Problem and interface characterization during ramp-up in the low volume industry

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T H E S E

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PROBLEM AND INTERFACE CHARACTERIZATION DURING RAMP-UP IN THE LOW VOLUME INDUSTRY

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To my step father Jean

Who has always believed in me more than myself

To my brother Adrien

Thanks for being always there

To my mom Jacqueline

The best mom on earth

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MANY THANKS TO…

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ACRONYMS

BD: switchgear subassembly, developed and produced by Siemens E T HS (see section 6.4.1)

BOM: Bill of Material

B-to-B: Business to Business, transactions between businesses (as opposed to direct sales to end customers, B-to-C)

CAD: Computer Assisted Design

CEM: Contract Electronics Manufacturer

CIFRE: Industrial convention of education through research (Convention industrielle de formation par la recherche).

DE: Germany

DfA: Design for Assembly

DFM: Design for Manufacturing

DQ: switchgear product, developed and produced by Siemens E T HS (see section 8.1)

E T HS: Energy power transmission, high voltage substations (see Figure 1.2)

ERP: Enterprise Resource Planning

FMEA: Failure mode and effects analysis

FR: France

GE: switchgear product, developed and produced by Siemens E T HS (see section 6.3.1)

G-SCOP: Laboratory of Grenoble for Sciences of Conception, Optimization and Production (Laboratoire des Sciences pour la Conception, l'Optimisation et la Production de Grenoble)

KPI: Key Performance Indicator

NPD: New Product Development

NSI: Non-Structured Information (see section 5.3.3.3)

OEM: Original Equipment Manufacturer

PM: Project Manager

SCM: supply chain management

SI: Structured Information (see section 5.3.3.3)

SIE: switchgear product, developed and produced by Siemens E T HS (see section 4.1.2)

SME: Small and medium enterprises

SOP: Start of production

SSI: Semi-structured Information (see section 5.3.3.3)

XJ7: switchgear product, developed and produced by Siemens E T HS (see section 8.1)

XS: switchgear product, developed and produced by Siemens E T HS (see section 6.2.1)

ABSTRACT AND KEYWORDS

The extended globalization and the increasing competition urge firms to constantly innovate and launch new, high technological products on their markets. Therefore, New Product Development (NPD) has become a key process to master for successful companies. NPD has received a great attention over the past years in the research literature. NPD has been studied from different points of view, varying from marketing to engineering design and to operations management.

The final phase of the NPD process is called “production ramp-up”. Production ramp-up is the period when manufacturing of the new product is gradually accelerated until reaching the period of mature production. Production ramp-up is a crucial step for the whole NPD project. Indeed, its success conditions the NPD project success.

In this dissertation we address the issue of production ramp-up in the context of the low volume industry. Indeed, several works focusing on the ramp-up phase have been published but their findings are extracted from high volume industries such as the microelectronics industry or the automotive industry. This dissertation builds upon cases studies carried out at Siemens E T HS, a company producing electrical bays for high voltage substations, sold to Transport System Operators.

There are three issues investigated in this dissertation.

First we realized a thorough state of the art so as to provide a map of the existing research body on the ramp-up issue. The different classifications of existing literature that we provide are useful to position the research presented here within the research body and to confront existing results to the specificities of low volume industries.

Second, we focus on ramp-up problems. Problem handling is a major activity during ramp-up. We looked for typical problem types, classifying the different problem statements collected during a case study at Siemens E T HS. Again, we were able to compare our findings to existing findings in the literature.

Third, we examine the issue of information exchange and cooperation problems in the ramp-up phase. The approach taken is to focus on interfaces, i.e. the links and interactions existing at the boundary of different industrial functions that support communication and coordination. Building upon existing concepts of the literature, we design a new interface model. It aims at describing interface characteristics with a set of meaningful concepts (about the dynamics of information or the impact of information for example). The interface model is used to develop an auditing tool so that interface can be investigated with practical and concrete tools and evaluation rules in a field study. The auditing tool is then used on three different case studies. We draw valuable conclusions for our industrial partners but also outlined interesting results from a research point of view.

Keywords: Ramp-up, Low volume industry, Problem, Interface, Coordination.

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LA THESE EN FRANÇAIS

Cette section est consacrée à un résumé extensif de la thèse en langue française. Cette section est indépendante du reste de la thèse. Dans un souci de simplicité et pour éviter la redondance, les figures et tables présentées ci-après ne sont pas répertoriées dans la liste des figures et la liste des tables.

TITRE

Caractérisation des problèmes et des interfaces pendant la phase de montée en cadence dans l'industrie de faible volume.

MOTS- CLEFS

Lancement de produit, Industrie de faible volume, Problème, Interface, Coordination.

RESUME EN 200 MOTS

Dans cette thèse, nous nous intéressons à la phase de montée en cadence dans le contexte de l'industrie de faible volume. Nos travaux se fondent sur des études de cas réalisées à Siemens E T HS, une entreprise produisant des disjoncteurs haute tension. Nous nous sommes tout d'abord intéressé aux problèmes rencontrés lors de la phase de montée en cadence car leur gestion est une activité majeure pendant cette phase. Nous avons établi des problèmes types. En parallèle, nous avons réalisé un état de l'art complet sur la question de la montée en cadence afin d'établir une cartographie de la littérature existante. Enfin, nous nous sommes concentrés sur les problèmes d'échange d'information et de coopération en examinant les interfaces, c'est-à-dire les liens et interactions existantes aux frontières entre différentes fonctions industrielles. Nous proposons un nouveau modèle d'interface ainsi qu'un outil d'audit que nous avons utilisé sur trois études de cas, ce qui nous permet de tirer des conclusions tant d'un point de vue pratique pour nos partenaires industriels que d'un point de vue académique.

TABLE DES MATIERES

Chapitre 1 – Introduction

1.1 Contexte académique

Les conditions de compétition mondiale dans lesquelles évoluent les entreprises aujourd'hui les poussent à innover et à lancer constamment des produits nouveaux sur leurs marchés. Il en résulte que le Développement de Produit Nouveau (DPN) est devenu un processus clé que les entreprises doivent maîtriser pour réussir.

La dissertation présentée dans ce document se concentre sur la dernière phase du processus de DPN, la montée en cadence ou « ramp-up » en anglais (Clark and Wheelwright 1992; Ulrich and Eppinger 2004) (cf. Figure 1.1).

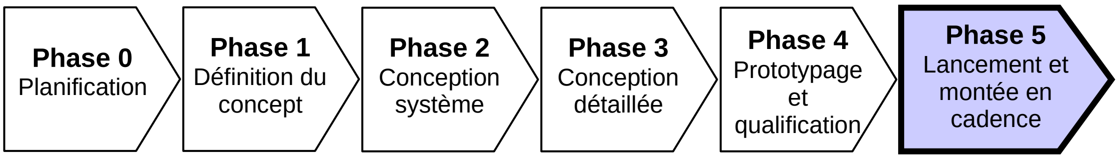


Figure 1.1 – La montée en cadence, dernière étape du processus de DPN, selon (Ulrich and Eppinger 2004)

La montée en cadence est l'accélération progressive de la production, jusqu'à atteindre la phase de production mature. La montée en cadence est une étape cruciale pour le projet de DPN, à la frontière entre la conception de produit et la gestion de production.

De nombreux auteurs s'accordent sur le fait que peu de travaux académiques se concentrent sur la phase de montée en cadence (Clark and Wheelwright 1992; Juerging and Milling 2006; Wolgast and Carlson 2007). (Krishnan and Ulrich 2001) estiment que la littérature sur la conception de produit possède des lacunes importantes sur le sujet de la montée en cadence. C'est pourquoi une étude approfondie de la phase de montée en cadence apparaît une contribution académique intéressante.

1.2 Contexte industriel

Le travail de recherche présenté dans cette dissertation a été mené dans le cadre d'une convention de thèse CIFRE (cf. acronymes). Le partenaire industriel de la convention est Siemens E T HS, une branche de Siemens AG spécialisée dans la fabrication postes isolés au gaz pour les sous-stations électriques haute tension.

Siemens E T HS est une entreprise qui opère sur le marché B-to-B de l'appareillage électrique haute tension (marché niche) et propose à ses clients, des entreprises gestionnaires de réseau d'électricité, une très grande diversité de produits. En effet, chaque réseau électrique ayant ses propres caractéristiques, Siemens E T HS fabrique ses produits à partir de variantes préexistantes choisies en fonction du cahier des charges client (cf. Figure 1.2). La production fonctionne donc sur le mode « engineering-to-order ».

Ainsi Siemens E T HS appartient à **l'industrie de faible volume**, qui a les caractéristiques suivantes (Jina et al. 1997; Maffin and Braiden 2001):

- produits vendus sur un marché B-to-B
- faibles volumes de production

- production en make-to-order ou engineering-to-order (donc très forte diversité de produits)
- les délais de production et délais de livraison sont les leviers majeurs.

A notre connaissance, il n'existe pas d'étude sur la phase de montée en cadence dans l'industrie de faible volume, qui présente des caractéristiques pourtant bien particulières. C'est pourquoi le travail de recherche présenté a pour but d'approfondir les connaissances académiques sur la phase de montée en cadence, dans le contexte de l'industrie de faible volume.

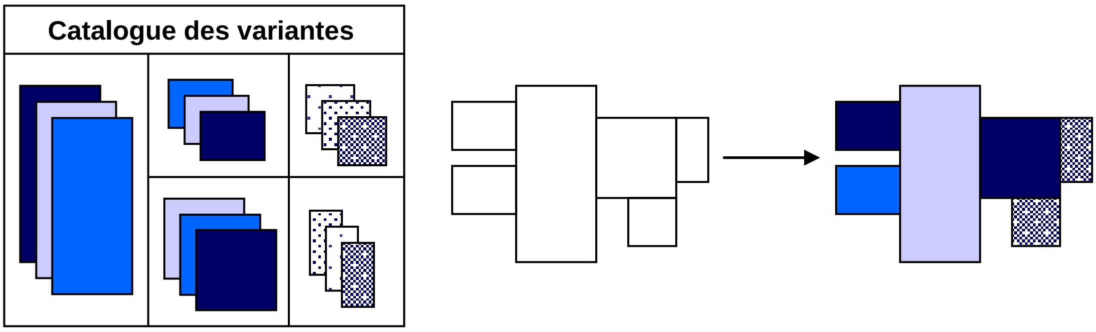


Figure 1.2 - Création d'un produit sur mesure à partir de variantes des modules d'un poste

1.3 Problématique étudiée

Nous avons structuré notre travail de recherche sur la phase de montée en cadence autour de deux questions de recherche. Nous avons conduit une première étude exploratoire sur les problèmes rencontrés lors de la phase de montée en cadence. En parallèle, nous avons conduit une étude approfondie de la littérature. Cela nous a conduits à identifier une nouvelle piste de recherche : l'examen des interfaces projets pour résoudre les problèmes de communication et de coopération, problèmes cruciaux durant la montée en cadence.

En résumé, nos deux questions de recherche sont les suivantes :

(RQ1) Quels sont les problèmes typiques rencontrés lors d'une phase de montée en cadence en industrie de faible volume ?

- quels problèmes types peuvent être identifiés ?
- parmi ces problèmes, quels sont les plus critiques ?
- les problèmes types identifiés sont-ils identiques dans d'autres industries ?

(RQ2) Comment peut-on caractériser la situation d'interface pendant la phase de montée en cadence ?

- quelles sont les interfaces majeures et comment l'information est-elle échangée ?
- quelles conclusions actionnables pour améliorer les prochaines montées en cadence peuvent être tirées de l'analyse des interfaces ?

Chapitre 2 – Méthodologie

2.1 Démarrage du projet de recherche

Le projet de recherche présenté ici a été mené en étroite collaboration avec les partenaires industriels de Siemens E T HS (des sites industriels de Grenoble et de Berlin). Afin d'aboutir à des résultats intéressants tant sur le plan académique que sur le plan pratique, nous avons défini les questions de recherche conjointement avec les industriels de Siemens E T HS (ainsi que recommandé par (Avenier 2009)). Ensuite, l'ensemble de notre travail de recherche a été piloté par un comité composé de deux chercheurs du laboratoire G-SCOP et quatre industriels de Siemens (cf. Figure 2.1).

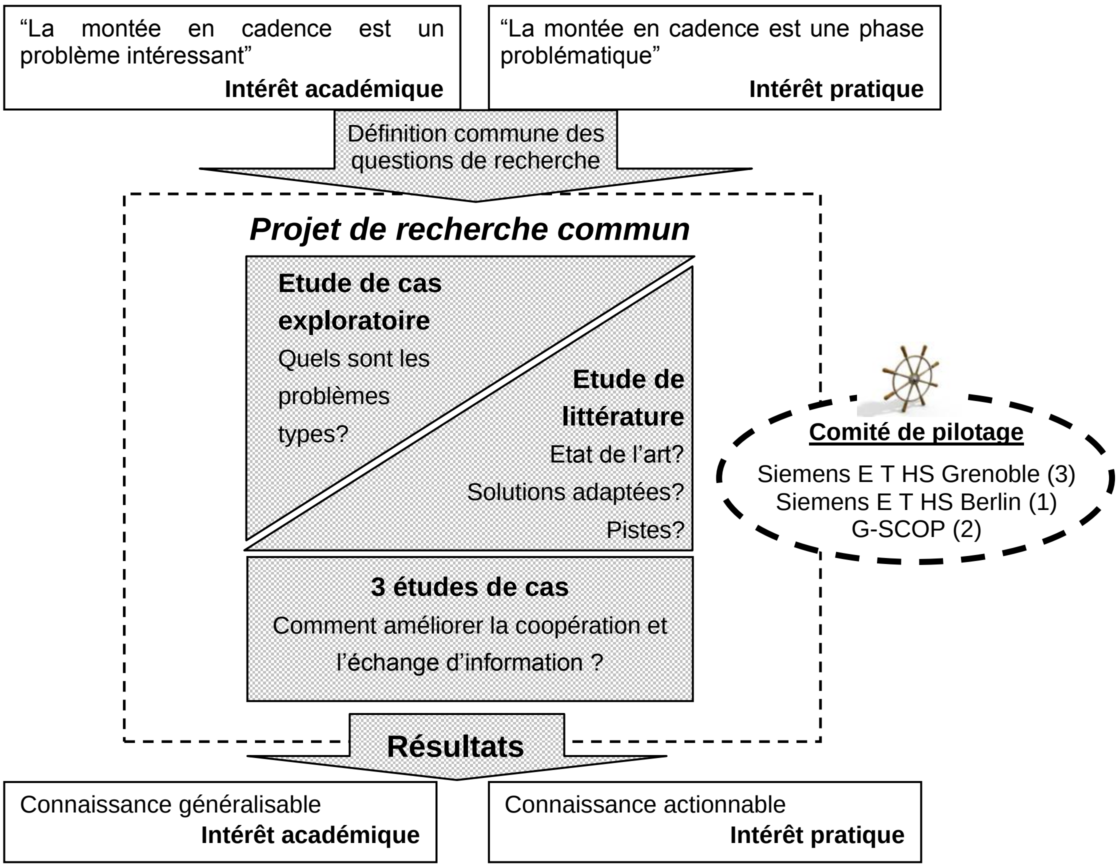


Figure 2.1 – Vue d'ensemble du projet de recherche présenté ici

2.2 Méthodologie pour l'approche terrain

Dans le cadre de notre projet de recherche, nous avons adopté la méthodologie de l'étude de cas afin de capitaliser les connaissances terrain. L'étude de cas est une méthodologie adaptée au but que nous poursuivons car :

- Elle permet d'étudier un phénomène dans son contexte industriel (Eisenhardt and Graebner 2007) et de générer des connaissances généralisables à partir d'observations de la pratique (Benbasat et al. 1987)

- Elle permet de répondre à des questions de type « quoi/quel ? » et « comment ? » (Yin 2009) lorsque l'état de l'art sur le sujet est limité (Stuart et al. 2002),.

