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6. CONCLUSION AND PERSPECTIVES

6.1. CONCLUSION

This PhD thesis deals with the solving of industrial problems in distributed contexts such as the supply chains. It provides a novel approach that emphasizes not only in the disciplined and structured approach required to tackle problems impacting the products that move across the supply chain. It also stresses on its extension to cover all the dynamics and aspects underlying the operation of the network and impacting the effectiveness of the process. Finally, it positions the experiential knowledge as a central lever of the process to contribute to the continuous improvement strategies at a more global level. Those elements, driving this research work, have been addressed from a global perspective and, in consequence, they have been articulated as part of a unique approach dealing in a consistent manner with all the problem solving, supply chain and experience feedback aspects.

The approach established by this research has been structured in terms of two main results:

- **Conceptual framework**: a body of knowledge, useful for studying the problem solving process within the frame of distributed contexts and integrating experience-based systems, has been developed. The conceptual framework, proposed as part of this point, contributes mainly with a new perspective for the study of the process. This is particularly important and represents a significant contribution to the three disciplines involved in this research. This can be explained because before this project, as far as we know, no research works or problem solving methods dealing with those three aspects as part of an integrative approach have been undertaken.
- **Process and Methodology**: the second driver of the proposed approach, established on the basis of the first one, is based on the proposal of both a generic process and a global methodology. Unlike the first point, providing the extent for understanding the principles and key factors behind the problem solving, the second one provides a set of elements enabling the effective solving of distributed problems in practice. This is significantly important in the frame of the highly competitive and rapidly changing marketplace, on which supply chains require effective methods to solve the problems impacting their performance and operation.

The **conceptual framework** has been established from a study combining both a review of the literature and a benchmark of the constructs used in the practice of the three disciplines positioned at the meeting point of this research. Thanks to this study, it has been shown that:

- The *Problem Solving Process* is a central element of the continuous improvement strategies of firms. In consequence, they make significant efforts to implement effective methods for eradicating the root causes at the origin of the problems, so that they are solved and they do not reoccur. Nevertheless, and unlike the existence of robust and well-tried methods, their effectiveness has been proven exclusively for problems within the firms' perimeter. Then, the effectiveness of those methods is strongly reduced when problems go beyond the boundaries of a single firm and, in consequence, they are unable to provide solutions when the contexts on which firms operate are distributed.

- The study of the *Supply Chains* allowed establishing, indeed, the list of aspects required to enable the effective operation of a process for solving problems issued from and in the frame of a network of partners. Those aspects, disregarded by existing methods, have been organized in three main categories:
    - **Modeling and operation**: the first category considers that, in order to solve problems at the supply chain level, it is necessary to position the process as a real key integrative process running the length of the network and not as the result of the residual action of disconnected local approaches. This category identified the requirements in terms of integration and coordination of the process as part of the supply chain. It also studied the models that support its operation.
    - **Technical aspects**: the second category laid out the importance of integrating, as part of a distributed process, a robust set of constructs enabling the modeling, gathering and consolidation of information and pieces of evidence related to the products moving through the supply chain, the processes that support their operation and the structural aspects influencing the configuration of the network. Those elements, setting out the technical dimension of the networks, can be critical in contexts in which problems, products, information, problem solvers and skills are extremely distributed, fragmented and decentralized such as in the supply chains.
    - **Collaborative aspects**: the third category highlighted the necessity for considering the collaborative and relational aspects underlying the relationships between the firms of the network. It has been demonstrated that aspects such as the trust, the power, the interdependence or the level of communication can lead to either success or failure of the process. This depending on whether or not they are considered and the way they are integrated into the process.
- Finally, and thanks to the study of the *Experience Feedback Systems*, this work shown that the experiential knowledge derived from the process could be capitalized and reused at a supply chain level to facilitate the solving of new problems. It has been demonstrated that, as well as for the problem solving, the constructs and concepts of the existing experience feedback models need to be re-thought in order to operate in more distributed contexts.

The study of the problem solving in light of both the supply chains and the experience feedback process, which led to the establishment of the conceptual framework, sets the foundations from which both the generic process and the global methodology have been developed.

In order to address the points and requirements developed as part of the conceptual framework, and based on the study of the interactions between the contributing disciplines, a **generic process** has been proposed. This process has been defined in two steps:

- Firstly, the generic problem solving process has been improved in a way such that it enables to deal with all the challenges imposed by its operation in networked and distributed contexts. It has emphasized not only in the disciplined approach required to solve the problems but, in addition, it has been defined to deal with problems for which: (1) problem and solutions spaces are spread through the network, (2) information, evidence and skills required to solve the problem are fragmented and distributed, (3) multiple partners among the network are concerned and there is not a single partner with the global picture of the problem, (4) the root causes at its origin may converge from multiple sources in the upstream flows and finally, (5) the relationships between partners are influenced by relational factors. The generic process that has been developed provides the extent through which partners of a supply chain can coordinate themselves to jointly solve a common problem characterized by the aspects above. To reach this objective, the proposed process has been specified on the basis of two structural elements. A **multi-level root cause analysis** approach, able to deal with the investigation of the causes at the origin of complex problems in distributed contexts, sets the first pillar of the process. Based on the breakdown of problems into more manageable entities, this element describes the structure of a given distributed problem as a set of nested sub-problems studying all the causes of the problem. Then, and considering that specific competencies and information can be required to study the different causes, a **generic four-step approach** is deployed, when necessary, at each problem/sub-problem stage. This approach, corresponding to the second pillar of the process, provides the disciplined approach required to solve problems in distributed contexts. It proposes a generic problem solving method based on four steps, each of which has been revised and improved to operate in distributed contexts. The interaction between both the multi-level root cause analysis and the four-step approach enabled the proposal of a generic process for the solving of complex problems, even if they are distributed across a network of partners.
- Secondly, and in order to position the process as a central lever of the improvement strategies at the supply chain level, it has been supported by a **distributed experience feedback system**. As part of this integration, the definition of an extended architecture able to deal with both the capitalization and reuse of the contextual knowledge derived from the solving of a given problem within distributed contexts has been specified.

The generic process represents a significant contribution to the problem solving area because it provides an extended and generic approach that deals simultaneously with all the problem solving, supply chain and experience feedback requirements. Additionally, it can be applied to the solving of problems that go beyond the boundaries of a single firm in a way such that it promotes the potential for collaboration between partners of the network.

As stated in the introduction, the purpose of this research work does not lie exclusively on the academic contributions to the problem solving and supply chain fields, but additionally on their extension to be applicable in practice. This strategy has been mainly achieved thanks to the establishment and proposal of a **global methodology** providing the extent required for the application of the generic process to solve distributed problems. The proposed methodology extended and structured all the process principles through three modules dealing respectively with the problem solving, the supply chain and the experience feedback (PSm, SCm, EFm). To ensure the operation of the methodology and enable the interaction between the modules, a set of six dedicated mechanisms supporting the methodology has been specified (FiM, PaM, CoM, CaM, ReM, AmM).

Each of the methodology **modules** accomplishes a particular mission and supports a certain part of the overall process. The more important results of the modules and their contribution to the collaborative solving of problems within distributed contexts are discussed hereinafter:

- The **PSm** (Problem Solving module) provides the disciplined approach and the workflow required to solve a problem. As well as for the generic process, this module is based in the articulation between both the ML-RCA and the G-PSP concepts. The **ML-RCA** defines the general structure of a given problem by the juxtaposition of two complementary flows: a top-down flow leading to the definition of the root causes and a second bottom-up flow leading to the definition and implementation of distributed solutions across the network. The **G-PSP** defines the critical steps required at each problem/sub-problem. It defines the steps and the framework through which the problems are solved.
- The **SCm** (Supply Chain module) acts as the enabler of the problem solving to operate within distributed contexts. It is based on a **two-layered approach** that provides a robust mean for modeling, studying and tracking all the elements of the network that are critical in light of the solving of problems occurring across it. This model articulates as part of a unique proposal the modeling of both the technical and collaborative dynamics of the network. Thanks to the support mechanisms, all this information can be used during the solving of a given problem to improve the critical steps of the process. Then, the first technical layer (**TBS**), addressing all the product, process and network related information of the network, can be filtered to obtain a meaningful set of evidence contributing to the understanding of the problem. Additionally, the second collaborative level (**CBS**), clustering the partners of a network on the basis of relational aspects, can be used to improve the assessment of partners in light of the definition of a team of capable and compatible partners. The two-layered model (TBS+CBS), as well as the supply chain knowledge capitalized through it (i.e. the SCK), plays a major role since it improves the effectiveness of the problem solving process in distributed contexts.
- Finally, the **EFm** (Experience Feedback module) enables the capitalization of the problem solving experiences into dedicated entities (ESSs) containing all the contextual information useful for understanding the process that led to its solution. This experience-based knowledge, stored into a dedicated problem solving repository (i.e. the PSK), can be reused to improve particularly the analysis of new similar problems.

Even if the three modules setting the methodology (PSm, SCm, EFm) cover aspects of the generic process that are different in nature, their relevancy is based on their interactions and the synergies they have to improve the overall problem solving process. In consequence, their articulation is a fundamental aspect with respect to the effectiveness of the process in distributed contexts. This is the reason why a dedicated set of mechanisms supporting the interactions between the modules has been integrated to the methodology.

Six **mechanisms** have been defined (FiM, PaM, CoM, CaM, ReM, AmM) in order to support the critical steps that involve simultaneously the interaction between more than one of the methodology modules. Each mechanism has been specified on the basis of operational models, tools and algorithms that enable the achievement of the methodology objectives in practice.

- The **FiM** (Filtering Mechanism) improves the gathering across the network of a meaningful set of evidence and its consolidation in light of a particular problem. It is able to filter the TBS to keep exclusively the elements that are relevant in light of the problem being faced. Those elements, structured through both a structural and a conceptual TBS, contribute to the understanding of the problem and the contexts that surrounds it. This mechanism is particularly important to face the inherent distribution and fragmentation of information and evidences across a network.
- The **PaM** (Partners assessment Mechanism) improves the assessment of partners distributed across the network prior to the constitution of the team. This mechanism allows evaluating both the technical and collaborative performance of partners in light of a particular problem. Then, it not only ensures that the more capable partners (i.e. partners with the ability to solve the problem) but also the more compatible ones are selected as part of the team of experts. Based on the estimation of a *capability* and a *compatibility* index, this mechanism enables to determine the degree to which the participation of each partner has a positive impact on the team operation. Both indexes, as well as the mechanism for its calculation, have been specified and integrated in a way such that they enhance the selection of a team of experts in the frame of distributed contexts.
- This mechanism is completed by the **CoM** (Collaboration Mechanism) that integrates the evaluation of the preference degree of the partner leading the process and defines the strategy for the constitution of the team. Based on both, the PaM and the CoM, the team constitution phase is significantly improved and able to deal with the relational dynamics underlying the supply chains.
- The **CaM** (Capitalization Mechanism) and the **ReM** (Reuse Mechanism) play a major role since they support both the capitalization of the experiential knowledge and its reuse to improve the solving of new similar problems. In addition to the contextual knowledge derived from the process, the CaM contributes to the capitalization and generalization of the partners' collaborative performance, which is a central lever for positioning the collaboration at the heart of the supply chain operation. It enables the evaluation of the *proven compatibility* between partners of the network and the *collaborativity* measuring the extent to which a partner is involved in the collaborative practices of the supply chains. The ReM, and the mechanism supporting the retrieval and reuse of information, provides a hybrid approach that evaluates the similarity between problems in terms of

both the problem attributes and the network structure. This is a key factor for the establishment of a distributed experience feedback system.

