# Enhancing co-design reliability by inter-organizational learning and loose coupling concepts

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**Abstract**

The aim of this article is to enable actors of different organizations to self-adapt, to self-organize and, *in fine*, to make functional and structural improvements together. We examine formal cooperative processes and informal cooperative practices which are expressions of tight and loose couplings within a complex socio-technical system. We use a systemic approach to understand close relations between loose couplings and their potential outcomes (in terms of organizational learning, cooperative effect and consequences). We propose a *co-design reliability model* which enables us to better understand intra- and inter-organizational learning during cooperative actions. Our findings confirm that loose couplings are crucial in complex organizations. Loose couplings enhance the reliability of co-design operations by enabling informal cooperative practices which often underlie the success of formal cooperative processes. Our future work will be to test the impact of enhancements to co-design operations through the application of newly developed material and process artefacts informed by the holistic understanding of cooperative actions.

**Keywords**

Co-design reliability model, organizational learning, loose coupling, informal cooperative practices, self-organization

## 1 Introduction

Aeronautical product and equipment design has become more and more complex in recent years [Alcouffe, Corrégé, 2004]. Operations and procedures are no longer confined to the inside of the company, but cross company boundaries [Lalouette, 2007]. Organizational learning and knowledge sharing with subcontractors is compulsory for sustaining competitive advantage [Ichijo, Nonaka, 2007; Paton, Mc Laughlin, 2008]. This is one reason why concurrent engineering design phase and co-design operations are carried out simultaneously during a *common design phase* in most of aeronautical companies. The aim of this article is to propose a new conceptual framework to enhance co-design reliability during this concurrent enterprising phase by enabling actors of different organizations to self-adapt, to self-organize and, *in fine*, to make functional and structural improvements together [Pavard et al., 2007]. To this end, we study formal cooperative processes and informal cooperative practices between actors and their environment. We explain how these cooperative actions are expressions of tight and loose couplings within a complex socio-technical system.

Loose coupling [Weick, 1976] and organizational learning [Argyris, Schön, 1978] concepts underlie the reputation of HRO, the High Reliability Organizations school [Bourrier, 1999]. In HRO, when loose couplings are enabled the organizational reliability is enhanced [Bierly, Spender, 1995]. Unlike tightly coupled systems, the outcomes of loosely coupled systems are not deterministic. The question is: "How to use indeterminism to enhance co-design reliability and how to consider this apparent paradox for organization theory and conventional management?" We present an argument for a *co-design reliability model* which provides dialectic and solves

[1] This work was supported by the Foundation for an Industrial Safety Culture (*Fondation pour une Culture de Sécurité Industrielle*)

this paradox by using a systemic approach. We propose a way to improve the loose coupling conceptualization [Orton, Weick, 1990] to assist with our specific research objectives. We achieve this by integrating several parameters including the level of organizational learning [Sinkula, 1994]. This new conceptual framework enables us to better understand organizational learning during cooperative actions (from both formal processes and informal practices).

The empirical part of this project concerns the study of co-design operations from an aeronautical company and several of its subcontractors during a *common design phase*. We examined cooperative actions and conducted semi-directed interviews. We employed a qualitative analysis method on the information and knowledge flows. We studied loose couplings according to several parameters determined based on our conceptualization of the notion. Finally we modelled cooperative actions in order to understand the close relations between loose couplings and their potential outcomes. Our findings confirm that loose couplings are crucial in complex socio-technical systems since they enable informal cooperative practices which often underlie success of formal cooperative processes. Loose couplings enable intra- and inter-organizational learning, by enabling actors of different organizations to self-adapt and to self-organize together, which in turn enhances the reliability of co-design operations. Therefore a *co-design reliability model* for concurrent enterprising is introduced into this article.