Nous avons conduit dans le cadre du projet de recherche présenté ici quatre études de cas (nommées ci-après projet SIE, projet XS, projet GE et projet BD, cf. acronymes). Le tableau 2.1 résume les caractéristiques de ces études de cas, notamment le type de projet DPN (projet de transfert de production ou développement de produit nouveau), le statut du projet au moment de l'intervention, le statut du chercheur au sein du projet (cf. (Junker 2004)) et les principales sources de données utilisées.

	Project SIE	**Project XS**	**Project GE**	**Project BD**
Début/fin projet	Juin 2006 – Juin 2007	Nov. 2004 – Déc. 2008	Mars 2006 – Mai 2009	Juil. 2008 – Avril 2010
Type de projet	Transfert de production	Développement de nouveau produit	Développement de nouveau produit	Développement d'un nouveau sous-système
Période d'intervention	Février – Juin 2007	Novembre 2007 – Avril 2008	Octobre – Novembre 2009	Octobre 2009 – Janvier 2010
Statut du projet	Montée en cadence	Début de la montée en cadence	Fin de la montée en cadence	Prototypage et qualification
Thème étudié	Problèmes	Interfaces	Interfaces	Interfaces
Statut du chercheur	Participant complet	Participant qui observe	Observateur qui participe	Participant qui observe
Lieu	Grenoble (FR)	Grenoble (FR)	Berlin (DE)	Grenoble (FR)
Principales sources de données	Participation + Observation du terrain	Participation + Interviews non-structurées régulières	Interviews structurées + Questionnaire e-mail	Participation + Interviews non-structurées régulières

Table 2.1 – Résumé des caractéristiques des quatre études de cas

2.3 Validité de la recherche

Dans cette dissertation, la validité de la recherche présentée est évaluée grâce à plusieurs concepts :

- L'échantillonnage (le choix des cas doit être justifié et pertinent par rapport au sujet étudié, (Eisenhardt and Graebner 2007; Yin 2009))
- La fiabilité (la même étude doit conduire aux mêmes résultats, (Stuart et al. 2002))
- La validité des concepts (les mesures opérationnelles choisies reflètent bien les concepts étudiés, (Stuart et al. 2002))
- La validité interne (les résultats trouvés sont valables, (Stuart et al. 2002))
- La validité externe (ou généralisation, ou dans quelle mesure les résultats trouvés sont valides au-delà de l'étude réalisée, (Meredith 1998)).

Les concepts présentés ci-dessus sont discutés en conclusion (Chapitre 7), une fois qu'auront été décrits les détails concernant la conduite du projet de recherche présenté ici.

Chapitre 3 – Revue de la littérature

3.1 Introduction

Notre revue de la littérature est construite autour de 41 travaux de recherche collectés dans des journaux scientifiques (Management Science, the International Journal of Operations and Production Management, International Journal of Production Economics...) ainsi que dans des conférences internationales (CIRP). Il n'existe à notre connaissance aucune revue de la littérature publiée sur le sujet de la montée en cadence. Notre revue de littérature répond deux objectifs : (1) proposer différents aperçus et classifications de la littérature existante sur la montée en cadence et (2) discuter les résultats déjà publiés au regard des spécificités de l'industrie de faible volume.

3.2 Concepts généraux

La définition généralement admise de la montée en cadence est celle donnée par (Bohn and Terwiesch 1999). La montée en cadence est décrite comme la période entre la fin du développement et l'utilisation de la totalité de la capacité industrielle (Bohn and Terwiesch 1999). C'est pourquoi la montée en cadence s'observe aussi bien lors de l'introduction d'un nouveau produit en production que lors d'un transfert de production (Bohn and Terwiesch 2001; Terwiesch et al. 2001).

Malgré le consensus général, certains auteurs pointent les limites d'une telle définition. (Fleischer et al. 2003) insistent sur l'imprécision de la limite “fin du développement ». En réalité, la conception d'un produit ne se finit pas à une date précise et certaines modifications ont encore lieu après le démarrage de la production (Juerging and Milling 2005). C'est ainsi que le démarrage de la production (ou SOP pour start-of-production en anglais) apparait comme une date de début plus pertinente pour la montée en cadence (Fleischer et al. 2003; Fjällström et al. 2009). D'autres auteurs soutiennent même que pour une compréhension holistique de la montée en cadence, les phases préparatoires doivent être incluses (Meier and Homuth 2006; Winkler et al. 2007).

La littérature mentionne plusieurs raisons qui poussent à s'intéresser à la montée en cadence dont les **délais** – les premiers entrants sur le marché peuvent vendre leur produit à prix fort (Fleischer et al. 2003; Terwiesch and Yi 2004; Carrillo and Franza 2006; Juerging and Milling 2006) – et la **complexité** – les produits manufacturés sont de plus en plus sophistiqués et de plus en plus variés, ce qui rend la montée en cadence de plus en plus complexe (Terwiesch et al. 2001; Schuh et al. 2005; Winkler et al. 2007).

La phase de montée en cadence a aussi ses caractéristiques propres : faible niveau initial de connaissances sur le produit et le processus de production (Fleischer et al. 2003; Juerging and Milling 2005), faible volume de production (Haller et al. 2003), faibles capacités de production (Bohn and Terwiesch 2001), demande forte (Terwiesch et al. 2001) et nombreuses perturbations dans le processus de production, la chaîne d'approvisionnement ou la qualité produite (Almgren 2000; Fleischer et al. 2003; Nyhuis and Winkler 2004; Fjällström et al. 2009).

3.3. Etat de l'art en fonction du contexte industriel

Nous avons identifiés un nombre croissant de publications qui s'intéressent à la montée en cadence. Une première catégorisation intéressante est de répartir ces travaux en fonction du contexte industriel duquel ils sont issus. La figure 3.1 résume la répartition des 41 publications sur la montée en cadence que nous avons identifiées.

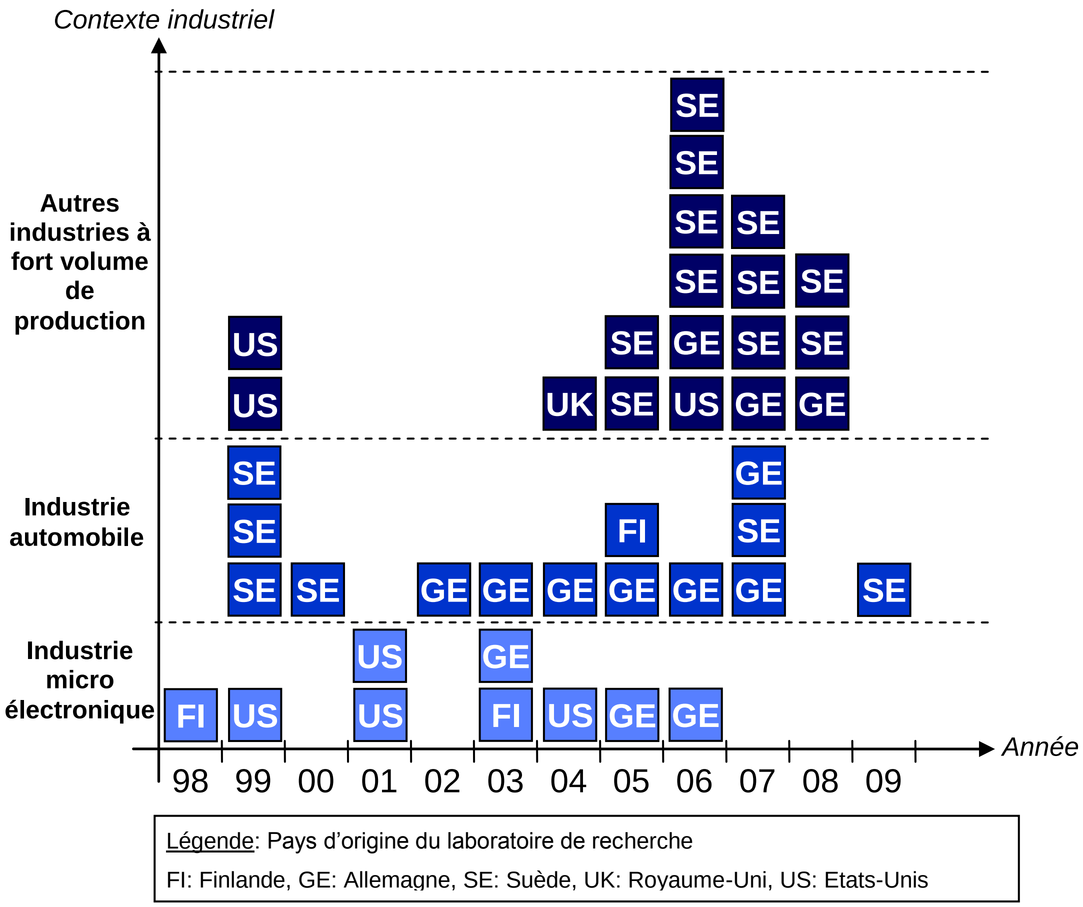


Figure 3.1 – Contexte industriel et pays d'origine des publications sur la montée en cadence entre 1998 et 2009

Les principaux travaux réalisés dans le contexte de l'industrie de la microélectronique sont ceux de (Simola et al. 1998), (Bohn and Terwiesch 1999), (Bohn and Terwiesch 2001), (Terwiesch et al. 2001), (Apilo 2003), (Haller et al. 2003), (Terwiesch and Yi 2004), (Juerging and Milling 2005) et (Burmer and Görlisch 2006). Ces soulignent principalement l'importance de deux leviers de la phase de montée en cadence : le rendement (ou yield en anglais) et l'apprentissage.

De nombreux travaux sur la phase de montée en cadence ont pour contexte industriel l'industrie automobile. Nous avons identifié les travaux suivants : (Almgren 1999a), (Almgren 1999b), (Almgren 1999c), (Almgren 2000), (Kuhn et al. 2002), (Fleischer et al. 2003), (Nyhuis and Winkler 2004), (Kontio and Haapasalo 2005), (Schuh et al. 2005), (Juerging and Milling 2006), (Winkler et al. 2007), (Wolgast and Carlson 2007), (Scholz-Reiter et al. 2007) et (Fjällström et al. 2009). Ces travaux se concentrent notamment sur les indicateurs de performances de la montée en cadence ainsi que sur l'évaluation de la complexité des phases de montée en cadence. (Almgren 1999a) notamment propose de classifier les situations de montée en cadence dans une matrice nouveauté produit / nouveauté processus.

Enfin, les autres travaux identifiés ont pour contexte d'autres industries à fort volume de production fabriquant notamment des produits pharmaceutiques, de l'électronique grand public, du matériel de bureau, des produits outdoor etc. Ces travaux sont les suivants : (Bowersox et al. 1999), (Di Benedetto 1999), (Van der Merwe 2004), (Berg et al. 2005), (Berg and Säfsten 2005), (Berg and Säfsten 2006), (Carrillo and Franza 2006), (Fjällström et al. 2006), (Meier and Homuth 2006), (Säfsten et al. 2006a), (Säfsten et al. 2006b), (Berg 2007a), (Berg 2007b), (Fjällström 2007), (Pufall et al. 2007), (Fransoo et al. 2008), (Säfsten et al. 2008a) et (Säfsten et al. 2008b).

En conclusion, si la littérature existante est placée sur une matrice volume de production / diversité des produits, plusieurs espaces blancs peuvent être identifiés. Ces espaces blancs (dont le contexte faible volume / forte diversité de produit, auquel appartient Siemens E T HS) apparaissent comme des domaines de recherche prometteurs car encore inexplorés.

3.4 Classifications de l'état de l'art

Nous proposons dans cette dissertation plusieurs classifications de la littérature existante sur la montée en cadence. Nous proposons une classification selon les mots-clefs (cf. Table 3.5 dans le document principal). Cette classification nous a permis d'identifier les précédents travaux qui touchent à nos problématiques de recherche, notamment les publications traitant des « problèmes » de la montée en cadence (première question de recherche) et ceux qui traitent du thème « coopération, coordination et interfaces » (deuxième question de recherche).

Nous proposons ensuite une deuxième classification, selon les acteurs de la montée en cadence pris en compte (cf. Table 3.6 dans le document principal). En effet, de nombreux acteurs sont impliqués dans la phase de montée en cadence et les différents travaux englobent plus ou moins dans leur étude ces acteurs.

Enfin, une dernière classification proposée catégorise les différents travaux de la littérature selon les « domaines de recherche » identifiés par (Kuhn et al. 2002) (cf. Table 3.7 dans le document principal). Là encore, nous pouvons en conclure que le thème de la coopération entre acteurs de la montée en cadence est un sujet important mais peu traité par la littérature jusqu'alors.

3.5 Conclusions au regard du contexte de l'industrie de faible volume

Nous avons présenté un état de l'art concernant la question de la montée en cadence. Néanmoins, nous trouvons, à la lumière du contexte industriel très spécifique de Siemens E T HS, quelques limites aux résultats tirés de l'industrie à fort volume de production.

Nous proposons par exemple un nouveau découpage du processus de montée en cadence (cf. Figure 3.13 du document principal), qui prend en compte les suggestions de la littérature (intégrer les étapes de préparation) mais qui est mieux adapté au contexte des industries de faible volume (pas de préséries). Nous proposons également d'adapter le modèle d'(Almgren 1999a) (cf. Figure 3.14 du document principal). En effet, un produit ou un processus « modifié » ne fait pas l'objet d'une phase de montée en cadence dans un contexte où la variabilité des produits est très forte.

L'étude de l'état de l'art nous a permis de conclure entre autres que la résolution de problèmes était une activité conséquente lors de la montée en cadence. De plus, une approche par les problèmes apparaît comme une approche pertinente pour une étude exploratoire, afin de mieux appréhender les difficultés rencontrées par les industriels sur le terrain. C'est pourquoi, le chapitre suivant est consacré à l'étude des problèmes rencontrés lors de la montée en cadence.

Chapitre 4 – Problèmes de la montée en cadence

4.1 Introduction

Nous nous sommes intéressés aux problèmes rencontrés par les industriels lors de la montée en cadence. La littérature souligne que la phase de montée en cadence est particulièrement problématique et la gestion des difficultés rencontrées est une activité majeure pendant cette phase. Pour étudier les problèmes rencontrés, nous avons conduit une étude terrain lors d'un projet de transfert de production de Siemens E T HS, le projet SIE.

Le projet SIE a été piloté par l'équipe de l'usine de Grenoble entre juillet 2006 et juillet 2007. Ce projet avait pour but de transférer la production du produit SIE de l'usine de Berlin à l'usine de Grenoble. Une spécificité importante du projet SIE concerne l'approvisionnement des composants. En effet, lors de la phase de montée en cadence du projet, plusieurs sources d'approvisionnement ont coexisté. Certains composants ont été approvisionnés par l'usine « mère » de Berlin et d'autres composants ont été directement approvisionnés par l'usine de Grenoble auprès de ses fournisseurs. Enfin, la visserie quant à elle a été spécialement délivrée par un fournisseur berlinois directement à l'usine de Grenoble.

Le projet SIE est le premier projet commun entre l'usine de Grenoble et l'usine de Berlin. Le projet est considéré comme un succès car il a abouti en juillet 2007 à la qualification de l'usine de Grenoble en unité de production du produit SIE.

4.2 Approche méthodologique

Pour cette investigation du projet SIE, nous avons choisi d'utiliser la méthodologie de l'étude de cas. Le chercheur principal a été impliqué opérationnellement dans le projet de Siemens E T HS. Son positionnement correspond à un statut de « participant complet » selon (Junker 2004). Les données concernant cette étude ont été collectées via des conversations informelles, les notes de recherche, des participations à des réunions, des interviews non structurées etc. (cf. Table 4.1 dans le document principal).

A l'aide d'un modèle de « description type » de problème dérivée de la méthode QQOQP (Qui, Quoi, Où, Quand, Pourquoi), nous avons collecté 107 descriptifs de problèmes que nous nous proposons ensuite de classifier en « problèmes types ».

