Risk information formalisation with graphs

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A B S T R A C T

The logistics is an essential economic activity that is intended to manage the physical and data flows (informative, customs and financial), in order to provide the resources corresponding to more or Jess determined needs in compliance with the specified economic and legal conditions (subject to the quality-of-service targets and the security and safety conditions are satisfactory). The links between formalized information, risk management in production logistics and adaptation to technological and market changes, are essential to industrial companies. In this paper, we have followed a structured approach, keeping within a formai risk management framework, for continually improving production logistics practices and procedures by experience feedback processes. The information derived from the risk assessment in production logistics is formalized by the conceptual graphs, permitting to ease the logical expressions and enhance the semantic quality of visual representation produced. The proposai is illustrated more clearly by a concrete case study of the production logistics adopted for aircraft manufacturing in an European Aeronautic Company.

1. Introduction

An industrial system, from a systemic point of view, is both an open system and a finalized system, meaning that it is conceived and managed according to some objectives. The objectives that can be assigned are numerous: the cost, the quality, the production volume, the delay and the sustainability. These objectives encountered can be classified into three main categories:

- Customer service improvement: understanding the needs, response time, quality and guidance provided.
- Cost contrai: the direct and indirect costs imposed on businesses.
- Productivity growth: the overall and individual productivity of the various actions.

The strategies of industrial systems that are intended to contribute to achieve these objectives can be challenging but their attainment helps to develop the economic potential and ensures the survival, protection and prosperity of the considered enterprises. This requires a level of productivity and profitability that is supported by the consistency and continuity of events occurring between the internai and externat environments. In particular, there is a growing need for promoting good risk management practices [23] in order to anticipate and prevent ail risks which may occur within the company and work continuously to eradicate them.

Risk management is defined as the identification, assessment, and prioritization of risks followed by the engagement of resources to treat (minimization or avoidance) and monitor the probability and/or impact of unfortunate events [13]. Furthermore, risk management is not limited to a purely static and negative outlook of these events. It also integrates a dynamic dimension showing a temporal distribution of the actions in the short, medium and long term with the options to exploit the realization of opportunities [19]. According to these constraints, the heart of the risk management is thus to find a suitable combination of provisional, preventive and curative actions, contributing to a significant reduction of the risks; and through the implementation of three main categories of risk analysis and assessment techniques (qualitative, quantitative, hybrid) [26].

In the industrial environment, within production logistics, the organization is often a full reflection on the way in which it could improve the means to achieve customer requirements and resources efficiency. Meanwhile, the production systems can operate in a constantly changing environment that causes the effect of uncertainty or hazards on target objectives (e.g. production rate of finished products). In this document, the selected domain of interest is ***production*** *logistics* that aims to

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ensure that each machine and workstation receive the right product in the right quantity and quality at the right time within a value- added system (e.g. a manufacturing unit or an industrial company) [28]. As the supply chain management encompasses ail logistics management activities, the production logistics is a part of the supply chain that streamlines and controls the flow of things (goods and services) through value-added processes.

The core characteristics of supply chain risk can be classified in three main categories [18]:

- Risk-affected objective (efficiency and effectiveness),
- Risk exposition : disruptive triggers (triggering event and probability), time-based characteristics, and affected supply chain (vulnerability and resilience),
- Risk attitude (aversion, seeking, neutrality).

The risk exposition is particularly determined by the occurrence of a triggering event, as well as by time-based characteristics of the underpinning supply chain. Indeed, ail the logistics associated with the production chain can be based on the importation of parts and tools from external suppliers. In such situations, there is an increase in the risk factors, particularly in terms of delays, non-compliance issues and damaged or missing parts. Add to this the internai factors of risks including the loss and damage of parts or tools, misunderstood requirements and overproduction. That is a disadvantage to the smooth functioning of the production systems of industrial companies and therefore with possible different risks, particularly in terms of the timetables and processes for delivery in the supply chain. Indeed, production logistics management is required to properly analyze the production chain and consider various risks to this chain in order to try to eliminate, minimize or overcome some of the generated drawbacks by reducing the vulnerability of enterprises.

The paper is structured as followed. Section 2 describes related research works. Section 3 exposes a process of risk management in production logistics with a focus on the risk identification and risk assessment. Section 4 presents the graph-based representation for a formalized description of risk information following identified production logistics risks and validates our approach with a real case study from the aeronautical industry. Section 5 provides a discussion on risk identification and assessment using formalization with conceptual graphs Finally, Section 6 gives the conclusion based on research findings and underlines some challenges.

2. Related works

According to standard ISO 31000 [17]. risk management should be a systematic and structured process (including establishing the context, risk identification, risk assessment, risk control and risk monitoring), which is capable of continuai improvement and enhancement. Risk management is of great interest to ensure continuity of production, proper supplies and the stability of the enterprise. In production logistics, each phase of the risk management process can be identified by the issues and questions that many researchers and engineers working in the field ask themselves:

- Risk identification: does it have a risk? What are the damages associated with risks in the enterprise and its partners? What is the impact on customers, on the organization, etc.?
- Risk assessment: what is the severity of a considered risk? What is the probability of a risk occurrence?
- Risk control: through the implementation of actions planned in the short, medium and longer term: how to master, contain and control a risk? By implementing techniques of prevention and protection measures (e.g. training of company personnel), it is possible to develop proper mitigation measures of a risk or shared it with some partners?
- Risk monitoring: What are the indicators to be put in place to monitor the evolution of risk and the effectiveness of a given action that was implemented?

This four-step process is cyclic and it may be supplemented, if necessary, by the assessment of the residual risks remaining after the risk response or after the application of risk mitigation measures. In spite of ail the measures and precautions aimed at reducing a risk, what consequences should follow on from the occurrence of this risk?