- Finally, the **AmM** (Action management Mechanism) has been defined to emphasize the necessity of dedicated mechanisms to effectively coordinate the partners and ensure that actions are defined and reached in a timely and cost-effective manner.

The mechanisms not only support the operation of the methodology in practice but also contribute to the establishment of a novel set of constructs providing a concrete approach to solve industrial problems.

The articulation of all the modules and mechanisms as part of a unique approach ensures the effectiveness of the proposed methodology to solve distributed problems from a new perspective based on collaboration. The benefits of such a methodology, stressing on the problem solving as an integrative process of the supply chain, has been illustrated all along the document through its application into a simplified case study. The case study allowed, indeed, illustrating and validating the applicability and relevancy of the proposed approach, the methodology and the mechanisms to answer industry needs in terms of quality and continuous improvement solutions. Unlike the existing methods in the area, the proposed approach deals with distributed problems and with the capitalization and reuse of the knowledge derived from its solving process. This is an important factor in light of the increasing emphasis in the supply chains and the strengthening of the time, quality and performance requirements that are exhibited by current markets on which firms operate.

Some aspects have not been developed as part of this PhD thesis but deserve, however, further research in order to envision the integration of the proposed methodology as part of more global strategies contributing to the quality management and other fundamental practices of the supply chain. These aspects, potentially broadening the scope of this research, are discussed in the next section.

6.2. PERSPECTIVES FOR FURTHER RESEARCH IN THIS AREA

Three perspectives have been identified. Two of them are particularly interesting from an academic point of view since they suggest possible courses of action that could continue to broaden the understanding and scope of the three contributing disciplines underlying this research. The third perspective, concentrating on the next steps foreseen to improve the implementation in practice of the global methodology, is discussed at the end of this section.

6.2.1. Integration of the proposed methodology with other supply chain processes

Once implemented, the proposed methodology should contribute to the gradual consolidation of a central knowledge base relating to both (1) the problems that have been detected for the products moving across the network and (2) the collaborative performance and involvement of partners as part of the collaborative solving of those problems. In the frame of this research, both problem and collaboration related knowledge have been capitalized and reused as a source of improvement for the problem solving and the methodology operation. Indeed, the extent and the mechanisms supporting this task have been developed along this document and integrated as backbone elements of the proposed methodology. Nevertheless, the reuse of this meaningful information –as well as the knowledge that can be generalized from it– to improve other key processes and collaborative practices of the firms and the supply chains has not been explored. The nature and the content of the information capitalized through the application of the methodology could be exploited, for instance, in light of some other global processes such as the systems/products design and the suppliers' selection/assessment (Romero Bejarano et al., 2012b). Even if the information relating to both problems and collaborative behavior of the supply chains could be generalized and integrated as a source of improvement in a broader scope of supply chain practices (e.g. risk management, product lifecycle management), the two above processes have been retained as they allow illustrating some concrete applications of the proposed global methodology.

- *New system/product design process*: it encompasses the process during which a new system is brought from the conceptual stage to detailed specification plans (Mavris and Pinon, 2012). All along this process including some preliminary, detailed and critical reviews, the system structure evolves through different maturity stages with different business, technical, industrial, quality and risk factors being leveraged (Handfield et al., 1999). Sometimes, the lessons learnt from previous development projects are also included throughout these stages to improve the current system specification (Abeille et al., 2010; Vareilles et al., 2012). Nonetheless, the information provided by past development experiences and by classical product development approaches can be completed and enhanced through the application of structured knowledge processes defined in a larger scope including the whole product lifecycle. For instance, when a new system is being specified, it could be useful to have access to all the quality-related information capitalized for similar and/or same family systems in series phase. The proposed global methodology could provide, indeed, some meaningful and structured information relating to: (1) problems detected for constituents, similar and/or same-family systems, (2) root cause analysis used for solving those problems, (3) corrective and preventive solutions adopted to definitively fix the problem, and (4) technical and collaborative structures deployed. The integration of these information is valuable to: (1) highlight risks not considered before for the current system development, (2) improve current design by leveraging all problems occurred on similar or same family systems/components, (3) justify functional and structural choices for materials and/or components in the light of proved performances, (4) find design alternatives for evaluation of economic scenarios and finally (5) boost the supplier selection phase.
- *Supplier selection/assessment process*: it focuses on searching, selecting, evaluating and contracting with suppliers (Aminoff et al., 2007; Beil, 2010). This process could be improved not only by integrating the information relating to the problems in the scope of a given partner but, most important, by integrating the collaborative performance and involvement of partners in the collaborative initiatives deployed across the supply chain. Then, a novel approach coupling both partners' proven technical and collaborative performances as part of a more global strategy to select/assess suppliers is envisioned.

Such a strategy, emphasizing and positioning the collaboration as a central lever of the supply chains practices, could allow extending current approaches to consider the degree to which a partner is involved in the common initiatives. The proposed methodology could provide, indeed, a rational basis for this evaluation through the extension and integration of the *collaborativity index* developed in this research work as part of the partners' selection/assessment processes. This integration will strengthen the potential for collaboration and will promote higher involvement from partners.

Above applications highlight two of the concrete links that could be envisioned to improve the making decision process in the supply chains. Their scope of application is summarized in Figure 6.52.

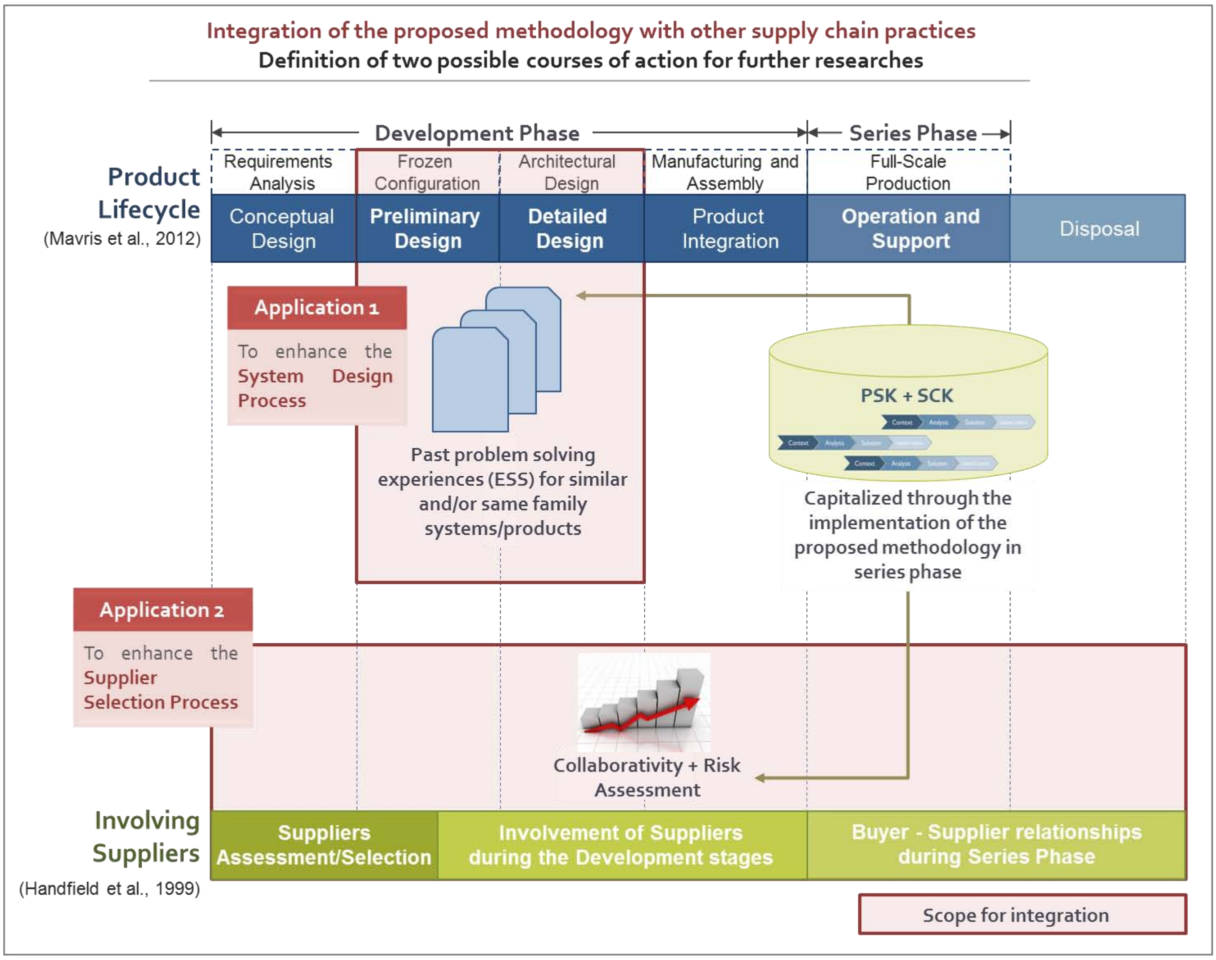

Figure 6.52 - Integration of the proposed methodology with other supply chain processes

Further research and detailed studies are required to enable and support those applications.

