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COLLABORATIVE GLITCHES IN DESIGN CHAIN: CASE STUDY OF AN UNSUCCESSFUL PRODUCT DEVELOPMENT WITH A SUPPLIER

Hélène Personnier[1], Marie-Anne Le Dain[1] and Richard Calvi[2]
(1) Grenoble Institute of Technology, France (2) Savoie University, France

ABSTRACT
The focus of the firms on their core competencies associated with the increasing complexity of products due to an integration of various technologies has led to an extension of their New Product Development (NPD) activity across organisational boundaries. The concept of *design chain* defines the network of participants included in this extended activity of product development. This paper focuses on the collaborative design with suppliers within the design chain. It seeks to appraise the benefits of such collaboration on the product development performance. The approach proposed is based on the "*glitch*" concept which enables to tackle this issue from the opposite direction i.e. by identifying what happens when the collaboration with suppliers in design is absent. A case study analysis of an unsuccessful collaborative development with a supplier enables to identify ten "*glitches*" that would prevent from reaping the benefits of supplier involvement. Informed by findings from this exploratory case, a categorisation of the collaborative "*glitches*" is proposed in order to analyse their impact on product development performance and to define preventive actions to avoid them.

Keywords: New Product Development (NPD), Early Supplier Involvement (ESI), Collaborative Design, Design chain, Glitch

1 INTRODUCTION
Today's aggressive and expanding global marketplace and competitive pressures compel firms to consider new strategies in order to compress time between each stage of the value chain [1]. Clark and Starkey [2] were the first to introduce the concept of "design chain" to describe the network of participants, both internal and external to the focal firm and created throughout the NPD process. Twigg [3] pointed out later that an important insight to manage the "design chain" was to choose the appropriate level of responsibility given to the supplier in the development process. Furthermore, part supplied in new products is quite important and thus collaboration with suppliers a strategic element to reach both more productivity for the R&D activities keeping in-house and an extended spectrum of technologies to include in the future final products. A means that companies can adopt to gain competitive advantage is to involve suppliers earlier in the design phases. Early Supplier Involvement (ESI) is generally defined as a form of vertical cooperation in which manufacturers involve suppliers at an early stage in the NPD process [4]. The notion of ESI covers a variety of collaborations and may range from simply consulting suppliers about design orientations to delegating them full responsibility for designing the outsourced product [5]. ESI practice has been advocated to be the first step to *Lean Product Development* by Karlsson and Ahlström [6]. Early Supplier Involvement benefits on new product performance have been investigated by numerous authors through both in-depth qualitative and increasingly large-scale quantitative research methods. A large body of research confirmed the positive influence of ESI on performance measured by shorter time to market, improved product quality and reduced development and product costs [4], [7], [8]. Other authors have pointed out long-term benefits for future projects obtained by client companies creating privileged relationships with their suppliers in order to fully benefit from new technologies and innovation [5], [9], [10], [11], [12]. Nonetheless, when companies are dealing with projects characterised by a high technological uncertainty, contradictory results concerning ESI influence have been published [13]. For some authors, the major obstacle for the success in collaborative design with suppliers is mainly due to the lack of capability in managing inter-organisational collaborations [4], [10], [14]. This capability refers to the social dimension of the design engineering activity. Some researchers have distinguished

between engineering work occurring in the object-world and the social-world [15], [16]. These two worlds are all the more important to take into account when the collaborative work involves external partners.

The customer capability to collaborate in design phases with suppliers refers in particular to the "*absorptive capacity*" defined by Cohen and Levinthal [17] as the capacity to value, assimilate and use external knowledge. The selection of the appropriate suppliers [13], [18] and the capacity to build the appropriate interface between both project teams [8], [19] are also required to successfully collaborate with suppliers. However, these capabilities are not self-evident for most of the customer firms. This is particularly verified when they have to evolve from an "in-house" product development to a more collaborative product development with external partners owing to their industrial context evolutions. In this case, using the Sako's analysis [20] of industrial relationship, the firm must shift from an *arm's-length contractual relation* (ACR), where the buying firms are reluctant to seek ideas or contributions on design and development from their suppliers, to a more collaborative relationship that has been called *obligational contractual relations* (OCR). In the OCR view, suppliers' contribution to design is encouraged and their willingness to offer ideas for design improvements is seen by the customer as an indication of supplier commitment. For Sako [20], the path to evolve from an extreme supplier-customer relationship to another is a difficult one. The project team in charge of the supplier integration process within a NPD project must be able to quickly measure the gap between their current practices and best practices to identify the improvement ways that they should follow.

