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Abstract: *The Supply Chain (SC) represents a complex and dynamic open system characterized by a dissipative structure and a 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 found 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 behavior.*

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

Keywords: *Supply chain system, entropy-negentropy, traceability system, French Wood supply chain.*

1 Introduction

These past few years, the environment in which companies evolve has becoming more and more complex, increasing the demand variability and reducing, as a result, companies visibility (Forrester, 1958). Then, For this, 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 (Beamon 1998; Lambert et al. 1998). According to (Mentzer et al.,2001) SC exist, as a natural phenomena (Min et al., 2008), whether managed or not. The SC is system composed of many companies, and each of them has simultaneously convergent and divergent interests, which generates an ago-antagonistic system where both cooperation and competition strategies drive, at the same time, the SC dynamic (Zouaghi and Spalanzani, 2009) and affect its operational performance (Wang, 2008).

For the purpose of this article, the management of the SC, dominated by the cooperative paradigm, is based on a systemic and strategic integration of SC flows and processes within and across companies in the SC with the aims 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, the information flow management and the performance management (Lambert, 2008). From this, 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. Performance improvement would be possible through more effective release and use of accurate information.

Indeed, we consider the SC as an inherently complex system (Lee et al., 1997) due to its dynamic and decentralized characteristics (Towill et al.,1992; Beamon, 1999; Zhang et al., 2006; Bozarth et al., 2009).For this article, we define the SC as a dynamic and a complex system composed of autonomous firms that dynamically interact with one another contributing fulfilling a common goal. To understand the SC system complexity, we will focus on the dissipative nature of the information flow. In fact, the level of 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 phenomena within complex systems such as SC limits access to some available information relevant for decision making process. Swink and Robinson (1997) cited by (Manuj and Sahin, 2011) illustrate the potential role of Information systems as complexity 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 mainly an operational and optimization research approach, focuses primarily on large industries and few wood bio-diversity. Whereas, the French forest-wood sector companies' size and the richness of the bio-diversity are more different from those in Nordic regions. These structural differences led us to think that the WSC in France is more complex and need 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, concerned with dealing with complexity in the French WSC, we use system theory and SC complexity management to provide a conceptual framework highlighting that increased effective traceability information 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 is utilized to identify the effect of an effective traceability information management, through an RFID system, on the WSC performance in terms of wood allocation and value added creation.

In the next part, we start by presenting what's a complex SC system and why the French WSC is relatively more complex, and highlighting the concept of entropy and information dissipation which it engenders

2 Supply chain system, entropy and information dissipation

Complexity is representing more and more an important explicative approach in various scientific fields, particularly in management sciences. Complex systems has 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). He postulates 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 which escapes the central system control. The non-holonic constraint has been described by Flood and Carson (1988, p.27) by the following expression "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) there are various companies; (b) there are high number and variety of relations, processes and interactions between and within companies (c) these processes and interactions are dynamic; (d) many 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 supply constraints or the needs of other demand point"*. More the SC is complex; more the traceability becomes a major issue in its management because 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 omplexity. Static or structural complexity is associated with the variety embedded in the system, involving the variety and the interdependences of the subsystems and 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 & oodcock 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) understanding, who has been primarily used this distinction to study complexity in manufacturing systems, Sivadasan et al., (2002) cited by Sivadasan et al., (2006), proposed 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 namely decision-making complexity which involves both static and dynamic complexity, should be considered (Manuj and Sahin, 2011).

We have to 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.

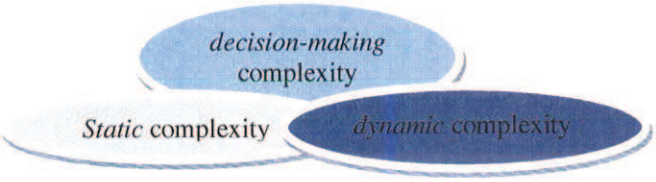


Figure1: Types of supply chain complexity

From the static perspective, the decision making process in the SC system becomes complex when making a decision is goes beyond the human capacity decision maker (Simon, 1974). From the dynamic perspective, the nonlinearity, the dynamic and the un-expected of the SC system behavior makes the complexity of 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 in 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 information 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 (Prigogine, 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 system can create a negative entropy, which is a essential factor in system organization, measuring the degree of order creation in the system and permitting the system to self-regulate (Brillouin, 1959), and moderate information dissipation within it.