The literature comprises several methods on risk assessment in the field of production logistics; only two of the most well-known methods will be described: the Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) [30]. FMEA is a method that thoroughly analyses the elements and their failure mode features to assess risk and reliability in production systems. It begins by the decomposition of the system into subsystems. This method identifies and evaluates ail potential causes that may be sources of error to determine the effect they have at the element level. However, it does not clearly integrate element interactions but relies only on experienced knowledge.

FTA describes event itineraries from failure root causes to top-Ievel consequences. This method is applied in the production system to guarantee the safety and improve the reliability of product development. FTA is intend to permit an actor to detect ail serious routes that might lead to an undesirable event such as system malfunction or failure. Nevertheless, FTA also particularly depends on knowledge and experiences of stakeholders that are working in the target system. The collaborations and dynamics of the performance requirements are not sufficiently apprehended for supporting the principles of supply chain resilience in complex organizations of enterprises [20]. In practice, complex systems require means to supplement and reinforce the performance impact of their supplier integration operations through production logistics risk management policies in risky environments (40). Furthermore, with the increased competition among the production logistics of organizations, modelling is important for analysing the level of maturity in enterprise risk management in complex international companies (29). Such large companies have to comply with security initiatives and build a higher level of safety measures to reduce the frequency of supply chain disruption occurrences [32]. In an environment of networked enterprises, it is admitted that the identification and management of these supply chain disruptions and risks is therefore crucial for the effective management of production logistics [12]. Effective management of supply chain risks requires a comprehensive yet rapid assessment of internai and external sources of risk events in the supply chain and their potential impacts in complex production systems (e.g. manufacturing system) [1]. Simulation and optimization models can be combined through some iterative procedures to achieve the best values for risk reduction by selecting a combination of mitigation strategies [2]. lt is significant that most of the existing methodologies of risk management in production logistics lack inbuilt and practical techniques that take into consideration the complex interactions and dynamic feedback properties, which can meaningfully affect the reliability of risk management results (25].

ln the following section, a methodological approach is presented with three steps including risk identification, risk assessment and risk treatment. This methodological approach provides an information formalization for intluencing factors in risk management for production logistics.

3. Risk management in production logistics

In this paper, a major emphasis is piaced on the first three phases of risk management processes including risk identification, assessment and contrai, which are essentiaI to proper achievement of the next phase of risk monitoring. The proposed approach (see Fig. 1) applies the well-known Ishikawa diagram to a company case to identify root causes of the most important risks. Then we appiy the Failure Mode, Effects and Criticality Analysis (FMECA) technique to determine the criticality of those risks. Finally, we add a conceptual graph and a logical expression to visualize and describe the actions to be taken when dealing with certain risks.

The proposed approach is illustrated by the risk management in a leading Aeronautic company (belonging to the European Aeronautic Defence and Space Company (EADS)) with production and manufacturing facilities. In the following sections, we focus on the risk identification and risk assessment, with some suggestions for the risk contrais (sharing, reduction, or avoidance of risk).

3.1. Risk identification

The risk identification is made to categorize the production logistics problems encountered in the organization of a network of suppliers. So, the considered production logistics risks are associated with certain strategic and organizational choices of the company. More specifically, the focus is on the production logistics risks in the aircraft manufacturing induced either internally or externally by the suppliers, when the company is committed to respect deadlines and product quality in accordance with contractual obligations to the clients. Hence, the manufacturing, management and delivery of products are conditioned by the contractual deadlines negotiated between the company and the clients at the time the order is placed. Table 1 provides a summary of the identification of production logistics risks in the considered aeronautic context.

There is a strong interaction between the logistics and ail other enterprise stakeholders: marketing in the definition of products, studies and research in the design of these products, methods in the definition and provision means of production, trade for evaluating sales volume and orders, production for the realization of the products, but also quality, etc. Specifically, the considered experts are specialists involved in the logistics activities covering the organization of flows shares, planning, customer relationship upstream (orders), purchase and supply of components, inventory management, transportation and commissioning available, relationship to the downstream customer (delays, service rate), etc. Those experts include various transversal professions involved in the operation of major collaborative programs : project managers, quality specialists in project and product, logistics experts, but also of people dedicated to the planning, configuration management, customer support, etc.

On the basis of an empirical study of the available data and expert estimations on the various existing risks in the considered aeronautic company, it appears that assessment of the risks related to production logistics function are obviously presented in the form of a table (see Table 2).

In the Table 2, there are two colour scales which are intended to reflect the occurrence of a logistic risk and its potential severity. The first scale consists of four colour-coded occurrence levels (*Certain* (red), *Likely* (orange), *Possible* (honey), *Rare* (yellow)), and the second scale consists of three colour-coded severity levels (very *serious* (red), *serious* (orange), */ess serious* (yellow)). In Table 3, the risk rating is specified using a two-dimensional matrix, with severity in one axis and occurrence in the other.

Frequency describes how many times the adverse consequence being assessed will actually be realized. The frequency-based score is suitable in most situations and is easier to determine in practice. A simple set of definitions for frequency is described as follows: Rare (this will probably never happen/recur), Possible (Might happen or recur occasionally), Likely (Will probably happen/recur but it is not a persisting issue) and Certain (Will undoubtedly happen/recur, possibly frequently).

3.2. *Risk assessment*

Risks are typically analysed by combining assessments of severity (also described as consequence) and occurrence (frequency or likelihood) in the setting of existing contrai procedures. On the whole, a risk rating is specified using a two-dimensional matrix, with severity as one axis and occurrence as the other. Following the presentation of the risk mapping associated with the production logistics function in Table 3, we seek to analyze the most important risks from the mapping done according to their severity and their occurrence.

