: a decade later. *International Journal of Physical Distribution & Logistics Management*, *46*(1), 43–61. http://doi.org/10.1108/IJPDLM-07-2015-0164

Spekman, R. E., & Davis, E. W. (2003). *The Extended Enterprise: Gaining Competitive Advantage Through Collaborative Supply Chains*. (D. Cullen-Dolce & T. C. Moore, Eds.). Upper Saddle River: Prentice Hall PTR.

Spekman, R. E., & Davis, E. W. (2004). Risky business: expanding the discussion on risk and the extended enterprise. *International Journal of Physical Distribution & Logistics Management*, *34*(5), 414–433. http://doi.org/10.1108/09600030410545454

Srinivasan, A., & Leveque, F. (2016, December). Digitising Freight – one truck at a time | A Frost & Sullivan perspective on the emerging digital freight brokerage systems. Retrieved from https://ww2.frost.com/frost-perspectives/digitising-freight-one-truck-time-frost-sullivan-perspective-emerging-digital-freight-brokerage-systems/

Srinivasan, R., & Swink, M. (2015). Leveraging Supply Chain Integration through Planning Comprehensiveness: An Organizational Information Processing Theory Perspective. *Decision Sciences*, *46*(5), 823–861. http://doi.org/10.1111/deci.12166

Strader, T. J., Lin, F.-R., & Shaw, M. J. (1998). Simulation of Order Fulfillment in Divergent Assembly Supply Chains. *Journal of Artificial Societies and Social Simulation*, *1*(2).

Su, Q., Song, Y. tao, Li, Z., & Dang, J. xiang. (2008). The impact of supply chain relationship quality on cooperative strategy. *Journal of Purchasing and Supply Management*, *14*(4), 263–272. http://doi.org/10.1016/j.pursup.2008.08.002

Sunstein, C. R. (1996). Social Norms and Social Roles. *Columbia Law Review*, *96*(4), 903. http://doi.org/10.2307/1123430

Supply Chain Consortium. (2011). *Supply Chain Core Benchmarks: Understanding Key Metrics*. Retrieved from http://www.tompkinsinc.com/wp-content/uploads/2012/07/corebenchmarksreport.pdf

Supply Chain Council. (2012, April). Supply Chain Operations Reference Model.

Sutherland, J. L. (2006). *Collaborative Transportation Management_A solution to the current transportation crisis*. Retrieved from http://www.werc.org/assets/1/workflow_staging/Publications/598.PDF

Tejpal, G., Garg, R. K., & Sachdeva, A. (2013). Trust among supply chain partners: a review. *Measuring Business Excellence*, *17*(1), 51–71. http://doi.org/10.1108/13683041311311365

Telles, R. J. (2016). *Digital Matching Firms: A New Definition in the "Sharing Economy" Space*. Washington. Retrieved from http://www.esa.doc.gov/reports/digital-matching-firms-new-definition-"sharing-economy"-space

The Economist Intelligence Unit. (2008). Role of trust in business collaboration, 28. Retrieved from http://www.worldwork.biz/legacy/www/downloads/role_of_trust.pdf

Trkman, P., Stemberger, M. I., Jaklic, J., & Groznik, A. (2007). Process approach to supply chain integration. *Supply Chain Management: An International Journal*, *12*(12), 116–128. http://doi.org/10.1108/13598540710737307

Tseng, M., Yan, J., & Cruijssen, F. (2013). *Position paper on compensation rules. CO3 Deliverable D2.5* (Vol. 31). Retrieved from http://www.co3-project.eu/wo3/wp-content/uploads/2011/12/CO3-D-2-5-Position-Paper-on-Compensation-Rule.pdf

Tuomela, R. (1995). *The importance of us: A philosophical study of basic social notions*. *Stanford series in philosophy*. Stanford, CA: Stanford University Press.

Vangen, S., & Huxham, C. (2008). Nurturing collaborative relations: Building trust in interorganizational collaboration. *The Journal of Applied Behavioral Science*, *39*(3), 490–504. http://doi.org/10.1177/0021886303253179

VICS. (2004). *Collaborative Transportation Management: White Paper. Lawrencevill, NJ: Voluntary Interindustry Commerce Solutions Association*.

VICS. (2007). Implementing Successful Large Scale CPFR Programs and Onboarding Trading Partners Business Guide. Retrieved from www.vics.org

Wang, X., & Kopfer, H. (2011). Increasing efficiency of freight carriers through collaborative transport planning: Chances and challenges. *Dynamics and Sustainability in International Logistics and Supply Chain Management-Proceedings of the 6th German-Russian Logistics and SCM Workshop (DR-LOG 2011)*, (JANUARY 2011), 41–50. Retrieved from http://www.sfb637.uni-bremen.de/pubdb/repository/SFB637-B9-11-005-IC.pdf

Wang, X., & Kopfer, H. (2014). Collaborative transportation planning of less-than-truckload freight: A route-based request exchange mechanism. *OR Spectrum*, *36*(2), 357–380. http://doi.org/10.1007/s00291-013-0331-x

Wang, Z., Ye, F., & Tan, K. H. (2014). Effects of managerial ties and trust on supply chain information sharing and supplier opportunism. *International Journal of Production Research*, *52*(23), 7046–7061. http://doi.org/10.1080/00207543.2014.932931

Warden, T., Porzel, R., Gehrke, J. D., Herzog, O., Langer, H., & Malaka, R. (2010). Towards ontology-based multiagent simulations: The plasma approach. *Proceedings - 24th European Conference on Modelling and Simulation, ECMS 2010*, 50–56.