4.3 Classifications de problèmes

4.3.1 Classification par ressource

La première méthode utilisée pour classifier les 107 descriptifs de problèmes est similaire à celle utilisée par (Harper and Rainer 2000). Harper et Rainer ont défini des règles (cf. Appendix III, section 8.3), qui permettent de regrouper les descriptifs de problèmes selon la ressource concernée. Dans notre cas, cela a abouti à la classification présentée en Figure 4.1.

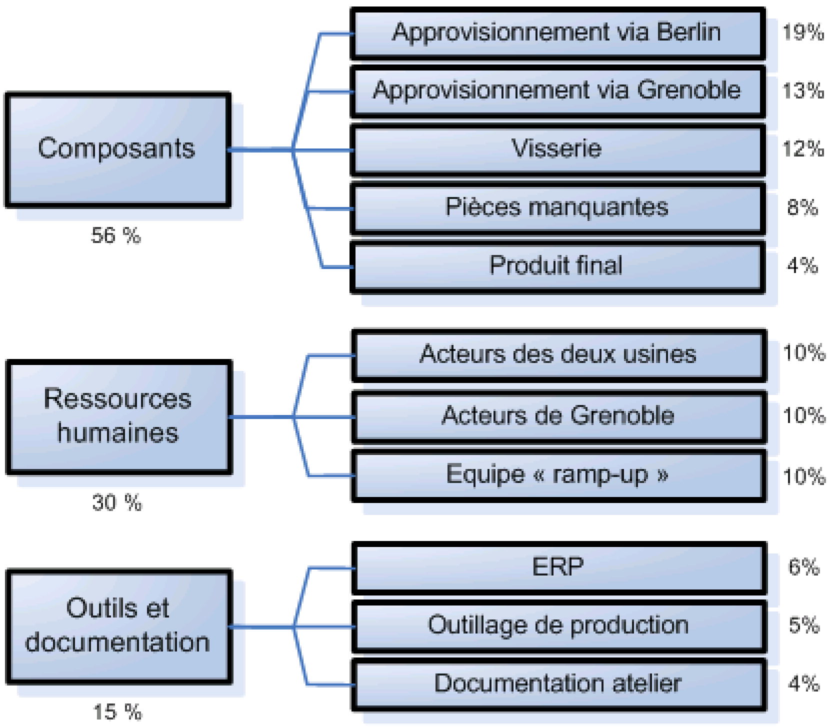


Figure 4.1 – Classification par ressource des 107 problèmes collectés

Nous avons donc identifié 11 catégories de problèmes. Nous pouvons conclure de cette première classification que les deux ressources concernées par une majorité des problèmes relevés sont :

- les composants (issus des différentes sources d'approvisionnement)
- les ressources humaines.

Concernant les composants, la classification illustrée en Figure 4.1 met en exergue l'importance des processus secondaires. Concernant les ressources humaines, elles totalisent 30% des descriptifs de problèmes, ce qui est assez inattendu.

Afin de compléter l'analyse tirée de la Figure 4.1, nous avons conduit une étude d'impact des problèmes rencontrés lors de la phase de montée en cadence.

4.3.2 Analyse d'impact

Dans la classification présentée en Figure 4.1 figure la répartition des problèmes (via les pourcentages). Mais cette classification ne donne pas d'indication supplémentaire sur l'impact réel de chaque problème. En effet, dans la classification par ressource, tous les problèmes ont le même impact (c'est-à-dire 1/107). C'est pourquoi nous proposons de conduire une analyse supplémentaire pour évaluer plus en détail l'impact de chaque problème. Nous avons pour cela utilisé la méthode AMDEC (Analyse des Modes de Défaillance et des Effets Critiques). Dans le cadre de notre analyse d'impact, nous avons pris en considération un sous-ensemble de 46 problèmes tirés des 107 descriptifs de problèmes récoltés dans l'investigation du projet SIE. Nous nous sommes concentrés sur les problèmes relatifs à l'approvisionnement des composants. L'évaluation de la criticité a été réalisée par chacun des acteurs du projet SIE. Le résultat présenté en Table 4.1 est le « top dix » du tableau obtenu.

Catégorie classification par ressource	Pb N°	Probabilité	Gravité	Détectabilité	Indice de criticité
Visserie	11bis	5	5	5	125
Visserie	92	5	4	5	100
Appro. Berlin	100	5	4	5	100
Visserie	65	5	5	4	100
Visserie	26	5	4	4	80
Visserie	51	4	5	4	80
Pièce manquante	53	4	5	4	80
Visserie	96	5	4	4	80
Appro. Berlin	104	3	5	5	75

Table 4.1 – Top dix du tableau d'analyse de l'impact des problèmes

Nous pouvons conclure de l'analyse d'impact qu'au sein de tous les problèmes d'approvisionnement, les plus critiques concernent la visserie. La visserie semble être un composant insignifiant et négligeable du produit final (« que des vis et des boulons ») et pourtant, ils posent les problèmes les plus critiques.

4.3.3 Classification par ressource

Il est important de connaître la cause d'un problème pour pouvoir le résoudre. Afin d'avoir un meilleur aperçu des causes des problèmes relevés pendant la phase de montée en cadence du projet SIE, nous proposons une nouvelle classification, dans laquelle les problèmes sont regroupés par cause. Cette classification est présentée en Figure 4.2.

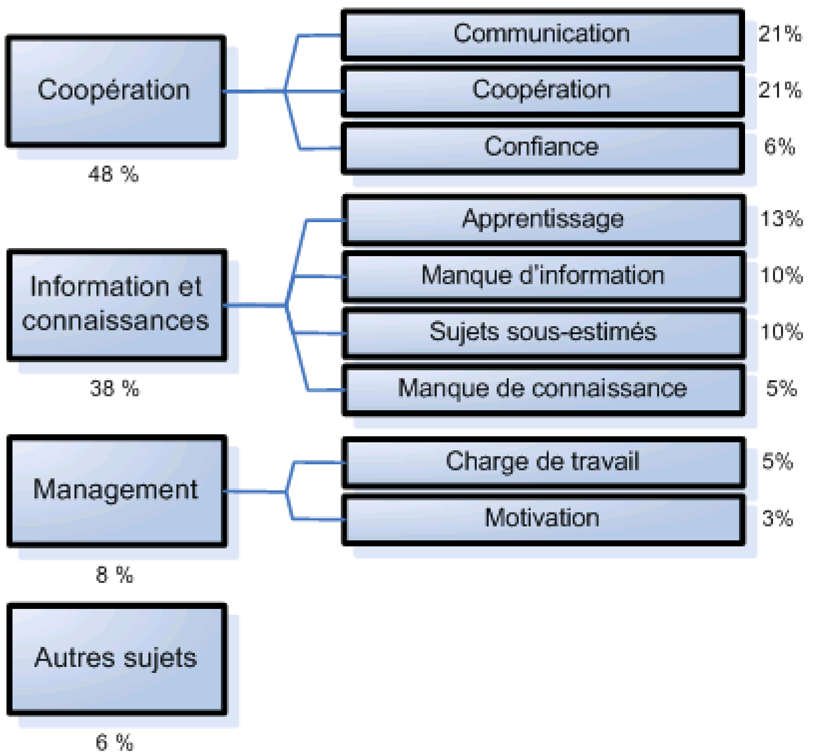


Figure 4.2 – Classification par cause des 107 problèmes collectés

La classification des problèmes par cause souligne que la plupart des difficultés pendant la phase de montée en cadence trouvent leur origine dans des problèmes de coopération et d’échange d’information.

4.4 Conclusions

4.4.1 Conclusions pour les partenaires industriels

De notre étude du projet SIE, nous avons tiré plusieurs propositions d’amélioration qui ont été présentées à nos partenaires industriels de Siemens E T HS. Au vu des nombreux problèmes concernant l’approvisionnement des composants, nous proposons que dans les futures phases de montée en cadence, la question de l’approvisionnement des composants soit supervisée par un acteur identifié. Afin de diminuer l’impact des difficultés sur la visserie, nous proposons que la relation avec le fournisseur de visserie soit renforcée. Enfin, pour diminuer le nombre de difficultés dues aux problèmes de communication et de coopération, nous suggérons que les futures phases de montée en cadence soient systématiquement pilotées par une équipe dédiée.

4.4.2 Conclusions académiques

Dans cette partie, nous avons répondu à notre première question de recherche. Nous avons identifié plusieurs catégories de « problèmes types » qui affectent la phase de montée en cadence dans l’industrie de faible volume. Ces catégories de problèmes types et l’analyse d’impact réalisée permettent de conclure que :

- L’approvisionnement des composants est un sujet crucial de la phase de montée en cadence. Nous croyons que ceci est particulièrement vrai pour l’industrie de faible volume, où l’assembleur final a peu de pouvoir vis-à-vis de ses fournisseurs.
- Les problèmes d’échange d’information et de coopération sont prédominants dans la phase de montée en cadence.

Par la suite, nous nous proposons donc de nous intéresser plus particulièrement aux problèmes d’échange d’information et de coopération dans la phase de montée en cadence. Le chapitre suivant présente le modèle d’interface ainsi que les grilles d’analyse centrées sur le concept d’interface qui ont été développés pour étudier plus en profondeur les interactions entre les acteurs de la montée en cadence et ainsi résoudre leurs problèmes de coopération et d’échange d’information.

Chapitre 5 – La montée en cadence du point de vue des interfaces

5.1 Introduction

Le concept d'interface est un concept intéressant pour investiguer les problèmes d'échange d'information et de coopération entre acteurs. Dans ce travail de recherche, une interface est définie comme « la collection de liens et d'interactions qui existe à la frontière entre différentes fonctions industrielles et qui supporte la communication et la coordination ». Nous nous proposons ici de répondre à la question de recherche suivante :

(RQ2) Comment peut-on caractériser la situation d'interface pendant la phase de montée en cadence ?

5.2 Modèles pour étudier la coopération et les flux d'information

Dans la littérature, nous avons trouvé plusieurs modèles qui permettent d'étudier la coopération et les flux d'information. Nous avons étudié et comparé quatre modèles : le modèle d'activité (Engström 2000), le modèle d'analyse des flux d'information (Forza and Salvador 2001), la grille des situations collaboratives (Gruat La Forme et al. 2007) et le modèle d'interface des acteurs projet (Koike et al. 2005). La Table 5.1 donne un résumé de ces modèles et de leurs avantages et inconvénients par rapport au but initial de notre recherche.

Modèle	Description courte	Avantages	Inconvénients
Modèle d'activité	Description des artefacts, règles et division du travail entre un sujet et un objet	Description précise de chaque élément de l'activité, y compris l'environnement	Concentré sur un sujet. Analyse d'acteurs multiples trop consommatrice de temps
Modèle d'analyse des flux d'information	Centré sur les flux d'information, les processus et la performance	Carte précise des flux d'information et de leurs caractéristiques	Pas de focus sur les acteurs, considère uniquement les échanges d'information
Grille des situations collaboratives	Grille en trois dimensions pour identifier le profil collaboratif d'une entreprise dans sa supply chain	Description précise de quatre niveaux de maturité pour chaque situation collaborative	Pas de détails sur les caractéristiques de l'information échangée ou sur les moyens utilisés
Modèle d'interface des acteurs projet	Modèle d'interface avec cinq caractéristiques principales	Prise en compte des acteurs, des flux d'information et du contexte	N'envisage pas la dynamique de l'information (évolution, maturité...)

Table 5.1 – Les différentes approches trouvées dans la littérature

Chaque modèle mentionné par la Table 5.1 possède des inconvénients par rapport à notre but initial d'étude des interfaces. C'est pourquoi nous proposons, dans la section suivante, un modèle (adapté du modèle d'interface des acteurs projet) pertinent pour notre étude.

5.3 Modèle d'interface proposé

Le modèle d'interface que nous avons conçu dans ce travail de recherche est présenté en Figure 5.1. Il contient certains éléments proposés par (Koike et al. 2005) tels que les acteurs d'interface, les objets intermédiaires, les outils d'interface et les temps d'interface, mais est complété par d'autres concepts de la littérature. En effet, nous utilisons également :

- des concepts qualifiant la caractérisation de l'information (support de l'information, l'évolution de l'information et la fréquence de mise à jour de l'information)
- un concept qui permet d'évaluer l'impact de l'information sur la source de l'information (durée de mise à jour)
- des concepts relatifs à la qualification de l'information (l'ouverture, la sensibilité de l'information, la structure de l'information)
- un concept reflétant l'étendue de diffusion de l'information (le niveau de diffusion de l'information).

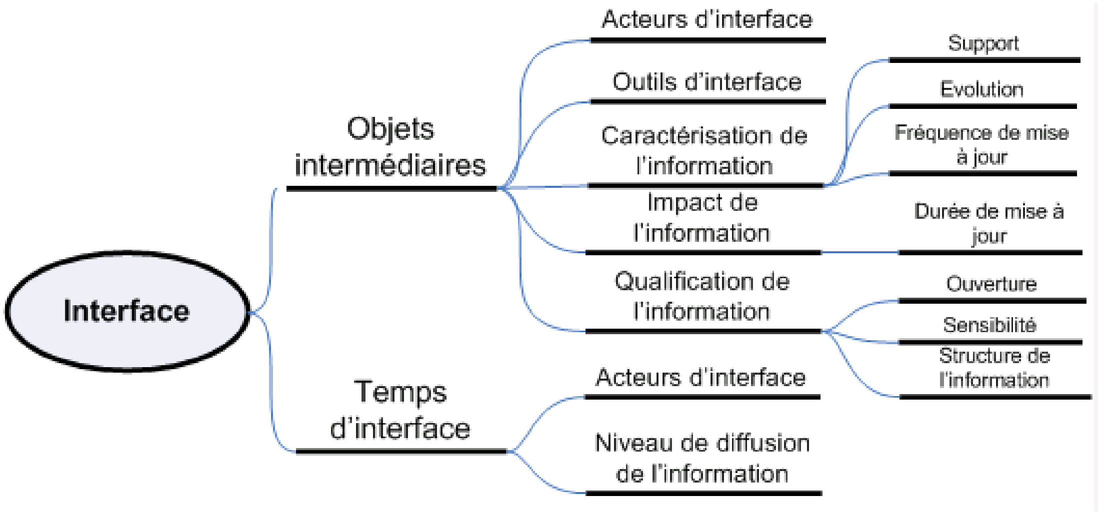


Figure 5.1 – Modèle d'interface proposé

A l'aide de ce nouveau modèle d'interface, nous avons construit un outil d'audit, afin de concrétiser ce modèle en outils pratiques pour l'étude d'un projet industriel sur le terrain.

5.4 Outils d'audit

Nous avons développé trois outils d'audit, afin d'analyser les projets de montée en cadence :

- Une grille des objets intermédiaires (IO Grid) qui permet d'étudier les différentes caractéristiques de l'information échangée entre les acteurs projets via les Objets Intermédiaires (cf. Table 5.2).
- Une grille des temps d'interface synchrones (SIT Grid), qui permet d'étudier les différents temps d'échange d'information et de coopération entre les acteurs, ainsi que les principaux flux d'information (cf. Table 5.3).
- Un diagramme résumé (summary diagram) qui détaille les principales interfaces entre acteurs d'un projet de montée en cadence, et met en avant les différents flux d'information et les éléments fondamentaux des interfaces (cf. Figure 5.2).

