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## Conference Paper

# The Forest Supply Chain Management: An Entropic Perspective

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# The Forest Supply Chain Management: An Entropic Perspective

Tarik Saikouk, Ismail Badraoui and Alain Spalanzani

## Abstract

The Supply Chain (SC) represents a complex and dynamic open system characterized by a dissipative structure and positive entropy (Wang, 2008). To better understand the SC dynamic behavior, we present in this paper a conceptual framework to explain how the SC complexity can decrease the operational performance and the value-added creation. A review of the literature shows that the SC positive entropy is a source of its inherent unnecessary uncertainty and its underperformance. Indeed, the non-linear interactions between the SC actors and their incapacity to share relevant information represent a source of several entropic behaviors.

To reach our research objective, and after presenting the literature review of the SC complexity, we show that the incapacity to share relevant information and the ineffective traceability information management can represent a SC positive entropy amplification source. Then, we highlight how a traceability system and automatic information sharing process can reduce the Wood SC information dissipation and improve the wood allocation. After that, we use empirical results from the European project "Indisputable Key" to highlight how Radio Frequency IDentification (RFID) traceability system can create "negative entropy" in the Wood SC, and improve the wood allocation by quickly allowing companies to access relevant wood information. Since the forest-wood sector is a low economical margin sector; any wood allocation improvement would be a source of added value and a competitive lever for companies.

**Keywords:** supply chain system, entropy-negentropy, traceability system, forest supply chain, french case

## 1. Introduction

These past few years, the environment in which companies evolve has become more and more complex, with increasing demand variability and reducing companies' visibility (Forrester, 1958). Therefore, SC is becoming a central organizing units in nowadays' industries (Miles and Snow, 2007). SC is a complex network of business entities (e.g., suppliers, manufacturers, distributors, service providers, warehouses, customers) involved in the upstream and downstream flows of products/services, finances and information (Sanders, 2012; Carter et al., 2014; Ellram and Cooper, 2014). According to Mentzer et al. (2001) and Min et al., (2008), SC exists as a natural phenomenon whether it is managed or not. It represents a system composed of many companies with both convergent and divergent interests, which generates an ago-antagonistic system where both cooperation and competition strategies drive the SC dynamic (Zouaghi and Spalanzani, 2009) and affect its operational performance (Wang, 2008).

The management of the SC, which is dominated by the cooperative paradigm, is based on a systemic and strategic integration of SC flows and processes within and across companies with the objective of reducing costs, improving customer satisfaction and gaining competitive advantage for both independent companies and the SC as a whole (Mentzer et al. 2001). Among the key SC management domain, with note the presence of the information flow management and the performance management (Lambert, 2008). Consequently, and in order to apprehend the SC complexity management, we will focus on the relationship between the information flow management and the overall SC performance in the context of the French forest-wood sector, believing that performance could be improved through more effective release and use of accurate information.

Indeed, we consider the SC as inherently a complex system (Saikouk et al., 2012) due to its dynamic and decentralized characteristics (Bozarth et al., 2009. Serdarasan, 2013, Leeuw, 2013). We define the SC as a dynamic and a

complex system composed of autonomous firms that interact with one another in order to fulfill a common goal. To understand the SC system complexity, we will focus on the dissipative nature of the information flow. In fact, the SC system complexity depends on the quality of information sharing mode between the SC actors. Beamon (1999) considers information as a fundamental component for each activity of any company system. He considers the quality of a decision as a function of the quality of the information available in the system.

However, information dissipation phenomenon within complex systems such as SC limits access to some relevant information in the decision making process. Swink and Robinson (1997) cited by Manuj and Sahin (2011) illustrate the potential role of Information systems as moderators for reducing decision-making complexity when designing the SC networks.

The study of the SC complexity has not been widely addressed in the field of wood industry, particularly, in the French forest-wood sector. The SC literature deals mainly with forest-wood sector in North Europe and North America, with mostly an operational and optimization research approach, focusing primarily on large industries and, to a less important degree, wood bio-diversity. Considering the fact that the French forest-wood sector companies' size and the richness of the bio-diversity are quite different from the Nordic regions, the French Wood Supply Chain (WSC) is more complex and needs a system theory approach to understand how its static complexity can both affect its dynamic complexity, relative to information dissipation and entropy, and its overall performance. According to Bozarth et al. (2009), the information sharing difficulties and the SC complexity impact negatively its industrial performance.

In this article, we use system theory and SC complexity management to provide a conceptual framework highlighting that increased effective information traceability management between SC members reduces the SC information dissipations and increases wood allocation through the French WSC. Empirical results from a case study on traceability system are used to identify the effect that an effective information traceability management, through an RFID system

has on the WSC performance, in terms of wood allocation and added value creation.

In the next section of the paper, we start by presenting what a complex SC system is and why the French WSC is on, while highlighting the concept of entropy and information dissipation it engenders

## **2. Supply chain system, entropy and information dissipation**

Complexity has gained more and more importance as an explicative approach in various scientific fields, particularly in management sciences. Complex systems have been defined in the literature by several authors. Weaver (1948), states that a complex system is made up of a large number of parts that interact in a non-simple way. Simon (1962) considers that in complex systems the whole is more than the sum of its parts. Yates (1978) affirms that every system that have one or more of the following five attributes is complex: (1) significant interactions, (2) high number of parts, degrees of freedom or interactions, (3) non-linearity, (4) broken symmetry and (5) non-holonic constraints.