Warden, T., Wagner, T., Langer, H., & Herzog, O. (2012). Towards Multi-Agent Interactive Adaption of Individual Models for Decision Support. In *Proceedings of the 4th International Conference on Agents and Artificial Intelligence* (pp. 553–559). SciTePress - Science and and Technology Publications. http://doi.org/10.5220/0003886905530559

Weinelt, B. (2016). *Digital Transformation of Industries: Logistics Industry*. Retrieved from http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-logistics-industry-white-paper.pdf

Williamson, O. E. (1993). Calculativeness , Trust , and Economic Organization. *The Journal of Law & Economics*, *36*(1), 453–486.

Wong, C. Y., & Boon-Itt, S. (2008). The influence of institutional norms and environmental uncertainty on supply chain integration in the Thai automotive industry. *International Journal of Production Economics*, *115*(2), 400–410. http://doi.org/10.1016/j.ijpe.2008.05.012

Wooldridge, M. (2009). *An Introduction to MultiAgent Systems* (Second). Chichester: John Wiley and Sons.

Wooldridge, M., & Jennings, N. R. (1995). Intelligent agents: theory and practice. *The Knowledge Engineering Review*, *10*(02), 115. http://doi.org/10.1017/S0269888900008122

World Economic Forum. (2009). *Supply Chain Decarbonization, The Role of Logistics and Transport in Reducing Supply Chain Carbon Emissions*. Geneva. Retrieved from file:///C:/Users/dau/Downloads/SupplyChainDecarbonization%255B1%255D.pdf

World Economic Forum. (2011). *Logistics & Supply Chain Industry Agenda Council*. Cologny/Geneva.

Wosskow, D. (2014). *Unlocking the sharing economy: An independent review. Department for Business, Innovation and Skills, UK Government*. London. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/378291/bis-14-1227-unlocking-the-sharing-economy-an-independent-review.pdf

Wu, I. L., Chuang, C. H., & Hsu, C. H. (2014). Information sharing and collaborative behaviors in enabling supply chain performance: A social exchange perspective. *International Journal of Production Economics*, *148*, 122–132. http://doi.org/10.1016/j.ijpe.2013.09.016

Xiang, X., Kennedy, R., & Madey, G. (2005). Verification and Validation of Agent-based Scientific Simulation Models. *Agent-Directed Simulation Conference*, 47–55. Retrieved from http://www.nd.edu/~nom/Papers/ADS019_Xiang.pdf

Xu, X. (2013). Collaboration Mechanism in Horizontal Logistics Collaboration. *PhD Thesis*.

Yao, Y., & Dresner, M. (2008). The inventory value of information sharing, continuous replenishment, and vendor-managed inventory. *Transportation Research Part E: Logistics and Transportation Review*, *44*(3), 361–378. http://doi.org/10.1016/j.tre.2006.12.001

Yin, M., & Zhao, S. Z. (2008). Information sharing as antecedent of dynamic trust and cooperation intention in supply chain: Evidence from China. *2008 International Conference on Management Science and Engineering 15th Annual Conference Proceedings, ICMSE*, 298–305. http://doi.org/10.1109/ICMSE.2008.4668931

Zacharia, G., & Maes, P. (2000). Trust management through reputation mechanisms. *Applied Artificial Intelligence*, *14*(9), 881–907. http://doi.org/10.1080/08839510050144868

Zhang, C., & Zhang, C. (2007). Design and simulation of demand information sharing in a supply chain. *Simulation Modelling Practice and Theory*, *15*(1), 32–46. http://doi.org/10.1016/j.simpat.2006.09.011

Zhao, X., & Xie, J. (2002). Forecasting errors and the value of information sharing in a supply chain. *International Journal of Production Research*, *40*(2), 311–335. http://doi.org/10.1080/00207540110079121

Zhou, Q., & Lee, T. (2014). The Interactive Effects between Internal and External Resources Constraints on Supply Information Sharing. *Journal of System and Management Sciences*, *4*(3), 22–41.

Zolfagharinia, H., & Haughton, M. A. (2012). The benefit of information sharing in a logistics outsourcing context. *International Journal of Logistics Systems and Management*, *13*(2), 187. http://doi.org/10.1504/IJLSM.2012.048935

Publications used directly in this Dissertation

Daudi, M. (2015). *Trust Dynamics in Early Phases of Supply Chain Collaboration. Research Report*. Bremen. Retrieved from http://www.logistics-gs.uni-bremen.de/fileadmin/Upload/Research_Report_2014_2015.pdf

Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2016a). Behavioral factors influencing partner trust in logistics collaboration: a review. *Logistics Research*, *9*(1), 19. http://doi.org/10.1007/s12159-016-0146-7

Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2016b). Effects of Decision Synchronization on Trust in Collaborative Networks. In H. Afsarmanesh, M. L. Camarinha-Matos, & A. Lucas Soares (Eds.), *IFIP Advances in Information and Communication Technology* (Vol. 480, pp. 215–227). inbook, Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-45390-3_19

Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2016c). On Analysis of Trust Dynamics in Supply Chain Collaboration. In *Building a Resilient Future: Conference paper of the 6th International Conference on Information Systems, Logistics, and Supply Chain (ILS), Bordeaux, France* (pp. 1–8).

Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2017a). A Trust Framework for Agents' Interactions in Collaborative Logistics. In M. Freitag, H. Kotzab, & J. Pannek (Eds.), *Dynamics in Logistics: Proceedings of the 5th International Conference LDIC, 2016 Bremen, Germany* (pp. 53–63). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-45117-6_5

Daudi, M., Baalsrud Hauge, J., & Thoben, K.-D. (2017b). Influence of Information Sharing Behavior on Trust in Collaborative Logistics. In L. M. Camarinha-Matos, H. Afsarmanesh, & R. Fornasiero (Eds.), *Collaboration in a Data-Rich World: 18th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2017, Vicenza, Italy, September 18-20, 2017, Proceedings* (pp. 493–506). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-65151-4_44

Appendix

Appendix I: A matrix of preferences, award, and penalty

Preference	Incentive due to persuasion	Penalty due to rejection
P_1	Receiver increases sales (purchased orders to shipper) by 4%	Receiver charges 1.5% of the purchase price per pallet in case of back orders
P_2	The carrier pays storage cost of 4 % per pallet (in case of undistributed goods)	For non-FTL goods, carrier charges shipper per pallet than per trip
P_3	Shipper pays receiver at 1.5% of the purchase price per pallet in case of a backorder	Shipper charges receiver at 4% per pallet as storage cost (in case of inventory)
P_4	Carrier lowers transportation cost by 5 % per pallet	Carrier charge extra 5% of transportation cost per pallet
P_5	Carrier lowers transportation cost by 5 % per pallet in case of the FTL	Carrier charges extra 5% of transportation cost per pallet in case of non-FTL

Appendix II: Tukey simultaneous tests for differences of means trust level

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
Exp2 - Exp1	0.452	0.140	(-0.044, 0.948)	3.23	0.128
Exp3 - Exp1	0.139	0.140	(-0.357, 0.635)	0.99	1.000
Exp4 - Exp1	0.669	0.140	(0.173, 1.165)	4.78	0.000
Exp5 - Exp1	0.385	0.141	(-0.114, 0.884)	2.73	0.405
Exp6 - Exp1	0.085	0.137	(-0.402, 0.572)	0.62	1.000
Exp7 - Exp1	0.100	0.140	(-0.396, 0.596)	0.72	1.000
Exp8 - Exp1	0.305	0.141	(-0.194, 0.804)	2.16	0.823
Exp9 - Exp1	0.345	0.141	(-0.154, 0.844)	2.45	0.625
Exp10 - Exp1	0.331	0.144	(-0.179, 0.841)	2.30	0.738
Exp11 - Exp1	0.146	0.138	(-0.344, 0.636)	1.06	1.000
Exp12 - Exp1	0.167	0.140	(-0.329, 0.662)	1.19	1.000
Exp13 - Exp1	0.017	0.141	(-0.482, 0.516)	0.12	1.000
Exp14 - Exp1	-0.054	0.138	(-0.544, 0.435)	-0.39	1.000
Exp15 - Exp1	0.166	0.141	(-0.334, 0.665)	1.17	1.000
Exp16 - Exp1	-0.103	0.138	(-0.593, 0.387)	-0.75	1.000
Exp17 - Exp1	-0.002	0.140	(-0.498, 0.494)	-0.01	1.000
Exp18 - Exp1	0.062	0.140	(-0.434, 0.557)	0.44	1.000
Exp19 - Exp1	-0.005	0.142	(-0.508, 0.497)	-0.04	1.000
Exp20 - Exp1	-0.086	0.138	(-0.576, 0.404)	-0.62	1.000
Exp3 - Exp2	-0.314	0.142	(-0.818, 0.191)	-2.20	0.801
Exp4 - Exp2	0.216	0.142	(-0.288, 0.721)	1.52	0.994
Exp5 - Exp2	-0.068	0.143	(-0.576, 0.440)	-0.47	1.000
Exp6 - Exp2	-0.367	0.140	(-0.863, 0.129)	-2.62	0.487
Exp7 - Exp2	-0.352	0.142	(-0.857, 0.153)	-2.47	0.607
Exp8 - Exp2	-0.148	0.143	(-0.656, 0.360)	-1.03	1.000
Exp9 - Exp2	-0.108	0.143	(-0.616, 0.400)	-0.75	1.000
Exp10 - Exp2	-0.122	0.146	(-0.640, 0.397)	-0.83	1.000
Exp11 - Exp2	-0.306	0.141	(-0.805, 0.192)	-2.18	0.816
Exp12 - Exp2	-0.286	0.142	(-0.791, 0.219)	-2.01	0.901
Exp13 - Exp2	-0.435	0.143	(-0.943, 0.073)	-3.04	0.213
Exp14 - Exp2	-0.507	0.141	(-1.005, -0.008)	-3.60	0.042
Exp15 - Exp2	-0.287	0.143	(-0.795, 0.221)	-2.00	0.903
Exp16 - Exp2	-0.555	0.141	(-1.054, -0.057)	-3.94	0.012
Exp17 - Exp2	-0.454	0.142	(-0.959, 0.051)	-3.19	0.144
Exp18 - Exp2	-0.391	0.142	(-0.896, 0.114)	-2.74	0.397
Exp19 - Exp2	-0.458	0.144	(-0.969, 0.054)	-3.17	0.152
Exp20 - Exp2	-0.538	0.141	(-1.037, -0.039)	-3.82	0.019
Exp4 - Exp3	0.530	0.142	(0.025, 1.035)	3.72	0.028
Exp5 - Exp3	0.246	0.143	(-0.262, 0.754)	1.72	0.977
Exp6 - Exp3	-0.054	0.140	(-0.550, 0.442)	-0.38	1.000
Exp7 - Exp3	-0.038	0.142	(-0.543, 0.466)	-0.27	1.000
Exp8 - Exp3	0.166	0.143	(-0.342, 0.674)	1.16	1.000
Exp9 - Exp3	0.206	0.143	(-0.302, 0.714)	1.44	0.997
Exp10 - Exp3	0.192	0.146	(-0.327, 0.710)	1.31	0.999
Exp11 - Exp3	0.007	0.141	(-0.491, 0.506)	0.05	1.000
Exp12 - Exp3	0.028	0.142	(-0.477, 0.533)	0.19	1.000
Exp13 - Exp3	-0.122	0.143	(-0.630, 0.386)	-0.85	1.000
Exp14 - Exp3	-0.193	0.141	(-0.692, 0.305)	-1.37	0.998
Exp15 - Exp3	0.027	0.143	(-0.481, 0.535)	0.19	1.000