	Objet intermédiaire	Description	Responsable	Utilisateurs	Support	Structure	Fréquence MAJ	Evolution	Ouverture	Sensibilité	Durée de MAJ
1	Nom de l'objet	Description de l'objet	Acteur du projet	Acteurs du projet	Logiciel, papier…	SI, SSI ou NSI	Elevée, moyenne ou faible	Rapide ou Lente	Ouvert ou fermé	Elevée ou Faible	En heures, jours…
2	…	…	…	…	⋮	⋮	⋮	⋮	⋮	⋮	⋮
3	…	…	…	…	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 5.2 – Analyse des objets intermédiaires du projet – la IO Grid

	Réunion	Description	Responsable	Participants	Nombre de réunions	Spécifique projet?	Espace de travail public	Espace de travail projet	Espace de travail privé
1	Nom	Description du but de la réunion	Acteur du projet	Acteurs du projet		Oui ou non	A cocher		
2	…	…	…	…	…	…			
3	…	…	…	…	…	…			

Table 5.3 – Analyse des temps d'interface synchrones– la SIT Grid

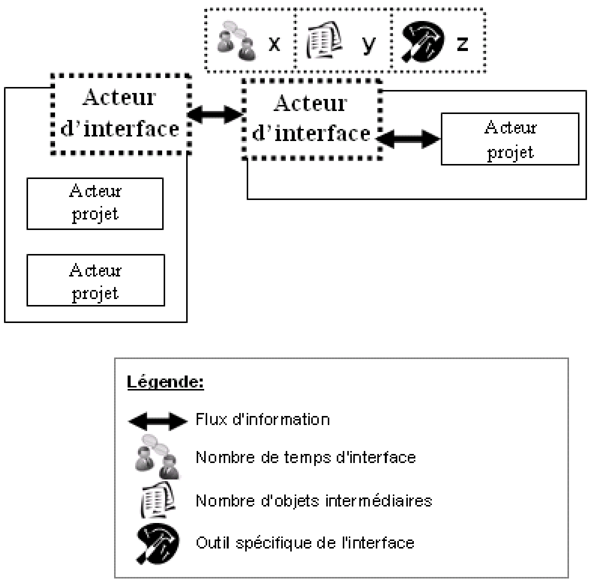


Figure 5.2 – Le schéma-résumé – le Summary Diagram

5.5 Conclusion

Nous présentons dans le chapitre suivant trois étude de cas où nous avons utilisé le modèle d'interface ainsi que les outils d'analyse présentés ci-dessus pour investiguer les problèmes d'échange d'information et de coopération dans la phase de montée en cadence.

Chapitre 6 – Etudes de cas

Ce chapitre a pour but de répondre à notre deuxième question de recherche :

(RQ2) Comment peut-on caractériser la situation d'interface pendant la phase de montée en cadence ?

Pour répondre à cette question, nous avons conduit trois études de terrain que nous détaillons dans les sections suivantes.

6.1 Le projet XS

6.1.1 Description du projet

Le projet XS concerne l'introduction du produit XS au sein de l'usine de Grenoble. Le produit XS a été développé à partir de Novembre 2004 par le centre R&D de Grenoble et le projet s'est terminé en Décembre 2008.

Au total, six départements (Production Grenoble, R&D Grenoble, R&D Berlin, Achats Grenoble, Approvisionnements Grenoble et Qualité Grenoble) ont travaillé sur ce projet. Classé dans notre adaptation du modèle d'(Almgren 1999a) (cf. §3.5), le projet XS apparaît comme ayant une phase de montée en cadence très complexe.

Grâce à des interviews (au total 23 interviews concernant 13 acteurs différents du projet) et l'implication opérationnelle du chercheur principal, nous avons pu d'une part identifier les trois problèmes majeurs rencontrés lors du projet XS et d'autre part pu conduire notre analyse en construisant la IO grid, la SIT grid et le schéma-résumé (cf. §5.4).

6.1.2 Conclusions pratiques

Notre analyse montre d'une part que les objets utilisés lors du projet sont un moyen important pour les acteurs de la montée en cadence d'échanger de l'information critique. En conséquence, nous avons attiré l'attention du top management de Siemens Grenoble sur certains objets clés de la phase de montée en cadence, en conseillant de les pérenniser. Nous avons notamment proposé l'amélioration et la pérennisation de la « liste des composants à acheter », document central du projet XS.

Notre analyse a également mis en exergue la position affaiblie du département Achats pendant la phase de montée en cadence du projet XS. Or cet acteur doit jouer un rôle central, pour la qualification des pièces nouvelles notamment. Ceci est particulièrement vrai dans l'industrie de faible volume, où la valeur ajoutée de Siemens se situe dans l'assemblage de pièces achetées. C'est pourquoi nous avons proposé à Siemens de renforcer la position du département Achats dans le projet de montée en cadence en consolidant notamment la fonction d'Acheteur Produit Nouveau.

Enfin, nos outils d'analyse démontrent que lors de la phase de montée en cadence, la collaboration entre acteurs se situe au sein de petits groupes. Nous proposons donc d'encourager la communication à l'échelle du groupe-projet. Cela notamment afin d'éviter l'exclusion d'une équipe « éloignée » (culturellement ou géographiquement), tel que ce fut le cas lors du projet XS.

6.2 Le projet GE

6.2.1 Description du projet

Le projet GE concerne l'introduction du produit GE au sein de l'usine de Berlin. Le produit GE a été conçu par une équipe du centre de R&D de Berlin à partir de Mars 2006 et le projet s'est terminé en Mai 2009.

Au total, quatre départements (Production Berlin, R&D Berlin, Achats Berlin et Préfabrication Berlin) ont travaillé sur ce projet. Classé dans notre adaptation du modèle d'(Almgren 1999a) (cf. §3.5), le projet GE apparaît comme ayant une phase de montée en cadence très complexe.

Grâce à des interviews (au total 12 interviews concernant 16 acteurs différents du projet) nous avons pu d'une part identifier les trois problèmes majeurs rencontrés lors du projet GE et d'autre part pu conduire notre analyse en construisant la IO grid, la SIT grid et le schéma-résumé (cf. §5.4).

6.2.2 Conclusions pratiques

Notre analyse nous a permis de faire plusieurs propositions opérationnelles à notre partenaire industriel Siemens E T HS.

Tout d'abord, au vu de la réussite du projet concernant l'approvisionnement des composants, nous insistons encore sur l'importance du rôle d'APE (Advanced Purchasing Engineer). Dans l'organisation berlinoise, le rôle d'APE n'existe que depuis peu mais nous suggérons à l'organisation berlinoise de pérenniser cette fonction et de s'assurer que l'APE soit toujours impliqué le plus tôt possible dans les projets R&D.

Ensuite, nous proposons d'introduire dans l'organisation des projets de montée en cadence un deuxième acteur d'interface entre la Production et le département R&D. En effet, de nombreux problèmes existent à cette interface. De plus, les acteurs du projet GE ont créé beaucoup d'objets et de temps d'interface pour échanger de l'information et coopérer : un acteur d'interface permettrait de réduire le nombre d'objets et de temps d'interface.

Enfin, étant donné que les acteurs du projet GE ont eu l'impression de manquer d'outils pour manager la phase de montée en cadence, nous proposons d'établir une « boîte à outils » spécifique à la montée en cadence. Cette boîte à outils permettra d'une part de capitaliser les connaissances acquises lors des précédentes montées en cadence en pérennisant les outils mis en place. Cette boîte à outils permettra également de proposer aux futurs managers de projets de montée en cadence une série d'outils propres à les aider.

6.3 Le projet BD

6.3.1 Description du projet

Le projet BD concerne l'introduction du sous-système BD au sein de l'usine de Berlin. Le sous-système BD a été conçu par une équipe du centre de R&D de Grenoble à partir de Juillet 2008 et le projet s'est terminé en Avril 2010.

Au total, six départements (Production Berlin, R&D Grenoble, Marketing Berlin, Qualité Grenoble, Achats Grenoble et Achats Berlin) ont travaillé sur ce projet. Classé dans notre adaptation du modèle d'(Almgren 1999a) (cf. §3.5), le projet BD apparaît comme ayant une phase de montée en cadence moins complexe que celle des projets XS ou GE par exemple. En effet, dans le cas du projet BD, la nouveauté porte sur un sous-système : le processus de fabrication n'est donc pas nouveau.

Grâce à des interviews (au total 10 interviews concernant 5 acteurs différents du projet) ainsi qu'à l'implication opérationnelle du chercheur principal, nous avons pu d'une part identifier les trois problèmes majeurs rencontrés lors du projet BD et d'autre part pu conduire notre analyse en construisant la IO grid, la SIT grid et le schéma-résumé (cf. §5.4).

6.3.2 Conclusions pratiques

Suite à notre analyse, nous avons proposé au top management de Grenoble de pérenniser les objets utilisés lors de la phase de montée en cadence du projet BD en implémentant les documents (Excel, papier) utilisés dans SAP. En effet, l'utilisation de SAP permet de diminuer le risque d'erreurs manuelles et permet une mise à jour plus rapide de l'information.

Notre analyse a également mis en exergue qu'un objet, l'objet n°6 (Minutes of weekly net meetings, cf. Table 6.12 du document principal), et le temps d'interface n°2 (weekly net meetings, cf. Table 6.13 du document principal) étaient des éléments clés de la coopération réussie entre les acteurs du projet BD. Nous proposons d'intégrer ces éléments, spécifiquement créés pour le projet BD, dans la « boîte à outils » générale pour le management de la phase de montée en cadence.

Ensuite, dans le but d'améliorer la communication entre le département R&D et la production, nous avons proposé au manager du projet R&D de présenter son nouveau système à l'équipe de production berlinoise. Cette présentation a été faite et les retours, que ce soit des côté R&D ou côté Production, ont été très positifs. Cela a permis d'améliorer l'acceptation du produit par les équipes de production.

Enfin, notre analyse montre une fois de plus le rôle clé joué par l'APE (Advanced Purchasing Engineer). Dans le cas du projet BD, deux APE ont été impliqué (APE Berlin et APE Grenoble) et ces deux acteurs ont fortement contribué au succès, d'un point de vue approvisionnement des composants et logistique, du projet BD. Nous conseillons une fois de plus au top management de Siemens E T HS de maintenir ce rôle dans toutes les futures phases de montée en cadence.

6.4 Comparaison des études de cas

Nous avons conduit trois études de cas au sein de trois projets différents (projet XS, projet GE et projet BD) de Siemens E T HS. La comparaison des trois cas nous amène à tirer des conclusions académiques, présentées dans les sections suivantes.

6.3.1 Groupes d'acteurs clés et flux d'informations principaux

Nos différentes études de cas soulignent que les acteurs-clés d'un projet de développement de produit nouveau (DPN) diffèrent selon la phase du projet :

- avant la phase de montée en cadence (phase de prototypage et tests), le département de R&D est l'acteur-clé. Le principal flux d'information est dirigé vers le département Achats.
- Quand la phase de montée en cadence commence (phase de pré-production), les acteurs clés sont toujours ceux de la R&D et du département Achats, mais le département Production est de plus en plus fortement impliqué.
- A la fin de la phase de montée en cadence (phase de run-up), les acteurs clés sont la R&D et la Production. Les autres départements impliqués initialement sortent progressivement du projet.

6.3.2 Acteurs d'interface clés

Dans les études de cas réalisées, nous avons pu constater la présence :

- d'un acteur d'interface au sein de l'équipe de Production (projet XS, projet GE)
- d'un acteur d'interface au sein du département Achats (APE, projet XS, GE et BD).

Alors que l'équipe R&D est un acteur clé de la phase de montée en cadence, aucun acteur d'interface issue de cette équipe n'a été identifié.

6.3.3 Niveau de diffusion de l'information

Dans les projets GE et BD, le principal niveau de diffusion de l'information était le niveau « projet ». Or les phases de montée en cadence de ces projets sont des réussites. Lors du projet XS, une des difficultés majeures a été la communication avec l'équipe R&D de Berlin. Or lors de ce projet, le principal niveau de diffusion de l'information était le niveau « proximité ». Nous pensons donc que le niveau de diffusion de l'information est lié à la réussite du projet.

6.4 Conclusion

Le tableau 6.1 résume nos conclusions notre question de recherche initiale : comment peut-on caractériser la situation d'interface lors d'une phase de montée en cadence dans l'industrie de faible volume.

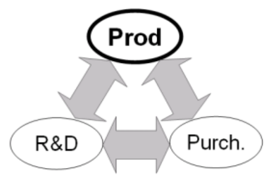
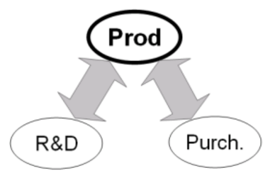
Aspect	Projet BD	Projet XS	Projet GE
Phase du DPN	Prototypage / Tests (Développement)	Pre-production (Montée en cadence)	Run-up (Montée en cadence)
Acteur principal	R&D	Production	Production
Interfaces clés			
Structure de l'interface	Peu dense (peu d'objets et de temps d'interface)	Dense en objets et en temps d'interface	Dense en outils et en acteurs d'interface
Sensibilité de l'information échangée	Moyenne ou forte	Forte uniquement	Forte uniquement

Table 6.1 – Résumé de la comparaison des trois études de cas

Chapitre 7 – Conclusions et perspectives

Dans ce chapitre, nous présentons les contributions majeures de cette thèse.

7.1 Contributions au niveau de la littérature sur la phase de montée en cadence

Tout d'abord, nous avons proposé en section 3.3 un état de l'art détaillé de la littérature concernant la phase de montée en cadence. Nous proposons plusieurs classifications détaillées en section 3.4. Nous pensons que ces résultats enrichissent les connaissances académiques actuelles sur la phase de montée en cadence. Nous identifions notamment des nouvelles pistes de recherche non encore explorées dans la littérature. La question de la gestion de la supply chain lors de la phase en montée en cadence est notamment une piste intéressante.

Ensuite, le travail présenté ici est une contribution à la littérature sur la phase de montée en cadence car il s'intéresse à une issue non encore explorée : la question de la coopération et de l'échange d'information dans la phase de montée en cadence. Nous proposons dans cette dissertation un outil d'audit qui permet d'analyser les problèmes d'échange d'information et de coopération lors de la phase de montée en cadence.

De plus, concernant la question des problèmes rencontrés lors de la phase de ramp-up, une de nos classifications présentées en section 3.4 confirme les résultats précédemment publiés.

Enfin, nous soulignons dans la section 3.5 les limites de certains résultats précédemment publiés, notamment dans le contexte industriel de l'industrie de faible volume. Nous mettons notamment en exergue que :

- l'indicateur de performance pour la phase de montée en cadence basé sur le « rendement » n'est pas pertinent dans tous les secteurs industriels
- le modèle d'(Almgren 1999a) doit être adapté pour les projets de l'industrie de faible volume
- une nouvelle décomposition du processus de montée en cadence est nécessaire, étant donné que les entreprises de l'industrie de faible volume ne réalisent pas de préséries et doivent conduire d'importantes phases de préparation avant la phase de montée en cadence elle-même.

7.2 Pertinence de l'outil

Nous avons présent en section 5.4 un outil d'audit qui permet d'analyser les interfaces projet afin de résoudre les problèmes d'échange d'information et de coopération. Nous voyons trois gros avantages à cet outil.

Tout d'abord, l'outil présenté en section 5.4 permet de conduire une analyse en profondeur des interfaces projet. Grâce à l'outil d'audit, un investigateur peut identifier les acteurs principaux impliqués dans la phase de montée en cadence, ainsi que les objets critiques qui permettent l'échange d'information.

De plus, l'outil d'audit a été conçu pour être facilement utilisable lors d'une étude de terrain. Les grilles peuvent être facilement complétées par les acteurs principaux du projet, ce qui permet une analyse in situ du projet.

Enfin, nous pensons que l'outil présenté ici n'est pas limité à l'analyse des situations de montée en cadence. Nous sommes convaincus qu'il peut être utilisé dans n'importe quelle autre situation complexe, où beaucoup d'acteurs sont impliqués. En effet, les concepts utilisés relèvent purement de l'échange d'information et de la coopération et ne sont pas liés au contexte de phase de montée en cadence.

Néanmoins, nous avons également identifié deux limites à l'outil d'audit présenté ici :

- l'outil d'audit ne permet qu'une analyse a posteriori de la phase de montée en cadence.
- L'outil d'audit se concentre sur les objets et les réunions existantes du projet et ne permet pas d'investiguer les possibles besoins en objets et réunions (à créer).