According to Flood and Carson (1988) cited by Bozarth et al., (2009) the complexity of a system increases when one of its parts is not available for others, which may be explained by the asymmetry of the system or the existence of a non-holonic constraints that escapes the central system control. The non-holonic constraint has been described by Flood and Carson (1988, p.27) as "go off and do Their Own Thing".

According to Yates' (1978) definition, we can say that SC is a complex system since we can observe one or more of the following features in it: (a) various companies; (b) high number and variety of relations, processes and interactions between and within companies (c) processes and interactions are dynamic; (d) several levels of the system are involved in each process; and (e) the quantity of information needed to control the system is huge. To illustrate the concept of

non-holonic constraints in the context of SC system, Bozarth et al., (2009) gave an example of a SC "with multiple downstream demand points that independently place orders on a centralized supply point without regard to the supply constraints or needs of other demand points". The more the SC is complex the more the traceability becomes a major issue in its management as the complexity of a system depends exponentially on its size

Casti's (1979) cited by Frizelle and Woodcock (1995) and Sivadasan et al., (2002, 2006) distinguish between two classes of system complexity: (1) static or structural complexity and (2) operational or dynamical complexity. Static or structural complexity is associated with the variety embedded in the system, involving the variety and the interdependences of the subsystems with the large number of elements of the system. It can be measured by the number and variety of processes and products involved and the interactions between them (Frizelle & Woodcock 1995). The operational complexity is associated with the system dynamism, the connectivity between the sub-systems with its inherent uncertainty. Inherent SC chain uncertainties arise when the activities of supply chain actors are not in harmony with one another. It can be measured by the positive entropy contained in the SC system. Based on Frizelle and Woodcock (1995), who has been among the first to use this distinction to study complexity in manufacturing systems, Sivadasan et al., (2002) cited by Sivadasan et al., (2006) suggest an information-theoretic entropy-based methodology to measure quantitatively the operational complexity of supplier-consumers systems associated with the uncertainty in information transfer of the internal and interface system. When dealing with SC system complexity, a third type of complexity, namely decision-making, which involves both static and dynamic complexity, should be considered (Manuj and Sahin, 2011).

We note that the decision making complexity involves both static and dynamic aspects of complexity and it is associated with the information relevance that should be considered when making a SC related decision. These three complexities (static, dynamic, and decision-making) are interrelated.

From the static perspective, the decision making process in the SC system becomes complex when making a decision goes beyond the human capacity (Simon, 1974). From the dynamic perspective, the nonlinearity, the dynamic and the unexpected SC system behavior makes the decision making process more complex. As result, the complexity of decision making in the SC is directly related to the volume and the relevance of the information contained in the system. In other words, the decision making complexity depends directly on the positive entropy or the missed information that characterized the SC system at a given time. When dealing with SC complexity, two major approaches of complexity measurement researches can be distinguished: studies using the SC metrics (Beamon 1999; Vachon & Klassen 2002) and studies using theoretic information (Frizelle & Woodcock 1995; Sivadasan et al. 1999; Efstathiou et al. 2002; Sivadasan et al. 2002a; Sivadasan et al. 2004; Sivadasan et al. 2006; Wu et al. 2007; Martinez-Olvera 2008).

Considering the dependency of SC activities on information, we will focus on information sharing mode to apprehend the management of the SC system inherent complexity. To better understand the information transfer in the SC system, we consider the idea of entropy from its theoretical and mathematical basis. In the information theory, (Shannon, 1948) considers the entropy as the probability of information loss in a communication. Indeed, entropy measures the amount of missing information needed to describe the state of a system. Positive entropy is a measure of the level of informational disorder between SC system actors and characterizes the probability of information loss within the system. In general, entropy grows if nothing is done. This means that information loss is a growing phenomenon but may be regulated by negative entropy, called negentropy. The more entropy is present, the more dissipative the SC becomes. In an open system like the SC (Wang, 2008), entropy is used to describe the system disorder degree.

Overall, we can say that the SC is a complex entropic system characterized by its dissipative structure (Prigo-gine, 1955), and that entropy increases if nothing is done to reduce the system inherent uncertainty. In practice, we can use and

detect this entropy to master the operational complexity in sharing information process between the SC system actors. Based on this, and after presenting the French WSC, we will show how traceability systems can create a negative entropy, which is an essential factor in system organization, as it allows to measure the degree of order creation in the system, permits the system to self-regulate (Brillouin, 1959), and moderates information dissipation within it.

### **3. The French Wood Supply Chain**

In this section, we will first describe the specific characteristics of the French forest-wood sector to explain the complexity of its SC.

