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Collaborative Methodology for Supply Chain Quality Management: Framework and Integration With Strategic Decision Processes in Product Development

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Abstract: The new generation of network-based organizations has triggered the emergence of distributed and more complex contexts for the analysis of firms' strategies. This gradual change in the way we understand enterprises has induced radical evolutions on the *Quality Management* domain. As a consequence, the *Problem Solving Methodologies (PSM)* widely used in industry and positioned up to now as one of the key elements for achieving continuous improvement efforts within local scopes are now insufficient to deal with major and distributed problems and requirements in this new environment. The definition of a generic and collaborative *PSM* well-adapted to supply chain contexts is one of the purposes of this paper. Additional requirements linked to specificities carried out by the introduction of a networked context within the methodology scope, the relational aspects of the supply chains, complexity and distribution of information, distributed decision-making processes and knowledge management challenges are some of the aspects being addressed by the proposed methodology. A special focus is made on benefits obtained through the integration of those elements across all problem-solving phases and particularly a proposal for multi-level root-cause analysis articulating both horizontal and vertical decision processes of supply chains is presented.

In addition to laying out the expected benefits of such a methodology in the *Quality Management* area, the article studies the reuse of all the quality-related evidence capitalized in series phase as a driver for improving upstream phases of product development projects. This paper addresses this link between series and development activities in light of the proposed *PSM* and intends to encourage discussion on the definition of new approaches for *Quality Management* throughout the whole product lifecycle. Some enabling elements in the decision-making processes linked to both the problem-solving in series phase and the roll-out of new products are introduced.

Key Words: Problem Solving Methodology, Supply Chain Quality Management, Product Development, Experience Feedback, Collaborative Supply Chains

1. Introduction

In the past, firms used to work based essentially on achievement of local objectives. This way of working produced short-sighted, standalone and conflicting strategies between firms and their stakeholders, which led up to misalignment and poor global performances. In that context, the quality was consequently managed in a reduced perimeter characterized by local continuous improvement efforts (Foster 2007). For instance, centralized *PSM* well-adapted for dealing with local problems gained a place as a cornerstone element within firms' strategies for meeting quality exigencies.

Nonetheless, the higher levels of competition and the intensification of cost, quality and delivery requirements have forced enterprises to cross their own boundaries towards more collaborative models involving stakeholders (Derrouiche 2008). Thereby, approaches based on the notion of an *Extended Enterprise* and including principles such as objectives alignment, strategy synchronization, collaborative practices and common-to-all processes appeared (Cao et al. 2011). This new environment led up to the emergence of *Collaborative Supply Chains* defined as self-organized networks of organizations acting as a whole and looking for global fulfillment of final customer needs (Knowles et al. 2005).

The introduction of this concept has radically changed the quality management paradigms. The continuous improvement practices, such as the *PSM*, are now faced to deal with networked, distributed and more complex environments including amongst others a larger number of partners, huge quantities of fragmented and distributed information, higher impact problems defined at a supply chain level, distributed and no more centralized activities and collaborative aspects not addressed before.

The aim of this paper is to meet the challenge of successfully extending the *PSM* and their benefits to *Supply Chain* contexts and intends to propose a generic and collaborative methodology adapted to new-generation of network-based organizations. The proposed methodology aims to be a driver for the enhancement of quality management and continuous improvement efforts at a supply chain level. It has been improved with a two-layered structure for modeling all the technical and collaborative aspects of supply chains and synchronized with a distributed *Experience Feedback System* enabling the methodology dealing with knowledge management across distributed contexts. This methodology is presented in Section 2.

Once the proposed global methodology has been deployed across all the stages of the Supply Chain, access to huge quantity of meaningful and structured quality-related information capitalized for products and partners in series phase is available to be exploited. All the problem solving experiences can thus be used not only to enhance solving of new problems in series phase but also as an input for improving and enhancing new products design in development ones. In Section 3, the general guidelines for a global continuous improvement approach linking series and development phases are presented.

2. A collaborative Problem Solving Methodology adapted to Supply Chain contexts

In order to deal with all the critical aspects of new generation of network-based organizations, the proposed *PSM* has been defined as a whole solution composed by three cornerstone elements as shown in Figure 1. The first element is defined by the *Methodology* itself and aims to structure the whole solving process. The second element is based on a *Two-layered Model* dealing with the study of distributed contexts. This model is composed of two complementary levels handling with both technical and collaboration dimensions of supply chains. The third pillar of the methodology corresponds to the distributed *Experience Feedback Process* dealing with the capitalization and reuse of problem solving experiences through networked and distributed contexts.