## 2 Relation to Existing Theories and Work

Concurrent enterprising has been a common practice for more than 20 years in the aeronautical domain. Examining concurrent enterprises projects during the past decade, we observe a significant increase in uncertainties, project risks and complexity [Capraro, Baglin, 2002]. In spite of the fact that concurrent enterprising objectives (mainly concurrency, cooperation, integration, and standardisation) remain the same, new challenges appear. These challenges relate to the management of:

- Subcontracted work packages whose sizes are more and more significant.
- Subcontractors whose social and legal status change substantially as they contractually become actual strategic partners (e.g: risk sharing partners [Lalouette, 2007]).
- Technological performance requirements which necessitate radical innovations and which have very high time, cost, and quality constraints.

During a concurrent engineering design phase, actors of an organization design products together in a transversal and cooperative way [Boughzala et al., 2001]. A co-design is also carried out, simultaneously, between actors of the extended enterprise: the contractor and the subcontractors which form the pool of concurrent enterprises. This co-design enables products to emerge from multiple design interactions between organizations. These teams are multi-functional and inter-organizational (due to concurrent engineering and co-design respectively). They work within a single spatial location commonly called a *plateau*, the *common design plateau* [Alcouffe, Corrégé, 2004].

To enhance co-design reliability, we try to model and understand the complex socio-technical system that comprise this *plateau* to enable organizational learning [Nobre, 2004]; and particularly learning across multiple organizations [Chena et al., 2007]. Organizational learning is a characteristic of an adaptive organization whose actors are able to sense changes in signals from their environment. Actors adapt organizational functions and structures according to these signals. Three types of organizational learning are used in management of design [Docherty, Shani, 2003] and we presented them just below. First, single-loop learning is a simple error-and-correction process. Then, double-loop learning is an error-and-correction process modifying organization's underlying norms, policies and objectives. Finally, deutero-learning is learning about how to carry out single-loop and double-loop learning. Difference between intra- and inter-organizational learning seems to be a question of degree rather than of kind, in terms of practices, processes and outcomes. Inter-organizational learning is just more difficult to implement because it relies on cooperation among actors who possess different values and identities due to differences in company cultures [Holmqvist, 2003].

We mobilize the concept of loose coupling between individuals and their environment as a way of studying informal cooperative practices. Loose coupling was originally cited by Glassman [Glassman, 1973] and then developed further in Weick's work on loosely coupled systems [Weick, 1976]. More recently this latter phrase was more clearly conceptualized by Orton & Weick [Orton, Weick, 1990]. The loose couplings we consider include interactions, between actors and their environment, concerning social aspects, informal routine, or underspecified working methods. The tight coupling concept popularized by Perrow is the opposite of loose coupling; it is an interaction resulting from strong dependencies between elements of a system [Perrow, 1984]. It is expressed through procedures, official meetings, or contractual descriptions of actors' tasks, for example. Concerning our opening question, the main difference is that functions of loose couplings are indeterministic while those of tight couplings are deterministic.

## 3 Research Approach

First we conducted a literature review to establish the state-of-the-art[2] and from this we defined an improved conceptualization of the loose coupling according to seven parameters:

1. The cause(s)[3] of the loose coupling (e.g: authority delegation or culture).
2. The consequence(s)[3] (e.g: innovation or information buffering).
3. The category[3] (e.g: intra-organizational or inter-organizational).
4. The organizational learning level (from single-loop[4] one to deutero-learning).
5. The cooperative effect (socialization[5], coordination or cooperation).
6. The modality if it exists (e.g: face-to-face discussion or gestural language).
7. The interaction medium if it exists (e.g: e-mail or freehand drawing).

Inputs and outcomes of the loose coupling conceptualization are presented below (cf. Figure 1).

For documenting formal cooperative processes and informal cooperative practices, and to study loose couplings, we employed a qualitative analysis method on the information and knowledge flows [Wybo et al., 2003]. The objective of this methodology is to closely examine tasks, activities and work of the actors in order to determine:

- The actions inside and between organizations.
- The links between the sequences of events.
- The sense-making enacted by actors concerning artefacts, events and environment.