3 The French wood SC

In this section, we will describe first 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 economical relationships between the foresters and the wood industries. In fact, the French forest-wood sector is fragmented into heterogeneous multi-activities actors. In upstream, there are a large number of foresters and small enterprises that are situated between the forest and sawmills which lack technologies and production capacity investment. In downstream, there are a 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 conducted in 2008 by the Department of Regional Planning in France: AGRESTE and the Technological Institute FCBA to point up on the important fragmentation level of the French forest-wood sector. This study allow us to show that the different activities necessary to transform wood in France require, in fact, the intervention of several heterogeneous actors. We think that this fragmentation don't creates conditions to better share information, simplify and standardize data exchange process between companies. According to the FCBA in France, the standardization of information in the forest-wood sector is representing a major issue in the absence of a unique data referential system adopted by all actors in the sector.

	Forest management	Sale of standing timber	Purchase of standing timber	Harvesting, Forwarding	Sale logs "on the road side"	Purchase logs "on the road side"	Transport	Sale logs delivered at the mill gate	Purchase logs delivered at mill gate	Number of companies in France
ONF (Public Forest Management)	■	■		■						1
CRPF (Regional Professional Center for Forest Ownership)	■									18
Forest management operators	■	■								195
Forest cooperatives	■	■		■	■		■	■		28
Supply companies (< 1 000 m3 : 1 687, < 10 000 m3 : 1 263, < 20 000 m3 : 247, > 20 000m3 : 343)										3 540
Independent			■	■	■	■	■	■		2 476
Integrated in an industrial group (mill)			■	■	■	■	■	■		1 064
Logging companies (800 harvesters, 1200 skidders, 1400 forwarders, 10 000 power saw operators)				■						7 000
Transporters										870
Independent Transport company							■			450
Integrated in a supply company				■	■		■			420
Wood industry										1 991
Sawmill						■			■	1 958
Pulpmill						■			■	11
Particle and Fiberboard mill						■			■	22

Source : Agreste 2008, FCBA

Figure2: Limited level on integration in the french wood supply chain

According to (Simchi-Levi et al., 2000) the lack of integration within a SC can be explained by the heterogeneity of the information systems and the format of exchanged data. This, leads to loss relevant information about the wood characteristics and its evolution in the SC. This increases the uncertainty about the qualitative properties and the measurements of logs and reduces the companies visibility, regarding scheduling and planning of their production and logistic capacity, which prevent them to provide the right product to the right client. This logs properties' visibility problem is central in our approach, that's why we have to do define visibility. Indeed, Gattorna (2009) defines the visibility as "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 leads on the one hand, companies to organize themselves into "Silos" approaches, and in 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., 2009).In fact, the SC management role is to eliminate the barriers by enabling the synchronization and sharing of valuable information among trading partners (Kouvelis, Chambers, and Wang 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.

For Moyaux et al., (2007) sharing information is considered as a mechanism of coordination that can reduces the bullwhip effect 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 actors' asymmetry access to information generated by their incapacity to share information. We can 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, revenues 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, reduce inventory levels and stock-outs.

The wood SC represents for us a relevant example to highlight the effect of the complexity, information dissipation and entropy on the SC visibility, information sharing and operation performance. Indeed, the WSC has a divergent structure (Vila et al., 2006) characterized by a single entry point to the raw material in upstream at the forest level 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.