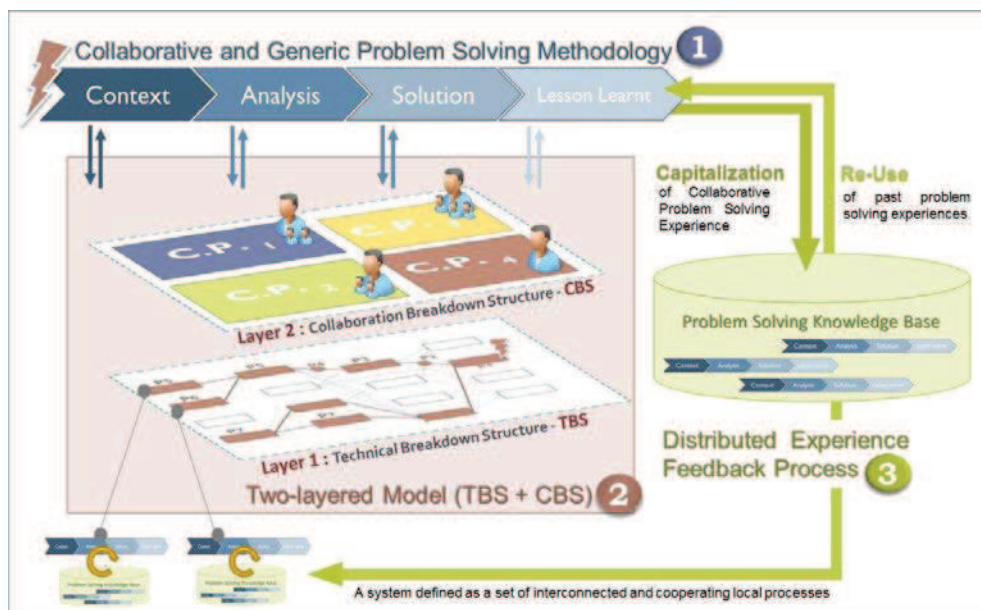


Figure 1: The global Problem Solving Methodology

The *Methodology* considers that the Problem Solving is a generic process that can be understood from a simplified approach with four phases: *Context*, *Analysis*, *Solution* and *Lesson-Learnt* (Kamsu-Foguem et al. 2008). The fact that existing methodologies for problem solving such as the plan-do-check-act (PDCA), the 8-Disciplines (8D) and the six-sigma DMAIC (Define, Measure, Analyze, Improve and Control) can be expressed in terms of these four standard phases provides this choice with a generic reasoning contributing to adaptability and deployment in a wide range of industrial contexts (Jabrouni et al. 2010).

2.1 Specification of the problem context

The *Context* phase of the *Methodology* aims to border the problem by keeping only relevant information contributing to problem understanding and providing with meaningful evidence for further solving phases. Due to the nature of problems to be handled within the frame of network-based organizations, the quantity and quality of information become a critical issue (Cantor et al. 2009). The proposed methodology specifies a relevant problem context through the accomplishment of four phases: *Formalization, Filtering, Pilot Team constitution* and *Reusing*.

2.1.1 Formalization

When dealing with complex contexts characterized by the multiplicity, fragmentation, distribution and heterogeneity of information across a network, the first step is to define common-to-all frameworks and harmonized mechanisms for formalization and sharing of that information (Buzon et al. 2007) (Zhou et al. 2007). This first objective has been achieved by coupling the methodology with a proposal for the modeling, diagnostic and analysis of supply chains in the light of problem solving processes. This model corresponds to the second cornerstone element of the global methodology as shown in the Figure 1.

