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27th CIRP Life Cycle Engineering (LCE) Conference

# Towards a Modeling framework of collaboration in PSS development project: a review of key factors

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## Abstract

Inter-enterprise collaboration is one of key important issues that affect the successful of a PSS (Product-Service System) project. This paper sets the bases of a global model that help characterizing and assessing collaboration processes along the PSS lifecycle. Based on a critical literature review of main papers dealing with collaboration issues, a list of ten key factors has been identified. Social capital theory is used to clarify the definitions and impacts of some of these factors. A UML class diagram of PSS collaboration processes is then proposed to connect these factors with other characteristics of PSS.

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*Keywords:* Product-Service Systems; Collaboration; Factors.

## 1. Introduction

Reaching economic and social sustainability became a real challenge for nowadays companies. More and more firms are interested in providing integrated offers as a potential solution to such challenges. This solution, commonly defined as product service system, consists on changing the business plan of companies from selling pure products to the combination of products and services [1]–[3]. By adopting this strategy, manufacturing companies increase their competitiveness and reduce the risk of imitation [1], [4]. Moreover, many authors examined the potential economic and social sustainability impacts of PSS through the long term relationship between the various stakeholders of the socio-economic system [5]–[7]. The PSS development and life-cycle management require the involvement of different stakeholders (including the client and suppliers) [1], [2] for the integration of product and service elements, and to support the Original Equipment Manufacturer (OEM) with specific competences and resources to deal with

the complexity of the PSS paradigm [8]. Indeed, comparing to product development, developing services requires a higher intensity level of collaboration processes [9]. Schweitzer [10] suggest that the service component pose a challenge for structuring of the value creation network, beside of only providing physical products. Thus, the complexity is higher when the service development is combined with product development process. Considering the whole lifecycle of PSS with various possible scenarios at every stage is also challenging and require continuous interaction with the customer after the PSS delivery [1]. This means that managing the collaboration between partners in the PSS context is of great importance to reach the required performance.

The purpose of this paper is to analyze the collaboration processes and issues in PSS development and to identify the different factors impacting the collaboration performance. This conducts to the proposition of a generic PSS collaboration model as an initial stage towards a management framework of collaborations along the whole PSS lifecycle.