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
Exp16 - Exp3	-0.242	0.141	(-0.741, 0.257)	-1.72	0.977
Exp17 - Exp3	-0.141	0.142	(-0.646, 0.364)	-0.99	1.000
Exp18 - Exp3	-0.077	0.142	(-0.582, 0.428)	-0.54	1.000
Exp19 - Exp3	-0.144	0.144	(-0.655, 0.367)	-1.00	1.000
Exp20 - Exp3	-0.225	0.141	(-0.723, 0.274)	-1.60	0.990
Exp5 - Exp4	-0.284	0.143	(-0.792, 0.224)	-1.98	0.911
Exp6 - Exp4	-0.584	0.140	(-1.080, -0.088)	-4.17	0.005
Exp7 - Exp4	-0.568	0.142	(-1.073, -0.064)	-3.99	0.010
Exp8 - Exp4	-0.364	0.143	(-0.872, 0.144)	-2.54	0.553
Exp9 - Exp4	-0.324	0.143	(-0.832, 0.184)	-2.26	0.763
Exp10 - Exp4	-0.338	0.146	(-0.857, 0.180)	-2.31	0.727
Exp11 - Exp4	-0.523	0.141	(-1.021, -0.024)	-3.71	0.028
Exp12 - Exp4	-0.502	0.142	(-1.007, 0.003)	-3.52	0.053
Exp13 - Exp4	-0.652	0.143	(-1.160, -0.144)	-4.54	0.001
Exp14 - Exp4	-0.723	0.141	(-1.222, -0.225)	-5.14	0.000
Exp15 - Exp4	-0.503	0.143	(-1.011, 0.005)	-3.51	0.056
Exp16 - Exp4	-0.772	0.141	(-1.271, -0.273)	-5.48	0.000
Exp17 - Exp4	-0.671	0.142	(-1.176, -0.166)	-4.71	0.000
Exp18 - Exp4	-0.607	0.142	(-1.112, -0.102)	-4.26	0.003
Exp19 - Exp4	-0.674	0.144	(-1.185, -0.163)	-4.67	0.001
Exp20 - Exp4	-0.755	0.141	(-1.253, -0.256)	-5.36	0.000
Exp6 - Exp5	-0.300	0.141	(-0.799, 0.200)	-2.13	0.843
Exp7 - Exp5	-0.284	0.143	(-0.792, 0.224)	-1.98	0.910
Exp8 - Exp5	-0.080	0.144	(-0.591, 0.431)	-0.55	1.000
Exp9 - Exp5	-0.040	0.144	(-0.551, 0.471)	-0.28	1.000
Exp10 - Exp5	-0.054	0.147	(-0.576, 0.467)	-0.37	1.000
Exp11 - Exp5	-0.239	0.142	(-0.741, 0.263)	-1.68	0.981
Exp12 - Exp5	-0.218	0.143	(-0.726, 0.290)	-1.52	0.994
Exp13 - Exp5	-0.368	0.144	(-0.879, 0.144)	-2.55	0.546
Exp14 - Exp5	-0.439	0.142	(-0.941, 0.063)	-3.10	0.182
Exp15 - Exp5	-0.219	0.144	(-0.730, 0.292)	-1.52	0.994
Exp16 - Exp5	-0.488	0.142	(-0.990, 0.014)	-3.44	0.069
Exp17 - Exp5	-0.387	0.143	(-0.895, 0.121)	-2.70	0.430
Exp18 - Exp5	-0.323	0.143	(-0.831, 0.185)	-2.25	0.766
Exp19 - Exp5	-0.390	0.145	(-0.905, 0.125)	-2.69	0.439
Exp20 - Exp5	-0.471	0.142	(-0.973, 0.031)	-3.32	0.099
Exp7 - Exp6	0.015	0.140	(-0.481, 0.511)	0.11	1.000
Exp8 - Exp6	0.220	0.141	(-0.280, 0.719)	1.56	0.992