The gathered empirical data includes:

- Discourse from the semi-directed interviews.
- Pictures and notes from field observations (contexts, actors' actions and behaviours, *etc.*).
- Official companies documentation such as contracts, procedures or meeting minutes.

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[2] This literature review will not be described here since over one-hundred works were reviewed.

[3] This parameter comes from the conceptualization of Orton & Weick but we have extended it through a taxonomy.

[4] In fact, five knowledge levels [Sinkula, 1994] have been used for single-loop learning: 1) Dictionary or "*What is?*", 2) Episodic or "*What has been?*", 3) Endorsed or "*What is the espoused way of doing things?*", 4) Procedural or "*How things are actually done?*" and 5) Axiomatic or "*Why things are done the way they are?*".

[5] Socialization is considered in a more broad sense concerning to the knowledge conversion model of Nonaka & Takeuchi [Nonaka, Takeuchi, 1995]. We extended it to any exchange – tacit or explicit – of knowledge to one entity (individual or group) to another one.

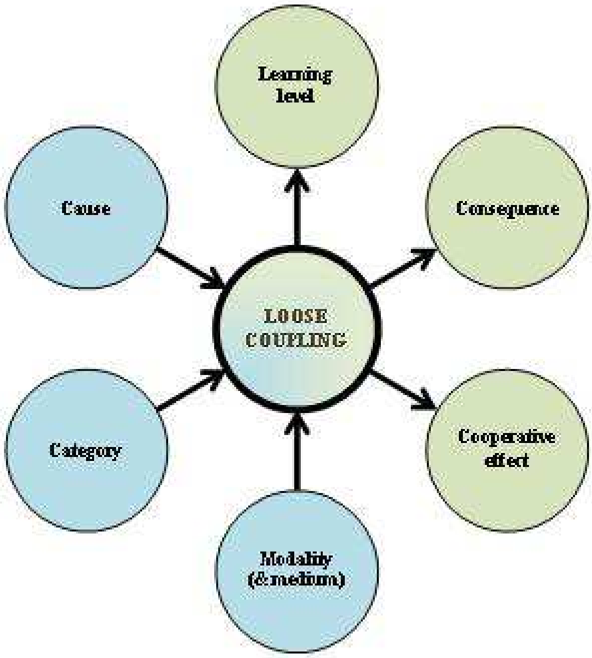


Figure 1: Improved conceptualization of the loose coupling

We analyze the data according to the three spheres of continual interaction existing within socio-technical systems: the technical, the human and the organizational spheres. Data then are treated according to three modelling dimensions. The temporal modelling allows us to reconstitute the various steps of the co-design operations. The spatial modelling shows us where, in the physical environment, the actors interact. Finally the organizational modelling enables us to represent how the actors work, network and fulfil their tasks. We then use our loose coupling conceptualization to instance couplings from cooperative actions that we have recorded.

During a participatory observation on a *common design plateau*, we performed an initial analysis. Twenty-five semi-directed interviews, lasting approximately one hour each, were conducted with engineering and management executives of the aeronautical company under study. Discourses with these employees dealt with their tasks, activities and cooperative actions. These interviews combined with other empirical data (field notes and official company documentation) comprised our *corpus.*

# 4 Findings

The empirical data in the *corpus* enabled us to identify formal cooperative processes and informal cooperative practices. These first results showed strong support for relationships between couplings and co-design reliability. This encouraged us to continue to pursue this research direction. Finally, we built a *co-design reliability model* that we present below:

## 4.1 Informal cooperative practices

Here we describe two interviews as examples of part of the analysis method.