The issue addressed in this paper concerns collaborative design work with suppliers. Our research work aims at obtaining a good understanding of this practice in order to promote it near industrial managers who are searching for involving their suppliers in product development more often and in a better way. The lack of clear appraisal of advantages concerning the collaborative design with suppliers in literature seems to be a real hindrance for the development of this practice. Indeed, for many industrial actors it is difficult to invest resources in collaborative design with suppliers when real expected benefits and the best practices that would be performed to reap these benefits are unknown. In addition, gaining experience from these collaborations is important for both companies, the customer and the supplier, in order to improve their practices. We draw inspiration from the approach adopted by Hoopes and Postrel [21] to measure the importance of shared knowledge on product development performance. Those authors considered that if shared knowledge is important for product development, then we ought to be able to identify what happens when it is absent. Instead of trying to see how the resource contributes positively to performance, they examined how lack of the resource detracts from performance. To operationalize this approach of the problem from an opposite direction, they introduced the concept of *glitch* i.e. "*a costly mistake that could have been avoided if some of the parties involved had understood things that were known by other participants* (p838)". The objectives of the approach proposed to appraise the ESI benefits are twofold: (1) identifying collaborative *glitches* in the design chain and categorise them and (2) identifying their impact on product development performance and hence defining preventive actions to avoid these "*glitches*".

This paper is structured as follows. First the research methodology adopted is presented and the in-depth case study is described. Then our results about *glitches* observed and associated causes and costs enable us to build a *glitch* categorisation. Next, thanks to an impact analysis of *glitches* observed on ESI potential benefits identified in the literature, preventive actions are proposed aiming at improving collaborative development practices with suppliers.

2. RESEARCH METHODOLOGY

2.1 Case study methodology

This paper explores an unsuccessful collaborative development between a customer and a supplier. Yin [22] stated that when investigating events that may have little or no theoretical background, the researcher may select an exemplary case that provides the best example of a phenomenon. The case study selected in this paper meets this criterion. The customer was willing to charge suppliers with more responsibilities in the design on technologies that are not in its core competencies (not included into internal resources). But the first experience of collaborative design with a supplier was judged as unsuccessful by both partners. Thus the customer expressed the need of understanding the reasons of this failure. This analysis aimed at preventing from a deadlock concerning internal actors (R&D engineers, technical and purchasing actors) and suppliers in the implementation of this practice due to this bad past experience. Therefore, an appraisal of expected ESI benefits and elements about appropriate actions were expected. This research is designed to enable a longitudinal case study which provides a single setting with a large observation over an extended period of time [22], [23]. This allows us to study managerial actions regarding supplier involvement in-depth, in a retrospective as well as on a real-time basis. The unfolding events play an important role in building explanations [24]. Furthermore, case studies are appropriate for analysing complex mechanisms [22], [25], [26]. Therefore, case study research was regarded as an adequate method to gain information and to identify relevant problems in collaborative development.

The unit of analysis adopted in this research is the co-development project carried out between a customer and a supplier. The customer is a French company considered as a global market leader for roller shutter motorisation. This company has a strong tradition of external growth with multiple acquisitions and considers innovation and new product introduction as a major issue in order to maintain its market position. Its main activities are designing and assembling suppliers' parts. Supplier involvement is mostly used for production delegation but less for design delegation. The supplier is the world leader for cable manufacturer industry (for high voltage, energy cables...) and it is an historical supplier for the customer. The collaboration concerned occurred during a new roller shutter motorisation development project. An *ex post* analysis of this relationship considered as unsuccessful both by the customer and the supplier was carried out. This case acted as "learning history" and was used to stimulate thinking and encourage learning in the project teams [27]. The *glitch* concept introduced by Hoopes and Postrel [21] was used to identify what makes unsuccessfully ESI efforts in this inter-organisational design collaboration. This approach enabled us to list the dysfunctions of the collaboration observed and to categorise them. Fifteen interviews were carried out with project purchasing, technical, quality and industrialisation members and project managers of this project. Thus a reconstruction of the studied relationship between the supplier and the client was obtained. The case study was conducted at the customer's R&D centre during a seven months in-depth observation with an access to internal documents. Notwithstanding the supplier's point of view was gathered and its opinion was reported in our proposition. Propositions were discussed and validated during workshop sessions with involved actors. Thus a data triangulation was possible.