As regards the risk estimation, in order to reduce some disruptions throughout supply chains and the associated prohibitive costs, the working group of experts (including logistics experts and project managers and quality managers) structured reflections to deal effectively with the growing complexity of the logistics fonction. ln order to estimate risks, the experts elaborate some analysis concerning the deployment of the following elements: (i) a logistics protocol; (ii) benchmark assessments of logistics organizations and (lii) logistics performance indicators. Among the reflections, the group of experts also studied the possibility of developing a guide and a questionnaire for optimizing the implementation of collaborative engineering throughout the value chain, and for measuring the integration of analysis into professional practices. In this case, it is interesting to offer an

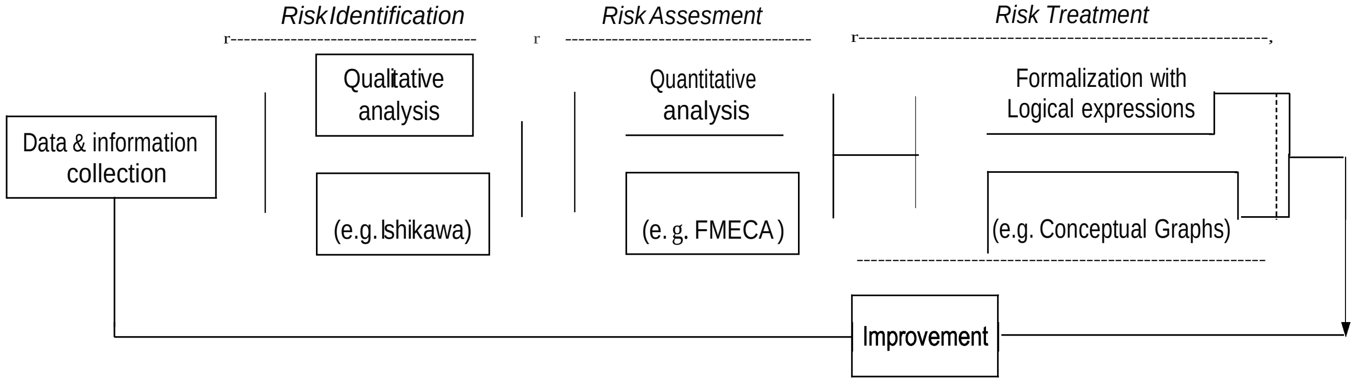

Fig. 1 the flowchart of the proposed research methodology.

Table 1
Identification of production logistics risks.

Risks engendered by the:		
Network of suppliers	Aeronautic companies	Companies commitments to logistics performance
• Risk related to non-compliance with quality	• Risk generated by strategic choices.	• Risk associated with waiting times.
• Risk related to procurement space.	• Risk generated by cost optimisation decisions.	• Risk generated by overproduction.
• Risk related to professional failures of production logistics and transport providers.	• Risk generated by shortage of stock.	• Risk associated with the delivery of finished products to the clients on the contractual dates and hours.
	• Risk generated by missing tools.	
	• Risk generated by non-compliance with quality.	

Table 2
Risk assessment related to the production logistics function.

Risk	Occurrence of the risk	Severity of the risk
n°1 :Risk related to non-compliance with quality.	Possible O	Very serious (major damage)
n°2 :Risk related to procurement space.	Possible O	Serious (important damage) Ü
n°3 :Risk related to professional failures of production logistics and transport providers.	Rare O	Serious (important damage) Ü
n°4 :Risk generated by strategic choices.	Likely O	Serious (important damage) Ü
n°5 :Risk generated by cost optimisation decisions.	Likely O	Serious (important damage) Ü
n°6 :Risk generated by shortage of stock.	Possible O	Very serious (major damage)
n°7 :Risk generated by missing tools.	Certain	Ve (major damage)
n°8 :Risk associated with waiting limes.	Likely O	ry serious Very serious (major damage)
n°9 :Risk generated by overproduction.	Rare O	(major damage)
n°10 :Risk associated with the delivery of finished products to the clients on the contractual dates and hours.	Certain	Very serious Serious (important damage) Ü

enriched analysis allowing quick examination of the situation in terms of logistics and customer supplier relationships. The proposed logistic performance assessment framework is used in bath the self-assessment and the external audit by the aerospace industry companies. The specified analysis defines six common logistics performance indicators that can be used by the supply chain partners (including carriers and logistics providers). These six indicators are combined to enable a standard measure of the performance and its development: (1) respect of the deadline for the arrivai of parts and transportation, (2) waming on anomalies in the loading, (3) number of incidents (forgotten or damaged parts), (4) waming on delivery delays, (5) occupancy rate in transport and (6) reliability of stocks.

The information exchanged with the experts helped to have a more comprehensive vision of the different industrial contexts. It is a crucial step to find through group assessment the most dangerous risks and their different causes. For instance, the very serious risks have been targeted through group discussions in collaboration with the key domain experts in the identified aeronautic industrial site. ln this way, the priority risks for this production logistics function were focused on a more restricted number of risks. The selected five very serious risks are the following:

Table 3
Risk mapping associated to the production logistics function.

	Rare	Possible	Likely	Certain
Very Serious		1, 9, 6	8	7
Serious	3	2	4, 5	1
Moderate				

- n°7: Risk generated by missing tools.
- n°8: Risk associated with waiting times.
- n°1: Risk related to non-quality.
- n°9: Risk generated by overproduction.
- n°6: Risk generated by shortage of stock.

The analysis of the root causes can take place using the Ishikawa diagram [[16,15,14]] (also called fishbone diagrams) for each identified risk. lndeed, this diagram is one of the seven basic tools of quality and its purpose is to break down (in progressive layers of detail) root causes that possibly contribute to a specific effect. Causes are typically grouped into main categories (People, Methods, Machines, Materials, Measurements and Environment) to identify the sources of problems. The root causes analysis is important to determine the relevant corrective actions to avoid reoccurrence

of identified problems and associated risks. For example, for the risk generated by missing tools, an Ishikawa diagram shows the root causes in Fig. 2. Particular attention is paid to certain parameters (state, lack of duplications, non-repairable and criticality). These contribute to better detection of the manufacturing tools requiring both an urgent analysis of the underlying causes and a deeper reflection on the most reliable methods for achieving a substantial and sustained reduction of risks.