Such approach is defined by two complementary levels addressing the whole technical and collaboration dimensions of Supply Chains through a unique two-layered model. The first technical layer aims to address the entire product, process and network related aspects while the second one intends to complete the model by dealing with all the relational and collaboration aspects of supply chains. Each level is materialized in the proposed model through a breakdown structure modulating both technical and collaboration aspects in more manageable units. Then, the *Technical Breakdown Structure (TBS)* or first layer is thus defined by the set of all the *Technical Packages (TP)* summarizing all the technical attributes for each node of the network while the *Collaboration Breakdown Structure (CBS)* or second layer is defined by the set of all the *Collaboration Packages (CP)* representing the clustering of partners across the same network for solving purposes. Unlike the first level, characterized as static and aiming to provide robustness to the model, the second one is defined dynamically with regard to supply chain collaboration aspects evolving constantly through the time and being specific for each problem. Aspects such as confidentiality, trust and power between partners correspond to criteria being critical on the effectiveness of Supply Chain practices operation. Other characteristic of this second level is that it can be modulated through multiple sub-levels representing nested and dynamic collaboration structures. This adaptability and flexibility allow the model to provide up-to-date and reliable contexts in the light of problem solving processes. Figure 2 synthesizes and positions the different aspects of the TBS+CBS model.

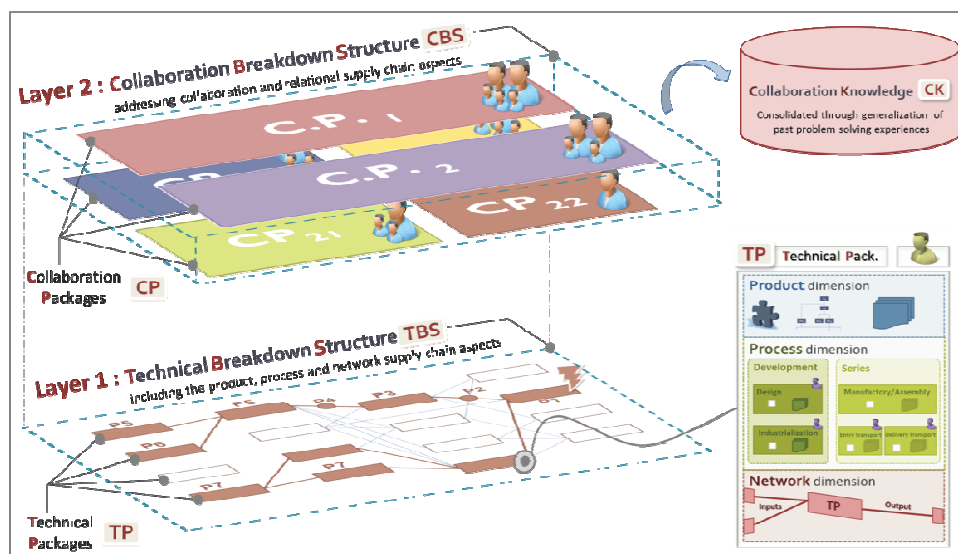


Figure 2: The two-layered approach for the modeling of Supply Chains

The *Formalization* phase, enabling the specification of relevant contexts within networked environments, is based on: (1) the first level of the two-layered model summarizing the

technical context of the supply chain where problems are occurring and (2) the entire *Collaboration Knowledge* generalized from past problem solving experiences. At this stage, available *Technical Breakdown Structure (TBS)* and *Collaboration Knowledge (CK)* provided by the model are defined at a global *Supply Chain* level and do not include yet all the specificities linked to current problems being solved.

2.1.2 Filtering

This phase focuses on the filtering of the networked contexts issued from previous steps with regards to specific problems in order to keep only the relevant problem-related information. To do so, a mechanism intending to filter the context issued from the two-layered model and get thus a simplified *TBS* adapted to current problem has been specified. This *Filtering Mechanism (FM)*, aiming to keep the most relevant *TPs* for the current problem solving experience, is based on the assumption that when a problem appears, the partner directly concerned by this problem is able to define a reduced number of relevant problem-related criteria. These criteria are the inputs for the filtering mechanism and are formalized through a *Preliminary Problem Context Record (PPCR)* including:

- *Impacted element*: Product on which the problem has been detected. After it has been identified, the corresponding *TP* summarizing all the product, process and network dimensions for this element can be identified.
- *Problem width*: Criterion based on the selection of the more relevant *n-1 level TPs*. It allows reducing the number of branches (or width) of the *TBS* to be analyzed.
- *Problem depth*: Criterion defined in function of the number of levels to be included at the analysis and filtering stages. It allows reducing the depth of the *TBS*.
- *Problem domain*: Criterion allowing characterizing current problem with regard to pre-defined types of problems. The domains characterizing current problem are then matched with the domains characterizing the *TPs* of the *TBS* in order to reduce the already filtered scope.
- *Relevant processes*: Criterion defined in function of processes being considered as relevant for current problem solving experience. This choice is done taking into account the *Design, Industrialization, Fabrication and Transport* dimensions studied by the *TPs*. It allows reducing for already filtered *TPs*, the quantity and nature of information to be kept.