2.2 Case description

Our case study concerns a development of a new roller shutter motorisation. This is a new product developed to compete with Asian market. The level of exigencies is very high as the roller shutter manufacturer want to distance itself from competitors by launching the development of a high-of-the-range product. According to the project typology of Wheelwright and Clark [28], this project could be qualified as a "breakthrough project" because it involves significant changes to existing product and process. In addition, the objectives of the project are ambitious as regards several aspects: technical objectives are very high as the aim is to obtain a new generation of motorisation; quality targets are outstanding compared to previous ones; a cost diminution is also expected and as regards supplier relationship, the project team wants to promote collaborative work. For this project, the customer chose to outsource the development of the external connector. This sub-system includes the development of a cable and a plug. Figure 1 shows an illustration of a roller shutter motorisation and the external connector. The main reason of this choice is that the customer did not beneficiate of internal resources for this specific design and the development of this connector is not a core-activity for the customer. Thus, it was relevant to take benefit of the experience of a specialist that can do the development work more efficiently than the customer. This connector is a specific sub-system that must handle the power supply of the motor. It is considered as a critical component because it has a considerable impact on the performance. The function to be developed is also a critical function as regards part of cost structure, safety, resistance to humidity, resistance to handling, robustness, earth connection, resistance to transport, multi-sourcing and compatibility with voltages and currents. The previous roller shutter motor external connector was co-developed 15 years ago with the selected supplier. Since this previous project, this supplier manufactured most of cables purchased by the customer but the latter has not been re-mobilised for its design expertise concerning the cables development. For this reason, this supplier was more known as a key commodity supplier than as a designer supplier. At the beginning of the considered project, the customer needed design expertise and intuitively the project team consulted the historical supplier for this technology. Some negative signals were observed before the definitive choice but with the past experience and the amount of trust toward this supplier, the project team minimized them. Nonetheless, as collaboration progressed, those negative signals become more and more harmful. In order to understand what happened as regards the collaborative relationship and to learn by this experience, an analysis of the construction and the management of this collaboration was carried out. A sequence of events of the studied relationship was built. Through the help of this sequence, a diagnosis has been made in order to better understand this unsuccessful collaboration.

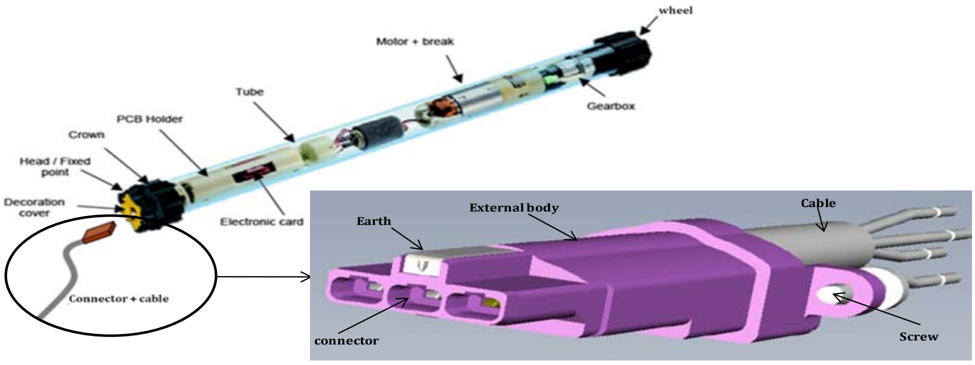

Figure 1.External connector concept in a roller shutter motor

3. COLLABORATIVE *GLITCHES*

Information gathered after our interviews enabled us to reconstruct what happened between the two partners in order to identify the collaborative *glitches* encountered. First and foremost, we explain the *glitch* concept.

3.1 *Glitch*: a project failure due to a lack of collaboration

Hoopes and Postrel [21] introduced the *glitch* notion. *Glitch* is defined as "*an unsatisfactory result on a multi-agent project that is directly caused or allowed by a lack of inter-functional or inter-specialty knowledge about problem constraint*" (p843). Three requirements have to be verified for a *glitch* to be declared on a project: (1) More than one functional or product group was involved, (2) Multiple interviewees suggested that the result of the project, or some aspect of it, had been unsatisfactory, (3) The unsatisfactory result could have been avoided using the knowledge of one of the participating group.

Hoopes and Postrel [21] used this concept in order to approach the influence of sharing knowledge on product development because this notion was hard to quantify. The authors have carried out a study over two years in an intra-organisational context with 250 persons of a firm that develops and sends cutting-edge scientific modelling and simulation software. As Hoopes and Postrel [21] encountered the difficulty to control and know what the common knowledge is shared and that some knowledge models are hard to quantify, they chose to approach the issue from the opposite direction. Therefore instead of trying to see how resources contribute to the performance, the authors decided to examine how the lack of those resources detracts from performance. Nevertheless, they noticed that each *glitch* depends on a sharing knowledge problem but all differences in sharing knowledge are not a *glitch* cause. To summarize, their idea is to consider that if shared knowledge is important for product development, then we ought to be able to identify what happens when it is absent. Identifying a *glitch* and its costs enables to evaluate the marginal benefit of knowledge integration mechanisms (actions that may have prevented a *glitch*). In their research work, Hoopes and Postrel [21] specified that their aim is not only identifying *glitches* but also determining how much they are important quantitatively. They speak about making an estimation of the *glitch* cost. An important indicator is lost work-months (unused or additional work). In addition, there are customer complaints and problems or release delays. Thus one can attach a value to a mistake: the cost in terms of wasted work or over-runs [29]. In our work, we use the term "collaborative *glitch*" as we consider both intra-organisational and inter-organisational collaborations.