The waiting times represent the time periods during the production where no value is added to the product, including the waiting time for materials, information, equipment, tools, stock-outs, long processing times, downtimes and bottlenecks. Thus, the waiting times causes some risks in the supply chain. For the risk generated by the waiting times, an lshikawa diagram shows the root causes in Fig. 3.

The non-quality is the difference found between the target quality and the quality actually obtained. Consequently, some elementary parts, components and tools can be obtained at a lower quality. This clearly lead to a risk of clearly some sub-standard outputs of the required products ordered by the clients. The non-quality is a risk which also engendered other problems: significant contrai costs, unexpected delays in deliveries, and the waiting times for production operations. For the risk generated by the non-quality, an lshikawa diagram displays the root causes in Fig. 4.

Overproduction is a production with supply exceeding consumer demand of products. lt can add to the cost of inventories, work in progress, additional transportation requirements, additional contrais, delays on other products, waiting times, and manufacturing slowdown or the interruption of the product flow. Indeed, it represents the worst forms of wastage, because it is the source of many others. For the risk generated by the overproduction, an Ishikawa diagram displays the root causes in Fig. 5.

The stock shortage represents the moment where the company's inventories are insufficient to meet the customer demand. Frequent shortages of stock causes some delays in carrying out tasks and thus a delay in the delivery of work, creating a negative picture of the organization. Moreover, the prolonged execution time may be behind the departure of certain clients following a crisis of confidence in business relationships regarding the client expectations. This can have a negative effect on the brand image and the economic performance of the considered aeronautic company. For the risk generated by the stock shortage, an lshikawa diagram displays the root causes in Fig. 6.

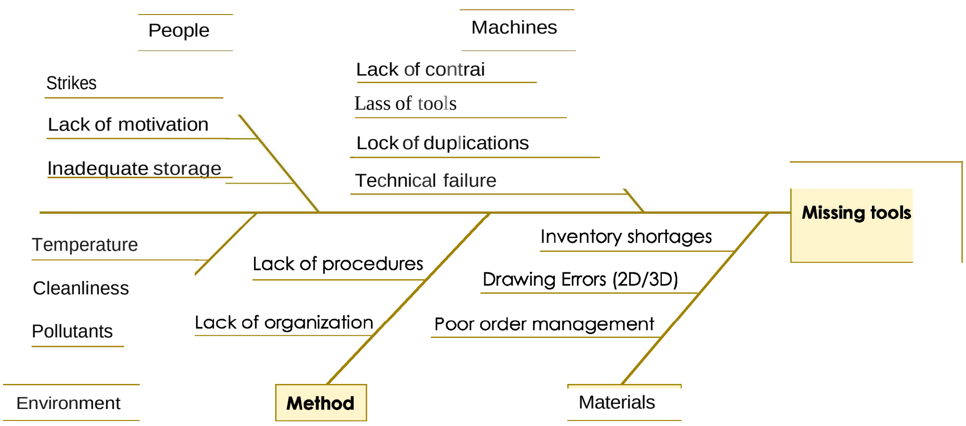

Fig. 2. Ishikawa diagram for missing tools.

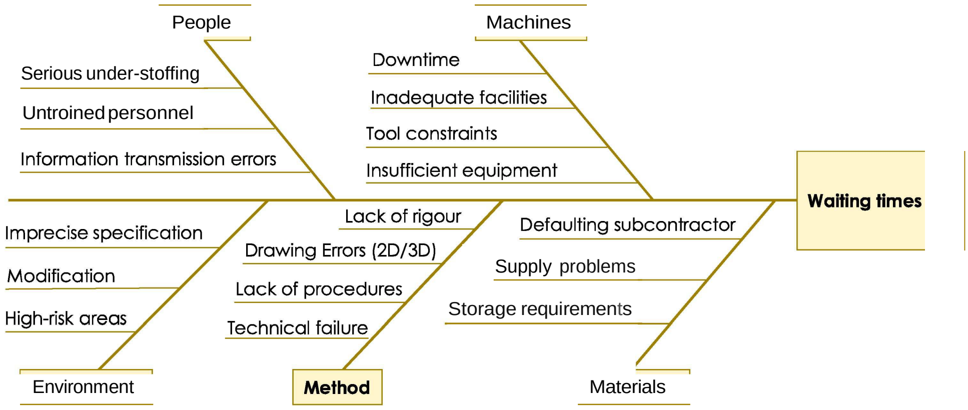

Fig. 3. Ishikawa diagram for the waiting times.

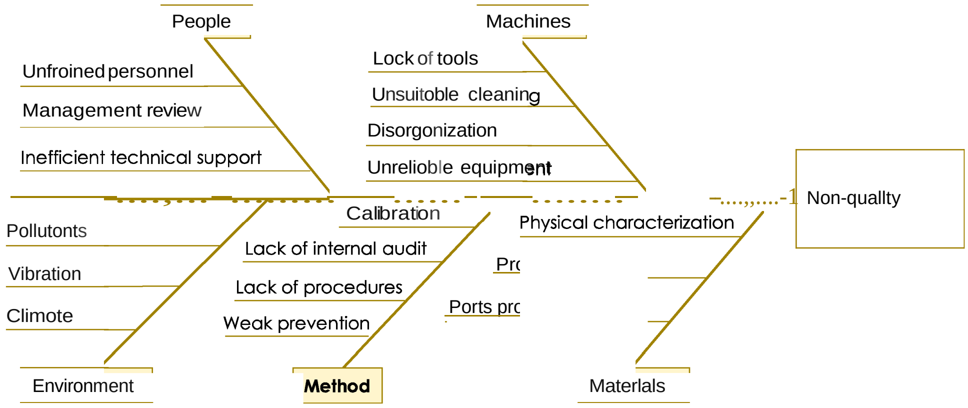

Fig. 4. lshikawa diagram for the non-quality.