First, we have to mention that there is a large number of foresters in France, which affects dramatically the potential of wood mobilization and limits the development of the economic relationships between the foresters and the wood industries. In fact, the French forest-wood sector is fragmented into heterogeneous multi-activities actors. At the upstream level, there are a large number of foresters and small enterprises that are situated between the forests and sawmills, which lack technologies and production capacity investment. At the downstream level, there are large companies such as furniture companies and paper mills. The fragmentation of the sector and the variety of resources don't encourage firms to form networks, which explains the low level of integration in the sector. A study was conducted in 2008 by the Department of Regional Planning in France (AGRESTE) and the Technological Institute FCBA to highlight the important fragmentation level of the French forest-wood sector. This study allows us to show that the different activities necessary to transform wood in France require, in fact, the intervention of several heterogeneous actors. We believe that this fragmentation doesn't create the appropriate conditions to better share information, and simplify/standardize data exchange process between companies. According to the FCBA in France, the standardization of information in the forest-wood sector represents a major



issue in the absence of a unique data referential system adopted by all actors in the sector.

According to Simchi-Levi et al. (2000) the lack of integration within a SC can be explained by the format of the exchanged data, which leads to relevant information loss. The increasing uncertainty about the qualitative properties and the measurements of logs reduces the companies' visibility, regarding scheduling and planning of their production and logistic capacity, which prevents them from providing the right product to the right client. The logs properties' visibility problem is central in our approach, which pushes us to first define what visibility is. According to Gattorna (2009), visibility is "the identity, location, and status of entities transiting the SC, captured in timely messages about events, along with planned and actual dates/times for these events". The loss of this ability to "see" and share information increases the opacity of the SC system, which, on the one hand, pushes companies to organize themselves into "Silos" approaches, and on the other hand, leads them to focus on their local objectives. The visibility on material flows movement from supplier to consumers enhance the SC performance (Joshi, 2000) like inventory management, product allocation and asset utilization (Delen et al., 2007). In fact, the SC management role is to eliminate the barriers by enabling the synchronization and sharing of valuable information among trading partners (Kouvelis et al., 2006). In our case, to enhance the wood SC visibility, in terms of wood quality and quantity, we consider sharing information as one of the most effective ways of improving SC visibility and performance.

Moyaux et al., (2007) considers sharing information as a mechanism of coordination that can reduce the bullwhip effect. This latter is characterized by high inventories level and long lead-time which estimated by 6 to 12 months in the wood industry. The bullwhip effect results from the information asymmetry triggered by their incapacity of actors to share information. We can also add that there is a direct relationship between Bullwhip effect and operational complexity (Ahmad and Alireza, 2006). These factors reduce the logs recovery rate due to the inadequacy of the supply and demand, leading to a lower

product quality, growth and service levels in the SC (Joshi, 2000). Holweg et al., (2005) show that collaboration within the SC and the visibility can reduce the Bullwhip Effect and improve the quality of service, reducing inventory levels and stock-outs probability.

The wood SC (WSC) represents for us a relevant example to highlight the effect of the complexity, information dissipation and entropy on the SC visibility, information sharing and operations performance. Indeed, the WSC has a divergent structure (Vila et al., 2006) characterized by a single entry point to the raw material at the forest level (upstream) and several access points to the different wood product market (lumber, paper, wood energy...). As the WSC is divergent and interrelated in terms of multiple products coming from a single input, the relative pricing between some of these products can be dynamic.

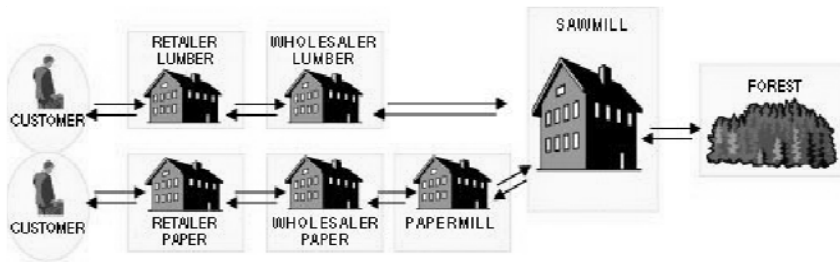


Fig. 1: The divergent nature of the forest products industry supply chain is simulated by dividing the material produced at sawmill into chips and lumber (Wood Supply Game at FOR@C)

The French WSC is both fragmented into many autonomous but interdependent companies (also asymmetric) because most of the activities in the first transformation, particularly at the forest, are not available to the companies of the second transformation. This asymmetry is characterized by a non-holonic (uncontrollable) constraint which represents the harvesting activities that escapes the control of companies in the second transformation.

This explains the decoupling point of the WSC at sawmills level. We can conclude that the WSC represents a complex and dynamic system. Moreover, the WSC complexity is increased by the interweaving of logistic flows to extract

value from sawmills wastes to produce the co-products (paper pulp and energy), which makes it even more difficult to manage.