3.2 Collaborative *Glitches* observed during our case study

Our interviews led to a list of ten *glitches* encountered during the relationship. Those *glitches* were gathered in order to structure our results and presented at the project team during an internal workshop at the customer company. Table 1 specifies for each *glitch* the reasons that lead to dysfunctions, the actors responsible of the *glitch* and the *glitch* cost often expressed in terms of lost work months.

Table 1. Synthetic view of glitches characteristics observed during our case study

Glitch	Reasons/causes	Customer / supplier responsibility	Glitch costs
Selected supplier non adapted to the project expectations	Purchasing project manager vs commodity manager vision concerning supplier selection Panel's issues prevailed Lack of internal collaboration Negative signals neglected	Customer	One year of rework
Confusing determination of roles expected by the supplier	Wrong understanding of acceptability criteria New tool of customer long to be used Lack of sharing of determination of roles	Customer	3 months lost
No alignment in expectations	Lack of sharing of mutual expectations, lack of communication and initial meetings	Customer & Supplier	6 months for alignment
Contractual arrangement hard to build up	Initial contract sent with delay (2 months) Lack of expectation matching No collaborative behaviours Ending of the relationship	Customer	One year of rework
Wrong understanding of needs	Supplier's difficulties as regards English language New way of working between the customer and this supplier	Customer & Supplier	Time necessary for a mutual understanding: 6 months
Problems for sharing of quality requirements	Breaking off in quality requirements Difficulties of adaptation of the supplier Difficulties of implementation of the customer	Customer & Supplier	Delay in FMEA realisation: 4 months, issues in qualification plan construction
No joint definition of specifications	Lack of communication between customer and supplier	Customer & Supplier	A delay of 2 months in prototype realisation
Unstable specifications	Customer's change Evolution of expectation	Customer	Rework on specifications changed: 3 months
Privileged interlocutor hard to identify	Lack of initial determination of communication matrix	Customer & Supplier	First meetings unsuccessful: 3 months lost
Verification plan hard to obtain	Lack of communication Problems not communicated by the supplier	Supplier	A delay of 3 months

The details about each *glitch* encountered are described below:

Selected supplier non-adapted to the project expectations: The purchasing project manager vision was not in accordance with the commodity manager vision concerning the supplier selection. Indeed, the purchasing strategy did not totally match with the project team vision. As the cost of the cable is important, a choice of a supplier providing cables was privileged. The selected supplier was in the supplier base for this commodity and it was an historical and trustworthy supplier. The commodity manager has influenced this choice because a development project concerning a manufacturing plant in a low cost country was in course with this supplier. The project team had carried out an audit to evaluate the ability of the supplier to co-design. The results of this audit pointed out an uncertainty related to the ability to the supplier to bring in the necessary R&D resources within a new product development project. On the whole everybody agreed with this supplier choice but specified that it was more a compromise than an appropriate answer to project needs. Finally, the historical relationship with this supplier and its manufacturing abilities prevailed upon its co-design abilities. During the pre-study stage, the supplier was not able to mobilise R&D resources. After several demands of improvement on this point without results, the customer team decided to change the supplier. One year of work was lost. This *glitch* is first of all linked to a failure in internal collaboration. It seems that when a customer wants to promote collaborative relationships with its supplier, collaboration must be a notion firstly mastered in intra-organisational relationships.

Confusing determination of roles expected by the supplier: Each partner had its idea of what was expected but this vision was not totally shared. At the beginning of the relationship, an appendix of the contract specified responsibilities of each partner in the project. However, it was not signed and therefore was subject to contestation. In addition, a project management tool was developed by the customer in order to control and manage the product quality within the collaboration. This tool is an EAQP (Electronic Advanced Quality Planner) and could have been helpful but as a new tool it was long to be used by the team members. Particularly, this tool enables both partners to clearly define the acceptability criteria concerning the connector. This new tool was introduced after the beginning of the collaboration and thus discovered too late by the supplier. The customer noted that the supplier had not understood those criteria and that it was unable to satisfy them. This *glitch* shows a lack of initial determination of roles and regular face to face meetings. As it was difficult to know who was in charge of what, time was lost (about 3 months) and product innovation affected.