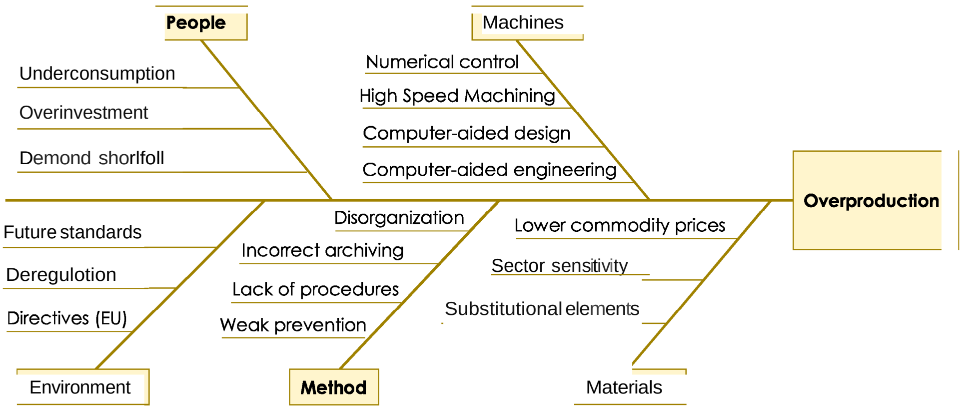

Fig. 5. Ishikawa diagram for the overproduction.

3.3. Risk treatment

In the risk assessment, we opted for the Failure mode, effects and criticality anaiysis (FMECA) [6], which is a reliability assessment technique allowing to study the potentiaI failure modes within a system. The FMECA is used to examine the associated parameters (detectability, severity and occurrence) of each identified risk, in order to determine their criticality. The risk priority calculation is a resuit of a multiplication of detectability x severity x occurrence and it provides a way to focus on the highest risks. Sorne recommendations are suggested according to their relevance to a specific risk; and are important to reduce the impacts of critical risks. In fact, these recommendations to manage the identified and assessed risks fall into four main categories [8]: avoidance, reduction, sharing and retention.

The different actions that can be used for recommendations of potential risk treatments are detailed in Table 4.

From an operational point of view, the benefits of this approach are many and varied:

- Identification of weaknesses in the system and suggested recommendations.

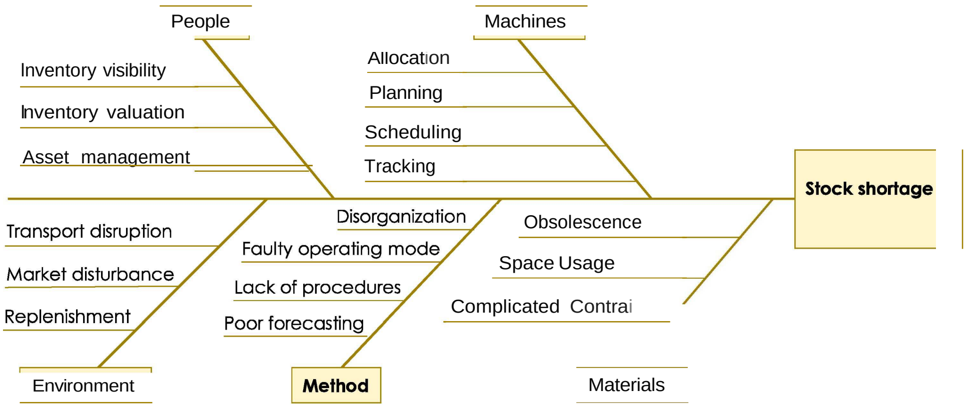

Fig. 6. Ishikawa diagram for the stock shortage.

Table 4
The type of actions recommended.

Type of action	
Avoidance	Action to eliminate, withdraw from or not become involved.
Reducdon	Action to optimize – mitigate the probability of the occurrence of the risk, while containing the causes of the risk to prevent its reoccurrence.
Sharing	Action to transfer – outsource or insure of the risk with one or more other parties.
Retenâon	Action to accept and budget the risk in order to limit the severity of adverse effects, when the risk occurs.

- Specification of the means to protect itself against certain failures.
- Study of the consequences of failures with regard to the different individual components.
- Classification of potential failures according to their impact on the risk management and mitigation actions.
- Incorporation of improvements identified through the business and operational process optimization with internai and externat controis.

The FMECA offive highest risks in the production logistics of the considered aeronautic company are described in Table 5 showing both numerical scoring and colour bandings. The risks situated in the cells identified with a red colour, are the risks that are most critical and that must be handled on a high priority strategy. The high risks are marked with an orange colour and the significant risks are marked with the yellow colour.

ln the aeronautic context, the advantage of this FMECA application resides in its assessable and functional description of identified risks and the fact that it suggests effective solutions to improve the production system and better manage the risks at the level of the production logistics fonction. For instance, in order to contrai the risk of missing tools, reverse engineering is recommended.

Specifically in order to deal with the risk generated by missing tools. reverse engineering is recommended. Reverse engineering is defined as the process of extracting design information or knowledge from anything man-made and re-producing it or reproducing anything based on the extracted information (9). In this case, the objective of the reverse engineering process is to produce an updated documentation of legacy manufacturing systems.

ln fact, some improvements on some earlier versions of many products have not been included in the technical drawings, so reverse engineering is useful for applications such as the updating of technical drawings of the outdated products without surface trimming or surface parameterization [11]. Indeed, a significant risk situation is one in which the manufacturing or contrai tools are not replaceable and do not have any duplicates. In case of a technical problem during the manufacturing process, their replacement will be too long given the complex and multi-layered nature of the production processes involved, together with the pressure for productivity. Ifa tool breaks down emergency reverse engineering will have to be used in order to manufacture the tool that allows the operations to continue in normal working conditions because it is difficult to create a new tool with existing 20 drawings. Therefore, it is important to carry existing physical geometry into numerical product development environments with 30 drawings and to create a digital 30 record that takes into account new modifications to recent product developments. Furthermore, it is noteworthy that reverse engineering became a practical method to make a 30 virtual mode! of an existing physical part for use in 30 computer-aided design (CAO), computer-aided manufacturing (CAM), computer-aided engineering (CAE) or other interoperable software [38,27,10,22,5,31]. In addition. an efficient reverse-engineered process can be used in an intelligent collaborative framework for minimizing redundant design stages and identifying design bottlenecks [24].