The filtering process computes and matches all these problem-related criteria with the attributes characterizing the *TPs* across the whole *TBS*. The definition of these criteria is initialized based on preliminary analysis performed with regard to problem evidence available at early stages of the solving process. Nevertheless, it is completed throughout the methodology in order to improve filtering results. The output of this phase is a simplified *TBS* adapted to current problem (identified as *TBS'*).

2.1.3 Pilot Team constitution

This phase aims to identify the actors that will pilot the solving efforts. Based on the previously simplified *TBS'* and taking into account that partners are linked to *TPs*, the model is able to identify all the relevant actors owning key processes and having problem-related competencies. This set of *eligible contributors*, grouping the partners being well-positioned across the network to potentially contribute to problem solving, can be updated manually throughout the methodology by adding actors in function of specific-to-problem requirements (e.g. domain experts or authority representatives). The selection of the *pilot team* members, issued from this set of *eligible contributors*, is executed by the partner directly concerned by the problem through a *Collaboration Mechanism (CM)*. This mechanism, aiming to optimize the *pilot team* constitution in regards to additional behavioral and collaborative aspects of the supply chains, led up to the definition of the second level of the two-layered model. The inputs for this mechanism are based on the one side on the *Collaboration Knowledge* generalized for the concerned *Supply Chain* and on the other one on the *Partner Preferences Record (PPR)* summarizing partners' preferences in regards to critical supply chain collaboration criteria such as power, trust, control, objectives alignment, information sharing and conflict (Cao et al. 2011). The output of this phase is the *pilot team* which is positioned as the header element of the second layer (*CBS₀*) of the two-layered model (*TBS+CBS*).

2.1.4 Reusing

This step intends to exploit the shared knowledge database. The purpose is to find the most relevant past problem solving experiences in order to enhance the current one. This phase is executed by the

pilot team and is based on the completion of the previously defined problem-related criteria, this time through a *Consolidated Problem Context Record (CPCR)*. This record is used as the input for the *Reusing Mechanism (RM)* whose output is the set of all the relevant past solving experiences having the higher similarity degree and providing with meaningful information being able to be adapted/reused in the current solving experience.

The output of the *Context* phase corresponds to a *problem context* characterized by the completeness, relevance, readiness and accuracy of its content. This reduced but relevant context provides problem solvers with meaningful and added-value information that enhances the decision-making processes all along the methodology. The possibility of reducing from a huge space of research to a more reduced scope with prior and more relevant problem-related information and the opportunity of reusing and adapting past problem solving experiences are fundamental gains that can be reached through the deployment of the proposed methodology. All the key elements of the Context phase are synthesized in Figure 3.