Exp9 - Exp6	0.260	0.141	(-0.240, 0.759)	1.84	0.953
Exp10 - Exp6	0.245	0.144	(-0.265, 0.755)	1.70	0.979
Exp11 - Exp6	0.061	0.138	(-0.429, 0.551)	0.44	1.000
Exp12 - Exp6	0.081	0.140	(-0.414, 0.577)	0.58	1.000
Exp13 - Exp6	-0.068	0.141	(-0.567, 0.431)	-0.48	1.000
Exp14 - Exp6	-0.140	0.138	(-0.629, 0.350)	-1.01	1.000
Exp15 - Exp6	0.080	0.141	(-0.419, 0.580)	0.57	1.000
Exp16 - Exp6	-0.188	0.138	(-0.678, 0.302)	-1.36	0.999
Exp17 - Exp6	-0.087	0.140	(-0.583, 0.409)	-0.62	1.000
Exp18 - Exp6	-0.024	0.140	(-0.519, 0.472)	-0.17	1.000
Exp19 - Exp6	-0.090	0.142	(-0.593, 0.412)	-0.64	1.000
Exp20 - Exp6	-0.171	0.138	(-0.661, 0.319)	-1.24	1.000
Exp8 - Exp7	0.204	0.143	(-0.304, 0.712)	1.43	0.997
Exp9 - Exp7	0.244	0.143	(-0.264, 0.752)	1.70	0.979
Exp10 - Exp7	0.230	0.146	(-0.288, 0.749)	1.57	0.991
Exp11 - Exp7	0.046	0.141	(-0.453, 0.544)	0.32	1.000
Exp12 - Exp7	0.066	0.142	(-0.439, 0.571)	0.46	1.000
Exp13 - Exp7	-0.083	0.143	(-0.591, 0.425)	-0.58	1.000
Exp14 - Exp7	-0.155	0.141	(-0.653, 0.344)	-1.10	1.000
Exp15 - Exp7	0.065	0.143	(-0.443, 0.573)	0.45	1.000
Exp16 - Exp7	-0.203	0.141	(-0.702, 0.295)	-1.44	0.997
Exp17 - Exp7	-0.102	0.142	(-0.607, 0.403)	-0.72	1.000
Exp18 - Exp7	-0.039	0.142	(-0.544, 0.466)	-0.27	1.000
Exp19 - Exp7	-0.106	0.144	(-0.617, 0.406)	-0.73	1.000
Exp20 - Exp7	-0.186	0.141	(-0.685, 0.313)	-1.32	0.999
Exp9 - Exp8	0.040	0.144	(-0.471, 0.551)	0.28	1.000
Exp10 - Exp8	0.026	0.147	(-0.496, 0.547)	0.17	1.000
Exp11 - Exp8	-0.159	0.142	(-0.661, 0.343)	-1.12	1.000
Exp12 - Exp8	-0.138	0.143	(-0.646, 0.370)	-0.96	1.000
Exp13 - Exp8	-0.288	0.144	(-0.799, 0.224)	-1.99	0.906
Exp14 - Exp8	-0.359	0.142	(-0.861, 0.143)	-2.53	0.556
Exp15 - Exp8	-0.139	0.144	(-0.650, 0.372)	-0.96	1.000
Exp16 - Exp8	-0.408	0.142	(-0.910, 0.094)	-2.88	0.304
Exp17 - Exp8	-0.307	0.143	(-0.815, 0.201)	-2.14	0.837
Exp18 - Exp8	-0.243	0.143	(-0.751, 0.265)	-1.70	0.980
Exp19 - Exp8	-0.310	0.145	(-0.825, 0.205)	-2.13	0.839
Exp20 - Exp8	-0.391	0.142	(-0.893, 0.111)	-2.76	0.386
Exp10 - Exp9	-0.014	0.147	(-0.536, 0.507)	-0.10	1.000
Exp11 - Exp9	-0.199	0.142	(-0.701, 0.303)	-1.40	0.998
Exp12 - Exp9	-0.178	0.143	(-0.686, 0.330)	-1.24	1.000