6.2.2. Extension of the experience feedback system supporting the methodology

An assumption done by this research work is that all the contextual knowledge derived from the problem solving process can be stored into a centralized problem solving knowledge base. Similarly, it considers that this knowledge, providing a picture of the problems and the elements that led to their solution, can be reused by all the partners of the network during the solving of new similar problems. This implies that the information, resulting from the cooperative work of a group of partners of the network to solve a common problem, will be available to be reused by any other partner across it. This aspect, and depending on the characteristics of each supply chain, may become an obstacle for the collaboration when information and elements required to solve problems are critical. In that case, for instance, some –or all of the– partners participating into the solving of a given problem would appreciate either not to formalize information or to formalize it but in a restricted perimeter. This could particularly restrain the effectiveness of the experience feedback module and, in consequence, the ability of the methodology to consolidate a meaningful repository of contextual knowledge. This problem is all the more relevant if we consider that partners of a given network, even if cooperating to solve common problems, can be in position of competition in the marketplace. An important course of action is thus to extend the proposed methodology to address this situation and mitigate the risk of reducing the potential for collaboration it may represent. Nevertheless, the specification of such an approach requires a comprehensive study of both the technical and collaborative aspects that may influence the process and their link with the proposed methodology. In such a study, the characterization of the experiential knowledge involved in the process as well as the identification of the levers that would motivate partners to accept to share critical information are required. It could include the study, for instance, of the establishment of an experience market on which partners receive incentives and get compensations by sharing all the information, even if critical, involved in the solving of a problem and being potentially useful for solving new similar problems that have significant impacts on the network performance. The nature of incentives to be used (e.g. economic rewards, contract re-negotiations, improvement of collaborativity indexes) is also to be studied. The possibility of defining a hybrid approach mutualizing both the (1) benefits of the proposed methodology to enable the solving of supply chain problems and improve the global performances with (2) an incentives system covering the sharing of critical information represents an important perspective of research. The contributions, for both researchers and practitioners, will stand at the meeting point between the experience feedback –or more generally speaking the knowledge management– and the supply chain management domains.

Additionally, and developing the convergence between those two disciplines, the experience feedback module could be extended to cover also the articulation between distributed and local approaches. This could provide new insights and could contribute to obtain superior performances at both the firms and the supply chain levels.

6.2.3. Validation under real conditions and specification of a business software tool

Even if the proposed methodology provides a consistent set of mechanisms that support its operation in practice, the specification of a business software tool encompassing all its functionalities will facilitate both its implementation and integration with other processes of the supply chain. This aspect, in addition to the possibility of applying the methodology in a broader scope with larger data sets and in the frame of a real context, could allow a complete validation of the principles and constructs behind it. Both (1) the definition of a larger scope for deployment and (2) the development of a software solution –or the extension of an existing one– are some of the ongoing actions that are being investigated.

With respect to the first point, both academic and industrial partners involved in this research project are working to extend the scope of their relationship. The strengthening of relations as well as the integration of new partners into the partnership is then envisioned to enable the application of the methodology under real conditions. Relating to the second point, and as part of the mutual interest of partners for developing problem solving solutions that combine fundamental approaches with concrete solutions, the specification of a software business tool is envisioned. In this field, however, partners have already made the first step thanks to the development of a first tool that supports the solving of problems confined to the frontiers of a single firm. This tool, named ProWhy® (Jabrouni, 2012), provides a resolution workflow that combines some standard methods such as PDCA, 8D and 9S. Nevertheless, it is not able to operate in distributed contexts yet. Then, the strategy adopted by partners lies on the extension of this tool to cover all –or at least the more important– elements of the proposed methodology. The extension/enrichment of the tool that is required to cover the modules and mechanisms of the methodology is one of the ongoing actions.

LIST OF ABBREVIATIONS AND ACCRONYMS

Conceptual Framework

SC	Supply Chain (§ 2.3)
PDCA	Plan, Do, Check, Act (§ 2.2.2)
DMAICS	Define, Measure, Analyze, Improve, Control (§ 2.2.2)
8D	8 Disciplines (§ 2.2.2)
9S	9 Steps (§ 2.2.2)
AIAG	Automotive Industry Action Group (§ 2.2.2)
IAQG	International Aerospace Quality Group (§ 2.2.2)
SCM	Supply Chain Management (§ 2.3)
CSCMP	Council of Supply Chain Management Professionals (§ 2.3)
SCC	Supply Chain Council (§ 2.3)
VMI	Vendor Inventory Management (§ 2.3)
CPFR	Collaborative Planning, Forecasting and Replenishment (§ 2.3)
APS	Advanced Planning System (§ 2.3)
EF	Experience Feedback (§ 2.4, 3.3.1)
LLS	Lesson Learnt System (§ 2.4)
MAS	Multi-Agent System (§ 2.4)
CBR	Case-Based Reasoning (§ 2.4, 3.3.1)
CCA	Closest Common Ancestor (§ 3.3.4, 5.2.2, 5.3.1)

Global Methodology

SCm	Supply Chain module (§ 4.2, 4.1)
TP	Technical Package (§ 4.2.1)
TBS	Technical Breakdown Structure (§ 4.2.2)
CP	Collaboration Package (§ 4.2.3)
CBS	Collaboration Breakdown Structure (§ 4.2.4)

PR	Partner Record (§ 4.2.6)
TI	Technical Information (§ 4.2.6)
CI	Collaborative Information (§ 4.2.6)
SCK	Supply Chain Knowledge (§ 4.2.7)
PSm	Problem Solving module (§ 4.3, 4.1)
ML-RCA	Multi-Level Root-Cause Analysis (§ 3.2.4, 4.3.1)
Ex-BoM	Extended Bill-of-Materials (§ 4.2.2)
G-PSP	Generic Problem Solving Process (§ 4.3.2)
PCR	Problem Context Record (§ 4.3.2.1)
PAC	Problem Assessment Checklist (§ 4.3.2.1)
EFm	Experience Feedback module (§ 4.4, 4.1)
ESS	Experience Synthesis Sheet (§ 4.4.1)
PSK	Problem Solving Knowledge (§ 4.4.2)
FiM	Filtering Mechanism (§ 5.2)
PaM	Partners Assessment Mechanism (§ 5.3)
PaM-T	Partners Assessment Mechanism - Technical (§ 5.3.1)
EC	Eligible Contributors (§ 5.3.1)
PaM-C	Partners Assessment Mechanism - Collaborative (§ 5.3.2)
CoM	Collaboration Mechanism (§ 5.4)
CoMax	Collaboration Matrix (§ 5.5, 5.3.2.1, 4.3.2.4)
CaM	Capitalization Mechanism (§ 5.5, 4.3.2.4)
ReM	Reuse Mechanism (§ 5.6, 4.3.2.2, 4.4)
AmM	Action Management Mechanism (§ 5.7, 4.3.2)
GOWA	Generalized Ordered Weighted Average (§ 4.2)

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APPENDIX

APPENDIX - I : TECHNICAL REQUIREMENTS

Summary of technical requirements for modeling supply chains in light of problem solving:

Product-oriented requirements *(referred to all physical flows moving through the network)*

The transition from domestic to extended scopes requires the modeling of all the physical flows contributing to the transformation and movement of goods from raw materials and up to final products in the hands of the ultimate customers of the network. This implies for the supply chain model to deal with:

■ More complex products with more complex functional configurations

■ Products distributed through complex networks of partners

■ Products becoming supply chain products

■ Products for which the technical knowledge (information, documentation, evidence) is extremely fragmented and distributed

→ necessity for tracing/tracking this technical information across the network

→ necessity for reusing this information in light of a particular problem

■ Products for which decomposition choices are no more exclusively done in terms of product functional aspects

Process-oriented requirements *(referred to all processes put in place to deliver products)*

The processes intending to both coordinate the partners and enable the effective flow of products across the network need to take into consideration the set of product-oriented requirements. Additionally, and in light of a supply chain model well-adapted to enable the common problem solving it is necessary to consider:

■ Processes coupled with products :

→ *Vertical integration*: processes covering the whole product structure (from raw material up to final product)

→ *Horizontal Integration*: processes covering the whole network (from raw material suppliers up to end customers)

■ Processes involving multiple partners that may interact through multiple economic structures :

→ *Cooperation model*: which can represent an advantage for the joint problem solving

→ *Competition model*: which can represent a barrier for the joint problem solving

→ *Sub-contractor model*: which can represent an advantage/a barrier for the joint problem solving

→ *Strategic partnerships and alliances*: which can represent an advantage for the joint problem solving

■ Processes covering a broader scope of activities within the product lifecycle. It means that such a supply chain model well-adapted to enable the common problem solving needs to be oriented towards a manufacturing/assembly supply chain integrating both upstream (design and industrialization) and supporting (transportation and logistics) activities/evidences:

The classic supply chain models represent exclusively the production stages for manufacturing/delivering a final product to a final customer. In consequence those models are able to provide a consistent picture of all the activities and the underlying evidence that are required to deliver a supply chain product during its series or full-scale production phase. However, they are unable to provide more global pictures including all the activities and the underlying evidence required during the upstream and supporting phases of the product all the long of its lifecycle. Within the frame of an extended problem solving approach, indeed, the consideration of the whole activities/evidences/partners involved on the upstream design and industrialization and supporting logistics and transportation phases set a fundamental element in light of the understanding of the problem, its contexts and the root causes. This is all the more relevant if we consider that all those elements are also distributed and externalized across the network. Then, the complete study of an extended supply chain model covering a wider scope of activities is necessary and enhances the model for tracing/tracking the most appropriate actors and evidences in light of the process of jointly solving problems. The set of processes and evidences that need to be considered at each stage of the supply chain covers:

→ *Design Process:* Involves the product design/development activities and cover all the engineering technical data related to the product. The tracking of the information and the actors contributing into this phase is particularly useful when problems to be faced concern the product performances and its functionalities. The design activities can be done either internally by the partner manufacturing the part in series phase or under a model involving contribution from other partners of the network (e.g. *cooperation*, *sub-contractor* or *partnership model*)

→ *Industrialization Process:* Involves bringing the product from development status to series production and cover all the industrial processes data. The tracking of the information and the actors contributing into this phase is particularly useful when problems to be faced relate to the industrial process used to manufacture the product that is being impacted. The industrialization activities can be done either internally by the partner manufacturing the part or under a model involving contribution from other partners of the network (e.g. *cooperation*, *sub-contractor* or *partnership model*)

→ *Build/Assembly Process:* Involves the manufacturing/assembly activities of the product during series phase and covers all the production data. The tracking of the information and the actors contributing into this phase is particularly useful since it provides an understanding of the context on which the problem has appeared. The production activities are the driver of the supply chain model as they define the way the stages of such a network are arranged

→ *Transportation and Logistic Process:* Involves both the entry and delivery transportation and logistics activities supporting the manufacturing/delivery of supply chain products during series phase. The tracking of the information and the actors contributing into these phases is particularly useful when problems to be faced relate to the handling and movement of goods across the network. These activities can be done either internally by the partner manufacturing the part or under a model involving contribution from other partners of the network (e.g. *cooperation*, *sub-contractor* or *partnership model*)

Network-oriented requirements *(referred to configuration of the network driving processes)*

An extended supply chain model that deals with the collaborative problem solving as an integrative process not only needs to fulfill the product and process requirements but needs also to cope with some structural aspects that govern the configuration of the network. Such a model has a structure characterized by:

■ Not more hierarchical but network-based organizations following the physical and information flows involved in the manufacturing of supply chain products:

→ From raw material suppliers up to ultimate customers of the supply chain

→ Arranged in tiers that represent production stages which are organized such that the outputs of one tier are the inputs to the next (i.e. each intermediate stage is a supplier to its adjacent downstream stage and a customer to its upstream stage)

→ Driven by the manufacturing/assembly activities (but including for each stage the design, industrialization, manufacturing and transportation activities/evidences)

■ One stage corresponds to the couple manufacturer partner / product

■ The industrial breakdown (i.e. the way on which the process to manufacture a product is decomposed into more manageable steps that are allocated to different partners) and the related accountabilities are distributed through the network similarly as products and processes

→ Partners may assume different roles in a supply chain network regarding structure of the network (e.g. customer or supplier) or nature of their activity (e.g. manufacturer/logistic operator/engineering partner, etc.)