4. Conceptual graphs for formalized information of risk management

4.1. Conceptual graphs representation

Conceptual graphs were introduced by Sowa as a diagrammatic system of logic with the purpose "to express meaning in a form that is logically precise, human readable and computationally tractable" [35]. Conceptual graphs encode knowledge as graphs and thus can be visualized in a natural way (36).Thus, the graph-based technique is used to represent information and knowledge about a considered domain [37] (e.g. the risk management).In fact. the formai conceptualization of shared representations

Table 5
The FMECA for the highest risks in the production logistics of the target aeronautic company.

Type of Risk	ldentified Risks	Occurrence (1-5)	Severity (1-4)	Detectability	Criticality (0 x S x D)	Action Plan	Type of Action
Internai risk	n°7 :Risk generated by missing tools.	4	3			Reverse engineering	Avoidance
Internai /Externat risk	n°8 :Risk associated with waiting times.	2	3		6	To outsource the adaptive opportunity management taking account of the manufacturing cycle and the most utilitarian allocation of resources.	Sharing
Internai /Externat risk	n°1 :Risk related to non-quality.		4	3		To ensure that a drawing (3D) conforms to the manufactured products (conformity assessment)	Reduction
Internai risk	n°9 :Risk generated by overproduction.		4	2	8	To apply Just-in-time (JIT).	Reduction
Internai risk	n°7 :Risk generated by stock shortage		4	2	8	To have a pertinent safety stock of finished parts for a minimum of one week.	Avoidance

significantly influences the manner in which collaborative work takes place, as evidenced by their contribution in the exchange of information and generated knowledge [21,34].

The factual and procedural knowledge are based on the representation of concepts and their relationships. This representation is encoded by a labelled graph, with two kinds of nodes, respectively corresponding to concepts (view by drawing a rectangle) and relations (view by drawing an aval), whereas edges link a concept node to a relation node. [7].Conceptual graphs have an operational semantics in first order logie and the decidability and complexity of the associated reasoning problems (consistency and deduction) has been analysed and discussed by some authors [3].Later, this decidability and complexity analysis was refined and interpreted with a coherent global view of decidable classes with conditions on conceptual graph rule dependencies and formai reasoning mechanisms (forward and backward chaining) [4].

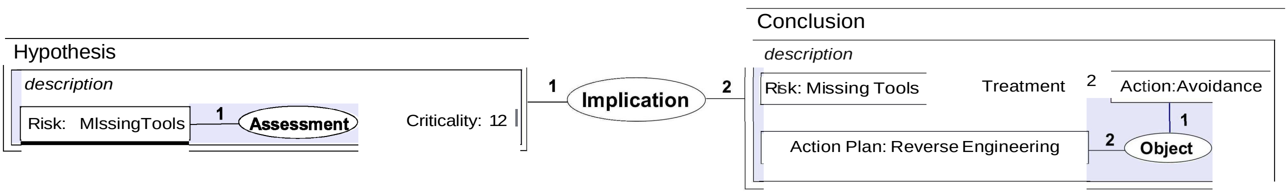

Fig. 7. A conceptual graph modelling a risk situation of missing tools.
Logical expression: (Risk (Missing Tools) /\ Criticality (12) /\ Assessment (Missing Tools, 12)) (Risk (Missing Tools) /\ Action (Avoidance) /\ Action Plan (Reverse Engineering) 11 Treatment (Missing Tools, Avoidance) 11 Object (Avoidance, Reverse Engineering))

A conceptual graph mie expresses implicit knowledge of the form: "if hypothesis, then conclusion", where the hypothesis and conclusion are both basic graphs. Using such a mie consists of adding the conclusion graph to some facts when the hypothesis graph is present. There is a one-to-one correspondence between some concept nodes of the hypothesis with concept nodes of the conclusion. Two nodes in correspondence refer to the same entity. These nodes are said to be connection nodes. The knowledge encoded in mies can be made explicit by applying the mies to specified facts.

4.2. Infonnation fonnalization of production /ogistics risks

After applying the FMECA for the production logistics risks, there is a need to formalise information of production logistics risks. So, the relevant conceptual graph mies are created to facilitate understanding of the logical description of the formalized information. In the considered study, only mies related to five highest risks in the production logistics will be examined. The associated concepts are "Risk", "Criticality", "Action Plan" and "Action". *Action Plan* is a concept describing the potential actions *(avoidance, reduction, sharing* and *retention)* to manage identified risks.

Fig. 7 represents the modelling of the risk generated by *missing tools* with an associated mie in the conceptual graph formalism. The mie in Fig. 7 means, if a risk is caused by missing tools (industrial resources) with a criticality value equal to 12 then the recommended action should be *avoidance* having as its object the *action plan* of reverse engineering.

Fig. 8 represents the modelling of the risk associated with the *waiting times* through an associated mie in the conceptual graph formalism. The rule in Fig. 8 means, if a risk is caused by waiting times with a criticality value equal to 6 then the recommended action should be *sharing* having as its object the *action plan* to outsource the adaptive Opportunity Management (OM) taking account of the manufacturing cycle and the most utilitarian allocation of resources.

Fig. 9 represents the modelling of the risk associated with the *non-quality* through an associated mie in the conceptual graph formalism. The rule in Fig. 9 means, if a risk is caused by *non-quality* with a criticality value equal to 12 then the recommended action should be *reduction* having as its abject the *action plan* to ensure that a drawing (30) conforms to the manufactured products (conformity assessment).