7.2 Contributions concernant la phase de montée en cadence

7.2.1 Problèmes de la phase de montée en cadence

Suite à notre étude de cas du projet SIE (présentée en section 4.3), nous avons pu identifier les problèmes types rencontrés lors d'une phase de montée en cadence dans l'industrie de faible volume. Nous concluons que ces problèmes sont similaires à ceux rencontrés dans d'autres contextes industriels.

Un résultat particulièrement intéressant de notre étude est que le problème d'approvisionnement des composants est particulièrement crucial dans le contexte de l'industrie de faible volume. Nous voyons trois raisons qui expliquent la complexité de l'approvisionnement des composants dans le contexte de l'industrie de faible volume :

- variabilité : les industries de faibles volume ont un portefeuille produit extrêmement varié, ce qui multiplie le nombre de composants et donc complexifie l'approvisionnement
- manque de pouvoir de négociation face aux fournisseurs : étant donné les faibles volumes de production, les assembleurs de l'industrie de faible volume disposent d'un pouvoir relativement restreint auprès de leurs fournisseurs
- haute-technologie : les industries de faible volume proposent des produits hautement technologiques qui sont donc composés de pièces complexes à produire.

7.2.2 Structure de la phase de montée en cadence dans l'industrie de faible volume

Notre étude nous a conduit à modifier la décomposition de la phase de montée en cadence proposée par la littérature pour mieux l'adapter au contexte des industries de faible volume.

Nous pensons que la phase de « préséries » doit être retirée de la décomposition, et ce pour trois raisons :

- contrainte de temps : dans l'industrie de faible volume comme dans les autres industries, il est important d'atteindre le plus vite possible la phase de maturité dans la production du nouveau produit.
- Variété des produits : à cause des importantes différences entre les possibles assemblages, il est difficile de réaliser une présérie pertinente
- Coût unitaire d'un produit : dans l'industrie de faible volume, les produits sont de haute technologie et sont souvent conçus pour un client unique. C'est pourquoi le prix unitaire d'un produit est souvent très élevé, ce qui rend d'autant plus difficile de trouver une seconde utilisation pour les produits assemblés en phase de préséries.

C'est pourquoi la décomposition de la phase de montée en cadence doit être adaptée et les tâches réalisées pendant la phase de préséries doivent être effectuées soit durant la phase de prototypage soit durant la phase de pre production run.

Néanmoins, nous avons pu observer à Siemens E T HS les nombreuses conséquences de l'abandon de la phase de préséries : de nombreux paramètres ou aspects de la production ne sont pas testés : la capacité de la ligne n'est pas testée, les outils de production ne sont pas testés, le système d'approvisionnement des pièces n'est pas testé et certains problèmes ne sont pas résolus (sorte de bullwhip effect) avant la phase de pre production run.

C'est pourquoi, même si de bonnes raisons poussent à ne pas conduire de préséries lors d'une montée en cadence dans l'industrie de faible volume, nous pensons que les managers doivent considérer avec plus de précaution les différents avantages et inconvénients de conduire ou ne pas conduire une phase de préséries. Une étude sur les coûts engendrés dans les différentes phases de la montée en cadence devrait rendre possible de démontrer le retour sur investissement de la phase de préséries.

7.2.3 Caractérisation des interfaces

En ce qui concerne la caractérisation des interfaces, nous proposons en section 5.3 un modèle d'interface qui permet d'identifier les différentes caractéristiques de l'information échangée entre les acteurs au sein de leurs interfaces.

Nous voudrions souligner ici que notre étude a conduit à la conclusion que plusieurs facteurs doivent influencer la conception des interfaces. Nous avons identifié quatre facteurs :

- le niveau de confiance au sein de l'équipe
- l'utilisation d'outil pendant la phase de montée en cadence
- la similitude entre les processus des équipes impliquées dans le projet
- la dimension internationale du projet.

7.3 Perspectives

7.3.1 Perspectives à court-terme

Suite au travail de recherche présenté ici, nous sommes à même d'identifier plusieurs pistes et perspectives pour de futures recherches conduites sur le thème de la montée en cadence.

Tout d'abord, en ce qui concerne la problématique des types de problèmes rencontrés dans la phase de montée en cadence, il pourrait être intéressant de réutiliser le protocole présenté en section 4.2 afin de conduire une étude similaire à la nôtre, toujours dans l'industrie de faible volume mais sur un autre projet ou dans une autre entreprise. Cette étude similaire permettrait d'améliorer la généralisation de nos résulta ts.

De plus, la littérature actuelle ne propose pas d'étude dans d'autres contextes industriels (industrie automobile, industrie micro-électronique) qui nous renseigne sur la répartition des types de problèmes. Une telle étude pourrait permettre de comparer la répartition avec celle de notre étude de case dans l'industrie de faible volume.

Deuxièmement, en ce qui concerne l'outil d'audit proposé dans cette dissertation, nous pensons que plusieurs améliorations peuvent être proposées à court-terme :

- l'outil d'audit pourrait être utilisé dans un contexte plus grand, incluant les fournisseurs et les clients de l'entreprise.
- L'outil d'audit pourrait être complété en ajoutant d'autres critères à évaluer. Il manque notamment des critères sur « l'incertitude » portée par l'information (cf. Figure 5.9).
- L'outil d'audit et notamment la grille des objets intermédiaires pourrait être complétés en prenant en compte les besoins en information des utilisateurs de l'information. La grille des objets intermédiaires ne prend en compte que les flux d'information existants.

7.3.2 Perspectives à long-terme

Nous proposons également plusieurs perspectives à long-terme.

Tout d'abord, de futures recherches sur le thème de la phase de montée en cadence devraient se focaliser sur la création d'un outil de pilotage qui permettrait de manager la phase de montée en cadence. Dans le projet de recherche présenté ici, nous avons conçu un outil d'audit, qui pourrait être un premier bloc d'un outil plus large de management de la phase de montée en cadence.

Ensuite, nous pensons que des résultats intéressants pourraient être amenés par une recherche sur le sujet de la conception des interfaces pendant la phase de montée en cadence. En effet, le travail présenté ici manque d'éléments quantitatifs sur l'influence de la conception des interfaces sur la réussite des projets de montée en cadence. Une étude plus poussée sur le retour sur investissement d'un acteur d'interface par exemple, pourrait être très intéressante et apporter un point de vue complémentaire aux connaissances actuelles sur la montée en cadence.

Enfin, notre étude des types de problèmes de la montée en cadence a aboutit à la conclusion que l'approvisionnement des composants était un problème majeur de la phase de montée en cadence. La littérature manque de recherche sur ce sujet, c'est pourquoi nous pensons qu'une étude sur le design et le management de la supply chain dans la phase de montée en cadence est une piste très intéressante de recherche.

CHAPTER 1   INTRODUCTION

Chapter outline:

This chapter presents the background of the research detailed in this dissertation. It concludes with the research questions that guide the research presented here.

1.1 Academic background

New Product Development (NPD) has become a key process to master for successful companies and it has thus received a particular attention from academic research over the last decades.

In today's high-technological environment, the capacity to innovate is an important factor which pulses companies towards the top ranks of the competition. Besides, globalization is greatly influencing the business models of today's enterprises. To stay competitive, a global company has to be cost-effective, fast responding and capable of coping with the diversity required by the customer. The increasing competition as well as high speed technological advances urge companies to innovate their offer and develop better products to be put on the market faster than their competitors. Therefore, New Product Development (NPD) can no longer be considered as an exceptional situation, since the company has to cope with it all the time.

This research focuses on the **production ramp-up phase**, the last step of New Product Development (Clark and Wheelwright 1992; Ulrich and Eppinger 2004) (see Figure 1.1). The ramp-up phase is at the borderline of the design and the operations management. This is a crucial phase in the life cycle of a new product for several reasons, such as time (Terwiesch and Yi 2004) or cost (Terwiesch et al. 2001).

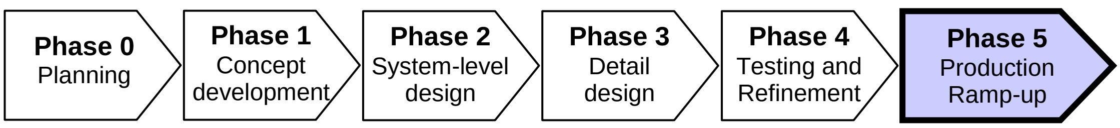


Figure 1.1 – Ramp-up, the last step of the NPD process, according to (Ulrich and Eppinger 2004)

There is a common consensus widespread in the literature that only very limited body of research works dealing with the issue of production ramp-up exist (Clark and Wheelwright 1992; Juerging and Milling 2006; Wolgast and Carlson 2007). In their extensive literature review about product development decisions, (Krishnan and Ulrich 2001) identified the problem of production ramp-up as an important blank space on the map of product development research. For (Schuh et al. 2005), " *a complete overview of the ramp-up phase and the management of this complex phase does not exist […]. State-of-the-art approaches* *are mostly isolated applications and solutions of specific ramp-up problems*". (Terwiesch et al. 2001) highlight discrepancy between the importance of the ramp-up phase (repeatedly mentioned in research on product development) and the little attention it received. As a consequence, the ramp-up phase appears as an interesting area for future research.

Apart from the lack of investigation from the academic point of view, the importance of the ramp-up phase for industrials also urges to investigate further this particular issue. In the next section, we will detail the very specific industrial context of this research project, which is an additional incentive for investigating the ramp-up issue.

1.2 Industrial background

The research presented here is financed via an industrial partnership on the basis of a CIFRE agreement. The CIFRE agreement gathers together an industrial partner, a research laboratory and a PhD student, so as to carry out a common research project. It aims at encouraging exchanges between public research laboratories and socio-economic environments. The industrial partner involved in a CIFRE agreement gets funds from the French government.

The CIFRE project that made the research presented here possible has Siemens E T HS as industrial partner. Siemens E T HS is a branch of Siemens A.G. (see Figure 1.2), a global powerhouse in electronics and electrical engineering, operating in the industry, energy and healthcare sectors.

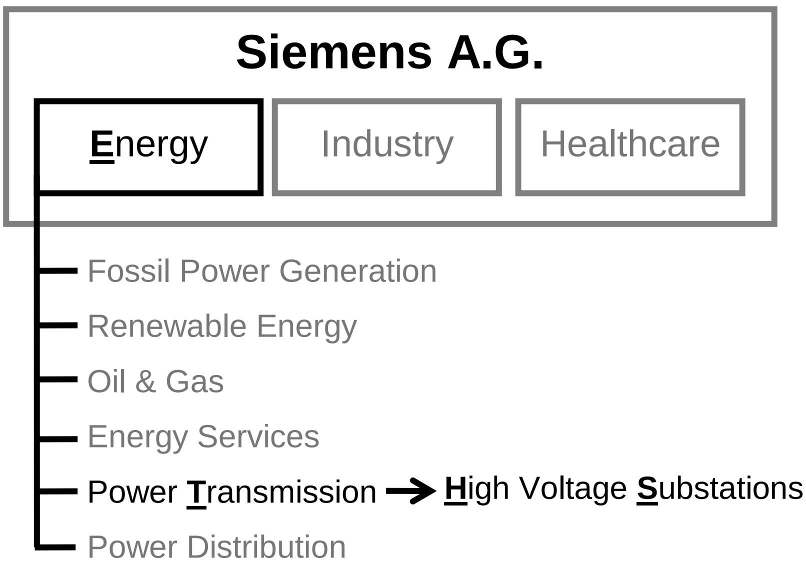


Figure 1.2 – Position of Siemens E T HS within the structure of Siemens A.G.

Siemens A.G. has around 405,000 employees working to develop and manufacture products, design and install complex systems and projects, and tailor a wide range of solutions for individual requirements. In fiscal year 2009, Siemens had revenue of €76.7 billion.

Siemens E T HS (**E**nergy power **T**ransmission **H**igh voltage **S**ubstations) develops and manufactures electrical bays for high voltage substations.

An electrical bay is a metal tank filled with gas, in which different electrical devices such as circuit breaker, disconnectors, current and voltage transformers are enclosed. The role of a bay is to distribute electricity and to secure the power grid, as desired by Transport System Operators, the customers of Siemens E T HS. Bays are integrated in an electrical substation, which is an element of the power grid for power transmission and distribution (see Figure 1.3). The major role of an electrical substation within power grid is either to rise the voltage at the exit of a power station for power transportation or to drop it to a low voltage level for end-users' utilization (either individuals or industrial customers). Electrical substations are positioned at the network nods and are at both ends of transportation or transmission lines.

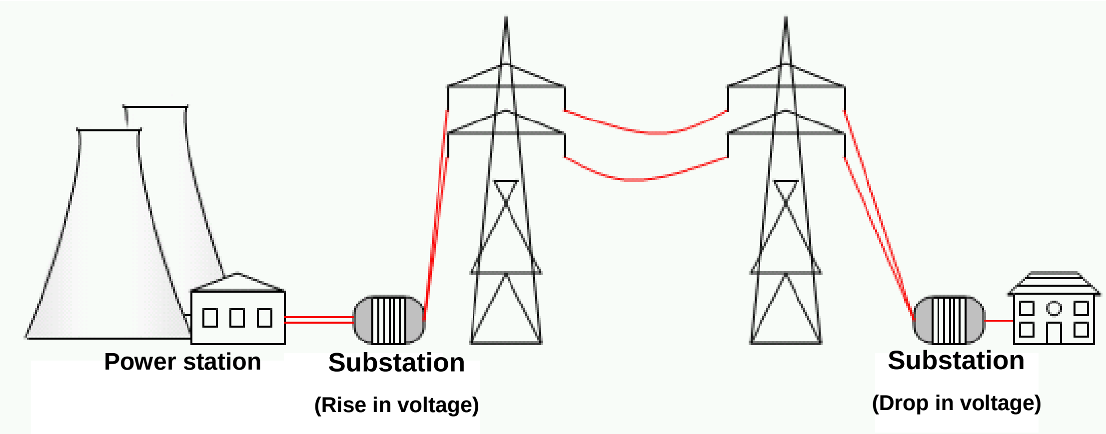


Figure 1.3 – Electrical substations in the power grid

Our industrial partners belong to two Siemens E T HS plants, Grenoble in France, and Berlin in Germany.

Siemens E T HS operates in the B-to-B market of high voltage electrical devices for the transportation and distribution of electricity. The customers of Siemens E T HS are mostly Transport System Operators, i.e. national or private companies that are in charge of power grids. These are for example RTE in France, Vattenfall or RWE in Germany or Energimyndigheten in Sweden. Each power grid has its own characteristics (line network, current level …). Hence, customers give Siemens E T HS clear requirement specifications so that the delivered electrical bays are totally adapted to their power grid and their needs. To propose specially adapted products, Siemens E T HS disposes of several pre-existing variants of each component of its products. The relevant variant is selected so that the final product fits to customer requirements (see Figure 1.4).

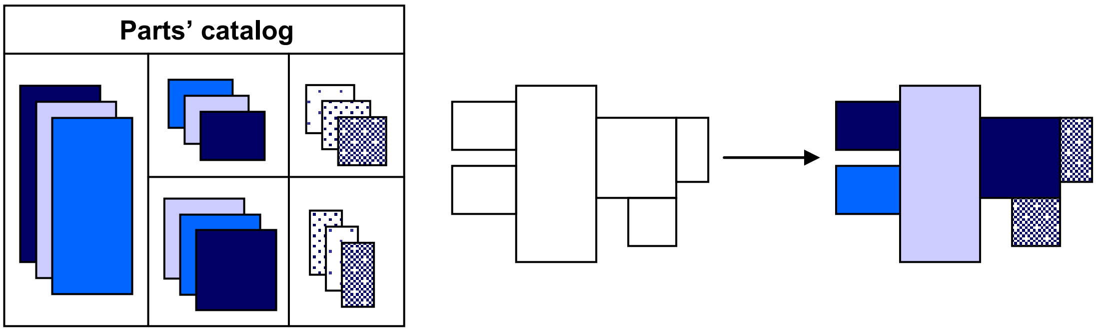


Figure 1.4 – Creation of customized product from a variant catalog

As a result, Siemens E T HS works in a make-to-order mode. The customization of each product to customer requirement renders Siemens E T HS product variety very high.