■ The network shall accept different configuration models at each stage

→ one responsible (manufacturer) but no to several contributors (engineering partners, logistic operators...)

→ each partner deal with a specific process (design, industrialization, built, logistics and transport)

■ Depending on supply chain specifics, the model needs to address complex network configurations including nested structures, complex loops and multi-layered subcontracting levels at each stage (this if necessary in light of the nature, structure and complexity of problems to be faced)

APPENDIX - II : COLLABORATIVE ATTRIBUTES

Collaborative criteria influencing both effective supply chain operation and problem solving:

Collaborative attributes influencing the effective supply chain operation (in light of distributed problem solving)		**Cao and Zhang** (2011)		**Simatupang and Srisharan** (2002)		**Derrouiche et al.** (2008)		**Ring and Van de Ven** (1994) **Van de Ven and Thompson** (1976)		**Xu and Beamon** (2006)		**Tuten and Urban** (2001) **Mohr and Spekman** (1994)		**Anderson and Narus** (1990) **McDonald** (1999)	
		Planning / Forecasting / Replenishment		Planning / Forecasting / Replenishment		General framework for collaboration		Inter-organizational relationships		Attributes for coordination mechanisms		Partnerships formation and success		Partnership success	
1	Mutual trust/distrust			x	- Distrust triggers conflicts	x	- Trust favor collaboration practices - Reduction of uncertainty about potential opportunistic behavior	x	- Confidence in another's goodwill			x	- Mutual trust between partners is a key ingredient in a successful relationship	x	- Firm's belief that another company will perform actions that will result in positive outcomes for the firm
2	Conflicts and crisis management			x	- Source identification, level and management (resolution) of conflicts	x	-Disagreement between partners due to objectives misalignment	x	- Internal resolution of disputes			x	- Type of conflict resolution technique used by the partners (persuasion, smoothing, domination, arbitration)	x	- Overall level of disagreement - Determined by the frequency, intensity, duration
3	Formalization			x	- Decision rights and responsibilities converged through agreements as a prerequisite for overcoming conflicts	x	-Formalization of collaboration conditions	x	-The importance of the individual roles and efforts in the relationships			x	- Need to formalize the partnership - Both formal and informal agreements are needed		
4	Information sharing	x	- Should be: relevant, accurate, symmetric, complete, confidential	x	- Should cover: backward and forward flows	x	- Sharing of private information between producers/consumers					x	- Full disclosure of information - Extent to which critical information is exchanged	x	- Formal and informal sharing - Meaningful and timely information - Efficacy rather than quantity or amount
5	Goal congruency	x	- Own objectives are satisfied by achieving SC objectives or as a consequence of them	x	- Mutual objectives	x	- Objectives alignment								
6	Control					x	- Set of actions aimed at verifying that agreements and commitments are respected	x	- Can be: impersonal (rules), personal (supervision, communication) and group (formal, informal meetings)	x	- Can be: high (strict activity monitoring and control) and low (little to no monitoring and control)				
7	Level of dependency / inter-dependency					x	- Dependency in decision-making processes between two actors - Objective : mutual dependency	x	- Can be: pooled (independent), sequential, reciprocal, team arrangement	x	- Symmetric versus asymmetric	x	- Successful partnerships are truly one of inter-dependence rather than a lopsided dependence	x	- Firm's perceived difference between its own and its partner firm's dependence
8	Decision style and synchronization	x	-Coordinate critical decision-making processes			x	- Partners are involved and have common decision-making processes			x	- Decision style can be: centralized, decentralized	x	- The coordination is a key attribute for successful partnerships	x	- Similar or complementary coordinated actions taken by firms in interdependent relationships to achieve mutual goals

9	Risk/reward sharing	X	- Sharing risks, costs and benefits - Share gains and losses equitably	X	- Realignment of the benefits - Focus on behavior, pay-for-performance, equitable compensation	X	- Fair sharing of benefits	X	- Reciprocity in the sharing of inputs and outcomes - "Equally" sharing not required	X	- Can be: Fair and unfair				
10	Process integration	X	- Common processes	X	- Integrated policies										
11	Effectiveness of the relationship			X	- Appropriated performance measures	X	-Measurement of benefits and effectiveness of relationships					X	- Performance from the partnership is a characteristic of successful partnership		
12	Balance of power					X	- Ability to influence partners' behaviors in order to make them act as they wouldn't act spontaneously					X	- Maintain a balance of power such that opportunistic behavior is prevented by the partners	X	- Unequal power distribution could create a serious barrier to success
13	Resources sharing	X	-Accumulation of local capabilities - Fair financial and non-financial - Access complementary resources							X	- No resource sharing, operational resource sharing, tactical resource sharing , strategic resource sharing				
14	Collaborative communication	X	- Should be: open, frequent, balanced, two-way, multilevel - The glue that hold partners together									X	-Communication quality includes the accuracy, timeliness and credibility of the information sharing	X	- Communication facilitates achieving outcomes of the partnership - Necessary antecedent of trust
15	Joint knowledge creation and sharing	X	- Shared knowledge creation and exploitation												
16	Partners' external operating environment					X	- Includes the partner context external to the relationship itself but having a significant impact on it			X	- Factors associated with a firm’s operating environment (environmental uncertainty)				
17	Partner's internal environment									X	- Factors associated with a firm’s internal environment (behavioral uncertainty)				
18	Relationship lifecycle					X	- 5 phases: awareness, exploration, expansion, engagement, declination								
19	Use of information and communication technologies (ICT)	X	- IT is crucial to firm performance - IT reduces cost of communication			X	- Technological and tools integration by measuring intensity and depth of such integration								
20	Partners flexibility					X	- Ability to adjust, adapt and make evolve relationship conditions					X	- Potential for change or adaptations over time		
21	Degree of participation					X	- Degree of involvement of partners in collaborative practices					X	- Participation as the degree to which partners jointly plan and set goals		

22	Partners engagement					x	- Efforts of keep and investing on adding-value partnerships					x	- Partners commitment is a key attribute for successful partnerships		
23	Relationship economic model					x	-Quantification of financial transactions between partners			x	- Cooperative (win-win situation) versus competitive (benefits at the expense of the other firm's benefits)				
24	Implementation of shared planning					x	- Sharing of strategic assumptions for common and global planning								
25	Respect of engagements mutually agreed					x	- Respect and accomplishment of initially agreed engagements					x	- Respect of agreements is important in creating a successful partnership		

APPENDIX - III : ENABLERS OF THE DISTRIBUTED PROCESS

Details of the distributed problem solving process presented in Table 3.4:

			Determinants characterizing the distributed and networked contexts § 2.3.6		
			modeling and operation § 2.3.2 and § 2.3.3	**technical aspects** § 2.3.4	**collaboration aspects** § 2.3.5
Mayor phases / elementary activities of the generic problem solving process § 2.2.3	**Context**	**Problem characterization**	*- The initial characterization of a distributed problem is made on the basis of the visible symptoms that are observed in the product that is directly impacted by the problem at one specific stage of the network and by one specific partner (the one who first identified the problem and the one who is suffering the immediate effects of it). Nevertheless the origin of the problem can come from any of the multiple constituents madding up this product and distributed through the network in a larger scope exceeding the boundaries of that single partner. Then, the a priori characterization of distributed problems needs to consider this situation and, in consequence, requires the capture of a set of meaningful attributes enabling the further phases of tracking and filtering across the whole network in order to keep the most relevant constituents, partners and evidences in light of the specifics of each particular problem being faced.* *- This characterization requires the definition of a set of predefined and standardized attributes that allow linking the problem and its context with the network and its flows. (e.g. the association of a problem with a specific product of the network can be used as one of the elements to track the context through it. Another attribute can be the type of problem that allows filtering the network by nature of the products and capabilities of the partners).*	*- The characterization shall consider the structure of the network and the fragmentation of the physical and information flows across it. The problem scope in terms of products and processes impacted needs to be defined in terms of the network elements in order to enable the further tracking of technical knowledge of the problem across it.* *- The consideration of the product, process and network aspects can enable the characterization of the distributed problem and enhance the association of the problem with the network and the associated technical knowledge that is condensed on it. The definition of the problem attributes on the basis of the standardized elements of the network contributes to the definition of a model-based approach that could enhance the automated filtering of the problem space.*	
		Problem assessment	*- The assessment shall leverage not only the attributes, impacts and risks originated by the problem at the firm's level but instead it is necessary to integrate a more global evaluation including the concerns of all the firms across the network that are potentially impacted and concerned by a distributed problem.* *- The assessment needs to capture the degree of distribution of the problem and its scope since they*	*- The assessment shall consider the structure of the network and the fragmentation of the physical and information flows across it. The set of criteria for assessing the problem structure needs to be defined in terms of such a network.* *- The set of attributes used for the characterization can be reused at this stage as a way to associate the problem with the network and then have a support element to perform the study of the problem in light of*	