No alignment in expectations: At first the customer wanted to delegate the study and then a part of mass production if all suited whereas the supplier was more interested with the mass production. Thus, both project teams did not have the same alignment in expectations. Previously, the relationship between the customer and the supplier was mostly based on a manufacturing activity. The supplier underestimated the importance of the design activity. None of each part tried to tackle the misunderstanding. Therefore, product innovation and quality were affected. The proposed solution did not present real innovation or optimisation. The level of propositions made by the supplier concerning the solution was judged below what was expected. A delay of 6 months was observed from the beginning of the relationship (when the teams should have understood each other) to the time they reached a mutual understanding.

Contractual arrangement hard to build up: The initial contract for study was sent to the supplier 2 months after the choice of this supplier. This led to a blocking of the situation for 5 months because the teams did not collaborate anymore as their expectations did not match. The project contract taking into account the design stage and then the production stage was finally sent and the customer stopped the relation three months later (3 months lost). The ending of this relationship lead to about one year of rework. Indeed studies carried out in this collaborative work are specific to this supplier and it is not possible to reuse them totally with a new supplier.

Wrong understanding of needs: This issue is mostly due to the difficulties encountered by the supplier to work in the language adopted within the project. As a matter of fact, English was the language chosen for this project and especially for the specification sheet redaction because the design chain involved non French speakers. For instance, there was a German speaker second tier supplier with who the supplier of cables had to collaborate. In addition, the supplier’s lack of habit of functioning this way with the customer led to time lost. The supplier team continued working in the same way that during previous years that is to say by studying the need and producing in high quantity. Thus, about 6 months were necessary to get a common understanding of what was expected and the beginning of the relationship was non-productive.

Problems for sharing quality requirements: The project’s quality requirements were a breaking off compared to previous ones. As the supplier is an old one, he knew difficulties to understand and to reach this new level of exigencies. Important issues were encountered as regards the EAQP (Electronic Advanced Quality Planner) tool. Consequences were a delay in FMEA (Failure Mode and Effects Analysis) realisation of 4 months and issues in the verification plan construction.

No joint definition of specifications: Points were not considered by the supplier and this issue was raised late leading to a delay of two months for obtaining a prototype. The prototype obtained was not optimal which caused unproductive additional costs. For instance a wrong choice of material due to a non-consideration of a test demanded in the specification sheet led to an important delay and to the choice of a new material. Furthermore, new tests were carried out in order to qualify this new material.

Unstable specifications: The customer is blamed of often modifying specifications which was highly disturbing for the supplier development activity. The norms to be assured by the connector were modified two times in two months. Dimensions constraints were also modified several times. Similarly, the contract was subjected to several modifications. Those modifications were not discussed between the actors. There were also 3 months of rework due to specifications changed and to a non-adapted response to the need expressed.

Privileged interlocutor hard to identify: This remark was mentioned both by the supplier and by the customer. When an issue is raised, it is difficult to know who is accountable. This point led to time lost (3 months) and confusion. At the beginning of the relationship there were unsuccessful meetings. As regards customer’s expectations, a late mutual arrangement was observed.

Verification plan hard to obtain: The customer considered that, as a developer, the supplier was in charge of building and completing the verification plan of its sub-part. Owing to the supplier’s lack of habit with those practices, especially with this customer, they declared not to be able to understand what they were expected to do. So, a 3 months delay was observed concerning the getting of the verification plan.

4. PREVENTIVE ACTIONS TO AVOID *GLITCHES*

Findings gained from our interviews enriched with a literature review enabled us to obtain a preliminary proposition of *glitches* categorisation. Then, we aimed at preventing the occurrence of *glitches* observed. In this respect, impact of *glitches* on potential ESI benefits identified in the literature has been considered. It enabled us to see critical stages of a collaborative development with a supplier and to recommend some preventive actions in order to avoid collaborative *glitches*. The beginning of the following part presents the *glitches* categorisation proposal.

4.1 *Glitches* categorisation

Johnsen [13] proposed a model showing factors that have been identified as impacting on product performance measured by shorter time to market, improved product quality, and reduced development and product costs. This model distinguishes three main groups of success factors: (1) supplier selection, (2) supplier relationship development and adaptations, and (3) internal customer capabilities. This vision integrates a sort of chronological vision of the customer/supplier collaboration.

As *glitches* are costly mistakes harmful for project performance, our aim is to tackle those unproductive phenomena in order to be more efficient in future collaborative development with suppliers. In this respect, we had to classify *glitches* so as to set up appropriate actions. One can notice that a major part of *glitches* described in the previous section of this paper are linked to a lack of knowledge sharing and a failure in collaborative behaviour both on the customer side and on the supplier side. In order to promote Early Supplier Involvement (ESI) in new product development projects, a chronological view was necessary to understand what each part is supposed to do and not to do at each stage. Therefore, a chronological vision has been chosen for our *glitches* categorisation. Figure 2 represents this temporal repartition of the ten *glitches* encountered during our case study. Two stages are indentified in this representation:

- The relationship design. This stage takes into account the supplier selection and the construction of the relationship framework (contracting, determination of roles and resources, need specification, design or buy design decision).