In fact, Siemens E T HS belongs to a specific industrial context, the **low volume industry**. Indeed, low volume industries cover a wide range of companies producing capital goods (e.g. offshore structures, power generation plant, high voltage switchgears etc.) and intermediate products (Maffin and Braiden 2001). According to (Maffin and Braiden 2001) and (Jina et al. 1997), low volume industry companies have the following characteristics:

- Their products tend to be manufactured for downstream industrial producers and to be used in the production of other goods and services, rather than for final or household markets (namely B-to-B market).
- Low volume industry companies usually operate for engineer-to-order and customized make-to-order markets which render the level of product diversity extremely high and the product volume low.
- Due to the "make-to-order" policy with guaranteed delivery dates and lead times, companies operating in the low volume industry consider "time" as a major production driver.

(Jina et al. 1997) believe that organizations of the low volume industry are facing more manufacturing turbulences than any other typical organization. They argue that methods and tools cannot be applied and used "as is" in this specific context. The low volume context requires the adaptation of existing results or tools from other industries or the creation of new knowledge that is adapted.

As underlined by (Jina et al. 1997) and (Maffin and Braiden 2001), the low volume context is a very specific context. To the best of our knowledge, this specific context was not yet addressed in studies concerning the production ramp-up issue. Thus the purpose of this thesis is to examine the issue of production ramp-up within the context of a low volume industry, for the benefits of both practitioners and researchers.

1.3 Research topic

In this research, the research topic has been structured around different research questions. These questions were designed jointly with the industrials, so that they fit their concerns. In the research presented here we carried out first an exploratory study focused on the actual problems encountered by the industrials during the ramp-up phase in the low volume industry (see section 1.3.1). In parallel, we investigated the research literature to structure our research and have a better overview of previous research on the ramp-up issue. These two first steps led to the identification of a new research thread: the investigation of project interfaces to solve communication and cooperation problems (see section 1.3.3). As a consequence, in the dissertation presented here, we propose to study two different issues concerning the ramp-up situation in a low volume industrial context: ramp-up problems and project interfaces. We will detail in Chapter 2 how the research was designed.

1.3.1 Research question 1 – Encountered problems

The first issue we investigate refers to the problems encountered during the ramp-up phase. As stated by (Winkler et al. 2007), "*the ramp-up of production systems is often characterized by a number of significant problems*". In fact, solving problems is a very important ramp-up activity (Terwiesch et al. 2001). A sine qua non to be successful during ramp-up is the identification of the main reasons for disturbances (Juerging and Milling 2005).
Moreover, thanks to our CIFRE agreement, we had the opportunity to carry out a first exploratory study at Siemens E T HS. Investigating the issue of the ramp-up problems constitutes also an interesting opportunity to formalize and understand the difficulties encountered by Siemens E T HS. Besides, it was Siemens first interrogation: from where do the numerous problems encountered during ramp-up come?
Consequently, we propose to identify the typical problems encountered during a ramp-up situation in the context of a low volume industry, thanks to an exploratory study carried out during the ramp-up phase of a project of Siemens E T HS. Our goal is threefold:

(i) We look for typical problem types, so as to cluster problems into homogeneous categories.

(ii) We evaluate the impacts of different problems on the ramp-up situation, to discuss whether some problems are more crucial than others.

(iii) Having established typical problem types, we intend to compare our results to previous results found in other contexts, to see where the differences are.

To sum up, our first research question is the following one:

(RQ1) What are the typical problems encountered during a ramp-up situation in a low volume industry?

This research question has three sub-questions:

(RQ1.1) Can we establish typical problem types?
(RQ1.2) Within the identified problems, which issues are the most crucial ones?
(RQ1.3) Are the encountered problems similar in other industrial contexts?

1.3.2 Literature review

In parallel to our first research question, we investigated the research literature on the production ramp-up issue. Indeed, as explained in section 1.1, several different published articles mention the lack of literature concerning ramp-up (Clark and Wheelwright 1992; Krishnan and Ulrich 2001; Terwiesch et al. 2001; Schuh et al. 2005; Juerging and Milling 2006; Wolgast and Carlson 2007). However, thanks to a first overview of the field of ramp-up research, we noted that there exist several published works that deal with different ramp-up issues. These works constitute a growing research body about ramp-up. As a consequence, we decided to gather all the research works published concerning ramp-up and try to organize them so as to provide future researchers with a relevant map of ramp-up research.

In doing so, our first aim is to propose different overviews and classifications of previously published works. It makes it possible to have an overview of papers dealing with a certain issue. It allows also the identification of blank spaces or new tracks for future research.

In addition, mapping the actual body of research about ramp-up will also be helpful to identify previous results, so as to see to what extent these findings are relevant for the context of the low volume industry. Hence, the second aim of our literature review is to discuss existing results regarding the low volume industry context.

We note that our literature review allows the identification of several issues that are interesting future research. In this dissertation, we were able for time constraints to focus only on one further issue. Next section details which issue it is and gives our motivations.

1.3.3 Research question 2 – Ramp-up interfaces

Thanks to our literature review and our first exploratory study on ramp-up problems, we identified that communication and cooperation between actors are major issues during ramp-up. Indeed, the ramp-up literature highlights the importance of information exchange and communication problems (Terwiesch et al. 2001; Säfsten et al. 2006b; Scholz-Reiter et al. 2007). (Meier and Homuth 2006) identify “information and communication” as being one of the major sources of disturbance during the ramp-up phase in SME[1] networks. In a previous research, (Fjällström et al. 2009) focus on the role of information to solve problems during ramp-up. The authors conclude that to handle problems, ramp-up actors have to exchange information. Any hindrance in communication is an obstacle to ramp-up success.

Besides, our industrial partners at Siemens E T HS considered the issues of information exchange and cooperation as especially crucial so as to succeed in the ramp-up phase.

[1] Small and Medium Enterprises

As a result, we consider as very interesting the investigation of reasons for information exchange and communication problems during ramp-up. In this research, we use the concept of **interface** to analyze information flows. Indeed, an interface is the collection of links and interactions existing at the boundary of different industrial functions that support communication and coordination. Thus, the concept of interface appears as a very interesting concept to analyze information flows between ramp-up actors and thus determine the reasons for discrepancies in communication and coordination.

Consequently, the second issue addressed in this research concerns the project interfaces during ramp-up and our last research question is formulated as follows:

(RQ 2) How can we characterize the interface situation during ramp-up?

This research question can be divided into two sub-questions:

(RQ2.1) Where are the major interfaces and how is information exchanged?
(RQ2.2) Can we draw actionable conclusions to improve future ramp-up situations from the analysis of the interfaces?

1.4 Thesis outline

The dissertation presented here is structured as follows. Chapter 2 presents our research design. Chapter 3 focuses on the literature concerning the ramp-up issue. Then Chapter 4 presents our first exploratory case study realized at Siemens E T HS, where encountered problems are identified and clustered. Chapter 4 aims at answering our first research question, establishing problem types and comparing our results with previously published results. Chapter 5 details our approach to investigate information exchange and cooperation problems thanks to the concept of interface: our interface model is presented, as well as an auditing tool we designed in order to characterize project interfaces. In Chapter 6 are presented three case studies, where our auditing tool was used to characterize the interfaces during the ramp-up project. The case studies make it possible to draw valuable conclusions for our industrial partners. Finally Chapter 7 details our general results and findings concerning problem and interface characterization during ramp-up in the context of a low volume industry.

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CHAPTER 2 RESEARCH DESIGN

Chapter outline:

This chapter presents how we design the research presented here. In a first section, we detail how the research project is initiated, i.e. how the choice of research questions is jointly made with industrial partners. Then we describe our main research methodology, the case study. Finally we mention the different criteria used in order to evaluate research validity and generalizability.

2.1 Design of the research questions

In this research project, a specific approach is taken to design the research questions. Indeed, the issues investigated are developed jointly with the practitioners at Siemens E T HS. The aim is to define research tracks from which both practitioners and researchers could gain new knowledge. As researchers, we want to take advantage of the opportunities in the industrial field at Siemens E T HS to create new insights about the ramp-up phase, in the special context of low volume industries. From the investigation of the industrial field, we can draw valuable practical conclusions for our industrial partners.

As a matter of fact, the process we followed to define the research questions is close to the process presented by (Avenier 2009). Avenier developed a methodological framework for elaborating scientific knowledge both from practice and for practice (see Figure 2.1). Following her framework, researchers are able to create knowledge that is valuable for both practitioners and academics. Her framework includes three major steps in order to design relevant research questions:

(i) First, researchers and practitioners define together a problem, which is interesting for both parties. Avenier names it a “persistent practical problem”, since practitioners should find it problematic and persistent enough to seek help from academicians.

(ii) Then, literature is reviewed in order to find whether it provides clues to the above-defined problem.

(iii) If published knowledge does not provide clues to solve the problem, practitioners and researchers have identified what Avenier calls a “theoretical gap”. The investigation of this theoretical gap will lead (thanks to a common work between researchers and practitioners) to the construction of knowledge valuable for both parties (see Figure 2.1).

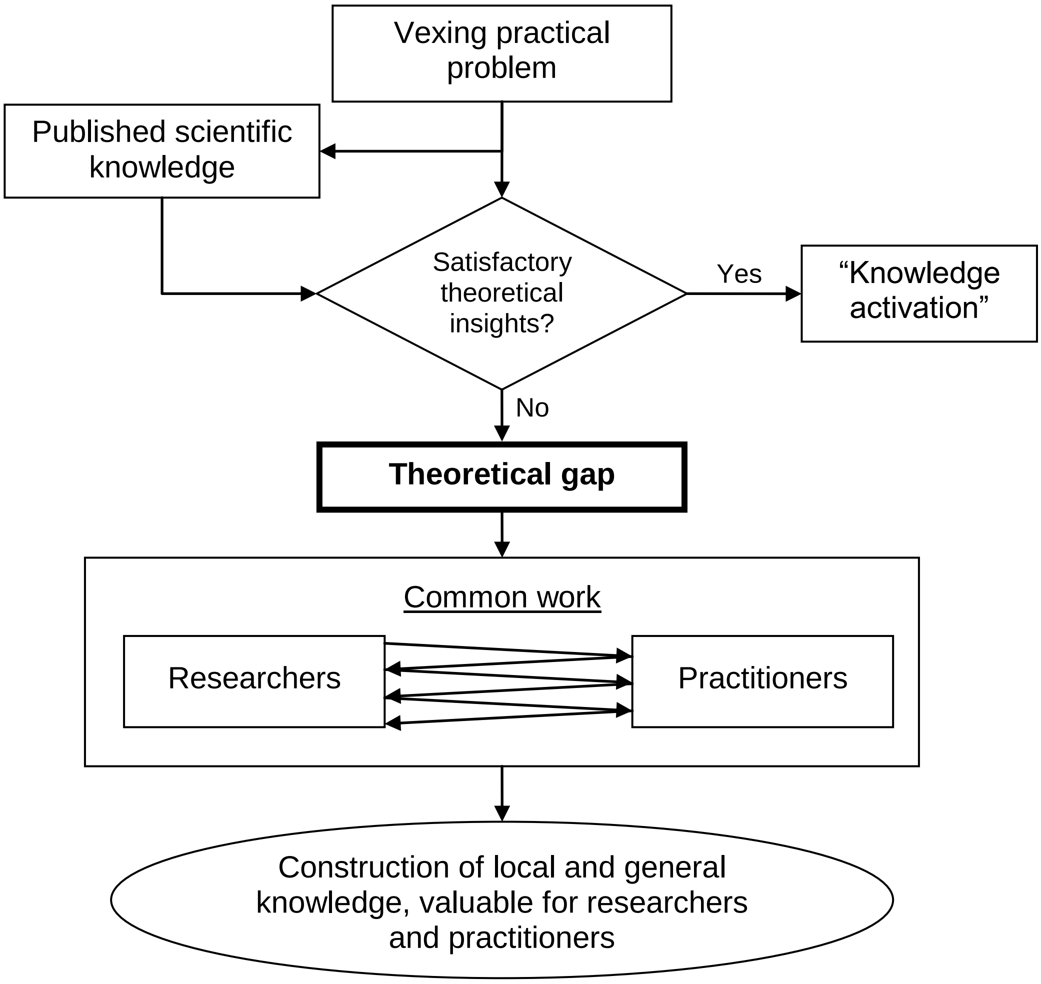

Figure 2.1 – Methodological framework for constructing academic knowledge by drawing upon practitioners' experience, adapted from (Avenier 2009)

The research presented here begins with the awareness of researchers and practitioners of the importance of the ramp-up phase.

2.1.1 Practitioners' awareness

Practitioners at Siemens E T HS were aware that the ramp-up phase is crucial in terms of time-to-market and profitability.

"*We know we have to decrease ramp-up time because especially during ramp-up, time is money*"

YDO, manager of the Siemens E T HS, Grenoble

Besides, a large number of "ramp-up" projects were carried out at Siemens E T HS between 2007 and 2010:

- the launch in Grenoble of the production of products and subsystems already produced in Germany and/or China, such as the SIE switchgear and the circuit breaker subsystem (see the glossary for the abbreviations)

- the initial commercial manufacture of new products and subsystems, such as the XS switchgear and the BD subsystem
- the launch in other locations of Siemens E T HS of the production of products already produced in Grenoble, such as the XS switchgear and the DN switchgear

At the CIFRE[2] project start, practitioners at Siemens E T HS acknowledged having numerous difficulties being efficient in the ramp-up phase. They described it as a “fuzzy phase” where cost, lead-time and quality are hardly manageable. Even if it is crucial, the duration and the outcomes of the ramp-up phase were hardly foreseeable for them.

2.1.2 Researchers’ awareness

A quick overview of literature gives a first hint that not many studies focus on the ramp-up phase. Even the first major works concerning ramp-up published some years ago admit that the body of research concerning ramp-up is being built (Almgren 1999c; Terwiesch et al. 2001; Schuh et al. 2005). Indeed, the ramp-up phase is a pivotal phase between New Product Development (mostly investigated in product design research) and classical Operations Management. As a matter-of-fact, this research project also originates from a shared feeling from two G-SCOP researchers (a first one from the Operations Management field, the other one from Product Design Research) that investigation about the ramp-up phase would lead to interesting results.

In addition, from an academician point of view, the context of low volume industry appears as very promising in order to build new knowledge. Indeed, at the start of the research project, researchers at G-SCOP were interested by the specificities of the low volume industry. Their first impression during the first exchanges with practitioners was that the low volume industry has very different drivers and success factors, compared to high volume industries – such as the automotive industry for example. G-SCOP researchers expected very interesting results in studying the issue of ramp-up in a low volume context.

2.1.3 Identification of research gaps

At the start of the research project presented here, both practitioners and researchers had beliefs that exploring the issue of ramp-up is attractive and will bring valuable results. As a result, a common PhD research project is started, supervised by a steering committee composed of both researchers from the G-SCOP laboratory and practitioners from Siemens E T HS (see Figure 2.2).

As Avenier advises, we then defined the research questions jointly with practitioners and researchers (Avenier 2009).

In a first step, in order to have a better knowledge of which are the specificities of the ramp-up phase in the low volume industry, the first issue investigated refers to the problems encountered (see section 1.3.1). The aim of this first exploratory investigation is to record thanks to a case study the different disturbances and difficulties that hinder ramp-up in the

[2] See section 1.2

low volume industry. This exploratory study was useful to then formalize our next research question.

In parallel, a literature study is carried out by researchers of the G-SCOP laboratory. The first goal of the literature review is to have a clear overview of previously published results on the ramp-up issue. The second goal is to examine to what extent these results are relevant for the low volume industry.