Fig. 10 represents the modelling of the risk generated by *overproduction* with an associated mie in the conceptual graph formalism. The rule in Fig. 10 means, if a risk is caused by *overproduction* with a criticality value equal to 8 then the recommended action should be *reduction* having as its object the *action plan* to apply just -in-time.

Fig. 11 represents the modelling of the risk generated by *stock shortage* with an associated mie in the conceptual graph formalism. The mie in Fig. 11 means, if a risk is caused by *stock shortage* with a criticality value equal to 8 then the recommended action should be *avoidance* having as its object the *action plan* to have a pertinent safety stock offinished parts fora minimum of one week.

5. Discussion

5.1. Risk identification and assessment

Major risks identified in the context of our case study and engendered by suppliers include the risks related to (1) non-compliance with quality, (2) procurement space, and (3) professional failures of production logistics and transport providers. Risks identified and engendered by aeronautic companies include the risks generated by (4) strategic choices, (5) the cost optimization decisions, (6) the shortage of stock, (7) missing tools, and (8) risk generated by non-compliance with quality. Other major risks identified and engendered by commitments of companies to logistics performance includes the risks associated with (9) waiting times, (10) overproduction, and (11) the delivery of finished products to the clients on time.

The keys domain experts include the logistics experts, the project managers and the quality managers who remain at the forefront of main risks. They play a significant role in providing experiences and advices to constmctors and equipment manufacturers, who need to have means of actions encouraging risks reduction and mitigation. These experts investigate and develop conceptual enhancements for reducing the risk of supply dismptions and the prohibitive costs. They provide stmctured reflections to effectively deal with the growing complexity of the logistics function and to enhance the competitiveness of the product and service offered to its clients. .

We exchanged information with experts from different industrial contexts and found through group assessments the most dangerous risks and their different causes. Particularly, we analysed the above ten major risks with a mapping associated with appropriate production logistics functions. In collaboration with key domain experts in the identified aeronautic industrial site considered, and using group discussion, we narrow down and ranked the identified ten major risks identified in our case to the following five critical risks: **(1)** risk generated by missing tools, (2) risk associated with waiting times, (3) risk related to non-quality, (4) risk generated by overproduction, and (5) risk generated by shortage of stock.

FMECA (Failure mode, effects and criticality analysis) was adopted in this paper as reliability assessment technique to study potential failure modes in our case study. The FMECA of the above five highest critical risks in the production logistics of the considered aeronautic company is quantitatively described as follows: **(1)** missing tools risk has 80% of occurrence, 75% of severity, 33% of detectability and 100% of criticality, (2) waiting time risk has 40% of occurrence, 75% of severity, 33% of detectability and 50% of criticality, (3) non-quality risk has 20%

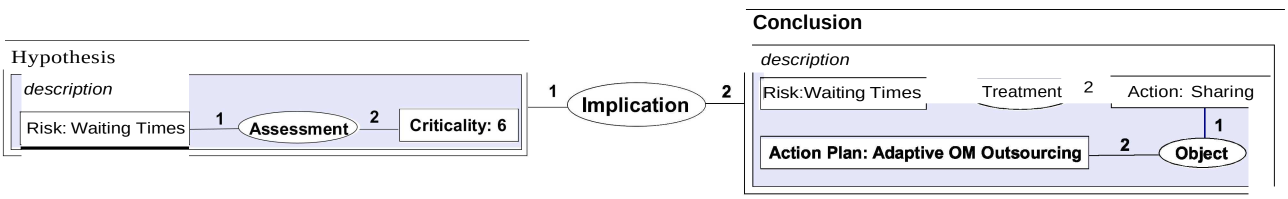

Fig. 8. A conceptual graph modelling a risk situation of waiting times.
Logical expression: (Risk (Waiting Times) ∧ Criticality (6) ∧ Assessment (Waiting Times,6)) , (Risk (Waiting Times) ∧ Action (Sharing) ∧ Action Plan (Adaptive OM Outsourcing) ∧ Treatment (Waiting Time, Sharing) ∧ Object (Sharing, Adaptive OM Outsourcing))

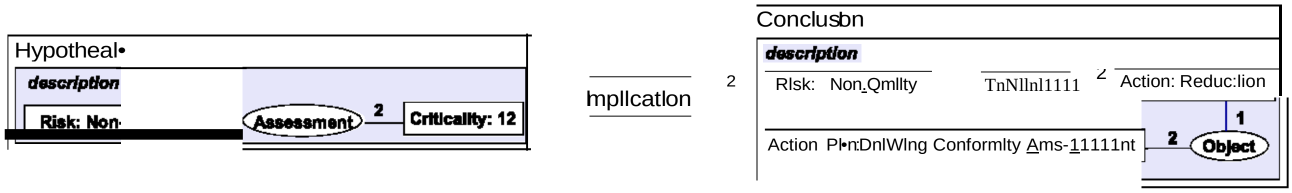

Fig. 9. A conceptual graph modelling a risk situation of non-quality.
Logka1expression: (Risk (Non-Quality) Il Criticality (12) Il Assessment (Non-Quality,12)) --+ (Risk (Non-Qµality) Il Action (Reduction) 11 Action Plan (Drawing Conformity Assessment) /\ Treatment (Non-Quality, Reduction) /\ Objec:t (Reduction, Drawing Conformity Assessment))