1. Interview A with an expert in material stress: "*Owing to size of organizations* [contractor and subcontractors]*, to look for, and to talk with, the right person is more and more difficult to do. We haven't other choice; we use our personal network to find the information that we need, even if we have to overstep hierarchical and structural marks.*"
2. Interview B with a manager of a subcontracted work package: "*Horizontal and informal cooperation already exists between subcontractors. It deals with merely technical topics*

*such as for example 'If I put my piece here, you'll be OK after or not?' Anyway, common design plateau is carried out in order to give more reactivity for this kind of action.*"

After employing the qualitative analysis method, we analyzed these interviews based on our improved conceptualization in order to instance loose couplings (cf. Table 1).

| | Interview A | Interview B |
|---|---|---|
| Causes[6] (main) | "*Limited opportunities for interaction*"<br>"*Organization size and complexity*" | "*Non-routine and unpredictable tasks*"<br>"*Higher order autonomy*" |
| Consequences[6] (main) | "*Opportunistic adaptation*"<br>"*Requisite variety*"<br>"*Social interaction deepening*" | "*Simultaneous adaptation*"<br>"*Reduction of coordination cost*"<br>"*Efficiency*" |
| Category | Inter-organizational | Inter-organizational |
| Organizational learning level | Single-loop | Single-loop |
| Cooperative effect | Socialization | Cooperation |
| Modality (with medium) | Dyadic discussion<br>(Phone) | Dyadic and face-to-face discussion<br>(Ø) |

Table 1: Loose coupling instantiations from informal cooperative practices

We observed that loose couplings between actors and their environment can have several consequences, some of which are presented in Table 1. In addition we noticed numerous others such as "*information buffering*" which enables actors to maintain local information repositories to support autonomous work, or "*adaptability by collective judgement*" of loosely coupled actors which is a decision-making aid. But to believe that loose couplings only involve positive consequences would be not sufficient. Several interviews showed us that the loose coupling caused by "*distant work practices*", for example, has numerous bad consequences such as "*inefficiency*" or "*complicating*".

## 4.2 Formal cooperative processes

Here we describe two co-design operations as examples of part of the analysis method.

1. Example A is a *Progress Review Meeting* (PRM). This contractual and inter-organizational process provides an overview of the progress of the subcontractor's project. The aim is to offer visibility of the current situation, future activities and recovery plans.
2. Example B is a *Lessons Learnt Operation* (LLO). This operation is an internal service proposed and provided by the company's *Knowledge Management Department*. The aim is to capitalize, share and re-use experience of past projects.

Again we analyzed these examples based on our loose coupling conceptualization (cf. Table 2).

We observed that tight couplings between actors and their environment only exhibit deterministic consequences; but these consequences are necessary and often critical, or even vital, for the organizations. Without PRM for example, project management troubles could occur. Although we are particularly interested in loose coupling outcomes, we present some tight coupling consequences in Table 2 for comparison purposes. We repeated the analysis several times and we were able to enumerate many other consequences of tight coupling such as the acceptance of deliverables, or the authorization of project progression. Logically there exist innumerable such consequences; each tight coupling has usually its own, unique, consequences.

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[6] Authors of phrases in italic dealing with causes and consequences will not be cited in order to stay brief and clear.

| | Example A: PRM | Example B: LLO |
|---|---|---|
| Causes (main) | Contracted reporting<br>Need to overview the project progress | Will to improve products / processes<br>Research of excellence |
| Consequences (main) | Knowledge of past and future events and operations | Anticipation of difficulties<br>Written text allowing resilience |
| Category | Inter-organizational | Intra-organizational |
| Organizational learning level | Single-loop | Double-loop / Deutero-learning |
| Cooperative effect | Coordination | Socialization |
| Modality (with medium) | Group and face-to-face discussion (Ø) | Dyadic and face-to-face discussion (Ø) |

Table 2: Tight coupling instantiations from formal cooperative processes

### *4.3 Co-design reliability model*

By formalizing organizational functions and structures (see examples A and B), tight couplings enables employees – and especially managers – to foresee process outputs, to plan projects in an idealistic optimized way and to improve project efficiency. By enabling informal cooperative practices (see interviews A and B), loose couplings often underlie the success of formal cooperative processes and improve project effectiveness. Our findings confirm Pinelle's findings [Pinelle, 2004] that loose couplings are crucial since they are considered the foundation for collective efficiency during the resolution of complex problems. We have also found that they enable innovation and job satisfaction, and they strengthen social interactions, for example. In fact organizational functions and structures evolve thanks to both types of cooperative action: this provides the balance between control and freedom required during co-design.