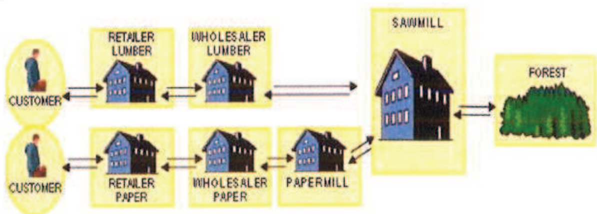


Figure3: The divergent nature of the forest products industry supply chain is simulated by dividing the material produced at the sawmill into chips and lumber (Wood Supply Game at FOR@C)

The French WSC is both fragmented into many autonomous but interdependent companies, and 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 is 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. Add to all of this, the WSC complexity is intensified by the interweaving of logistic flows to extract value from sawmills wastes to produce the co-products (paper pulp and energy), makes the WSC more difficult to manage..

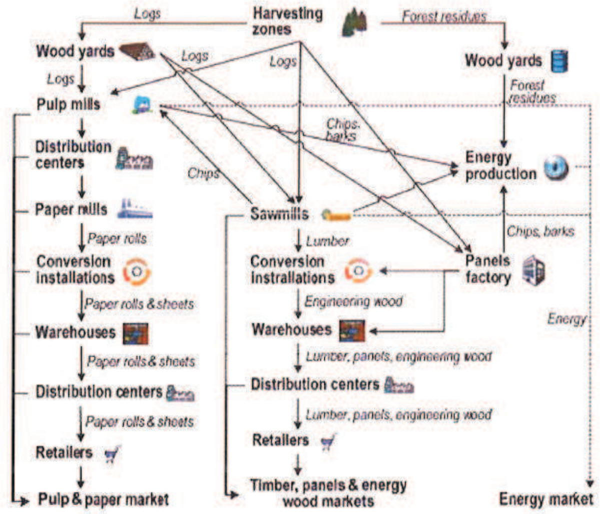


Figure4: The forest products value chain flows complexity

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

The complexity of the French WSC is amplified by the richness and diversity of wood. In fact, wood has always been considered a homogeneous structure and a bulk material. When 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 can be different in terms of their appearance, durability, strength, etc. Every wood market has its special requirements in terms of wood species and properties. This 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 structure in "V" makes essential, to maximize value extraction, the availability of information about logs properties. The access to these information can help to 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-utilization the wood what represents a source of wasting of natural resources and a waste of business profitability. To maximize WSC value-add, 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 this 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 frequency of changing wood supplier, 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 or use of information technology. This complexity makes the French forest wood a non-competitive at the European level despite its potential in terms of the wood richness, variety and available quantities. In the next, part, we develop our conceptual framework. Then use empirical results from an European project "Indisputable Key" to support our framework.

Conceptual framework: the French wood SC is an entropic SC

The research objective is to develop a conceptual framework to explain how the SC entropic behavior can decrease the operational performance and the value-added creation that characterized the French wood SC. Toward this end, we applied 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, we use the empirical evidence from the a pilot project in the use of RFID system in Europe to limit the dissipation of information on the wood quality. 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: particularly 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. That is why we 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 is characterized by 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. We can also categorized 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 is interesting only about the inherent complexity.

So, 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 our article we are interesting just by the inherent WSC complexity, that's why we will not study the external origin of complexity

	Internal	Supply/demand interface
Static	High number of wood product variety Divergent structure of the WSC	High Species diversity High number of WSC actors in France The fragmentation of the French WSC
Dynamic	Process uncertainties Log properties and quality uncertainty Forcast 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 (Investment difficulties in Technologies)	Open loop traceability system WSC Heterogeneous IT Non holonique (uncontrollable) constraint and WSC asymmetry

Figur5: Drivers of the French WSC complexity

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 think 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 involves additional costs (Frizelle & Efstathiou 2002) Within a WSC, all types of inherent complexity should be considered to improve overall 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 which is the information dissipation in the SC system by measuring and increasing the 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/SC, but involves additional costs and underperformance (Frizelle & Efstathiou 2002).