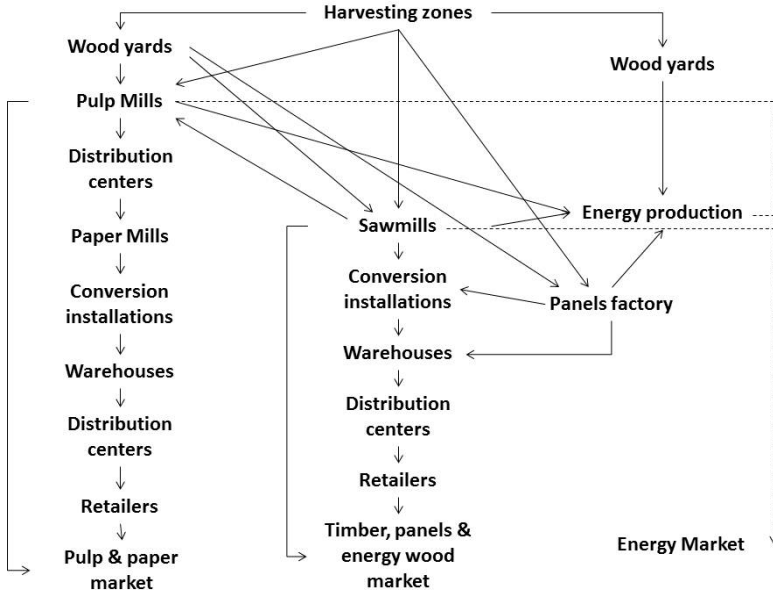


Fig. 2: The forest products value chain flows complexity

This figure shows the interweaving of forest product value chain making the WSC more complex. In fact, the WSC has traditionally been considered as complex with the presence of several intermediaries between resource extraction, manufacturing, and end use (Sinclair, 1992).

The complexity of the French WSC is amplified by the diversity of wood. In fact, wood has always been considered a homogeneous structure and a bulk material, while in reality it is a non-homogeneous biological material and its properties depend on growing conditions (growing season, natural regeneration or planting, etc. ...). Depending on its essence and its properties, logs differ in terms of their appearance, durability, strength, etc. Every wood market has its special requirements in terms of wood species and properties. This situation

changes the design of the French WSC from a traditional SC based on mass production to a mass customization SC, particularly in the furniture industry (Bullard et al., 2002). The French WSC "V" structure makes it essential to maximize value extraction through the availability of information about logs properties. The access to information can help effectively manage the WSC operational complexity in order to deliver the right wood to the right end user. A lack of knowledge of quality of wood leads to an under-usage of wood, which represents a wasting of natural resources and a waste of business profitability. To maximize WSC added value, selecting the right logs for a specific end-use is a demanding in relevant information. The challenge in the WSC actors is to accelerate and standardize the access to relevant information by automating the information sharing between the WSC actors.

Wood supply uncertainty can arise due to unpredictable (wood properties) and uncontrollable (non holonic constraint and "V" WSC structure) factors affecting wood supplier changing frequency, time specificity of materials, delivery frequency and fluctuations in the selling price (Ho et al.,2005).

To conclude this part, we can state that the French WSC represents a high level of static and dynamic complexity. It is fragmented and contains heterogeneous actors, both in terms of size and culture, equipment and use of information technology. This complexity makes the French forest wood non-competitive at the European level despite its potential in terms of wood richness, variety and available quantities. In the next, part, we develop our conceptual framework, after which we use empirical results from a European project "Indisputable Key" to support it.

The research objective is to develop a conceptual framework to explain how the SC entropic behavior can decrease the operational performance and the added value creation that in the case of the French wood SC. Toward the end, we apply a research methodology consisting on reviewing relevant literature in the field of SC management and system complexity theory and The RFID traceability system application in the management of the SC. For the empirical evidence, data collected from a pilot project in the use of RFID system in

Europe to limit the dissipation of information on the wood quality is going to be used.

Our initial investigations on the use of RFID in the French WSC have revealed a lack of initiatives to implement RFID to trace the wood. The explanations we have noted are various but could be summarized in two main reasons which are financial (the cost of the RFID tag compared to the value of the log should not exceed 1%, while the current biodegradable tag cost exceeds this limit) and organizational and technological ones. This is the reason why opted to use the results "Indisputable Key" which we will present in the latter part.

We have seen that the French WCS is an extremely complex system. This complexity could be categorized into three types: the static complexity, the decision making complexity and the dynamic complexity. According to Blecker et al. (2005) Complexity in a SC can be observed within a firm, between the firms and in their interactions. It is also possible to categorize the WSC complexity on the basis of its origin (internal sources, supply/demand interface sources and external sources) (Blecker et al. 2005). As we have said, this article focuses only on the inherent complexity.

Therefore, we can resume the French WSC complexity characteristics according to their origin (Internal, supply/demand interface) and to their types (static, dynamic, decision making). In the context of this article, we are only focusing on the inherent WSC complexity, the external origin of complexity will be covered.

Within a WSC, all types of complexity should be considered to improve performance of all the WSC actors and facilitate their integration.