			correspond to one of the main elements for identifying the underlying difficulty, complexity and associated priority that need to be allocated to solve the distributed problem. *- To execute such an assessment of the problems on the basis of a wider context, it is suitable to have a robust model-based approach to support the modeling of the network and the physical and information flows moving through it. This is fundamental to provide problem solvers with relevant information in light of the evaluation of the problem. Such a model can act as a decision support system by improving the analysis and study of the problem in regards of distributed contexts.*	*its evaluation.* *- The assessment needs to consider the fact that the impacts of the problem are not only for the firm that first identified the problem and its immediate customers but for the whole supply chain as the ultimate customers can be potentially impacted (e.g. through the potential delivery of non-quality products, through potential late deliveries or through potential significant impacts on performance of already delivered products)*	
		Constitution of the team	*- The increasing emphasis on networked contexts makes more complex the constitution of the team as now the capabilities, knowledge, resources and expertise regarding the products that are impacted by problems are extremely distributed and fragmented through the network. Then, in order to build a team with cumulated capabilities is necessary to track and filter the whole capabilities of the partners through the network and their proximity with the problem.* *- There is no one single firm that is capable to solve a problem in isolation as there is no one single firm with the global picture of the problem and its context. Firms work in inter-dependent networks and work on the basis of integrated processes. This needs to be considered during the team constitution phase.* *- The constitution of the team needs to match on the one hand the attributes and the requirements of the problem and on the other hand the capabilities held by the partners. As the partners are as well as the products and evidences distributed through the network, the use of a robust and automated model can result crucial to match the problem needs with the network capabilities. A first approach supporting the modeling of the networks and the technical knowledge condensed on it and a second more focused on capturing and matching the problem requirements with the network are then necessary to effectively constitute teams in distributed contexts.*	*- The partners that contribute into the activities of design, industrialization, manufacturing, assembly and transportation of products are distributed through the network. Then the constitution of a team shall not only consider the internal constraints of the partner that first identified the problem but needs to consider the whole supply chain and the whole distribution of activities/capabilities regarding the impacted product.* *- The team constitution shall then consider (1) the cumulated capabilities between selected partners and their adequacy with the capabilities required by the problem, (2) the proximity of the partners to the problem and the products impacted by the problem and (3) the contribution that the partners have into the problem. These elements shall be integrated into the model-based approach as it requires dealing with big quantities of data.*	*- Due to the fact that the effective operation of the networks of partners is regulated not only by technical but also by relational factors, the constitution of the solving team needs to pay particular attention to the way the teams are built and the influence that such criteria may have on the effectiveness of the team operation. Then, this phase needs to consider during the constitution of the teams not only the capabilities and proximities of partners but also leverage the set of relational criteria for the more capable ones.* *- The degree of collaboration and the effectiveness of the team work will depend on the assessment of this set of collaborative or relational factors in complement to the technical ones. As a result not only the more capable, but also the more compatible partners shall be selected as part of the team.* *- In addition to all the technical aspects of the team constitution, the model-based approach supporting this phase shall need to consider the collaboration criteria between partners. The model shall be able to compare not only technical capabilities but also relational adequacy between partners.*
		Gathering of evidences	*- The increasing emphasis on networked and distributed contexts makes very complex the gathering and consolidation of a meaningful set of evidence useful to understand and study the problems. It is then necessary to track and filter the whole information, technical knowledge, facts, figures, documentation and data across the network.*	*- For all the product, process and network aspects the set of information being useful in light of the understanding of the problem is distributed and needs to be gathered and consolidated. (e.g. technical documentation of the key constituents of one impacted product which are likely to be contributors to the problem are owned by different partners of the network and need to be gathered*	*- Depending on the collaborative criteria regulating the relationship between the partners of a supply chain, the sharing and exchange of critical information in light of the understanding of the problem can be strongly limited. (e.g. if there is no clear, balanced and bidirectional sharing of information and*

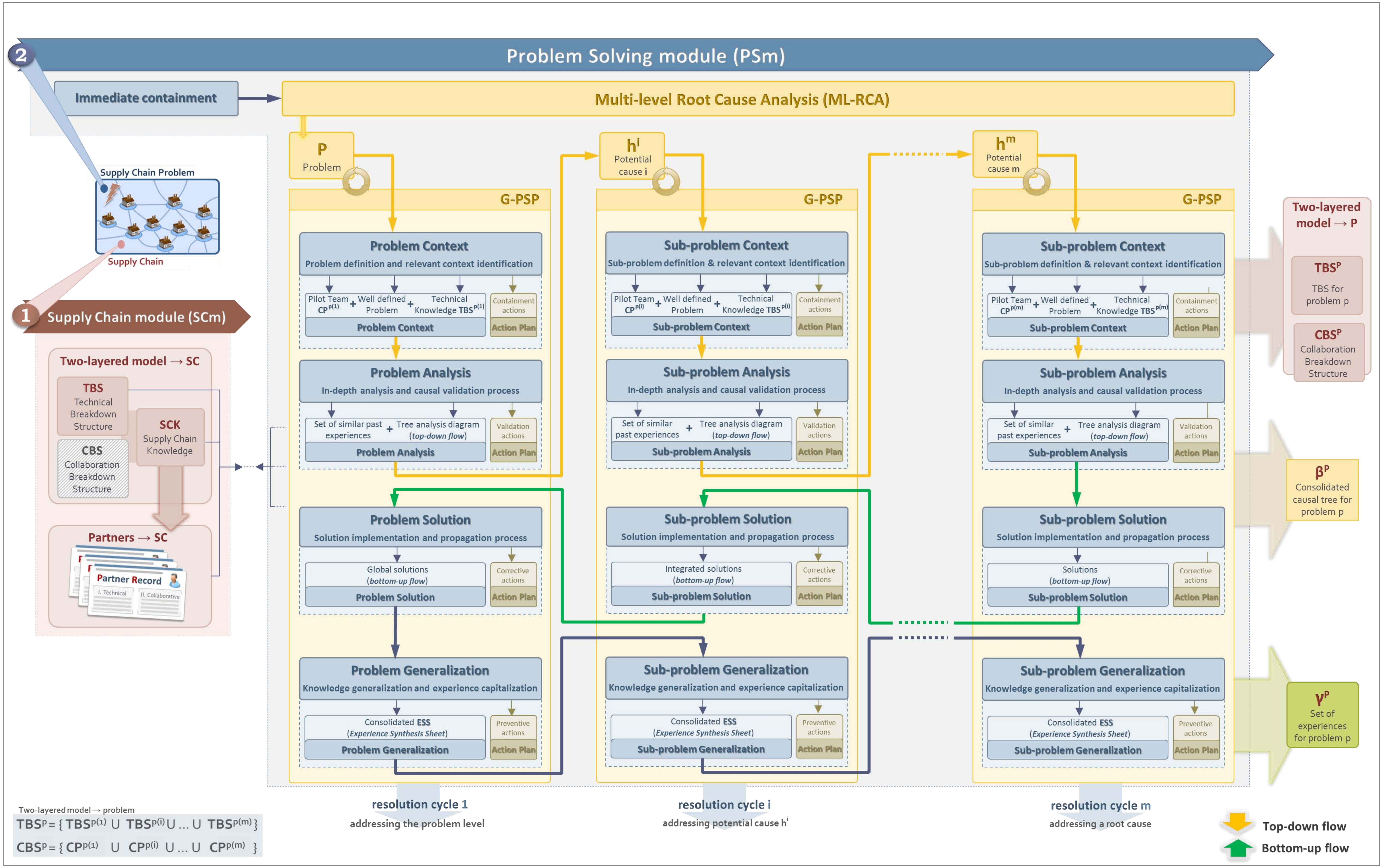
			- The new generation of network-based organizations triggers the explosive growth of data and information that can be potentially useful in light of the resolution of problems occurring on those networks. Then, in distributed contexts is necessary to have robust approaches/models allowing the modeling of the network and the flows distributed through it. Such a model shall be able then to allow the study and filtering of the distributed problem space in order to reduce it and track only the evidences and information which are relevant in light of the current problem that is being analyzed. Due to the nature of the network and the complexity of the information moving through it, is suitable to support this phase with automated models that track and filter the network in function of the meaningful set of criteria defined by the problem solver during the problem evaluation phase.	*and consolidated).* *- The approach/model used to support this critical step shall consider all the product, process and network aspects from both a technical and collaborative perspective. Then, all the relevant documentation, evidence, facts, parameters and technical knowledge regarding the problem (and the products impacted by it) shall be tracked through the network which is driven by the physical and information flows.*	*communication between partners, it will be difficult to consolidate a meaningful set of evidence to understand the problems even if they are common to all). Then it is necessary to consider the relational criteria and the potential for collaboration during this phase.* *- The model-based approach used to support this phase needs to consider the relational criteria of the supply chain since it can influence the relevancy of the evidence gathered in light of the problem understanding.*
		Problem statement	*- A distributed problem needs a clear statement in order to identify the products and partners that are involved across the network, their concerns and responsibilities, the impacts of the problems and the statement of both the current situation (based on evidence) and the objectives. All those elements need to be defined and consider the structure, configuration and processes of the network.*	*- The statement of the problem needs to be defined in terms of the elements of the network (products, processes, partners, evidences) in order to enhance the further phases of analysis and identification of the root causes.*	*- It is necessary that all the partners that are concerned by the problem and that are involved throughout the solving process share and agree on the problem and goal statements. This can be strongly limited if the partners have not the same vision and strategy. Then, the level of strategies convergence and objectives and incentives alignments need to be considered as they can impact the effectiveness of the process.* *- To enable a shared problem statement it is necessary to assess the set of relational criteria during the team constitution phase to be sure that the partners have mutual strategies and that there is a good communication and a high level of information sharing.*
		Problem containment	*- The impacts of the problem are not limited to the boundaries of the partner that first identified the problem. Then, the containment need to be done across the network to ensure that the problem will not degrade up to the root causes have been found and effectively eradicated. Additionally the containment for distributed problems needs to ensure that all the immediate and ultimate customers and stakeholders concerned by the problem have been protected from the negative effects of the problem.* *- The containment actions are distributed through the network. This means that strong coordination is required between partners to effectively manage, monitor and control their completion and effectiveness.*	*- The distribution of the physical and information flows and the configuration aspects of the network have a significant impact on the way the containment actions are propagated through the network. The more the networks are complex and the flows distributed across those networks, then the more difficult is to effectively propagate the containment actions and the strategies for protecting the ultimate customer of the supply chains.*	*- An effective containment of problems distributed through networked contexts requires a strong cooperation and intensive communication between all the partners. Then, the criteria regulating the relationships between them can influence the effectiveness of the containment strategies and need to be leveraged before establishing a collaborative method for jointly solving problems.*