To cope with 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 to incomes revenues and 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 a convergent goals, they cooperate and share information which creates an organization factor called negentropy or order index. In the opposite, when SC actors have a divergent goals, they compete without sharing information increasing entropy or disorder degree. In our case, we consider that actors from the second transformation must to cooperate and share demand information with actors of the first transformation to enhance their own performance by getting supply visibility on the wood properties, which vital to eliminate or reduce the unnecessary complexity (reduce information dissipation or entropy), enhance operational performance and increases incomes revenues.

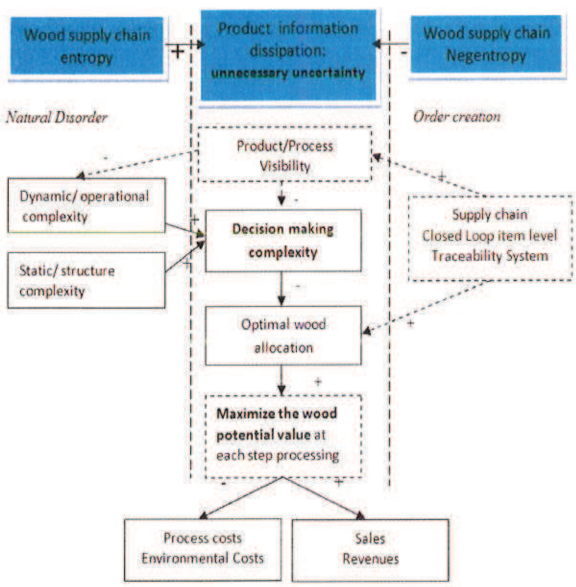
We are interesting by reducing decision making complexity by eliminating and reducing unnecessary source of uncertainty. About this, (Manuj and Sahin, 2009) have developed a model to identify antecedences of SC decision making complexity supported by the existing literature. However, they don't take 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 in product relevant information availability on the decision making complexity in
From the figure4, we can see that 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 to 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 additional cost. For (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, make 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, p.20). Concerning the nature of the SC performance, we consider as performance criteria the product sell value. More information is quickly available on the product, the more its value and its sale revenues (De Marco et al., 2012).

According to system theory and (Prigogine, 1955), 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 propose to this conceptual framework to highlight the role of a closed loop architecture traceability at the item level in order creation by enhancing the product/process visibility, moderating the operation complexity and optimizing wood allocation at each step processing in the SC. To mitigate the the SC entropic behavior, a RFID system can have a moderator by manifesting a negative entropy

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 et al. (2007).
Information imperfection	Tracks products precisely and improve the accuracy of the information. Improves information accuracy	Lee et al. (2004), Lee et Özer (2007), Heese (2007), Cannon et 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), Zhou (2009), Wang et al. (2008),
High uncertainty Decision making complexity Product sale revenues	Contributes to decrease the uncertainty in the SC Improves decision making Process cost savings, promises large potential benefits from revenue growth. increases sales	Cannon et al., (2008), Lin et al., (2006), Zhou (2009). (De Marco et al., 2012).

Figure6: RFID positive impact the SC entropic behavior

This can be consolidated by the following conceptual framework



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 which 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 a 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 to the traceability in the SCM by the maturity of the particular European legislation in food traceability and the need for transparency with the loss of proximity to production chains. 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 information secured and controlled information sharing, often this is intra-organizational traceability. When traceability system is in "open loop architecture" where the SC actors don't have homogenized their traceability systems, which can cause discontinuities in information flows. The good functioning of a traceability system essentially depends on the interoperability of inter-organizational ISs.