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
Exp13 - Exp9	-0.328	0.144	(-0.839, 0.184)	-2.27	0.755
Exp14 - Exp9	-0.399	0.142	(-0.901, 0.103)	-2.82	0.344
Exp15 - Exp9	-0.179	0.144	(-0.690, 0.332)	-1.24	1.000
Exp16 - Exp9	-0.448	0.142	(-0.950, 0.054)	-3.16	0.155
Exp17 - Exp9	-0.347	0.143	(-0.855, 0.161)	-2.42	0.648
Exp18 - Exp9	-0.283	0.143	(-0.791, 0.225)	-1.98	0.913
Exp19 - Exp9	-0.350	0.145	(-0.865, 0.165)	-2.41	0.654
Exp20 - Exp9	-0.431	0.142	(-0.933, 0.071)	-3.04	0.211
Exp11 - Exp10	-0.184	0.145	(-0.697, 0.328)	-1.27	0.999
Exp12 - Exp10	-0.164	0.146	(-0.683, 0.355)	-1.12	1.000
Exp13 - Exp10	-0.313	0.147	(-0.835, 0.208)	-2.13	0.843
Exp14 - Exp10	-0.385	0.145	(-0.898, 0.128)	-2.66	0.459
Exp15 - Exp10	-0.165	0.147	(-0.687, 0.357)	-1.12	1.000
Exp16 - Exp10	-0.434	0.145	(-0.946, 0.079)	-3.00	0.234
Exp17 - Exp10	-0.332	0.146	(-0.851, 0.186)	-2.27	0.755
Exp18 - Exp10	-0.269	0.146	(-0.788, 0.250)	-1.84	0.955
Exp19 - Exp10	-0.336	0.148	(-0.861, 0.189)	-2.27	0.759
Exp20 - Exp10	-0.416	0.145	(-0.929, 0.096)	-2.88	0.304
Exp12 - Exp11	0.021	0.141	(-0.478, 0.519)	0.15	1.000
Exp13 - Exp11	-0.129	0.142	(-0.631, 0.373)	-0.91	1.000
Exp14 - Exp11	-0.200	0.139	(-0.693, 0.292)	-1.44	0.997
Exp15 - Exp11	0.020	0.142	(-0.482, 0.522)	0.14	1.000
Exp16 - Exp11	-0.249	0.139	(-0.742, 0.244)	-1.79	0.965
Exp17 - Exp11	-0.148	0.141	(-0.647, 0.351)	-1.05	1.000
Exp18 - Exp11	-0.084	0.141	(-0.583, 0.414)	-0.60	1.000
Exp19 - Exp11	-0.151	0.143	(-0.657, 0.354)	-1.06	1.000
Exp20 - Exp11	-0.232	0.139	(-0.725, 0.261)	-1.67	0.983
Exp13 - Exp12	-0.149	0.143	(-0.657, 0.359)	-1.04	1.000
Exp14 - Exp12	-0.221	0.141	(-0.720, 0.278)	-1.57	0.992
Exp15 - Exp12	-0.001	0.143	(-0.509, 0.507)	-0.01	1.000
Exp16 - Exp12	-0.270	0.141	(-0.768, 0.229)	-1.91	0.934
Exp17 - Exp12	-0.169	0.142	(-0.673, 0.336)	-1.18	1.000
Exp18 - Exp12	-0.105	0.142	(-0.610, 0.400)	-0.74	1.000
Exp19 - Exp12	-0.172	0.144	(-0.683, 0.340)	-1.19	1.000
Exp20 - Exp12	-0.252	0.141	(-0.751, 0.246)	-1.79	0.964
Exp14 - Exp13	-0.072	0.142	(-0.574, 0.430)	-0.50	1.000
Exp15 - Exp13	0.148	0.144	(-0.363, 0.660)	1.03	1.000
Exp16 - Exp13	-0.120	0.142	(-0.622, 0.382)	-0.85	1.000
Exp17 - Exp13	-0.019	0.143	(-0.527, 0.489)	-0.13	1.000
Exp18 - Exp13	0.044	0.143	(-0.464, 0.552)	0.31	1.000
Exp19 - Exp13	-0.022	0.145	(-0.537, 0.492)	-0.15	1.000
Exp20 - Exp13	-0.103	0.142	(-0.605, 0.399)	-0.73	1.000
Exp15 - Exp14	0.220	0.142	(-0.282, 0.722)	1.55	0.993
Exp16 - Exp14	-0.049	0.139	(-0.541, 0.444)	-0.35	1.000
Exp17 - Exp14	0.052	0.141	(-0.446, 0.551)	0.37	1.000
Exp18 - Exp14	0.116	0.141	(-0.383, 0.615)	0.82	1.000
Exp19 - Exp14	0.049	0.143	(-0.456, 0.555)	0.34	1.000
Exp20 - Exp14	-0.031	0.139	(-0.524, 0.461)	-0.23	1.000
Exp16 - Exp15	-0.269	0.142	(-0.771, 0.233)	-1.90	0.939
Exp17 - Exp15	-0.167	0.143	(-0.675, 0.341)	-1.17	1.000
Exp18 - Exp15	-0.104	0.143	(-0.612, 0.404)	-0.73	1.000
Exp19 - Exp15	-0.171	0.145	(-0.685, 0.344)	-1.18	1.000
Exp20 - Exp15	-0.251	0.142	(-0.753, 0.251)	-1.77	0.968
Exp17 - Exp16	0.101	0.141	(-0.398, 0.600)	0.72	1.000
Exp18 - Exp16	0.165	0.141	(-0.334, 0.663)	1.17	1.000
Exp19 - Exp16	0.098	0.143	(-0.408, 0.603)	0.69	1.000
Exp20 - Exp16	0.017	0.139	(-0.475, 0.510)	0.12	1.000
Exp18 - Exp17	0.064	0.142	(-0.441, 0.568)	0.45	1.000
Exp19 - Exp17	-0.003	0.144	(-0.515, 0.508)	-0.02	1.000
Exp20 - Exp17	-0.084	0.141	(-0.583, 0.415)	-0.60	1.000
Exp19 - Exp18	-0.067	0.144	(-0.578, 0.445)	-0.46	1.000
Exp20 - Exp18	-0.147	0.141	(-0.646, 0.351)	-1.05	1.000
Exp20 - Exp19	-0.081	0.143	(-0.586, 0.425)	-0.57	1.000