Analysis	**Root cause analysis**	*- As the value chains of the products that are impacted by the problems are fragmented through complex networks of partners, the causes for problems affecting those products may potentially come from one of the multiples upstream stages and flows of the network. Then, the potential causes can concern simultaneously a larger number of partners, disciplines and constituents and in consequence its study can be as complex as the one of the problem. - The process of identifying the root causes is more complex since a larger number of factors may exist and since there is a higher uncertainty and is more difficult to consolidate and propose valid and plausible causes to distributed complex problems. - The root causes need to be identified in a top-down approach by starting with the initial problem which will be gradually break into more manageable sub-problems aiming at investigating the potential causes of the problem and up to identifying the root causes of the problem. This principle corresponds to the multi-level root cause analysis setting the first driver of the generic distributed problem solving process that is proposed as part of this research.*	*- Due to the nature of the networks and the distribution of the physical and information flows across them, the potential causes contributing to one problem can be very different in nature, impact a particular key constituent different from the product impacted by the initial problem and its study as complex as the problem to which they contribute. Then, the distributed complex problem solving requires applying in some cases a consistent and systematic approach made up of multiple reduced approaches for solving partial sub-problems and consolidating results to come up with effective solutions to the initial problem. - A top-down approach or multi-level root cause analysis based on a set of nested sub-problems resolution processes is required to be able to effectively investigate in a comprehensive way a distributed problem and to identify its root causes across the network. Such a model shall consider the network structure and the physical and information flows distribution during the breakdown of the problem and the structuring of the sub-problems (potential causes).*	*- The root cause analysis within distributed contexts requires the synchronization and a strong coordination between firms to be able to systematically investigate all the potential causes of the initial problem. To effectively find the root causes of problems distributed through complex networks of partners is necessary then to have collaborative methods that synchronize the efforts of the partners. Collaboration criteria is fundamental as part of this process and need to be leveraged during the constitution and the operation of the dynamic teams that will investigate the problem and its potential causes up to find the root causes. - The effectiveness of the root cause analysis is conditioned not only by the capability of the partners involved in the resolution process but also by the degree of collaboration and the relational criteria regulating their relationship.*
	Validation process	*- The validation actions are distributed through the network. This means that strong coordination is required between partners to effectively manage, monitor and control their completion and effectiveness. - Due to the complexity associated to the network, the study and investigation of the plausibility and validity of potential causes need to be based on the capabilities of the partners which are distributed across the network.*	*- All the product, process and network aspects shall be considered by the problem solvers during the definition of validation actions. - The validation process shall be coupled with the root cause analysis process in a way such that for each potential cause a validation action is deployed. This enables the consolidation in a top-down flow of the tree analysis diagram including all the root cause for a distributed problem.*	*- An effective validation of potential causes distributed through networked contexts requires a strong cooperation and intensive communication between all the partners. Then, the criteria regulating the relationships between them can influence the effectiveness of the validation process and need to be leveraged before establishing a collaborative method for jointly investigating the problems to find the root causes.*
Solution	**Definition of solutions** **Implementation of solutions** **Effectiveness verification**	*- The solutions for distributed problems need to be distributed as well. Then, the process of definition, selection, implementation and verification shall be done not only in accordance with the root-causes of the problem but also with the structure of the network and the distribution of both the physical and information flows. - The solutions need to be defined in a bottom-up approach by consolidating the inputs from all the involved partners gradually up to defining distributed and global solution tackling the root causes of the problem.*	*- The solutions need to be coupled with and consider the structure of the network, the products and the processes. This ensures the effectiveness of the solutions to tackle the problems at a supply chain level by covering not only the concerns of the partners that face the problems but the ones of all the partners that are involved across the network. It is necessary to consider a set of distributed solutions to enhance the improvement of the performances at a global level and the creation of value for the ultimate customers of the network.*	*- The relational criteria may have a significant impact on the way the solutions are defined and implemented. Factors such as the distribution of power and the sharing of benefits, costs and risks can seriously influence the way the solution is implemented and in consequence the effectiveness of the implemented solutions to eradicate the root cause of the problem. - The collaborative factors shall be leveraged during the team constitution phase (as each team is responsible for studying, analyzing and proposing solutions to each problem).*

	Generalization	**Standardization** **Generalization** **Closure and recognition**	*- The emphasis on networked contexts and the distribution of the flows makes that the solution to distributed problems can be potentially generalized to prevent some other similar problems on the network. Problems affecting similar products, similar technologies, concerning the same partners or impacting a wider set of partners across the network can be prevented.* *- As the objective of the firms that work as a cohesive entity through networked models is not only to achieve local improvements but to contribute and work collaboratively to create superior performances at the supply chain level, it is important that the solutions to complex and distributed problems could be standardized and generalized to other streams of the network.*	*- The product, process and network evidence can empower the partners during the generalization phase, as this set of network knowledge allows understanding the potential impacts of similar problems or even identifying critical parts on which the same (or similar) problems could appear.* *- The consolidation and use of model-based approaches to support the modeling of the network and the physical and information flows moving through it is fundamental to provide the problem solvers with relevant information.*	*- The collaboration criteria within a network can either favor or block the emergence of preventive and generalized actions. (e.g. if there is no goals alignment and good communication between partners, a preventive action cannot be promoted and implemented everywhere in the network).*
	Action Management	**Containment actions** **Validation actions** **Corrective Actions** **Preventive actions**	*- All the actions (containments, validation, corrective and preventive) that are deployed all along the process are distributed through the network. This means that strong coordination is required between partners to effectively manage, monitor and control their completion and effectiveness.* *- When multiple partners work simultaneously on the resolution of similar problems occurring on the same network, it is important to have robust methods and tools for coordinating the partners and ensure that the actions are executed in a timely and cost-effective manner.*	*- All the product, process and network aspects shall be considered by the problem solvers during the definition of actions.* *- The definition of actions on distributed contexts can be supported by the model-based approach supporting the modeling and representation of the networks and the technical knowledge that is on it (products, partners, processes, resources, etc.).*	*- As for the problem solving process itself, the management, monitoring and control of the actions can be impacted by the collaboration criteria regulating the relationship between partners. The level of control, of formalization, of flexibility and engagement are some of the factors that can influence the actions effectiveness on distributed contexts. That is the reason why the relational factors need to be leveraged as well.*

APPENDIX - IV : THE PROBLEM SOLVING MODULE (PSm)

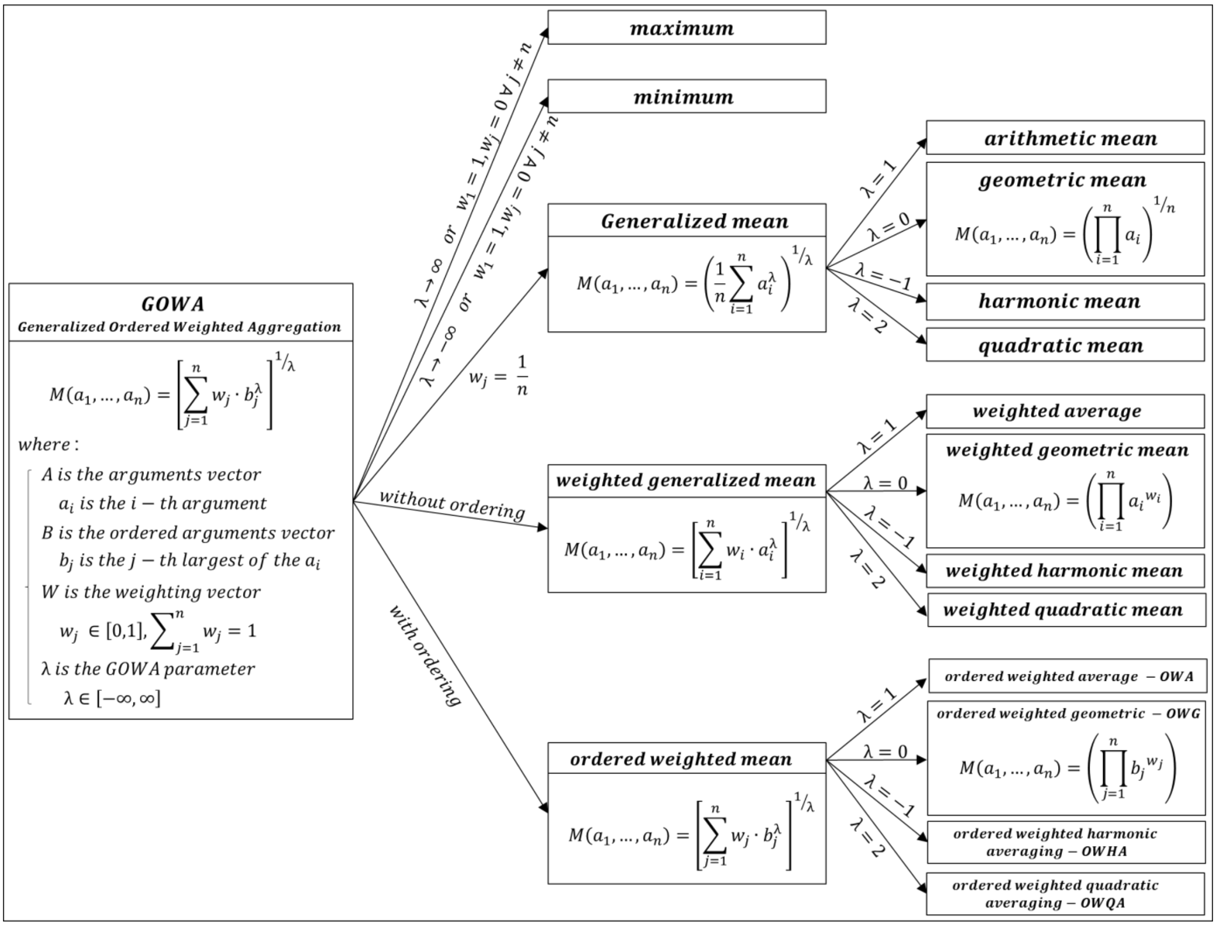
See next page.