- The day to day interaction. This stage embodies the interface between the supplier and the customer during the collaborative work (for instance project coordination between both partners, boundary objects exchanged). This is the daily work.

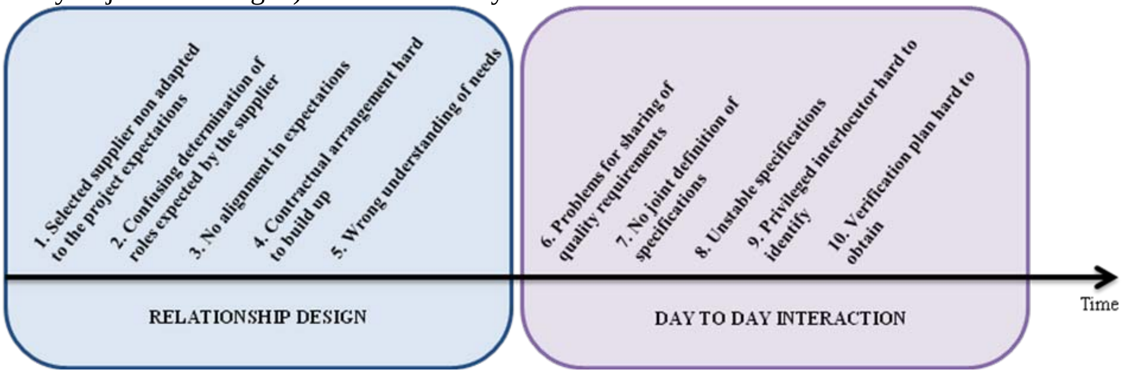

Figure 2.Glitch categorisation proposal

This proposal is oriented toward action. It enables to indentify actions to preliminary carry out before the relationship building and day to day actions during the building. Furthermore, this categorisation, thanks to advices proposed in the following part, enables to indentify who are the concerned actors by those actions at both a project level and a managerial level [8].

4.2 *Glitches* impact on ESI benefits and associated preventive actions

In order to act in an efficient way on those collaborative *gliches*, an impact analysis was carried out. Thus, thanks to interviews of project team members, we have evaluated the impact of each collaborative *glitch* on potential ESI benefits described in literature. An *a posteriori* evaluation has been made in this study as we performed an *ex post* analysis of the relationship. Table 2 represents a synthetic view of interviews results. ESI literature distinguishes four main benefits of ESI practice which are a time to market reduction, product quality improvement, product innovation improvement and development costs reduction. The dysfunctions observed may have a negative impact more or less important on these potential benefits. The evaluation is explained under Table 2. In order to know a successful collaborative design between a customer and one of its suppliers, preventive actions can be set up. Those advices are also mentioned in Table 2 and inspired of literature results.

Table 2 indicates that all the collaborative *glitches* do not have the same impact on project performance in terms of time to market, cost, product quality and innovation. If we link Table 2 and Figure 2, we can deduce the main critical points and thus necessary preventive actions in order to aim a successful collaboration. Therefore, a more important impact is noticed at relationship design phase (two *glitches* with an important impact on time to market and one with an important impact on product quality) whereas as regards day to day interaction, a medium impact has been noticed for three *glitches* (on delay and product quality) and one important impact on product quality. It seems that during relationship design, time must be passed to know respective needs and capacities in order to work in a common direction and in a common interest. During the day to day interaction, a collaborative capacity is expected from both the designer and the customer. All suppliers are not able to co-develop this way by sharing results and product evolution in a daily manner. Similarly, the customer has to continue to manage the relation by organising regular meeting points in order to go on in the appropriate direction.

Table 2. Glitches impact on expected ESI benefits and suggestions of preventive actions