We integrated each kind of coupling into a *co-design reliability model* for concurrent enterprises working and learning together. This model uses a holistic approach by considering and summarizing formal, informal, intra-organizational and inter-organizational functions and structures of organizational learning. It goes beyond a mere description of the system by offering new insight into the concurrent enterprising paradigm from both managerial and socio-technical perspectives. The formal structure is represented by formal cooperative processes of co-design; they have deterministic functions and they are enacted by the tight couplings that are the formal tasks of work. The informal structure is represented by informal cooperative practices of co-design; they have indeterministic functions and they are enacted by the loose couplings that are the informal activities of work.

Formal learning is already implemented within the studied *plateau* (by internal communication operations or by technical meetings with subcontractors, for example). However, few things are done to facilitate informal learning, especially from an inter-organizational point of view. Our *co-design reliability model* offers solutions to this lack of informal learning facilities. This model enhances functional and structural capacity to learn between organizations by increasing opportunities to create loose couplings between actors through the use of material and process artefacts. The aim of this model is to enable actors of organizations to use these artefacts at their discretion, according to their operational needs and opportunities.

Functional and structural improvements will result from an artefact-aided self-adaptation and self-organization which in turn enables intra- and inter-organizational learning. New functions and structures can emerge from these artefact-aided informal cooperative practices. Loose coupling increases local and emergent cooperative practices leading to organizational learning. In turn, organizational learning improves collective knowledge leading to enhanced co-design reliability. Through increased interactions with their environment, actors learn more, contributing to the collective knowledge and the global functioning of the pool of concurrent enterprises.