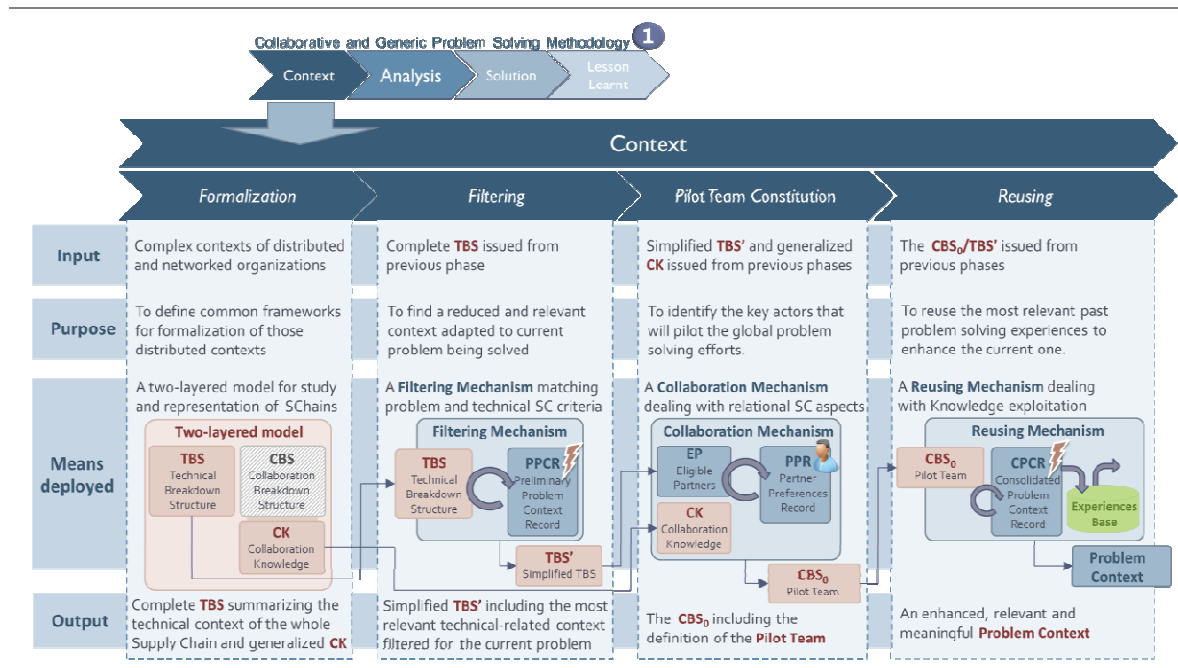


Figure 3: Key elements of the context phase

2.2 Multi-level root-cause analysis

The *Analysis* performed on the basis of the context issued from the previous phase. The objective is to perform a deep analysis of the problem and available information in order to find the root causes producing the problem. The identification of those causes is a critical factor within the quality domain as their identification is a mean for allowing a full eradication of problems (Wilson et al. 1993). The problem analysis efforts within the frame of supply chains demands from the methodology additional assets such as: (1) synchronization of distributed partners in regards of common decision processes, (2) clustering in order to optimize competencies, promote synergies and mitigate risks, (3) establishment of shared processes in order to improve decision flows and (4) dealing with relational and collaboration aspects of the supply chains in order to create positive communication and establishment of intensive long-term relationships. Within this context and as part of the current methodology, a proposal dealing with a *dynamic and multi-level root-cause analysis* adapted to *Supply Chain* problems has been specified.

This proposal is based on the coupling of two elements: the *causal tree* of a problem and the *two-layered model*. The first element is widely used within the continuous improvement area and the second one aims to enhance distributed decision processes by incorporating the whole technical and collaborative dimensions related to Supply Chains. The *causal tree*, breaking down problems until the root-causes are found, is considered as the driver of the proposed approach while the *two-layered model* is considered as the facilitator of this proposal within distributed contexts. The inputs for the

analysis phase are the *problem context*, the *pilot team* and the set of all the *eligible contributors* issued from previous phase. These elements are materialized in the two-layered model by the *TBS*' and the header level of the *CBS* containing the *pilot team*.

For each level of the *causal tree*, a corresponding collaborative structure being able to deal with the analysis of elements included at that level must be defined. Each collaborative structure, corresponding to one level of the *CBS* and being defined by a set of interconnected *CPs*, must fulfill the whole Supply Chains requirements. As a consequence, during the clustering of partners with problem analysis purposes not only technical issues and competencies owned by actors but also all the relational and collaboration aspects must be considered. For the header level of the causal tree dealing with the problem (H_0), this requirement has been fulfilled through the application of the *Collaboration Mechanism (CM)* enabling the constitution of the *pilot team*. This team, as shown in Figure 4, is positioned at the header level of the *CBS* (CBS_0) and has the accountability of analyzing the corresponding header level of the *causal tree* (H_0).