Three generic approaches emerge in the literature of the SC complexity: complexity management, complexity reduction and complexity prevention. We believe that the first approach would be to reduce/eliminate the source of unnecessary uncertainty, which is the information dissipation in the SC system, by measuring a negentropy index. Then we can manage and prevent any additional unnecessary complexity. It is important to differentiate between necessary complexity that the customer/market is willing to pay for and

unnecessary complexity that brings no additional benefits to the company/supply chain, but rather involves additional costs (Frizelle and Efstathiou, 2002). Within the WSC, all types of inherent complexity should be considered to improve SC actors' performance and facilitate their integration. To deal with SC complexity, three generic approaches emerge in the literature: complexity management, complexity reduction and complexity prevention. To cope with the French WSC complexity, we consider as a first approach the reduction and elimination of all sources of unnecessary uncertainty, considered to be the information dissipation, by measuring and increasing the negentropy index. Then, we can manage and prevent any additional unnecessary complexity.

	Internal	Supply/demand interface
Static	High number of wood product variety Divergent structure of the wood SC	High species diversity High number of wood SC actors in France Fragmentation of the wood SC
Dynamic	Process uncertainties Log properties and quality uncertainty Forecast driven bullwhip effect	The interweaving of forest product value chain Different languages Lack of visibility Lack of process synchronization
Decision making	Basic IT system especially for accounting Small business	Open loop traceability system Wood SC heterogeneous IT Non holonic constraint and WSC asymmetry

Tab. 1: Drivers of the French wood SC complexity

We propose a conceptual framework to highlight first the negative impact of the SC complexity, through information dissipation and positive entropy, on the operational performance in terms of revenues, product allocation and process

variability. According to systems theory, SC can be considered as a complex and dynamic system composed of autonomous firms that interact with one another contributing to fulfilling or not a common goal. When SC actors have convergent goals, they cooperate and share information which creates an organization factor called negentropy or order index. In the opposite, when SC actors have divergent goals, they compete without sharing information increasing entropy or disorder degree. In our case, we consider that actors from the second transformation must cooperate and share demand information with actors of the first transformation to enhance their own performance, through getting visibility on the supplied wood properties, which is vital to eliminate or reduce the unnecessary complexity (reduce information dissipation or entropy). Our focus is to reduce decision making complexity by eliminating and reducing unnecessary source of uncertainty. In this matter, Manuj and Sahin (2009) have developed a model to identify antecedences of SC decision making complexity supported by the existing literature. However, their work didn't take into account the decision making complexity related to the product properties uncertainty. In our article we try to fill this gap by considering the effect of product relevant information availability on the decision making complexity.

In order to deal with the static and dynamic complexity drivers, which make the French WSC a complex system, the implementation of a Closed Loop Traceability System (CLTS) can help capture and conserve all available logs relevant information throughout the wood value chains and then transform it into knowledge to improve decision making. A CLTS must to be interoperable with all information systems in the WSC without generating an organizational change or triggering additional cost. According to (Wang, 2008), promoting the use of advanced technologies (RFID systems) in the SC could increase the negentropy creation and decrease the positive entropy negative impact on the SC performance. Indeed, making all information flows visible throughout the SC is a part of twelve rules for better managing and preventing material flows uncertainty (Childerhouse and Towill, 2003). Concerning the nature of the SC performance, we consider as performance criteria the product selling value.

The more information is quickly available on the product, the better its value and its sale revenues get (De Marco et al., 2012).

SC entropic Behavior	Some RFID negative entropy	Authors
Information loss Information sharing	Improves information integrity. The use of RFID as a sole channel of information sharing between companies	Fosso Wamba and Boeck (2008), Zaharudin and al. (2007)
Information imperfection	Tracks products precisely and improves the accuracy of the information.	Lee and al. (2004), lee and Ozer (2007), Hesse (2007), cannon and al. (2008), Lapide, L. (2004)
Lack of item level visibility over information flows and inventory levels	Improves item level visibility and inventory information management. Improves visibility in real time (provided of effective management information)	Fosso, Wamba and Boeck (2008), Zahou (2009), Wang and al. (2008)
High uncertainty, decision making complexity, product sales revenues	Contributes to uncertainty decrease in the SC and improves decision making. Process cost saving, promise large potential benefits from revenue growth, increases sales	Cannon and al. (2008), Lin and al. (2006), Zhou (2009), De Marco and al. (2012).

Tab. 2: RFID positive impact the SC entropic behavior

According to Prigogine (1955) system theory, complex systems are dissipative and entropic systems. Entropy is inherent to complex system and it increases if



nothing is done to reduce the system information dissipation. We suggest a conceptual framework to highlight the role of closed loop architecture traceability at the item level in enhancing the product/process visibility, moderating the operation complexity and optimizing wood allocation at each step processing in the SC. To mitigate the SC entropic behavior, RFID systems can have a moderator by manifesting negative entropy.