Appendix III: Comparing performances of the TrustMech and FIRE

Two-Sample T-Test and CI: FIRE, TrustMech

Method

μ_1: mean of FIRE

μ_2: mean of TrustMech

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
FIRE	646	3.34	1.70	0.067
TrustMech	646	3.81	1.76	0.069

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-0.4727	1.7315	(-0.6617, -0.2837)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$

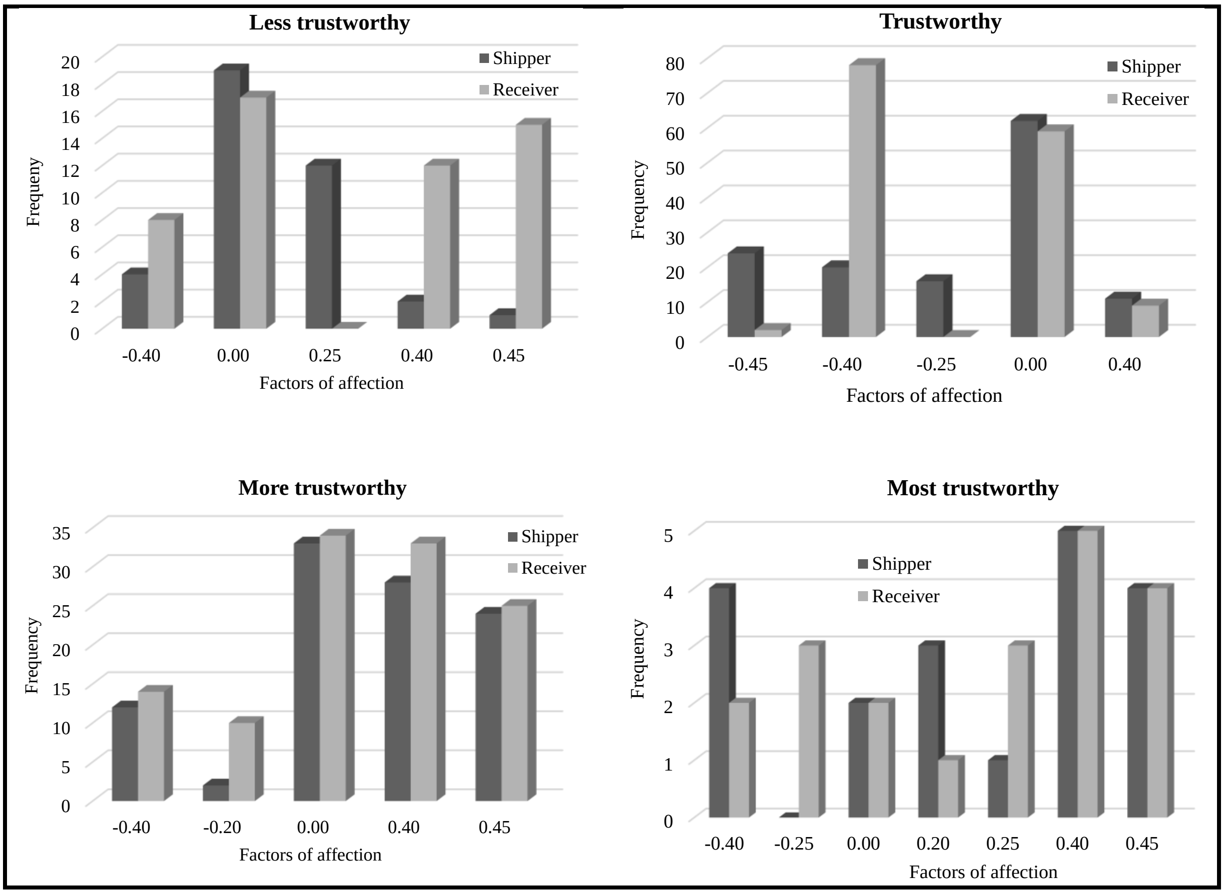
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-4.91	1290	0.000