	Glitches	Delay (Time to market)	Cost	Product quality	Innovation	Actions to avoid glitches
RELATIONSHIP DESIGN	**1. Selected supplier non adapted to the project expectations**	+++ (choice delayed, one year lost)	++ (rework, change of supplier)	++ (product proposed non-optimal)	+ (the supplier does not answer to the customer's design exigences)	Identification of appropriated selection criteria that respond to both project needs and purchasing strategy Joint selection between purchasing and engineering departments Make the decision at the most appropriate time Evaluation of the supplier capacity to answer customer's expectations
	2. Confusing determination of roles expected by the supplier	+ (delay: 3 months)	+ (rework)	+++ (some product quality demands are not satisfied)	+ (difficulty to know who is in charge of what)	Regular meetings Redefine and readapt roles Check good mutual understanding Make sure that the item is specified with straightforward and well-defined interfaces Intensive and reciprocal communication with supplier during the project
	3. No alignment in expectations	++ (6 months for alignment)	+	+(no alignment in product expectations understanding)	+ (less innovation than expected)	Mutual arrangement at the beginning Transparency
	4. Contractual arrangement hard to build up	+++ (several versions, one year of rework)	++ (modifications)			Transparency, trust Contract jointly elaborated Avoid closed contract without evolution margin
	5. Wrong understanding of needs	++ (time to agreement: 6 months)	+ (rework)	++ (understood need by the customer not in alignment with real demand)	+ (non productive relationship)	Regular meetings Redefine and readapt roles Check good mutual understanding Make sure that the item is specified with straightforward and well-defined interfaces Intensive and reciprocal communication with supplier during the project Make sure that the supplier has clearly understood the customer need
DAY TO DAY INTERACTION	**6. Problems for sharing of quality requirements**	++ (no common understanding, tools mastering, 4 months lost)	+ (time lost lead to money lost)	+++ (an important delay in FMEA realisation)		Change management Check good mutual understanding Make sure that the item is specified with straightforward and well-defined interfaces Intensive and reciprocal communication with supplier during the project FMEA Complementary verification tests on mock-up, simulation, correlation analysis. Share the impact analysis by clearly presenting the environment in which the outsourced item will be used in order that the supplier fully understands development and utilisation constraints and gets an overall picture of expected requirements Co-define the verification plan
	7. No joint definition of specifications	+ (2 months for prototype obtention)	+ (time lost lead to money lost)	++ (non-optimal prototype)		Share the impact analysis by clearly presenting the environment in which the outsourced item will be used in order that the supplier fully understands development and utilisation constraints and gets an overall picture of expected requirements Intensive and reciprocal communication with supplier during the project Complementary verification tests on mock-up, simulation, correlation analysis. Co-define the verification plan
	8. Unstable specifications	+ (3 months lost)	+	+ (non-adapted proposal)		Change in specification must be accepted, it is normal Make sure that the item is specified with straightforward and well-defined interfaces Intensive and reciprocal communication with supplier during the project
	9. Privileged interlocutor hard to identify	+ (unsuccessful meetings, late mutual arrangement, 3 months)		++ (mutual arrangement about quality exigencies hard to build)		Define communication matrix Make sure that the item is specified with straightforward and well-defined interfaces Intensive and reciprocal communication with supplier during the project
	10. Verification plan hard to obtain	+ (3 months)	+	+		Co-define the verification plan : Common approval of the verification plan concerning the supplied product Roles and responsibilities of the two parties clearly defined especially with regard to the actions and ressources needed to implement the verification process
	Impact:	+ small	++ medium	+++ important		

If we consider *glitches* individually, some particular points can be mentioned.

Concerning the first *glitch* “Selected supplier non-adapted to the project expectations”, it is necessary to determine adapted selection criteria that respond to project needs and purchasing strategy because their respective objectives can differ. The supplier choice should be collegial because if such decisions are made in isolation, a coordination problem often arises. When the supplier is early involved, it has to be hardly selected and involved in the appropriate time [5], [30]. In this respect, the survey carried out by Culley et al. [31] concerning the information flows between engineering designers and suppliers revealed that 32% of the respondents had access to formal guidelines to aid them in decisions such as when to contract suppliers, to involve them in the engineering process or concerning the level of involvement appropriated.

In order to respond to the *glitch* “Confusing determination of roles expected by the supplier”, authors advise to organise regular meetings. The use of face-to-face communication is advocated [31]. A very close and frequent information exchange is necessary in order to adapt and understand mutually [32]. This point is also adapted for the third collaborative *glitch* encountered “No alignment in expectations” and to the *glitch* “Wrong understanding of needs” as regular meetings are a good means for enabling mutual arrangement and promoting trust and transparent behaviours. Similarly “Unstable specifications” issues can be partly mastered by following those advices.

One other important point is trust as regards contracts agreements. Fraser et al. [33] advocates a joint identification and negotiation about the issues to be included in the contract (confidentiality agreement, deliverables expected from both the supplier and the customer, intellectual property and patent policies, risk- and gain-sharing, detailed planning,…) which should be seen as a basis for a win-win relationship, open to renegotiation, rather than as a mechanism against mistrust and opportunism. As a matter of fact it is difficult to anticipate some events which can explain the *glitch* “Contractual arrangement hard to build up” observed. For Schiele [18], it is challenging to include all possible outcomes in a contract but “closed” contracts are advised against. Moreover, team members have to be honest if they hope honesty from the other part.