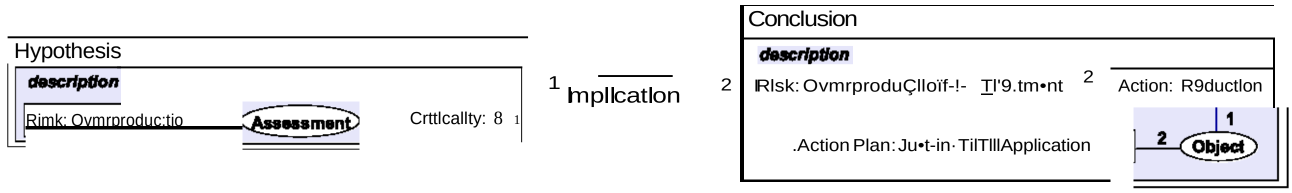

Fig. 10. A conceptual graph modelling a risk situation of overproduction.
Logka1spre5slon: (Risk (Overproduction) Il Criticality (8) Il Assessment (Overproduction, 8)) , (Risk (Overproduc:tion) Il Action (Reduc:tion) Il Action Plan Uust-in-Time Application) Il Treatment {Overproduction, Reduction) Il Object (Reduction, Just-in-lime Application))

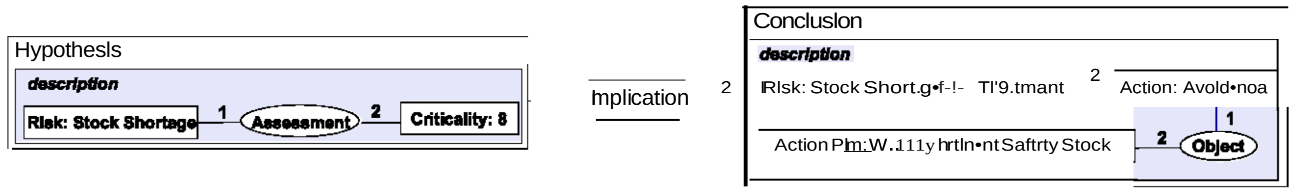

Fig. 11 A conceptual graph modelling a risk situation of stock shortage.
Logka1ll!:XPl'l!llSion: [Risk (Stock Shortage) Il Criticality (8) Il Assessment (Stock Shortage, 8)) --+ {Risk(Stock Shortage) Il Action (Avoidance) 11 Action Plan (Pertinent Safety Stock) /\ Treatment (Stock Shortage, Avoidance) /\ Object (Avoidance, Weeldy Pertinent Safety Stock))

of occurrence, 100% of severity, 100% of detectability and of 100% of criticality, (4) over-production 20% of occurrence, 100% of severity, 66% of detectability and 66% of criticality, and (5) stock shortage 20% of occurrence, 100% of severity, 66% of detectability and 66% of criticality.

5.2. Conceptual graphs and fonnalizations

In the case study described and examined in the aeronautic demain, a significant observation that can be made about the information and knowledge representation is the fact that experiences associated with the production logistics risks can be modelled using conceptual graphs. The visual modelling is enriched with logical expressions of formai rules to consolidate the reasoning process in risk management. The format visual representation of information and knowledge is intended to help relevant actors (within industrial production logistics organization) manage more efficiently at-risk situations with which they are confronted in their working situations. The operational procedure is to use computerized conceptual graph operations to highlight high-risk situations needing thorough investigation of observed facts and potential consequences. Dy structuring an experience knowledge base that includes descriptions of tessons leamt, it is possible to simplify the re-use of complex risk categorizations. lt analyses as well as the c:ontinuous improvement, enhancing existing practices with new arguments and interpretations.

As regards the aeronautic company of the case study, the evaluation of production logistic:s risk is thoroughly related to the objectives that are required to be achieved by the underlying production logistics organization. The Ievel of attainment of these objectives is determined by on the exposition of the identified production logistic:s organization towards unanticipated and uncertain evolutions in the internat and external collaborative partnerships in a globalized economy. Rigorous knowledge reasoning instruments (such as those provided by conceptual graphs) may enable companies to formalise risks more easily and tomanage their production logistics risk exposure more efficiently. ln accordance with its ability to handle the disruptive triggers, production logistics organization might also outline some guiding principles (formai rules from tessons learnt) for the risk management within a continuai improvement process. The company may use engendered tessons learnt and time-based characteristics to better manage its risk attitude and for potential improvements of risk treatments in its production logistics organization.

6.Conclusion

Risk identification (source analysis or problem analysis) and assessment polides have a fundamental and influential place within the business management of the enterprise system. Risk management in production Iogistics is particularly important in terms of manufacturing, transportation, inventory and provision of products or services. It is aimed at managing risks in complex and dynamic procurement and collaborative networks with variable customer requirements [39]. Production logistics risk management usually involves four processes: identification, assessment, contrai, and monitoring of production logistics risks. ln this paper a major emphasis is placed on the phases of risk identification and risk assessment with some recommended actions for risk contrai. Thus, improved reasoning is intended to manage risks and opportunities to advance their potential treatments through visual and logical modelling and figures prominently in the proposed approach to formalise information and knowledge for production logistics risk management.

To salve the initial problem of logistic risk management, we followed a structured approach with quality management tools. ln particular, we have established a methodology including the following three steps:

- For the risk identification in production logistics, the root causes for each type of risk are determined (source analysis or problem analysis) by using the lshikawa Diagram
- For the risk assessment in production logistics, FMECA is applied to highlight the highest risks, as well as providing recommendations to treat them.
- For the risk contrai in production logistics, conceptual graphs are used for visual modelling and formai reasoning with associated logical representation.

As a result of the formai representations chosen, the logical characteristics of conceptual graphs are used to represent formai rules for reasoning about risk modelling in production logistics. In conjunction with Ishikawa Diagram and FMECA, they can also be useful us to better understand the causes and consequences of significant risk situations with potential recommendations actions of risk contrais (reduction, avoidance or sharing). Hence, the generated lessons learnt and associated knowledge can contribute to ease continuai improvement and enhancement in risk management [45,44,41-43].

The research approach proposed can be used as a starting point, or it can be included in a decision support system [33] that allows risk managers to analyze, reduce or avoid the risk's detrimental effects, with integration of experts' knowledge and data provided by computational models. This is in line with the perspectives envisaged in our future research works in the risk management which calls for more graphical, formai and effective reasoning procedures in the field of production logistics.

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