The literature study highlights the lack of comprehensive and actionable knowledge about the ramp-up phase, especially in the context of the low volume industry (see Chapter 3). Indeed, the specific case of low volume industry is not addressed in the ramp-up literature, even though the specificities of a low volume industry highly influence NPD and the ramp-up phase itself (Maffin and Braiden 2001). Furthermore, we identify a lack of previous studies on the issue of communication and cooperation problems. As a consequence, a "theoretical gap" is identified (as defined by Avenier in (Avenier 2009)). Further research is necessary to bring insights about the ramp-up phase in the typical context of low volume industries, especially about the communication and cooperation issues. Besides, these topics were considered as very promising by the steering committee of this research project.

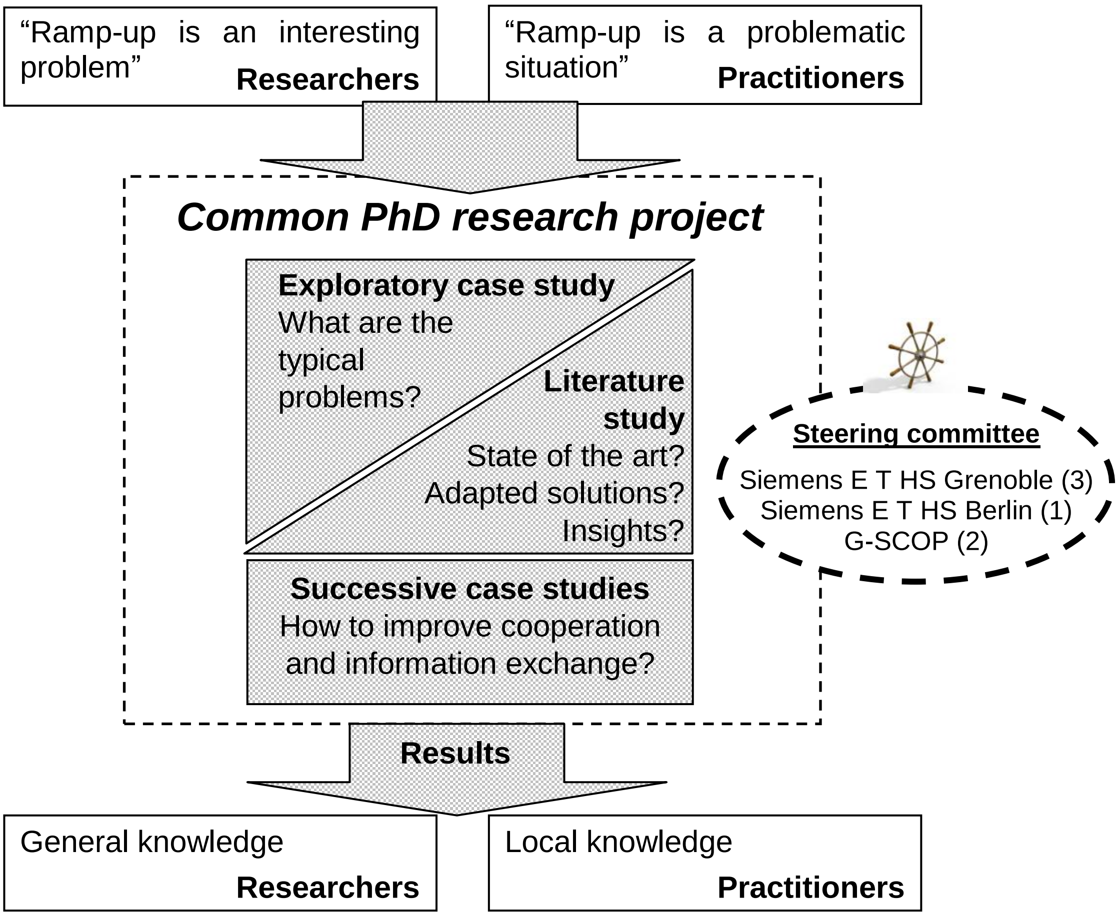

Figure 2.2 – Outline of the common research project presented here

As a result, the second issue that was considered here is the issue of information exchange and cooperation between ramp-up actors (see section 1.3.3). We design three successive case studies in order to make the investigation of this issue possible.
In Figure 2.2 is depicted the general outline of our research project, from the shared belief of researchers and practitioners that they will benefit from investigating the issue of ramp-up to the creation of both general and actionable knowledge, as conclusion of this PhD research project. The results of the research project are regularly presented to a steering committee composed of three actors of Siemens E T HS in Grenoble (the plant manager, the R&D manager and the production manager), an actor of Siemens E T HS in Berlin (the Global Manufacturing Network manager) and two researchers of the G-SCOP laboratory (the advisor and co-advisor of this PhD research).

In the next section are presented more in detail the methodological approach that was taken in this research for investigating the industrial field at Siemens E T HS and elaborate scientific knowledge from practice.

2.2 Methodological approach for field investigation

In this section, we will first detail the reasons for our choice of the case study methodology as leading research approach for our investigation. Then, we will tackle the problem of the researcher status in field research. Finally we will present our research protocol.

2.2.1 Case study approach

There are different types of methodological approaches, each one having its own advantages and drawbacks. Among the five types of research identified by (Karlsson 2009) (see Table 2.1), only four are relevant to elaborate scientific knowledge from practice.

The methodological approach adopted in this study is the case study methodology. Case studies are rich, empirical descriptions of particular instances of a phenomenon (Yin 2009). Case studies emphasize the *"rich, real-world context in which phenomena occur"* (Eisenhardt and Graebner 2007) and are especially relevant "*when the boundaries between phenomenon and context are not clearly evident*" (Yin 2009) (p18).
As a result, the case study methodology suits our purposes for the following reasons:

- The phenomenon we intend to study (namely the ramp-up phase in a low volume industry context) happens in a rich, real-world context, since it is a particular phase of NPD projects carried out by companies belonging to the low volume industry
- The studied phenomenon (i.e. the ramp-up phase) is at the overlapping area between product development and mature production (Scholz-Reiter et al. 2007). As a result, its boundaries with its context are not evident (Fleischer et al. 2003). Several different terms are used to describe this phase: initial commercial manufacture (Langowitz 1987), production launch (Bowersox et al. 1999; Di Benedetto 1999), production start-

up (Clawson 1985; Almgren 2000), product introduction (Säfsten et al. 2008b), which leads to confusion about what exactly the ramp-up phase is. Furthermore, the end of a ramp-up phase is also ambiguous. In the literature, several end-points are defined: full scale production (Almgren 1999b), full capacity utilization (Bohn and Terwiesch 1999), initial targets (quality, volume, cost…) are reached (Fjällström et al. 2009) etc.

Research approach	**Description**	**Capitalization from practice**
Longitudinal field study	In-depth case study of change processes inside organizations over time, implying significant researcher commitment and organizational access.	Yes
Action Research	Interactive inquiry process to solve real organizational problems, which outcomes are both action and research-based knowledge	Yes
Surveys	Questionnaire sent to a representative sample of the population under study	Yes
Case study	Study of a phenomenon in its context to gain understanding through observation of actual practice	Yes
Modeling and Simulation	Demonstration of the validity of quantitative models, based on a set of variables that vary over a specific domain while quantitative and causal relationships have been defined between these variables.	No

Table 2.1 – The five research approaches in Operations Management, according to (Karlsson 2009)

Besides, (Benbasat et al. 1987) point out three outstanding advantages of case studies (cited in (Meredith 1998)):

(1) Relevance: case studies allow the phenomenon to be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice
(2) Understanding: the case method allows the much more meaningful question of *why* rather than just *what* and *how*, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon (also mentioned by (Yin 2009) and (Eisenhardt and Graebner 2007))
(3) Exploratory depth: the case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood. According to (Stuart et al. 2002), case research methodology is especially suitable where either theory does not exist or does not provide relevant answers or where the theory exists but in a different context.

Again, the case study methodology seems particularly relevant for our research purposes for the following reasons:

- Our research is deeply embedded in an industrial setting (see section 1.2). The aim is indeed to gain understanding "through observing actual practice".
- As presented in section 1.3, the research questions of this work are "how" and "what" questions.
- The actual state of research literature about the ramp-up issue encourages conducting exploratory research, since most of the driving variables of the ramp-up phase are still unknown (see Chapter 3).

Nevertheless, drawbacks of the case study methodology are also pointed out:

- There is an important trade-off between efficiency and the richness of data (Voss et al. 2002). For this purpose, a steering committee is established for this research project, with members of the university and the company to follow-up the project and set targets (see Figure 2.2). The steering committee holds meetings every six months during the research project. It is responsible for taking decisions regarding the relevance of results and the depth of investigation.
- The investigator lacks control over its research (Meredith 1998; Yin 2009). Indeed, for this research project, the opportunities provided by the industrial field are limited and the actual progress of the company's projects can be limitedly influenced by the main researcher. Nevertheless, in this research we make the most out of the opportunities provided by Siemens E T HS, but also we are careful to take into account of case characteristics we can not influence.
- The rigorous procedure of case research is rather unfamiliar (Meredith 1998; Voss et al. 2002). Therefore, an overview of our research protocol is presented in the next section. Moreover, characteristics of case studies and exact data collection methods are detailed in the presentation of the case studies and in appendix. Hence, we believe that several elements are given for external readers to consider the research procedure objectively.

Once the methodological approach to investigate the industrial field defined, it is important to clear which position the researcher will have on the field. We present in the next section the four different statuses the researcher can adopt.

2.2.2 Researcher status

During field investigation, the position of the researcher in the study environment has major consequences on the data collected and its relevance (Junker 2004; Yin 2009). The position of the research can lead to different problems such as ethical issues, lack of distance to the subject, post-rationalism, difficulty to access data, etc. (Voss et al. 2002; Junker 2004)

(Junker 1960) describes four different roles the researcher can adopt in order to investigate an industrial field according to the degree of involvement of the researcher (see Table 2.2):

(1) *Complete Participant*. The researcher takes fully part in different activities of the field study. He does not reveal its status of researcher to the other participants, in order to access confidential data, which would not be accessible to someone “external” to the participants or the company.

(2) *Participant as Observer*. The researcher takes part in different activities but partially reveals his status and purpose of the study to the stakeholders. He gets most of the information, except very confidential one, since he is accepted as a participant (“good friend”).

(3) *Observer as Participant*. The researcher only observes the situation and the stakeholders’ behavior and is not involved further. His role is made publicly known at the participants of the situation under study. The researcher wanders in the company without taking part in any of its daily activities.

(4) *Complete Observer*. The researcher observes, without the participants being aware of its presence. The researcher can get access to all kinds of information but cannot interact with the stakeholders of the situation under study. This role can only be truly possible in laboratory experiences (where the researcher is behind a one-way mirror).

	Researcher status	**Researcher’s identity**	**Involvement of the researcher**
COMPARATIVE INVOLVEMENT: SUBJECTIVITY AND SYMPATHY	Complete Participant	Concealed to the participants of the situation under study	Full involvement in the company’s daily activities
	Participant as Observer	Not wholly concealed, kept “under wraps”	Light involvement
COMPARATIVE DETACHMENT: OBJECTIVITY AND EMPATHY	Observer as Participant	Publicly known	No involvement but researcher on the premises
	Complete Observer	Concealed or revealed	No involvement and presence not revealed

Table 2.2 – Researcher status and its implications, adapted from (Junker 2004)

The researcher status defines the role that the researcher will play in the industrial field so as the distance he has with its object of study. Thanks to the different opportunities provided by our industrial partners at Siemens E T HS, we adopted in the research presented here different statuses. This aspect and other aspects of our research design are detailed in the next section, dealing with our general research protocol.

2.2.3 Research design

There are different decomposition of case study research (Stuart et al. 2002; Voss et al. 2002; Karlsson 2009). In particular, (Voss et al. 2002) stress that after having developed the research questions, two major steps have to be taken before conducting field research (see Figure 2.3):

- the choice of the investigated cases
- the development of research instruments and protocols.

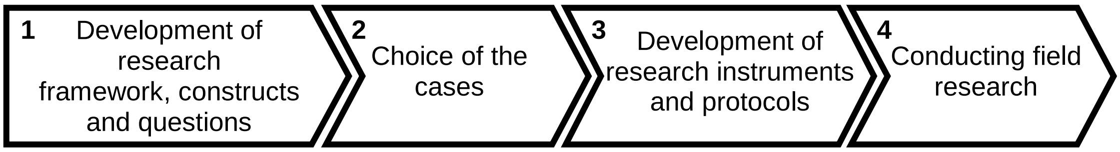

Figure 2.3 – Different steps of case study research, according to (Voss et al. 2002)

2.2.3.1 Choice of the cases

Four cases are investigated in this research work (see Table 2.3). They are named in this dissertation the SIE project, the XS project, the GE project and the BD project.

A first case, the SIE project is selected for the exploratory study focusing on ramp-up problems. It is the first production ramp-up project that the researchers were able to investigate at Siemens E T HS.

	SIE project	**XS project**	**GE project**	**BD project**
Project start	June 2006	Nov. 2004	March 2006	July 2008
Project end	June 2007	Dec. 2008	May 2009	April 2010
Type of project	Transfer project	New product	New product	New sub-system
Investigation time interval	Feb. to Jun. 07	Nov. 07 to Apr. 08	Oct. to Nov. 08	Oct. 09 to Jan. 2010
Investigation subject	Encountered problems	Interfaces	Interfaces	Interfaces

Table 2.3 – Four cases studies used for researching the ramp-up issue

Concerning the research on ramp-up interfaces, the opportunities for investigation provided by Siemens E T HS lead to the investigation of three projects (namely the XS project, the GE project and the BD project). These projects have slightly different characteristics. They were carried out at different time intervals at Siemens E T HS. The XS and the GE projects concern the design and the production launch of a new product (a new bay[3]) while the BD project concerns only a new subsystem. In addition, the aforementioned projects are investigated at different states in the progress of their life cycle (see Figure 2.4).

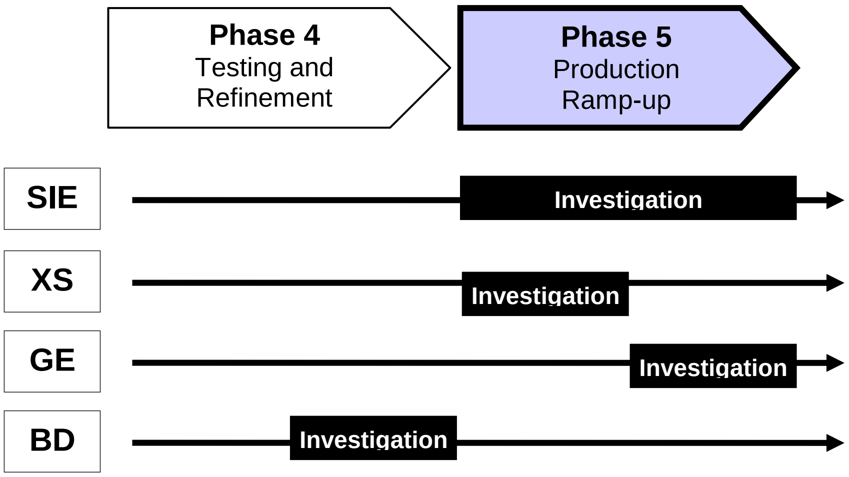

Figure 2.4 – Position of the different cases studies in the progress of a NPD project

The selection of the cases was both driven by theoretical and practical considerations. We aim at finding comparable cases but the sample selection was also determined by practical criteria (access issue, project on-going within the study time frame, involvement possibility…) determined jointly with the key respondents of Siemens E T HS.

2.2.3.2 Researcher status for the different cases

As depicted in Figure 2.5, the main researcher had different status on different projects
Concerning the exploratory study carried out during the SIE project, the main researcher was a "Complete Participant", fully involved in the company team. Her role was clearly defined as a member of the project team. Her status of researcher was not made public to the project team during the duration of her involvement. This choice of status was motivated first by the opportunity of the main researcher to be involved in the project. Secondly, this status enabled the main researcher to have an in-depth knowledge of the situation.

Concerning the XS and the BD case studies, the researcher adopted a "Participant as Observer" status. She had a defined role within the team responsible for the project. However, her status of researcher was made explicit and focused interviews were carried out to complete or validate her findings.