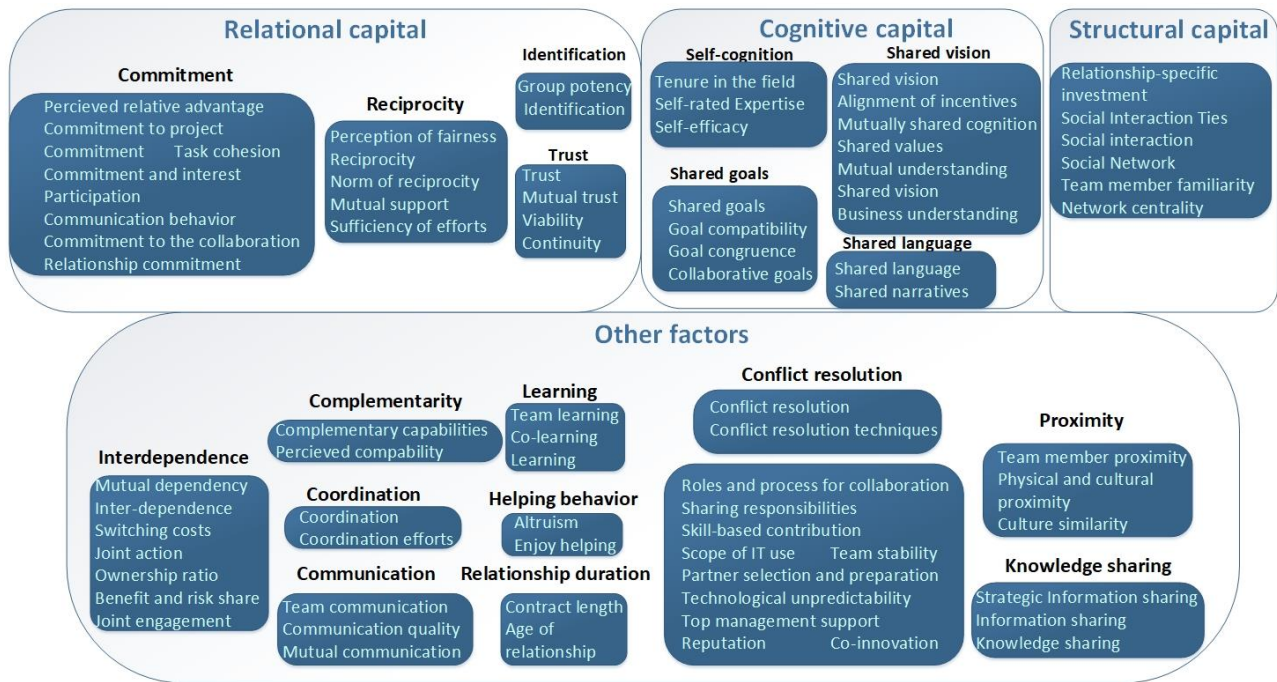


Fig. 1. Classification of collaboration factors

The remaining of this paper is organized as follow: based on literature survey, section 2 proposes a classification of the key factors impacting collaboration in PSS development process. A first conceptual model is proposed in section three to highlight the connection of the cited factors with other characteristics of the collaboration. Finally, we draw a conclusion and some perspectives in section 4.

## 2. Factors impacting collaboration: A literature review.

Several studies in literature focus on analyzing the factors that can impact collaboration between team members and organizations in industrial context. Our synthetic literature review has resulted on the most important factors impacting the collaboration performance within PSS development context. In this section we describe the research methodology then we present the results.

### 2.1. Research methodology

A review from a selection of 60 articles dealing with collaboration factors has been performed. These papers are chosen according to three criteria: (1) papers which focus on success factors; (2) dealing with the context industrial collaboration between organizations, and (3) showing links with concepts that have a close meaning as “collaboration performance”, or have similar characteristics. 44 articles from the selection treat the issues of inter-organizational collaboration, while few studies focused on intra-organizational collaboration. The different fields of collaboration covered in this review are: New Product Development (NPD), supply chain management (and more specifically purchasing), information and knowledge sharing

and finally some studies which treat the collaboration in a general case. It is to highlight the lack of papers that deals exclusively with the collaboration challenges in PSS domain. However, we suggest that studies from the fields cited above are necessary to learn from and represent a basis which can be adapted to PSS context. The reason is that the stakeholders of a PSS project are coming originally from conventional business fields (i.e. an OEM in automotive industry who wants to add specific services needs complementary skills). An example of a study of factors in PSS domain is performed by Windahl and Lakemond [11] who present six factors influencing the success of the development of integrated solutions (PSS): strength of the relationship, firms positions in the network, firms network horizon, the solution impact on existing internal activities, solution impact and external determinants (also process focus). As in NPD field, PSS development success is strongly related to inter-organizational collaboration within a value network. Moreover, adding a service component to a product development requires more intensity and challenges in the value network [9], [10].

First, around 41 distinct factors were identified as shown in Figure 1. They impact on various aspects related to “collaboration performance” as: success of partnership [12], collaboration quality [13], success of collaboration process [14], project collaboration quality [15], team effectiveness [16], quality and quantity of knowledge sharing [17], etc.

In literature, factors were represented in different ways, either antecedents or components (criteria) of collaboration. For example, trust was more mentioned as an antecedent, as the level of trust between partners has an effect on collaboration performance. On the other hand, communication quality was mentioned as a criterion which defines collaboration performance. For our study we selected both

representations (antecedents and criteria) since they are important for performance assessment. Secondly, we grouped the factors that have similar meaning but different wordings in the same category. The last step consists on the filtering of factors according to some criteria which are (1) the frequency of citation; (2) the adaptation to the context of this study, for example, factors which focus on personal behaviors are not adapted to our context; and finally, (3) the consistence and significance of the results that the studies show, regarding the impact of these factors.