This can be consolidated by the following conceptual framework:

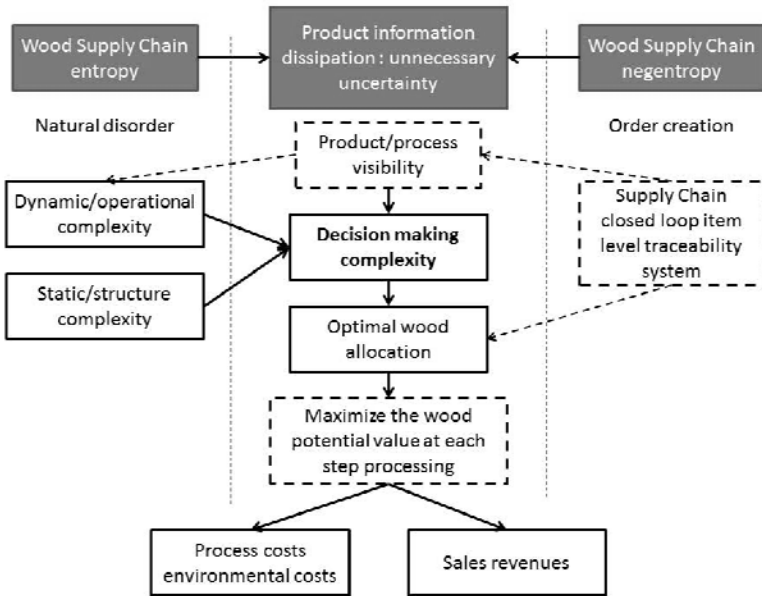


Fig. 3: Conceptual framework: the French wood SC is an entropic SC

#### 4. Traceability based Negentropy in Wood SC

Traceability is defined by the ISO9000: 2000 as: "the ability to trace the history, application or location of an entity by means of recorded identifications.» According to Alfaro and Rabade (2009), the use of traceability information can improve SC management. The ability to track and locate products accurately in

SCs can lower inventory levels. By incorporating traceability information with SC management, Wang et al., (2010) consider traceability systems as a key factor that can improve the operations management in the Food SC. In terms of tracking and tracing functionalities Fritz and Schiefer (2009) consider various principal traceability concepts: (1) Backward tracing for the origin of a product, (2) Forward tracing for the position of a product, (3) Backward tracing for the history of a product and (4) Forward tracing for the movement of a product. In the literature, several authors discuss the role of traceability in SCM with more security and regulatory dimensions (Fritz et al., 2009, Wang et al., 2010; Trienekens et al., 2011).

We can explain the security interests in the Food SCM by the maturity of the European legislation in food traceability and the need for transparency. However few theoretical models are mobilized in order to demonstrate the contribution traceability systems in the WSC.

According to the French National Center of Traceability and GS1France, there are two architectures of the traceability systems. The traceability system is in "closed loop architecture" when the SC companies are adopting a common protocols and standards of communication that enable interoperability and secured/controlled information sharing. When traceability system is in "open loop architecture", where the SC actors don't have homogenized traceability systems, discontinuities can be observed in information flows. The good functioning of a traceability system essentially depends on the interoperability of inter-organizational information systems.

The first results of a battery of interviews that we conducted with the Association "AB" in the region Rhône Alpes in France and some experts of the FCBA allow us to conclude that a CLTS like RFID system would achieve several objectives, among which we highlight the following: achieving material economy by improving the efficiency of wood through better adaptation of the production tool to different types of wood, enhancing the transparency of wood products with eco-labels, reassuring end users about the quality and correctness of their choices of wood, secure the modes exchange of products

and establishing a consciousness of belonging to a wood SC. However, the implementation of a RFID system represents a considerable financial and organization challenge for the WSC actors. At the moment, there is no finished project to explore the potential of RFID system benefits in the French forest wood sector. Fortunately, the project "Indisputable Key", a European research project launched in October 2006 by a consortium of 28 partners from five countries with a budget of € 12.8 million, provides us with some reliable field data. According to the project public reports, more than 25 million m<sup>3</sup> of raw material go to waste, equivalent to several billions € in Europe, and more than 20 % of final products do not correspond to customers demand. The principal source of waste is the information loss along at each step of wood processing in the SC. To cope with these economic and ecological wastes, the ultimate objective of the project was to develop a methodology and a traceability based RFID technologies that can improve the use of wood and optimize forest production through minimizing WSC environmental impacts. To achieve this goal, the technical solution was to use automatic traceability system and standardize all data communication within and between actors in the SC.

As a final result, we can observe in the figure 4 that a certain quantity of product information (original, cutting wood, measuring input sawmill, sorting products, etc.) is collected by different equipment and production machines are available during the process in progress, but most of the information is lost during the following process.

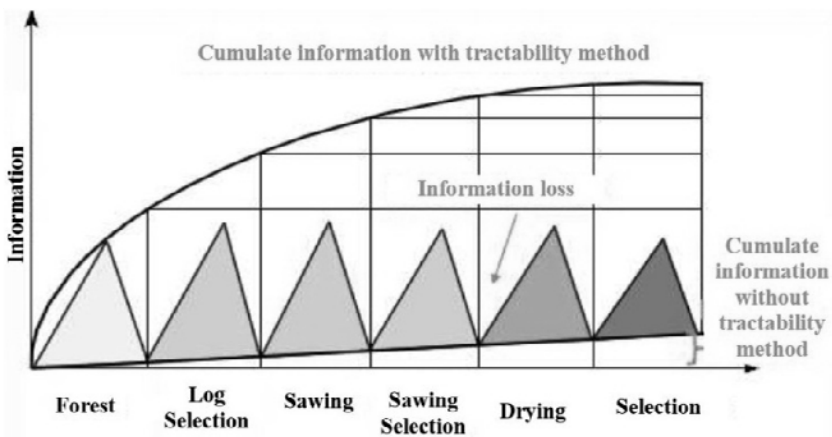


Fig. 4: Scheme of information losses at each step during wood SC (source: [www.indisputablekey.com](http://www.indisputablekey.com))