Problem Solving module (PSm)
Immediate containment
Multi-level Root Cause Analysis (ML-RCA)
P Problem
hi Potential cause i
hm Potential cause m
G-PSP
Supply Chain Problem
Supply Chain
Supply Chain module (SCm)
Two-layered model → SC
TBS Technical Breakdown Structure
CBS Collaboration Breakdown Structure
SCK Supply Chain Knowledge
Partners → SC
Partner Record
Problem Context
Problem definition and relevant context identification
Pilot Team CP + Well defined Problem + Technical Knowledge TBS
Containment actions
Action Plan
Problem Analysis
In-depth analysis and causal validation process
Set of similar past experiences + Tree analysis diagram (top-down flow)
Validation actions
Problem Solution
Solution implementation and propagation process
Global solutions (bottom-up flow)
Corrective actions
Problem Generalization
Knowledge generalization and experience capitalization
Consolidated ESS (Experience Synthesis Sheet)
Preventive actions
Sub-problem Context
Sub-problem definition & relevant context identification
Sub-problem Analysis
Sub-problem Solution
Integrated solutions (bottom-up flow)
Solutions (bottom-up flow)
Sub-problem Generalization
Two-layered model → P
TBSP TBS for problem p
CBSP Collaboration Breakdown Structure
βP Consolidated causal tree for problem p
γP Set of experiences for problem p
resolution cycle 1
addressing the problem level
resolution cycle i
addressing potential cause hi
resolution cycle m
addressing a root cause
Two-layered model → problem
TBSP = { TBSP(1) U TBSP(i) U … U TBSP(m) }
CBSP = { CPP(1) U CPP(i) U … U CPP(m) }
Top-down flow
Bottom-up flow

APPENDIX - V : THE GOWA AGGREGATION OPERATOR

The definition as well as a summary of the family of aggregation operators that can be generated from the *Generalized Ordered Weighted Averaging* (GOWA) proposed by Yager in (Yager, 2004) are synthesized in Figure hereafter:



As explained by (Merigó and Gil-Lafuente, 2008) by varying the value of the function parameter λ, the GOWA operator generalizes a wide family of aggregation operators. This can be synthesized as follows:

$$\lambda \text{ is the } GOWA \text{ parameter} \quad \lambda \in [-\infty, \infty] \quad \begin{cases} \text{some typical values:} \\ \lambda \to -\infty & \text{minimum} \\ \lambda = -1 & \text{harmonic mean} \\ \lambda = 0 & \text{geometric mean} \\ \lambda = 1 & \text{arithmetic mean} \\ \lambda = 2 & \text{quadratic mean} \\ \lambda \to +\infty & \text{maximum} \end{cases}$$

The geometric mean has two behaviors which are suitable for the purposes of this research: 1) extreme values are penalized and 2) operator requiring larger improvement in one element to compensate for a loss in another one. Nevertheless the results of the GOWA with λ=0 (i.e. strict geometric mean) are only relevant when all the argument values are different from 0 (Merigó and Casanovas, 2008). Then, and in order to obtain an aggregation operation that simultaneously offers the benefits of the geometric mean and is able to deal with zero values, we have studied the results of varying λ between 0 (λ=0) and 1 (λ=1) for a set of data composed by two arguments (x_1 , x_2) and being iso-weighted (w_1 = w_2). The more significant values are the following:

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)
					λ=0,00	λ=0,01	λ=0,10	λ=0,20	λ=0,25	λ=0,30	λ=0,40	λ=0,5	λ=1,00
	x_1	x_2	w_1	w_2									
(1)	1	1	0,50	0,50	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
(2)	0	1	0,50	0,50	0,000	0,000	0,001	0,031	0,063	0,099	0,177	0,250	0,500
(3)	0,1	0,9	0,50	0,50	0,300	0,302	0,319	0,338	0,348	0,358	0,379	0,400	0,500
(4)	0,2	0,8	0,50	0,50	0,400	0,401	0,410	0,420	0,425	0,430	0,440	0,450	0,500
(5)	0,3	0,7	0,50	0,50	0,458	0,459	0,462	0,467	0,469	0,471	0,475	0,479	0,500
(6)	0,4	0,6	0,50	0,50	0,490	0,490	0,491	0,492	0,492	0,493	0,494	0,495	0,500
(7)	0,5	0,5	0,50	0,50	0,500	0,500	0,500	0,500	0,500	0,500	0,500	0,500	0,500
(8)	0,3	0,7	0,50	0,50	0,458	0,459	0,462	0,467	0,469	0,471	0,475	0,479	0,500
(9)	0,3	0,75	0,50	0,50	0,474	0,475	0,479	0,484	0,487	0,489	0,495	0,500	0,525

Based on this set of data, we can verify that with λ =0.5 (column L):

- **The GOWA still penalizes the extreme values in comparison to the arithmetic mean**. In other words the GOWA captures and penalizes disparities in performances across criteria.

e.g. Consider that the arguments (x_1 , x_2) are two of the criteria of the capability index of a partner. Then, if there are high disparity between x_1 and x_2 (such in lines 2 to 6), this will yield a lower capability index (column L) than if –having the same average performance- the results are the same in all two criteria, as it is the case in line 7.

- **The GOWA still requires larger improvement in one element to compensate for a loss in another one** which is not the case for the arithmetic mean whose formulation treats the criteria as perfect substitutes for each other by assuming that a decrease in one element of a distribution can be compensated by an equal increase in any other element to yield the same level of overall performance.

e.g. Consider that the line 8 is obtained from line 7 by reducing the first element by 0.2 units, from 0.5 to 0.3, but increasing the second element also by 0.2 units, from 0.5 to 0.7. If the arithmetic mean is used (column M) to assess the overall capability index, then this would reflect no change in the overall achievement. However, if the geometric mean is used instead (column L), then this would reflect a lower overall achievement and in consequence a larger improvement would be required in the second criterion to compensate the loss in the first one (line 9).

- The GOWA still remains relevant when criteria contains zero.

e.g. Consider the line 2 for which the first criterion is equal to 0. If geometric mean is used, the capability would be 0. If arithmetic mean is used, the capability would be 0.5. If GOWA with λ =0.5 is used instead, the capability would be 0.25 which still penalizes the extreme disparity of x_1 and x_2 without becoming 0.

APPENDIX - VI : THE COLLABORATION MATRIX (CoMax)

See next page.

Collaboration Matrix - CoMax

0,00

CoMax - Part I

General environment assessment

Criteria used for evaluating the ***general compatibility***

Criteria		Description	Level 1	Level 2	Level 3	Level 4	Score
			The environment surrounding partners' relationship represents an obstacle for implementing collaborative practices between partners. In addition environment is unstable due to the significant uncertainty levels exisiting.	The environment surrounding partners' relationship includes more risks than oportunities to collaborate. Collaborative practices are difficult to implement and effectiveness of these practices are strongly limited. In addition environment stability is not ensured because uncertainty levels become important.	The environment surrounding partners' relationship includes more opportunities than risks to collaborate. Effective collaborative practices can be established if potential risks are leveraged and monitored. In addition environment can be considered as stable due to low uncertainty levels.	The environment surrounding partners' relationship favors the implementation of effective collaborative practices between partners. In addition environment has a proven stability due to very low uncertainty levels.	0,00
cg $_1$	**Operating environment structure**						0,00
cg $_{11}$	Relationship economic model	It captures the level to which the economic model regulating the relationship is favorable to and provides a positive context for collaboration	Direct competition model (Firms are direct competitors in common markets)	Indirect competition model (Firms do not compete in common markets but work with simmilar/substitute products which can potentially lead to direct competition model)	Market cooperation model (Firms have a direct or an indirect customer/supplier relationships)	Strategic cooperation model (Firms work in partnership)	
cg $_{12}$	Level of interdependency	It quantifies the level and nature of the interdependency between two firms	The relationship is asymmetric because only one firm depends on the other. The level of dependency is medium or high	The relationship is asymmetric because only one firm depends on the other. Nevertheless the level of dependency is low	The relationship is symmetric because both firms depend on each other. The level of dependency is low or medium	The relationship is symmetric because both firms depend on each other. The level of dependency is high	
cg $_{13}$	Balance of power	It quantifies the way the power is distributed between partners	A significant gap of power exists between firms. Smaller firm do not possess effective means for compensating influence of powerful one. The difference of power is big enough to difficult (or even block) the establishment of balanced relationships	A gap of power exists between firms. Smaller firm do not possess effective means for compensating influence of powerful one. Nevertheless, the difference of power is minimal enough to allow considering partners could establish effective relationships (even if they are unbalanced)	A gap of power exists between firms. Nevertheless smaller firm possess effective means for compensating influence of powerful one. This situation allows the establishement of balanced relationships	Both firms have equivalent power and none of them can influence the others' beliefs and behaviors. Then, a balanced scenario in terms of power distribution exists and favors the establishment of effective collaborative relationships	
cg $_{14}$	Goal congruency	It quantifies the level of consistency between partners' strategies as well as the consistency between partners' local strategies and the overall supply chain objectives	Firms have standalone (even conflicting) strategies. These are not in accordance with overall Supply Chain objectives	Firms have standalone (even conflicting) strategies. Only one of the firms has a strategy which is in accordance with overall Supply Chain objectives	Firms have consistent strategies. These are not in accordance with overall Supply Chain objectives	Firms have consistent strategies. These are in accordance with overall Supply Chain objectives	
cg $_2$	**Operating environment stability**						0,00
cg $_{21}$	Partner's internal environment stability	It captures the level of stability of partners' internal environment and the level of uncertainty of partners' behavior	Firms have very unstable internal environments. There is an important behavioral uncertainty with no possibility to implement means for monitoring and control	Firms have unstable internal environments. There is a medium or high behavioral uncertainty with difficulty to implement means for monitoring and control	Firms have stable internal environments. There is a low or medium behavioral uncertainty with possibility to implement means for monitoring and control	Firms have proven stable internal environments. There is a very low behavioral uncertainty	
cg $_{22}$	Partners' external operating environment stability	It captures the level of stability of partners' external operating environment as well as the associated environmental uncertainty	External environment surrounding firms' operation is very unstable. There is a high environmental uncertainty to become unfavorable	External environment surrounding firms' operation is unstable. There is a medium environmental uncertainty to become unfavorable	External environment surrounding firms' operation is stable. There is a low environmental uncertainty to become unfavorable	External environment surrounding firms' operation has a proven stability. There is a very low environmental uncertainty to become unfavorable	