## 2.2. Results

As shown in figure 2, among the 60 papers reviewed, ten key factors are then selected.

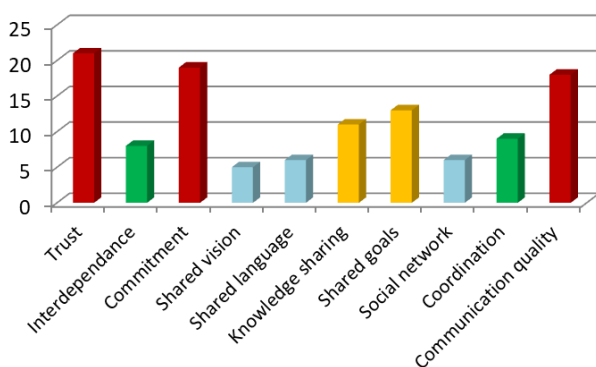


Fig. 2. Occurrence of key collaboration factors

Due to restriction on paper size, Table 1 summarizes the most important papers citing the above key factors.

Table 1. Review of collaboration factors

Factor	Authors
Trust	[9], [12], [14], [15], [17]–[35]
Commitment	[9], [12], [13], [15], [18], [19], [24], [29], [31], [34]–[39]
Shared vision, values and interests	[16], [17], [25], [30], [38]
Shared language	[17], [40]–[43]
Knowledge sharing	[12], [24], [29], [37], [38], [43]–[45]
Shared goals	[13], [15], [17], [18], [20], [25], [37], [39], [44], [45]
Social network ties	[21], [20], [17], [13], [36], [40], [25]
Coordination	[12]–[14], [21], [29], [44], [46]–[48]
Communication quality	[9], [12], [13], [18], [19], [21], [29], [32], [35], [39], [44], [45], [49]
Interdependence	[12], [13], [29], [30], [37], [38], [47], [50]

Since we noticed that a large part of factors were related to social capital, this theory [41] is used to clarify the definitions and impacts of the main factors. The social capital theory serves as a basis to analyze relationships between partners. Nahapiet and Ghoshal [41] define social capital as “the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network”. Previous authors studied the impact of social capital on different aspects in collaboration context, as for example knowledge sharing [17], [36], innovation and resource sharing [51], [52]. Social capital

comprises three dimensions: (1) cognitive dimension, which refers to resources which share common vision and understanding, by adopting common sense and terminology [41], (e.g. shared goals); (2) structural dimension, which concerns the pattern of the network of relations and the linkage between its components and how they are linked [41], (e.g. interaction ties); and (3) relational dimension, which treats interpersonal relationships that members of an organization developed with each other through a history of interactions [41], (e.g. trust). Therefore, the resulted factors are presented as follows:

**Trust :** We define trust as a state of mind and a confidence putted in a partner’s behavior which tend to be acceptable and predictable [22]. Trust is one of the most cited factors enhancing collaboration. Chin et al. [35] suggest that a high level of trust reduces conflicts, causes higher partner satisfaction and enhances cooperative behavior. Empirical evidences from literature show the positive impact of trust on collaboration. In particular, higher trust is significantly associated with performance and satisfaction with relationship [24], partnership efficacy [32], buyer performance [26] and collaboration quality in terms of the means of communication behavior and cohesion [15] and project or production performance [24], [32].

**Commitment:** Commitment can be defined as the effort taken on behalf of a relationship and the intention to maintain it [9]. Mohr and Spekman [12] suggest that this effort will balance short-term problems with long-term goal achievement. Commitment to the collaboration helps weather adversity and reduce conflicts [18]. It increases collaborators’ participation, mutual support and combination of their efforts to define collaboration priorities [15], but also reduces nonproductive behaviors such as job avoidance, defiance, or aggression [39]. Commitment is recognized as a key factor improving partnership success and satisfaction with relationship [12], [24].