Figure 4 shows that the quantity of information accumulated without a traceability system is significantly lower than the quantity accumulated with a traceability system. Unfortunately, the major simulation outcomes with real world production studies and development are presented in two confidential reports that are not available to the public. In general, the D1 24 final report recognizes the capacity of RFID system to maximize the wood potential value by providing eco-certified products and wood quality adapted to the demand at the right price. We can summarize RFID empirical benefits in the wood SC in the following points:

- Reducing wood quality losses due to inappropriate storage by 10 to 20 %;
- Improving knowledge about the origin of wood with full traceability in each specific board;
- Improving production efficiency: up to 10% better yield estimated to more than 1 400 millions € on EU basis;
- Reducing loss of timber. Even a 10% reduction represents a potential on EU basis is estimated to 80 million € annual payback.

By analogy to our conceptual framework, these empirical results represent a proof of the concept of information dissipation within a complex system such as the WSC, highlighting the relevance of using a traceability system using a biodegradable RFID technology. French WSC actors particularly sawmills, were able to stop traceability cuts and restrict the loss of information. This project has shown that the main interest of the SC traceability in forest is the capitalization of information and acceleration of the access to relevant information by having a real image of wood evolution status at each stage of wood industry.

This reduces both the quantitative information dissipation and the loss of its relevance, which is generally due to errors of interpretation by the various companies, given that the structure and forms of information are different in the wood sector. According to Saikouk et al., (2011), the use of RFID system can regulate the entropic dissipation in SC systems.

Entropy characterizes complex systems dissipative structure as informational common disorder between companies. Generally, entropy grows if nothing is done. This means that information loss is a growing phenomenon but may be regulated by negative entropy, called negentropy. Consequently, information quality, quantity and the mode of sharing constitute important elements that contribute to making the SC system more stable. We suggest that an effective management of the SC can be reached through creating order by Negentropy based RFID traceability system. The traceability in the forest context aims to improve the process operational complexity control and add value to product by helping decision makers to select the right logs characteristics to meet the end user specifications. Poor decision making can contribute to operational complexity amplification.

## **5. Conclusion**

As we have seen in this paper SC represents an inherent complex system. In fact, we can distinguish between three types of supply chain complexity: First, a static or structural complexity depending on the number of companies within

the system, the variety of these companies and the non-linearity of the system. Second, a dynamic or operational complexity depends on dynamism, the interactions between the companies and the high level of uncertainty. Third, the decision making complexity results from both static and dynamic complexity. In this paper we have focused on the wood supply chain complex system uncertainty characterized by its entropy due to its dissipative structure.

Supply chain dynamics fluctuate between order and disorder. Fundamentally, organization of a supply chain system is the creation of order out of current disorder by effective management. The more a supply chain is organized, the less the subsisting entropy. This entropy materialized by information dissipation and remains a source of inherent supply chain system operational complexity.

We have also seen that the French WSC is a divergent industrial process which is fragmented into many autonomous interdependent actors that usually have heterogeneous information systems. The WSC is also asymmetric due to the fact that one of its parts is not accessible to the others actors and has a non-holonic constraint. This constraint escapes from the control of the French WSCS second transformation industries. In addition, in the French WSC the traceability system follows an open loop architecture increasing the risk of information loss. This makes the WSC as complex entropic system in which information dissipation increases over time. To cope with this dissipation, we have suggested the concept of Closed Loop Traceability System as a Negentropy based system creating order. In fact, in the WSC the role of a traceability system is to capture and automatically conserve and provide relevant information about the wood quality and evolution in different process over the WSC from the forest to the different market. Finally, we relied on the Indisputable Key project results to confirm our theoretical development. As seen above, the implementation of a RFID item level system to track and trace wood from the forest to the market is a very big challenge for the professionals. Recognizing the role of RFID in improving actors' operations performance and their competitiveness, as well as the forest eco-interests and the RFID

decreasing cost (Moore's law) should improve the adoption of RFID in the French WSC.

In our further research we will develop a dynamic system based simulation model to first, highlight the impact of the Negentropy on the WSC industrial performance especially for the sawmill industries and then simulate the impact of different non-holonic constraints on the French WSC entropic behavior system. We will also develop a Negentropy index to measure the impact of a traceability system on reducing information dissipation, which is the main source of unnecessary uncertainty.