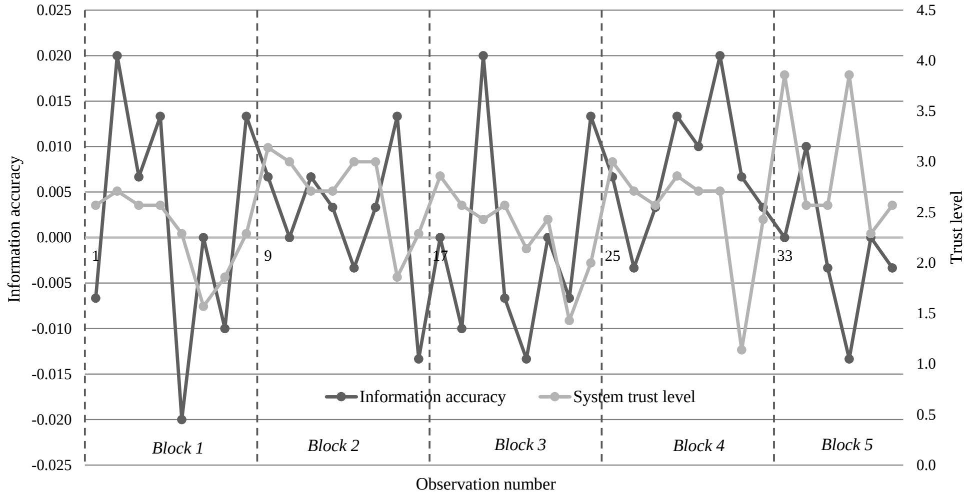
Appendix IV: Hsu Simultaneous tests for ranking response variables

Difference of Levels	Mean Difference	95% CI	Adjusted P-Value
Information sharing - Sharing scheme	0.1690	(0.0000, 0.3168)	0.026
Sharing scheme - Information sharing	-0.1690	(-0.3168, 0.0000)	0.026
Conflicting preference - Information sharing	-0.2377	(-0.3698, 0.0000)	0.001

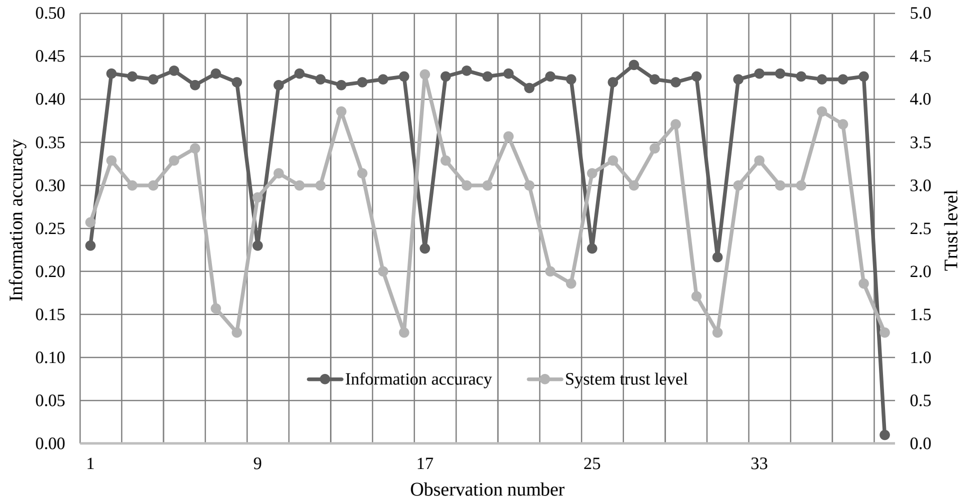
Appendix V: Top most five factors of information affection at different trust levels



Appendix VI: Trend of trust with respect to shipper's positive information accuracy



Appendix VII: Trend of trust concerning receiver's positive information accuracy



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Abbreviations

3PL	Third-Party Logistics
ABM	Agent-Based Modeling
ABN	Argumentation-Based Negotiations
AI	Artificial Intelligence
BDI	Belief-Desire-Intention
BDI+Repage	Integrating Repage in a multi-context BDI agent
C&F	Castelfranchi & Falcone
CFP	Call For Proposal
CI	Confidence Interval
CPFR	Collaborative Planning, Forecasting, and Replenishment
CRP	Continuous replenishment programs
DB	Database
DBMS	Database Management System
DCs	Distribution Centers
e-markets	Electronic markets
EU	European Union
FIPA	The Foundation for Intelligent Physical Agents
FIRE	Derived from “fides” (Latin for “trust”) and “reputation”
GD	Graphical Displays
InfQ	Information Quality
IT	Interaction Trust
JADE	JAVA Agent DEvelopment Framework
KPI	Key Performance Indicator

MAPE	Mean Absolute Percent Error
MAD	Modeling, Analysis, and Design
MAS	Multi-Agent Systems
N/A	Not Applicable
OG	Operational Graphics
PASSI	Process for Agent Societies Specification and Implementation
PlaSMA	Platform for Simulations with Multiple Agents
Repage	REPutation and ImAGE
SCOR	Supply Chain Operations Reference
SPORAS	Reputation mechanism for loosely connected online communities
SRS	Software Requirement Specification
TrustMech	Trust Mechanism
UML	Unified Modeling Language
US	United States
VMI	Vendor-Managed Inventory