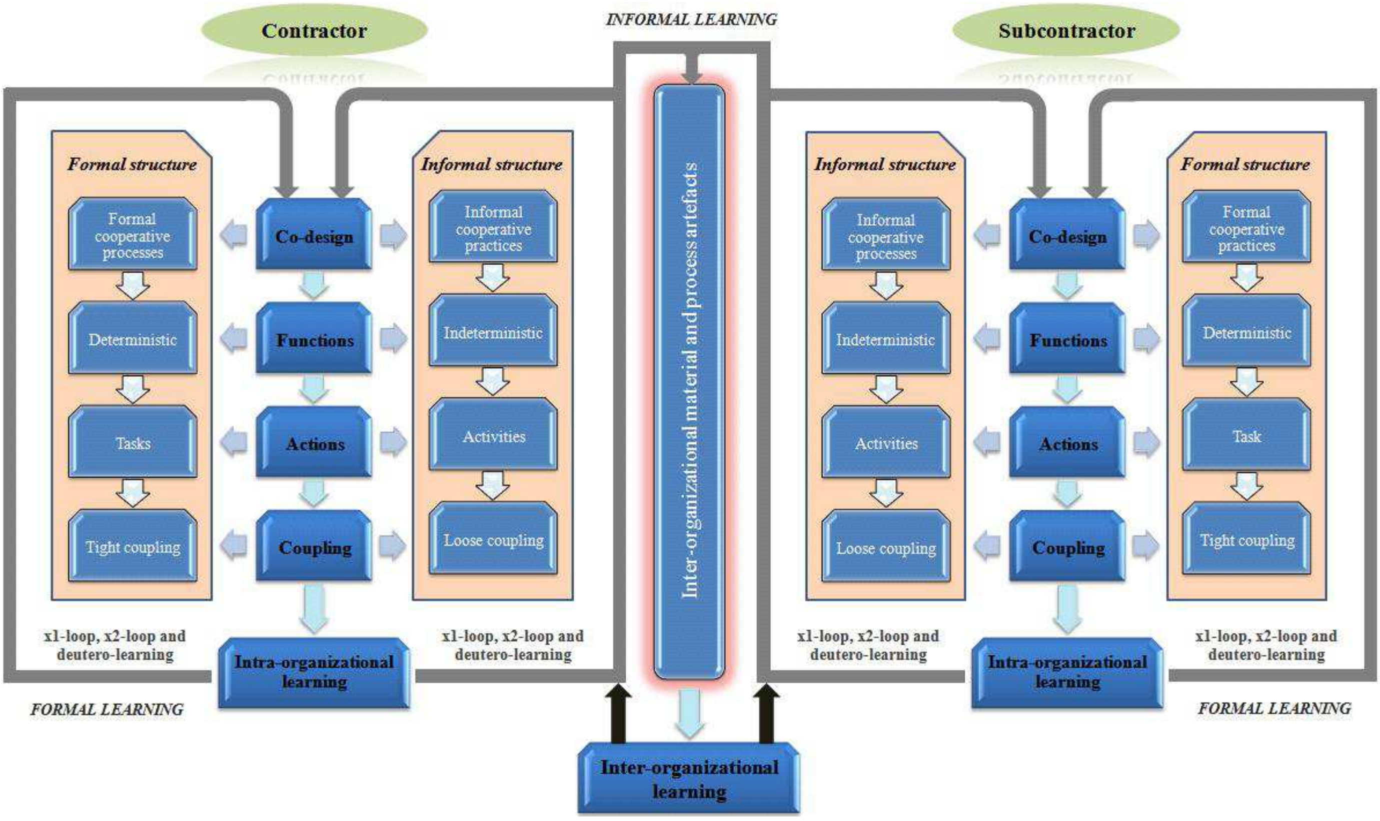


Figure 2: *Co-design reliability model* between a contractor and a subcontractor

## 5 Conclusion

Companies tend to focus on their own core business and competencies, outsourcing or participating in co-design in other areas. The latter defines their extended enterprise. The concurrent enterprise paradigm has recently been defined to reflect the high level of cooperation between organizations in an extended enterprise. Although the concurrent enterprises need and use systematic approaches and advanced technologies to increase effectiveness in the co-design of products, the efficiency of team work must be considered from a socio-technical point of view since modern work operations differ from those of the past. To understand how to manage these new challenges, we have presented the first results of a case study.

Within the scope of this work, we developed qualitative methodologies in order to document cooperative actions. The empirical part of this study examined one *plateau* within an aeronautical company where concurrent engineering design phase and co-design operations are carried out simultaneously. The results of the study suggest that co-design reliability could be enhanced through the application of inter-organizational learning and loose couplings concepts. We have not had the opportunity to test this hypothesis, and observe the impacts on the functions, organisational structures and formal cooperative processes of the company under study. For this reason, after the completion of further study of cooperative actions, our next step will be to develop and test the impact of enhancements to co-design through the application of newly developed material and process artefacts, with specific outcome objectives, informed by the holistic understanding of co-design operations.

We attempt to enable and reproduce loose couplings outcomes of informal cooperative practices related to the level of organizational learning, the cooperative effect and the consequences. We only plan to examine the impact of material and process artefacts according to informational and cognitive dimensions [Pavard, Salembier, 2003]. Currently, we imagine possibilities to enable employees of organizations to create their own self-organized learning group by giving them facilities and information on rule of the game. Since in the past, intra- and inter-organizational learning, formal cooperative processes and informal cooperative practices, and tight and loose couplings have only been studied independently, our integrated approach offers a novel contribution to the theoretical frameworks and practices of concurrent enterprising.

**Acknowledgement**

First and foremost we would like to thank the Foundation for an Industrial Safety Culture (*Fondation pour une Culture de Sécurité Industrielle*) for its financial support. We would also like to give our best regards to the Knowledge Management and Innovation team in Airbus without which the above mentioned collaboration would not have been possible. Thanks for having given us the possibility to anchor our theoretical problems into an industrial reality with such a technical, economic and cultural potential.

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