Once the *pilot team* has analyzed the problem level in the light of available technical context issued from the *TBS*', it must breakdown the problem into more manageable level-1 causes (H_1) potentially producing this problem. These are the causes answering to the question: Why has the current-level cause (H_0) occurred? When level-1 causes (H_1) are identified, the first level of the *CBS* (CBS_1) is initialized. This level includes one *Collaboration Package (CP)* for each cause on the corresponding level of the causal tree. For the definition of the team members belonging to each *CP*, the same *Collaboration Mechanism (CM)* used for the constitution of the *pilot team* is deployed. This mechanism, computing all the *Partner Preferences Record (PPR)* for partners included in the *eligible contributors* set, optimize the resources distribution and the clustering of partners in regards of the analysis and validation of current problem causes and behavioral aspects. After each *CP* is defined, the accountabilities and the different roles inside the package are distributed with regard to agreed *Collaboration Agreements* governing *CP* operation. To favor communication between different levels of collaborative structures, the *CP coordinator* at one level must be at least a *CP* member at the $n-1$ level. At this stage, the *CPs* are ready to start the analysis of the level-1 causes (H_1) in the light of available technical context issued from the *TBS*'. From this point, all steps are reproduced within the frame of a recursive approach intending to breakdown in a synchronized way the problem and the collaborative structures until the root-causes (n -level) are finally found. The principles of this collaborative approach positioned as a driver for complex problems analysis on extended and distributed contexts and its integration with the two-layered model (*TBS* + *CBS*) are illustrated on Figure 4.

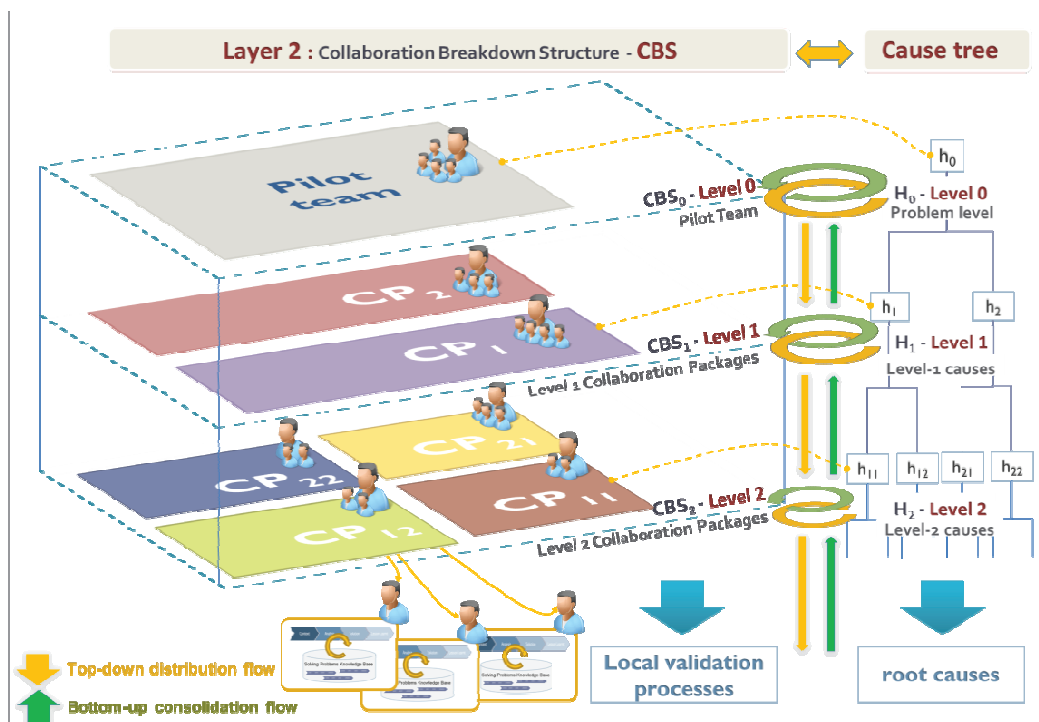


Figure 4: A multi-level approach for root-cause analysis on distributed contexts

A top-down and a bottom-up flow covering the *causal tree* and the definition of dynamic teams or *Collaboration Packages (CP)* across the *CBS* in a recursive way are the backbone elements of the global decision process of this model. The top-down flow aims to analyze and distribute causes through the *CBS* levels while the bottom-up flow aims to validate analysis and provide consolidated results. In both descending and ascending flows team collaborative work is deployed in order to align and coordinate efforts. After both flows have been completed, a *consolidated causal tree* listing all relevant root-causes producing the current problem is capitalized into the global knowledge database. Synchronization of *Supply Chain* and local decision processes are included as a way to promote the enhancement of *Learning Organizations*. Through this approach the resources participating to the problem analysis process are optimized and both individual and network competencies and knowledge are consolidated.