CoMax - Part II

Partners' collaborative performance

Criteria used for calculating the ***proven compatibility***

Criteria used for calculating the ***collaborativity***

Criteria		Description	Level 1	Level 2	Level 3	Level 4	Score
			Partners have common processes but there is not a collaboration dynamic established at all. Partners have standalone strategies and focus on internal environments and performances. No involvement or engagement of partners to create a real collaborative framework	Involvement of partners on common initiatives is minimal and only a reduced number of aspects of the relationship are addressed. Collaboration is considered more as an obligation than an opportunity to increase both local and global performances.	Partners collaborate and have common initiatives but relationship is not mature enough to have robust and effective processes. Collaboration is not still considered as a strategical driver and there is only a partial involvement of partners.	Partners have succeeded to establish a possitive environment for collaboration with effective relationships, collaborative initiatives and a real involvement of partners favoring the improvement of both local and global performances.	0,00
cs $_1$	**Involvement of partners**						0,00
cs $_{11}$	Risk/reward sharing	It captures both the level of fairness and coverage of the risks/rewards sharing strategy	No gains, losses or risks sharing	Unfair and incomplete sharing (covering only gains/losses or only risks)	Fair but incomplete sharing (covering only gains/losses or only risks)	Fair and complete sharing (covering gains, losses and risks)	
cs $_{12}$	Resources sharing	It quantifies the willingness of partners to share resources	No resource sharing	Operational resource sharing	Tactical Resource sharing	Strategic resource sharing	
cs $_{13}$	Joint knowledge creation and sharing	It quantifies the degree to which partners are able to create and share knowledge	There is no common initiatives for jointly create or share knowledge. At the best, firms have their own internal knowledge management processes	Firms have common initiatives that promote a non-intensive knowledge sharing. There is not yet a joint knowledge capture and creation policy	Firms have common initiatives that promote the sharing, capture and creation of knowledge. This process is not mature enough and it is not considered by partners as a driver for innovation	Firms have common initiatives that promote the active sharing, capture, creation and exploitation of knowledge. This process allows partners to jointly create value, enhances innnovation and improves long term competitiveness	
cs $_{14}$	Degree of participation	It evaluates the degree to which partners participate and involve themselves	Both firms have a passive participation	One partner has an active participation. The other one has a passive participation	Both firms have an active participation	Both firms have a proactive participation	
cs $_{15}$	Partners engagement	It captures the degree to which partners are committed to the relationship and are willing to invest on it	Firms do not make efforts or investments necessary to maintain the relationship	Firms make only minimal efforts and investments to barely ensure the survival of the relationship	Firms make efforts and investments that allow maintaining the relationship	Firms make significant efforts and investments to maintain and improve continously the relationship	
cs $_{16}$	Partners flexibility	It captures the degree to which partners are willing to adjust or adapt conditions of the relationship	There is only one of the partners that shows a willingness to adjust or adapt conditions. In addition his margin of fexibility is very low	There is only one of the partners that shows a willingness to adjust or adapt conditions. Nevertheless his margin of flexibility is important enough to potentially allow overcoming blocking situations	Both partners show a willingess to adjust or adapt conditions. Nevertheless their margin of fexibility is very low	Both partners show a real willingess to adjust or adapt conditions. In addition their margin of fexibility is important enough to allow overcoming blocking situations and keeping relationship evolving	
cs $_{17}$	Respect of engagements mutually agreed	It captures the degree to which partners respect engagements mutually agreed	No respect of engagements mutually agreed	Only one of the partners respect the engagements mutually agreed	Both partners respect the engagements mutually agreed	Both partners respect and exceed the engagements mutually agreed	
cs $_2$	**Integration and coordination**						0,00
cs $_{21}$	Process integration	It captures the degree to which firms have succeeded in integrating their processes	Firms have not integrated processes for key common activities	Firms have some integrated processes not robust enough and covering only part of the key common activities	Firms have robust and integrated processes covering only part of the key common activities	Firms have robust and integrated processes covering at least all the key common activities in the scope of the exchange	
cs $_{22}$	Decision style and synchronization	It captures the degree to which firms are able to synchronize with others to establish effective coordination mechanisms	Centralized decisions without coordination for key common activities	Decentralized decisions without coordination for key common activities	Centralized decisions involving effective coordination for key common activities	Decentralized decisions involving effective coordination for key common activities	
cs $_{23}$	Implementation of shared planning	It captures the willingness of firms to establish a collaborative and integrated planning	Standalone and confidential plannings	Sharing of some planning assumptions but still standalone and confidential plannings	Sharing of some planning assumptions and partial mutual visibility provided	Collaborative planning including sharing of strategic resources/assumptions	
cs $_{24}$	Conflicts and crisis management	It quantifies the ability of firms to identify and overcome conflicts	Firms do not possess a preventive approach to identify potentiel sources of conflicts or crises. In addition they do not have means for overcoming those situations	Firms possess a preventive approach to identify potential sources of conflicts or crises. Nevertheless they do not have means for overcoming those situations	Firms possess a preventive approach to identify potential sources of conflicts or crises. The means available for overcoming those situations are limited to the ones defined on contractual agreements	Firms possess a preventive approach to identify potential sources of conflicts or crises. In addition they have established proactive and collaborative methods and tools for overcoming those situations	
cs $_{25}$	Control	It quantifies the ability of firms to define meaningful control strategies	Insufficient or no controls to monitor the other firms' activity	Excessive controls to monitor the other firms' activity	Only necessary controls with strict and detailed rules as the only way of monitoring	Only necessary controls with a balanced mix of formal, informal and group rules for monitoring	
cs $_{26}$	Formalization	It quantifies the willingness of firms to formalize the relationship	No formalization	Not enough formalization to regulate partners exchanges and cooperation	Comprehensive formalization that regulates the relationship without flexibility	Comprehensive formalization that structures the relationship while staying flexible	
cs $_3$	**Information sharing and collaborative communication**						0,00
cs $_{31}$	Information sharing	It quantifies the willingness of firms to share information	No (or very low) exchanges of information	Unidirectional, Asymmetric or non-intensive exchanges at any decision level	Bidirectional, symmetric or Intensive exchanges at any decision level	Bidirectional, symmetric and Intensive exchanges at operational, tactic and strategic level	
cs $_{32}$	Collaborative communication	It quantifies the willingness of firms to establish a collaborative communication	No communication	Punctual communication	Regular but not balanced communication	Proactive communication (Frequent, balanced, bidirectional, open, formal and informal)	
cs $_{33}$	Use of ICTs	It quantifies the willingness of firms to use information and communication technologies	Firms have not implemented common ICT tools for key common activities	Firms have implemented some ICT tools not robust enough and covering only part of the key common activities	Firms have implemented robust ICT tools covering only part of the key common activities	Firms have implemented robust ICT tools covering at least all the key common activitiesin in the scope of the relationship	
cs $_4$	**Maturity and effectiveness of collaborative initiatives**						0,00
cs $_{41}$	Initiative Lifecycle	It captures the maturity and level of mutual understanding that firms achieved as part of collaborative initiatives	Exploration phase (mutual discovering)	Launching phase (mutual adjustment)	Maturity phase (good mutual understanding)	Consolidation phase (long-term partnership)	
cs $_{42}$	Effectiveness of the collaborative initiative	It quantifies the degree to which firms are able to establish effective relationships resulting on benefits at both firms' and supply chain level	Collaboration has a reduced impact on the overall performance of the Supply Chain with an oportunistic behavior in the allocation of efforts/benefits	Collaboration has a reduced impact on the overall performance of the Supply Chain with balanced efforts/benefits allocation	Collaboration has a significant positive impact on the overall performance of the Supply Chain with an oportunistic behaviour in the allocation of efforts/benefits	Collaboration has a significant positive impact on the overall performance of the Supply Chain with balanced efforts/benefits allocation	

Collaboration Matrix - CoMax

0,00

CoMax - Part I

General environment assessment

Criteria used for evaluating the ***general compatibility***

Code	Criterion	Description	The environment surrounding partners' relationship represents an obstacle for implementing collaborative practices between partners. In addition environment is unstable due to the significant uncertainty levels exisiting.	The environment surrounding partners' relationship includes more risks than oportunities to collaborate. Collaborative practices are difficult to implement and effectiveness of these practices are strongly limited. In addition environment stability is not ensured because uncertainty levels become important.	The environment surrounding partners' relationship includes more opportunities than risks to collaborate. Effective collaborative practices can be established if potential risks are leveraged and monitored. In addition environment can be considered as stable due to low uncertainty levels.	The environment surrounding partners' relationship favors the implementation of effective collaborative practices between partners. In addition environment has a proven stability due to very low uncertainty levels.	0,00
cg $_1$	**Operating environment structure**						0,00
cg $_{11}$	Relationship economic model	It captures the level to which the economic model regulating the relationship is favorable to and provides a positive context for collaboration					
cg $_{12}$	Level of interdependency	It quantifies the level and nature of the interdependency between two firms					
cg $_{13}$	Balance of power	It quantifies the way the power is distributed between partners					
cg $_{14}$	Goal congruency	It quantifies the level of consistency between partners' strategies as well as the consistency between partners' local strategies and the overall supply chain objectives					
cg $_2$	**Operating environment stability**						0,00
cg $_{21}$	Partner's internal environment stability	It captures the level of stability of partners' internal environment and the level of uncertainty of partners' behavior					
cg $_{22}$	Partners' external operating environment stability	It captures the level of stability of partners' external operating environment as well as the associated environmental uncertainty					

CoMax - Part II

Partners' collaborative performance

Criteria used for calculating the ***proven compatibility***

Criteria used for calculating the ***collaborativity***

Code	Criterion	Description	Partners have common processes but there is not a collaboration dynamic established at all. Partners have standalone strategies and focus on internal environments and performances. No involvement or engagement of partners to create a real collaborative framework.	Involvement of partners on common initiatives is minimal and only a reduced number of aspects of the relationship are addressed. Collaboration is considered more as an obligation than an opportunity to increase both local and global performances.	Partners collaborate and have common initiatives but relationship is not mature enough to have robust and effective processes. Collaboration is not still considered as a strategical driver and there is only a partial involvement of partners.	Partners have succeeded to establish a possitive environment for collaboration with effective relationships, collaborative initiatives and a real involvement of partners favoring the improvement of both local and global performances.	0,00
cs $_1$	**Involvement of partners**						0,00
cs $_{11}$	Risk/reward sharing	It captures both the level of fairness and coverage of the risks/rewards sharing strategy					
cs $_{12}$	Resources sharing	It quantifies the willingness of partners to share resources					
cs $_{13}$	Joint knowledge creation and sharing	It quantifies the degree to which partners are able to create and share knowledge					
cs $_{14}$	Degree of participation	It evaluates the degree to which partners participate and involve themselves					
cs $_{15}$	Partners engagement	It captures the degree to which partners are committed to the relationship and are willing to invest on it					
cs $_{16}$	Partners flexibility	It captures the degree to which partners are willing to adjust conditions of the relationship					
cs $_{17}$	Respect of engagements mutually agreed	It captures the degree to which partners respect engagements mutually agreed					
cs $_2$	**Integration and coordination**						0,00
cs $_{21}$	Process integration	It captures the degree to which firms have succeeded in integrating their processes					
cs $_{22}$	Decision style and synchronization	It captures the degree to which firms are able to synchronize with others to establish effective coordination mechanisms					
cs $_{23}$	Implementation of shared planning	It captures the willingness of firms to establish a collaborative and integrated planning					
cs $_{24}$	Conflicts and crisis management	It quantifies the ability of firms to identify and overcome conflicts					
cs $_{25}$	Control	It quantifies the ability of firms to define meaningful control strategies					
cs $_{26}$	Formalization	It quantifies the willingness of firms to formalize the relationship					
cs $_3$	**Information sharing and collaborative communication**						0,00
cs $_{31}$	Information sharing	It quantifies the willingness of firms to share information					
cs $_{32}$	Collaborative communication	It quantifies the willingness of firms to establish a collaborative communication					
cs $_{33}$	Use of ICTs	It quantifies the willingness of firms to use information and communication technologies					
cs $_4$	**Maturity and effectiveness of collaborative initiatives**						0,00
cs $_{41}$	Initiative Lifecycle	It captures the maturity and level of mutual understanding that firms achieved as part of collaborative initiatives					
cs $_{42}$	Effectiveness of the collaborative initiative	It quantifies the degree to which firms are able to establish effective relationships resulting on benefits at both firms' and supply chain level					