Busby [34]’s work deals with errors occurring during the design process. This author demonstrated the importance of work occurring in the so-called “social world” [15]. Interviews carried out by Busby [34] with design engineers of varying seniority and disciplinary backgrounds revealed that 87% of such errors could be attributed to failures in what he referred to as *distributed cognition* (referred to circumstances where the knowledge required to solve a particular problem is distributed between several collaborators, thereby necessitating interaction). Therefore, as regards “Wrong understanding of needs”, “Problems for sharing of quality requirements” and “No joint definition of specifications” *glitches*, communication skills are a very important element. In case of a common work, those specific skills must be mastered and refer to the “*interactive interface”* introduced by Araujo et al. [19] which is “*an outcome of decisions made on both sides of a dyad*” (p506). For these authors, this “*interactive interface*” allows an open-ended dialogue based on how the customer and supplier can combine their user and producer knowledge in order to develop specifications together. In the context of co-design that involves significant design input from a supplier, the later can “contribute to the design process by helping customers meet functional requirements, without including excessive specification requirements that lead to unproductive additional costs” ([35], p44). The case study analysis performed by Crabtree et al. [36] in order to examine coordination and social aspects revealed that 56% of the problem cases were due to information acquisition and information access difficulties alone. In addition the survey indicates that engineers spend about 29% of their time in problem solving and thinking.

“Problems for sharing of quality requirements” may be linked to “internal complexity” [37] and the fact that the product to be developed may include several technologies and sub-parts more or less internally mastered. Novak and Eppinger [38], Clark and Fujimoto [39] mentioned the notion of product complexity and vertical integration that can lead to some understanding issues. Therefore preventive actions are necessary when teams are aware of the existence of such a situation of complexity.

Other more general advice can be made such as for instance forecasting a first meeting with supplier and customer teams in order to know each part. A risk evaluation should be performed so as to identify some potential critical points. The sooner those critical points are known, the more they will be annihilated. The team must be particularly careful at the beginning of the relationship. As regards design delegation (i.e. black-box parts), this is not a total delegation. The beginning of this kind of relationship is very critical. The customer should make sure that he knows the supplier in a suitable way and he beneficiates of a good overview of the supply market. In addition, it is important to have a good overview of the status of suppliers referred in the supplier base (commodity suppliers or designer suppliers for instance). Following Culley et al. [31] the information management is difficult and especially when it is in inter-organisational configurations which can lead to costly issues. For Karlsson et al. [32], it is necessary to work with suppliers in a more collaborative way. Each supplier has a different role and thus appropriated specifications are necessary. Those elements must be considered and shared earlier in the relationship but it is not an automatism.

5. CONCLUDING REMARKS

The objective of our research work is to obtain an impact assessment of collaborative design between customer and supplier on project performance. The aim is to contribute to both academic research and industrial need of tangible elements as regards ESI benefits. In this paper we analysed an unsuccessful collaboration between a customer and one of its suppliers in a new product development project in order to determine a categorisation of possible collaborative *glitches* with a view to preventing them in future collaborative works. The research results have been generated by a case study research. This methodology was considered as suitable for our explorative objectives. It was relevant to carry out interviews with persons directly involved into the project considered. Thanks to our observation of a collaborative relationship, we have been able to notice some collaborative *glitches* and associated costs.

One limitation of our study could be that only one case study was carried out. The study presented here is an exploratory one. It is not and should not be interpreted as a complete study and evaluation of issues encountered during a collaborative development with a supplier in large scale design situations. This work provides a first approach for our research project and it is hoped that it will contribute to the overall understanding of collaborative design issues and possible preventive actions. Therefore we are aware of the fact our results may not be applied in a general way. Now, this approach must be applied with other organisations, other projects and other persons in order to improve the *glitch* list proposed in this paper. Our final aim is to obtain an identification of the possible collaborative *glitches* and associated preventive actions in order to promote ESI in new product development project and to enable its success. One can compare our final aimed work with a FMEA (Failure Mode and Effects Analysis) for collaborative design with suppliers.

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Contact: Hélène Personnier
Grenoble Institute of Technology, School of Industrial Engineering
G-SCOP Laboratory
46 Avenue Félix Viallet
38031 Grenoble Cedex 1
France
Tel: Int 33(0)4 56 52 89 06
Fax: Int 33(0)4 76 57 46 95
Email: helene.personnier@g-scop.grenoble-inp.fr

Hélène is a Ph-D Candidate at Grenoble Institute of Technology at the G-SCOP Laboratory. Her Research focuses on expected benefits of collaborative design with suppliers in New Product Development (NPD).