From a more global point of view, the possibility of having a central repository containing all the root-causes producing problems being detected on products moving through supply chains and the corresponding collaborative structures performing these analyses provides a very important competitive advantage in regards of strategic decision processes at a supply chain level. All this quality-related information can consequently be exploited for enhancing the *Supply Chain Quality Management (SCQM)* through the definition of generalized continuous improvement efforts tackling and eradicating recurrent and high impact *Supply Chain* problems.

2.3 Solution and Lesson Learnt phases

In this phase, the two-layered model allows focusing the team collaborative efforts on the definition of an action plan addressing the root causes. The same top-down and bottom-up flows can be used now to deploy an action plan distributed horizontally through the different stages of the network and vertically through the different organization decision levels. A global and aggregated approach synchronizing vertical and horizontal flows of supply chain ensures the effectiveness of the solutions deployed and contributes to the achieving of global continuous improvement objectives defined within the frame of the *SCQM* efforts (Harland et al. 2004).

The *Lesson Learnt* phase intends to encapsulate the whole *PSM*, related activities and associated knowledge in one individual experience being capitalized into the shared knowledge database. At this stage, great knowledge management benefits can be obtained because both global and local quality-oriented competencies are created, shared and distributed across the network. This allows gaining on higher performances and obtaining superior *Supply Chain* competitiveness levels.

3. The proposed methodology as a driver for enhancing strategic making decision processes during new product development

The new product development projects include some strategic activities having important impact over the whole product lifecycle. Two of these crucial activities concern on the one hand the *system design process* aiming to define and freeze product plans through both preliminary and detailed design reviews (Mavris et al 2011) and on the other one the *supplier selection* phase aiming to identify, evaluate, and contract with suppliers (Beil 2010). These two phases, being part of the classical product development approaches, have been retained for the purpose of this article as they allow highlighting some concrete links existing between the proposed global methodology for quality management in series phases and the new products roll-out in the development one (see Figure 5).

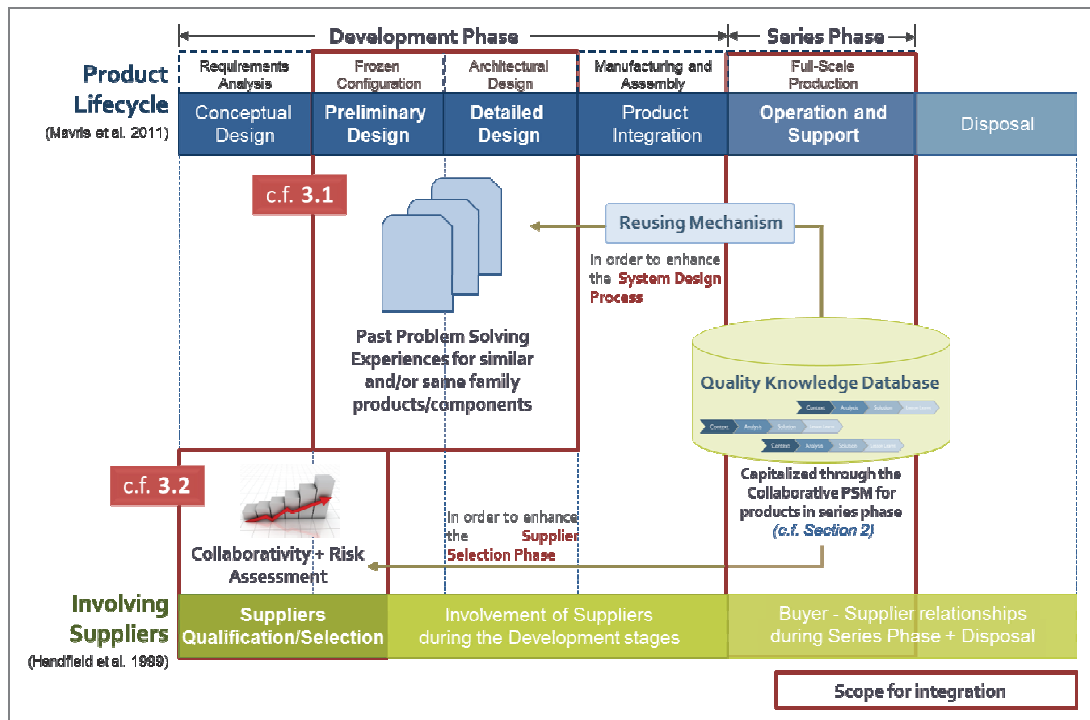


Figure 5: Integration of the PSM into strategic decision-making in development phases