**Shared vision, values and interests:** Shared vision, interests and values are important to improve the collaboration atmosphere. Chiu et al. [17] argued that common interests and visions in a virtual community will help members to see the meaning of their knowledge. When participants have the same meaning of the problem to solve, it will facilitate coordination and enables efficient decision making. Previous studies show that shared vision positively impacts the quality and knowledge [17], while shared values improve buying firm performance [38].

**Shared language:** Shared language is not limited to the language itself, but it concerns “the acronyms, subtleties, and underlying assumptions that are the staples of day-to-day interactions” [17]. Shared language facilitates access to people, organizations and their information, and allows entities to gain mutual understanding and being interoperable [17]. Therefore, using a common language enhance the effectiveness of information exchange and assistance [42]. When shared understanding is improved, the gained mutual awareness will help to predict actions and reduce unexpected behaviors of organization members [42].

**Information and knowledge sharing:** Information sharing refers to the extent to which a variety of relevant, accurate,

confidential and critical information is shared to partners [24], [45]. Accordingly, Doney and Cannon [53] argued that sharing confidential information provides a sign of that the party sharing the information has goodwill intentions and can be trusted, which could encourage parties to commit to the collaboration. Furthermore, misunderstanding and bad information sharing may be costly and should be avoided through improved knowledge and information sharing mechanisms [43]. Previous research identified information sharing as a dimension of effective supply chain collaboration [45] and buying firm performance [38].

**Shared goals:** Shared goals is the extent to which partners perceive a possibility of common objectives to join their efforts [54]. Common goals are likely to increase the information exchange between collaborating actors competitive goals are identified to be more related to suspicion and low information sharing. Shared goals also lowers inter-firm friction cost [47]. Previous research shows that congruent goals tend to avoid dysfunctional conflicts [15], and enhance buyer-supplier collaboration quality [13].

**Social network ties:** social network ties include interaction ties and social network links. Chang and Chuang [40] suggest that network-related social relationships “provide information channels that reduce the time and effort required to gather information”. Chui et al. [17] found that social interaction ties are associated with higher quality of knowledge sharing. In the strategic level, this kind of interaction can lead to unique opportunities and strategic benefits [25], [26]. Evidences from literature show that structural social capital improves buyer performance [25], and inter-firm relationship-specific investments are positively associated with collaboration quality [13].

**Coordination:** Coordination refers to the identification and the classification of existing interdependencies [46]. It comprises the pre-articulation of tasks, their follow-up and the post-articulation of group activities [44]. When the different parties’ efforts are structured and synchronized, non-value adding reworks and conflicts will be avoided [13]. According to [44], Coordination means ‘to keep the group alive’ and promotes productivity to the group. Yan and Dooley [13] found that coordination efforts are linked to higher collaboration quality. Mohr and Spekman [12] show that higher level of coordination implies more successful partnerships.

**Communication quality:** Communication quality is the extent to which communication is open, timely, accurate, reliable, frequent and balanced [39], [45]. Communication quality can be seen as a central factor. In fact, it helps to develop a shared understanding, improves the atmosphere of the relationship, promotes commitment, and enhances trust between partners [32]. It also fosters synergy in tasks, resource sharing efficiency and reduces interferences and rework [13]. Van den Bossche et al. [16] identified positive relationship between communication quality and team effectiveness.

**Interdependence:** Interdependence is the extent to which two partners integrate their resources and accept to lose some autonomy which would be compensated by mutual gains [12], [55]. It is more complicated nowadays in industrial context for

a firm to achieve project’s and operations’ success singly, without being dependent on another entity. In case of dependence, committed investments between firms induce for them more difficulty to switch partners, and thus invite cooperation [50].

After identifying the most important factors for collaboration, we characterize in next section the collaboration processes for PSS development and lifecycle management in a UML class diagram.

### 3. Collaborative process in PSS development

Collaboration has many advantages such as time reduction, decision making and communication improvements, learning and encouraging innovation [44]. In the context of PSS development and life cycle management, it is required to collaborate with external and multidisciplinary actors [1], [10], [56]. Therefore, we need to explore the collaboration issues in PSS context and how to make favorable conditions for its success. To do so, we start by proposing a model to characterize PSS collaboration in a global view (see Figure 1).