The first results of a battery of interviews that I conducted with the Association "AB" in the region Rhône Alpes in France and some experts of the FCBA allow me to conclude that a CLTS like a RFID system would achieve several objectives: make an economy of material by improving the efficiency of wood through better adaptation the production tool to different types of wood, enhance the transparency of wood products with eco-labels, reassure end users about the quality and correctness of their choices of wood, secure the modes exchange of products and establish 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. Until the writing of this article, there is no finished project to explore the potential of RFID system benefits in the French forest wood sector. fortunately, The project Indisputable Key (European research project, launched in October 2006 by a consortium of 28 partners from five countries and a budget of € 12.8 million. www.indisputablekey.com). According to the that project public documents, more than 25 million m3 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 these waste is the information loss along at each step wood processing in the WSC. To cope with these economical and ecological wastes, the ultimate mission objective of the project was to develop a methodology and an traceability based RFID technologies

that can improve the use of wood and optimize forest production trough the WSC minimizing environmental impacts. To do this, the technical solution was to use automatic traceability system and standardize all data communication within and between actors in the SC.
As final result, we can observe in the figure5 that a certain quantity of product information (original, cutting wood, measuring input sawmill, sorting pro ducts, etc..) generated, collected by different equipment and production machines are available during the process in progress, but for the most part lost during the following process.

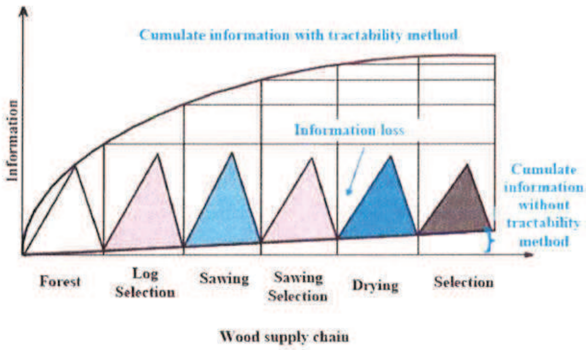


Figure7: Scheme of information losses at each step during wood SC (source: www.indisputablekey.com)

Figure7, shows that the quantity of information accumulated without a traceability system is significantly lower than those accumulated with a traceability system. Unfortunately, the major simulation outcomes with realworld 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 in maximizing the wood potential value by providing eco-certified products and wood quality adapted to the demand at the right price. We can resume RFID empirical benefits in the wood SC by:

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

By analogy to our conceptual framework, These empirical results represent both a "proof of the concept" of information dissipation within a complex system such as the WSC highlighting that the use of a traceability system using a biodegradable RFID technology. French WSC actors particularly sawmills, were able to stop rupture of traceability 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 an real image of wood evolution status at each stage of wood industry.
This reduces both the quantitative information dissipation and the loss of their relevance, which are 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 such as WSC, as the 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 it constitute important elements that contribute to making the SC system more stable. We propose that an effective management of the SC is the creation of order by Negentropy based RFID system traceability. The traceability in the forest context aims to improve the process operational complexity control and add value at best 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 that SC represents a 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 depending on dynamism, the interactions of the companies and the high level of the uncertainty. Third, the decision making complexity resulting of 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 better a supply chain is organized, the level of subsisting entropy decreases. This entropy is manifested in supply chain system disorder. It is 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 which usually have heterogeneous IT. The WSC is also asymmetric due to the fact that one of its part is not accessible to the others actors and its has a non-holonic constraint which escapes to the French WSCS second transformation industries control. Add to all of this, in the French forest SC the traceability system is 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 proposed the concept of Closed Loop Traceability System as a Negentropy based system order creation. In fact, in the WSC the role of a traceability system is to capture and conserve automatically 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 have based on the Indisputable Key project results to confirm our theoretical development. As seen above, the implementation of a RFID item level to track and trace wood from the forest to the market is a very big challenge the professionals. Recognizing the role of RFID to improve their operation performance and their competitively, the forest eco-interests and the RFID cost decreasing (Moore's law) should enhance the adoption of RFID in the French WSC.

In our further research we will develop a system dynamic based simulation model to highlight first, the impact of the Negentropy on the WSC industrial performance especially for the sawmill industries and secondly we will 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 reduction information dissipation which is the principal source of unnecessary uncertainty.

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