3.1 System Design Process

The system design process encompasses the process during which a new product is brought from the conceptual stage to readiness for full-scale production. All along this process including some preliminary, detailed and critical reviews, the system structure evolves through different maturity stages with different kind of business, technical, industrial, quality and risk factors being leveraged (Handfield 1999). In addition, sometimes the lessons learnt from previous development projects are also included throughout these stages to improve the current system specification (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 the 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 through the proposed PSM.

As detailed on Section 2, after the global methodology has been deployed across all stages of the supply chain, a central knowledge base including meaningful information in regards of new product development is available to be exploited. List of some structured, added-value and meaningful information available from this central quality repository includes but is not limited to:

- All problems detected for constituents, similar and/or same-family systems,
- Relevant root-causes analysis used for solving those problems,
- Solutions proposed and related action plans,
- Generalized knowledge issued from the lesson learnt phases and,
- Relevant technical context (TBS') and collaboration structures (CBS) deployed.

All this global relevant information encapsulated in the problem solving experiences can be exploited through the application of the *Reusing Mechanism (RM)* defined in Section 2.1.4. A *Design Requirements Record (DRR)*, characterizing the whole criteria specific to design/development activities, enables the reusing/adaptation process. This last one aims to reuse and keep only the more relevant information in order to: (1) highlight risks not before considered 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.

3.2 Supplier Selection

It could be useful to access during the supplier qualification/selection process to relevant information measuring partner involvement on collaborative practices already deployed across the whole supply chain. The proposed approach analyzes relevant information capitalized through the global *PSM* in order to come up with two complementary indicators aiming to measure this involvement and enabling decision-making at this early stage of *suppliers qualification/selection*:

- A first *collaborativity index* intends to define the degree of involvement, adherence and alignment of partners with quality strategies of collaborative supply chains. So, more the firms work in partnership with stakeholders to solve supply chain problems and more they deploy the proposed *PSM*, more its *collaborativity index* improves. This index, measuring the disposal degree of a partner to work in a collaborative way, can be reasoned from the past problem solving experiences including amongst others the entire CBS and CK context.
- A second *risk-oriented index* defined for each supplier/product couple can be aggregated from information available in the central knowledge repository. The number of high-impact problems detected for this couple and the related analyses performed can represent meaningful evidence during supplier assessment. This measure can be aggregated in order to define a *supplier risk index* aiming to reflect the trustworthiness associated to partners and their already industrialized products. The *risk-oriented index* must be analyzed in parallel with the *collaborativity* in order to favor the involvement of partners. The fact of increasingly cooperating with the other partners to solve problems will allow firms consolidating competencies and enhancing local processes, which consist in the long-term on a driver for improving product quality and reducing risks. Then, the involvement and engagement of partners with the proposed methodology represents a double gain.

Proposed measures enhance supplier qualification process by providing with additional meaningful information not being before deeply analyzed due to: (1) complexity of gathering this kind of information on distributed and more complex contexts such as the supply chains and (2) the lack of maturity of links existing between series and development phases in the quality management area. These new indicators must be understood as two complementary and interdependent elements for assessing suppliers' performance on problem solving and continuous improvement processes. Finally, this set of index can be articulated by the buyers with more global sourcing strategies in order to promote higher involvement from suppliers in supply chain collaborative practices.

4. Conclusion

In this paper, a collaborative methodology for problem solving adapted to supply chain contexts has been defined. It has been positioned as a key driver for achieving an effective *Supply Chain Quality Management*. The methodology addresses the whole technical and collaboration aspects of the supply chains and deals with knowledge management across distributed contexts. This proposal contributes to achievement of supply chain continuous improvement objectives and promotes the emergence of *Learning Supply Chains*.

This paper has shown that the quality-related information capitalized through this methodology is very useful not only for enhancement of future quality efforts in series phase but also for enabling and improving *system definition* and *suppliers selection* during roll-out of new products. The *risk* and *collaborativity* indexes enhance decision making process at these phases and allow the synchronization of *SCQM* with the new products development projects.

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