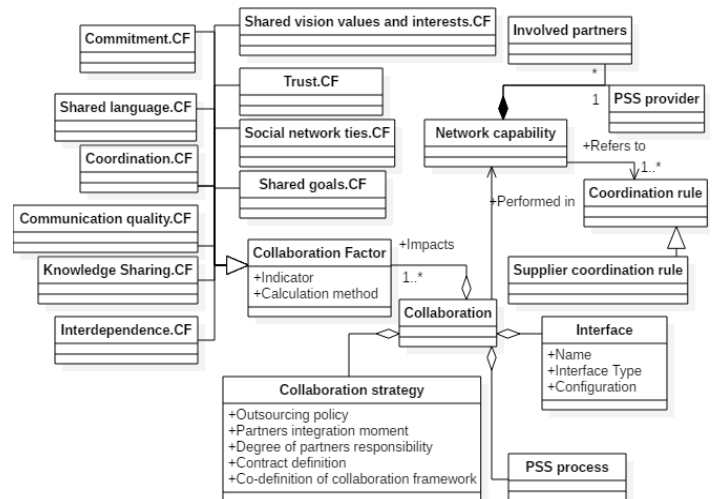


Fig. 3. Collaboration model for PSS development and lifecycle management

First, collaboration is performed in a network capability, which means that there are different partners involved in the collaborative PSS development. Different authors cited the stakeholders involved in PSS development and operation. For example, Meier et al. [57] mentioned the customer, the PSS provider and three types of suppliers : product supplier, service supplier and PSS module supplier (for specific components). They emphasize the role of customer as a stakeholder but could not be considered in the network of design. Schweitzer and Aurich [10] differentiated the production network from the service network. Production network is composed from the PSS-provider and its suppliers, while service network involves the same PSS-provider with service partners, dealers and branches, and customers. Moreover, da Costa Fernandes et al. [58] explored in a literature review the different stakeholders in the case of PSS design. The result was that the most mentioned stakeholders were the customer, the manufacturer, installation and service partner, supplier, user, government and local provider.



Furthermore, a supplier coordination rule is needed in case of PSS, since suppliers are complementary and not competitive [28]. The coordination rule is characterized by an entity which will deal with organizational issues [28], [59] and make the link between the PSS provider and the network of suppliers. This will allow the suppliers to cover more stages of PSS lifecycle and will insure the continuity and the coherence of the group [28], [59]. Collaboration within the value network implies different organizational and operational interfaces, which conduct to other types of physical and informational interfaces between tangible components, separately owned by the members of the network. A detailed classification of interfaces within PSS context is explained in [60]. According to this model, collaboration process is designed to implement a collaboration strategy that involves the critical long-term decisions in a given network capability. Outsourcing policy (develop, co-develop or buy decisions) [48], partners' integration moment, degree of partners' responsibility [49], contract co-definition [61], [62] and co-definition of the collaboration framework [63], [48] are examples of strategic choices that PSS providers (OEM) deal with. Finally, the collaboration factors resulted from our review are mentioned. This model is a starting point for building a collaboration management framework supporting the whole PSS lifecycle. It also can be used as a repository to prepare collaborations for PSS development and to analyze the different issues.

#### 4. Conclusion and perspectives

The aim of this article is a presentation of a literature review about factors impacting collaboration, and proposition of a collaboration model as a starting point for building a collaboration management framework supporting the whole PSS lifecycle. The objectives of this framework are twice: First, to estimate the potential of successful collaboration when an idea of PSS project emerged. Levers of actions can be suggested to avoid risk of failure; Second, to calculate in process the collaboration performance in order to anticipate some derivations from the initial objectives. To do so, further works will concern the building of a global model that identify and link a set of key performance indicators (KPIs) to the list of identified factors. For example, trust can be estimated by the history of relationship distinguishing successful and failure transactions. Qualitative modeling and inference tools like fuzzy logic are under experimentation to build the assessment framework.

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