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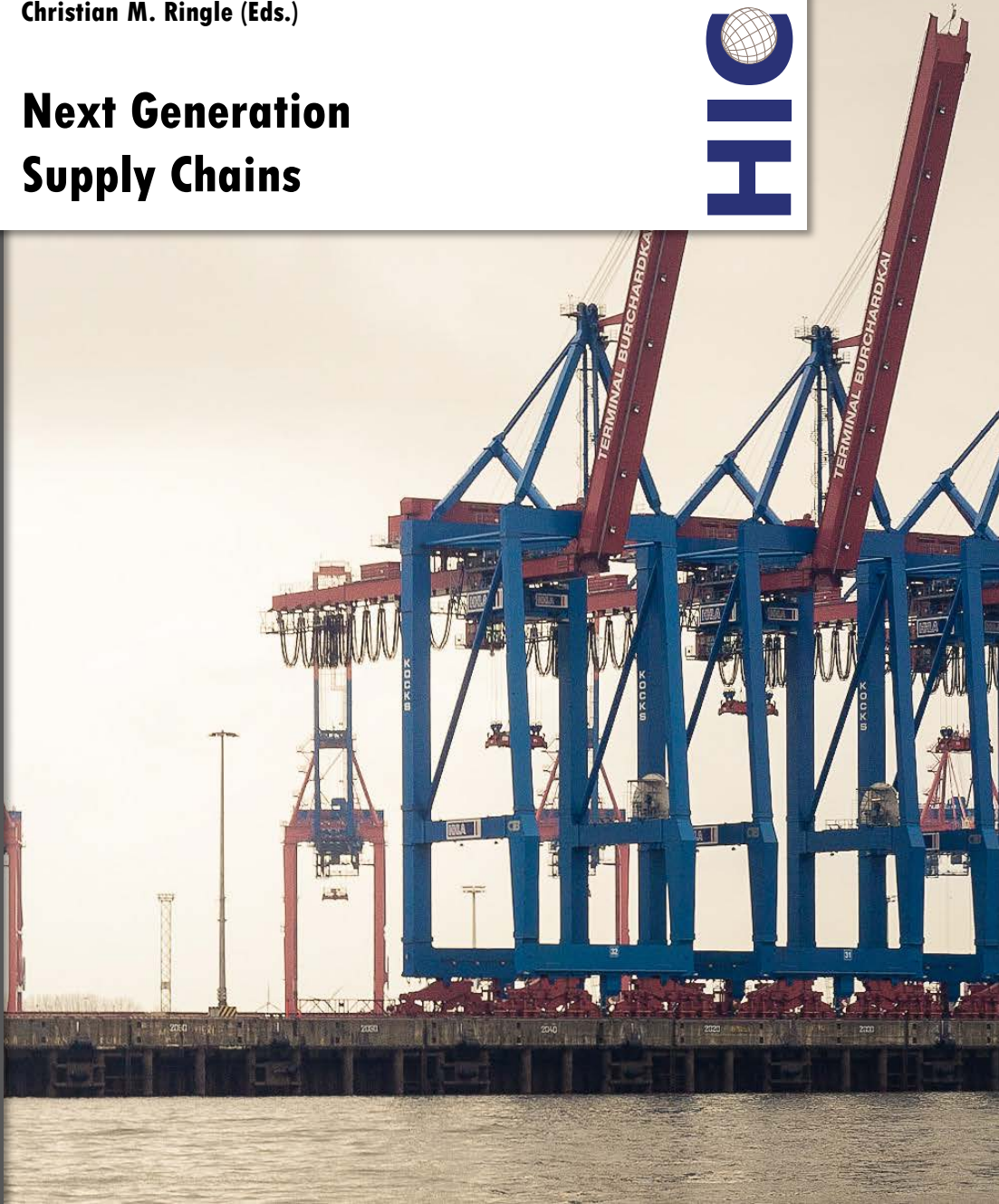
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**Wolfgang Kersten, Thorsten Blecker and  
Christian M. Ringle (Eds.)**

# **Next Generation Supply Chains**



Prof. Dr. Dr. h. c. Wolfgang Kersten  
Prof. Dr. Thorsten Blecker  
Prof. Dr. Christian M. Ringle  
*(Editors)*

# **Next Generation Supply Chains**

Trends and Opportunities

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## Preface

Today's business environment is undergoing significant changes. Demand patterns constantly claim for greener products from more sustainable supply chains. Handling these customer needs, embedded in a sophisticated and complex supply chain environment, are putting the players under a constant pressure: Ecological and social issues arise additionally to challenges like technology management and efficiency enhancement. Concurrently each of these holds incredible opportunities to separate from competitors, yet also increases chain complexity and risks.

This book addresses the hot spots of discussion for future supply chain solutions. It contains manuscripts by international authors providing comprehensive insights into topics like sustainability, supply chain risk management and provides future outlooks to the field of supply chain management. All manuscripts contribute to theory development and verification in their respective area of research.

We would like to thank the authors for their excellent contributions, which advance the logistics research progress. Without their support and hard work, the creation of this volume would not have been possible. We would also like to thank Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure and finalize this book.

Hamburg, August 2014

Prof. Dr. Dr. h. c. Wolfgang Kersten  
Prof. Dr. Thorsten Blecker  
Prof. Dr. Christian Ringle



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## **About HICL**

Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and SCM. HICL creates a creative environment which attracts researchers, practitioners, and industry thinkers from all around the world.



Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices. Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:

- Innovative and technology-based solutions
- Supply chain security management
- Cooperation and performance practices in supply chain management

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