[3] See section 1.2

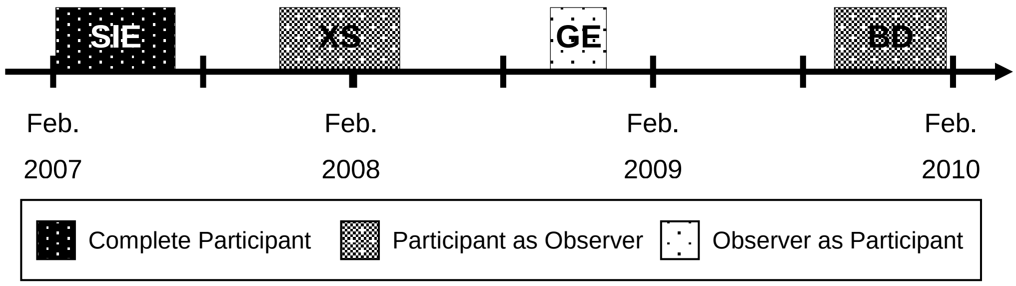

Figure 2.5 – Researcher status and its implications, adapted from (Junker 1960)

This status was interesting to have a smaller involvement in the projects under study but still be able to gather a lot of information.

Finally, concerning the GE case study (from October to November 2008), the researcher was accepted as an "Observer as Participant". She carried out interviews to collect most of the case study data, completed by factory tours, factory documentation and silent attendance to meetings. The "Observer as Participant" status was motivated by practical reasons: indeed, the project under study was carried out in Berlin, Germany. However, this status also enabled to investigate the GE project despite a lighter involvement of the main researcher. We were therefore able to conclude that our analysis of projects was also feasible even with a light involvement in the field.

2.2.3.3 Research instruments and data collection methods

Three different approaches (i.e. research protocols) are designed for this research work; depending on the researcher status in the different cases studies (see section 2.2.3.2).

For the project SIE, the status of the researcher being "complete participant", most of the data is collected thanks to her involvement in the project (namely through personal observation, informal conversations, attendance at meetings and events …). Unstructured interviews are also conducted but on an ad-hoc basis, in order to validate or to investigate further aspects of the direct observation. The main researcher looks for multiple viewpoints of the same event, taking into account the opinions and positions of the different stakeholders of the project.

For the XS and the BD project, the status of the researcher is "Participant as Observer". Case data is both collected through participation in the project and regular unstructured interviews with the main project actors (Project Managers, Department Managers, Work Package Managers…).

Finally for the GE project, most of the case data come from two rows of structured and unstructured interviews that are carried out among the project stakeholders. It is completed by silent attendance to meetings, personal observations and informal conversations. The results of the interviews are then corroborated via an e-mail questionnaire sent to each of the interviewees.

In all the cases, beyond the interviews and personal involvement, meaningful data is also collected from factory tours, organizational data on the company's intranet and various archival sources to provide a more complete picture of the context of the study. Moreover, after each data collection step, case data and findings are fed back to the interviewees and key respondents in the company, to validate them. The findings are also presented to co-researchers at the G-SCOP research laboratory for review and confrontation. Finally, field notes are recorded during the whole investigation duration.

2.2.4 Summary

Table 2.4 sums up the characteristics of four cases that are at the basis of the research work presented here.

	Project SIE	**Project XS**	**Project GE**	**Project BD**
Project start	June 2006	Nov. 2004	March 2006	July 2008
Project end	June 2007	Dec. 2008	May 2009	April 2010
Type of project	Transfer project	New product	New product	New sub-system
Investigation time interval	Feb. to Jun. 2007	Nov. 2007 to Apr. 2008	Oct. to Nov. 2008	Oct. 2009 to Jan. 2010
Status of the project	Ramp-up	Start of ramp-up	End of ramp-up	Testing and refinement
Status of the research	Complete participant	Participant as Observer	Observer as Participant	Participant as Observer
Location	Grenoble (FR)	Grenoble (FR)	Berlin (DE)	Grenoble (FR)
Main data source	Involvement + Direct observation	Involvement + regular unstructured interviews	Structured interviews + E-mail questionnaire	Involvement + Regular unstructured interviews

Table 2.4 – Summary of the characteristics of the four case studies

In the next section, we present the different aspects that are to be considered so as to evaluate the validity of case research.

2.3 Validity of the research

The validity of case research is an important issue for the quality of the research in conducting cases studies. (Meredith 1998) recalls that "*case studies exhibit the same level of* *rigor and adhere to the same requirements of good research as any other methodological approach, but achieve these goals by different means*".

The validity of case research is evaluated thanks to the following aspects:

(1) Sampling
(2) Reliability
(3) Construct validity
(4) Internal validity
(5) External validity (generalizability)

We present the different concepts in the next section. In Chapter 7, before concluding on our findings, we will return to the above mentioned concepts to discuss the validity of our findings. In fact, it is necessary to first present in detail how the research was carried out to be able to discuss the concepts related to validity.

2.3.1 Sampling

Each case should be selected according to precise criterion, so that the sample is relevant to the study. Since statistical sampling (such as done in survey investigation) is not possible in case studies, (Eisenhardt and Graebner 2007) introduce the concept of "theoretical sampling". Cases should be selected because they are highly suitable for illustrating and extending the theory and the concepts under study. In so far, theoretical sampling for single case study is simple: they ought to be chosen because they are unusually revelatory, extreme exemplars or opportunities for unusual research access (Yin 2009).

Concerning multiple case studies, cases should be picked so that (Voss et al. 2002):

- they predict similar results (literal replication) or
- they produce contrary results for predictable reasons (theoretical replication)

A second selection criterion of cases is to find "polar types" (Voss et al. 2002; Yin 2009), that is to say extreme cases with sharply contrasting characteristics that will highlight the difference being studied.

2.3.2 Reliability

Reliability is "*the extent to which a study's operations can be repeated, with the same results*" (Stuart et al. 2002). In order to enhance reliability (i.e. minimize errors and bias), two issues ought to be considered in a case study:

- A case study protocol, explaining the instruments and rules followed to carry out the case study should be documented (Stuart et al. 2002; Yin 2009)
- The steps of the research should be clearly itemized and described (Yin 2009)

2.3.3 Construct validity

Construct validity is the extent to which correct operational measures were established for the concepts being studied (Stuart et al. 2002; Yin 2009).

To ensure construct validity, the researcher should

- use multiple source of evidence to study the same phenomenon (data triangulation)
- have key informants review the draft case study report

2.3.4 Internal validity

Internal validity concerns the validity of the relationships, namely whether the conjectured relationships actually exist, as opposed to outcomes resulting from spurious relationships (Stuart et al. 2002).

2.3.5 External validity

External validity refers to the problem of knowing whether the results of the study are valid beyond the immediate case study (Stuart et al. 2002). To enhance external validity in a case study:

- The selection of cases should be based on theoretical sampling
- The possible effects of industry, organization, size, manufacturing processes and inter-organizational issues should be considered.

External validity is also improved in replicating case studies (Meredith 1998).

We recall that all the concepts related to the evaluation of the validity of findings will be discussed in regard to the research presented here in Chapter 7.

2.4 Conclusion

In order to draw valuable knowledge from practice, we decide in this research project to first design the issues investigated jointly with practitioners at Siemens E T HS. It leads to the identification of three different investigation tracks for this research project:

(i) investigating ramp-up literature in order to deepen our knowledge of the ramp-up phase and to have a better overview of previously published results (literature review)

(ii) investigating ramp-up problems, to capitalize on difficulties encountered during the ramp-up phase of a project in the low volume industry (first research question)

(iii) investigating ramp-up interfaces, to solve information exchange and coordination problems during ramp-up (second research question)

The last two issues are investigated thanks to the case study methodology. A total of four cases were chosen and analyzed within the different ramp-up projects of Siemens E T HS.

Next chapter examines the issue of ramp-up literature.

CHAPTER 3 LITERATURE REVIEW

Chapter outline:

This chapter presents a literature review on the production ramp-up. We synthesize results of the ramp-up literature on general concepts such as definition or characteristics. We provide a detailed state-of-the art which clusters works according to their industrial context. Then we propose three different classifications of ramp-up literature. Finally, we discuss the findings of ramp-up literature regarding our context of low volume industry.

3.1 Introduction

Investigating the issue of production ramp-up, we note this contradiction between major research works that mention ramp-up as an "*underresearched*" area of New Product Development (NPD) literature (Di Benedetto 1999) and the variety of published articles we found focusing on the ramp-up issue. Indeed, even if several authors in the late 90s argue that literature dealing with the ramp-up phase is poor, we were able to find in the literature a growing number of articles and research works dealing with the ramp-up issue. Notably, we reviewed major Operations Management or Product Design Research Journals over the last ten years (1999 – 2009), such as:

- Management Science
- International Journal of Operations and Production Management
- International Journal of Production Economics
- Journal of Operations Management
- Journal of Product Innovation Management.

We also reviewed the proceedings of international conferences, mainly CIRP Manufacturing Systems conferences and CIRP Design conferences. We looked for relevant references in the articles we found. Finally, other published works were mentioned to us by fellow researchers during discussions[4]. At the end of this literature search, we had gathered a total of 41 research works published between 1998 and 2009 (see Figure 3.1).

To the best of our knowledge, no literature review on the ramp-up phase is available so far. And yet, a literature review is a very helpful tool for researchers (Karlsson 2009). It allows the identification of blank spaces in the research body, that is to say interesting tracks for future research. Consequently, a detailed overview and several classifications of ramp-up research appear as interesting contributions to the field[5].

[4] We would like to thank Mrs. Säfsten, Mr. Almgren, Mr. Fransoo and Mr. Pufall for their kind help.
[5] Our extensive literature review article is under review.

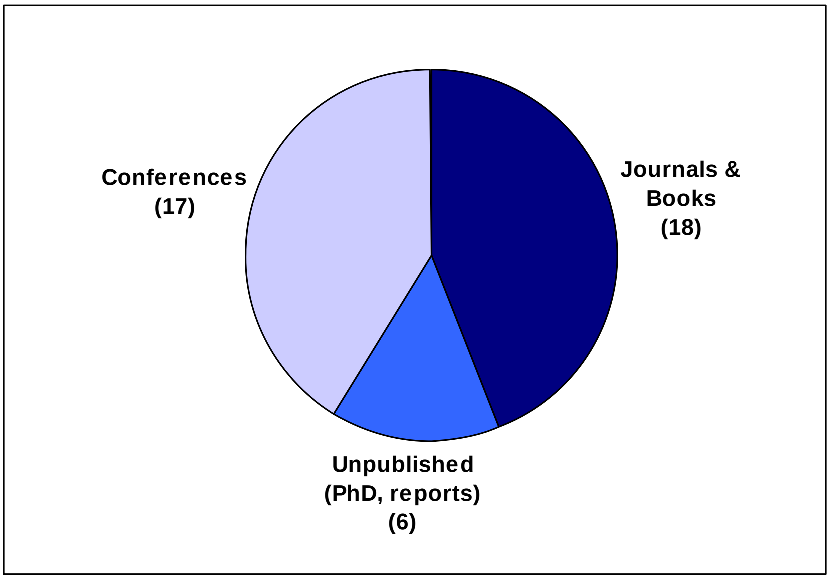

Figure 3.1 – Repartition of the 41 research works focusing on the ramp-up issue

Furthermore, a detailed overview of previously published results about ramp-up enables us to confront these results to the specificities of the low volume industry. Thanks to our involvement in Siemens E T HS and our close relationships with our industrial partners, we are able to discuss some concepts proposed by the ramp-up literature.

This chapter is structured as follows. In section 3.2, we propose a synthesis of literature propositions on general ramp-up concepts (definition, characteristics). In section 3.3, we propose a detailed state-of-the art of ramp-up literature, where research works are clustered according to their industrial context. In section 3.4, we propose three different classifications of ramp-up literature, so as to propose different perspectives on ramp-up literature and to position our work within the ramp-up research body. Finally, in section 3.5, we present a discussion of ramp-up literature findings in regard to the low volume industrial context

3.2 Production ramp-up – General concepts

We find in the literature different approaches of the ramp-up issue. There are different definitions; different characteristics that are spread out in the articles focusing on ramp-up. To have an overview of different approaches of previously published works on ramp-up general concepts, we gathered mentions of:

- ramp-up definitions (section 3.2.2)
- ramp-up activities (section 3.2.3)
- terms related to the ramp-up issue (section 3.2.4)
- incentives to focus on the ramp-up phase (section 3.2.5)
- characteristics of the ramp-up phase (section 3.2.6)

In doing so, we hope to provide a synthetic view of the state of the art on these concepts within the ramp-up research. In the next section, we introduce ramp-up literature which found its origin in the New Product Development literature.

3.2.1 Origin of the ramp-up issue

The production ramp-up issue stems from the New Product Development (NPD) literature. Indeed, the ramp-up phase is defined as the last step of the New Product Development process.

A first example is the NPD process break down given by (Clark and Wheelwright 1992). The authors name the last of their four NPD steps the "*Pilot production/Ramp-up*" (see Figure 3.2).

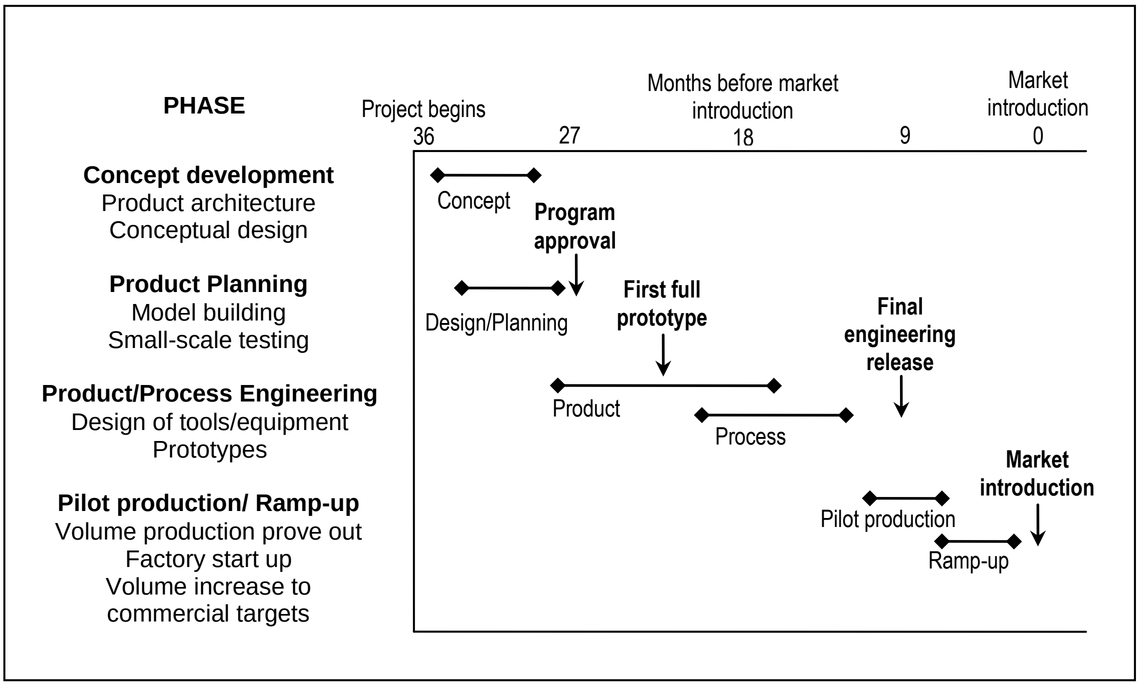

Figure 3.2 – Typical phases of the New Product Development process, according to (Clark and Wheelwright 1992)

In this representation, the ramp-up phase appears before market introduction.

A second NPD process break down is proposed by (Ulrich and Eppinger 2004). They split up the global process into six steps (see Figure 3.3): planning, concept development, system level design and Detail design, testing and refinement, production Ramp-up.

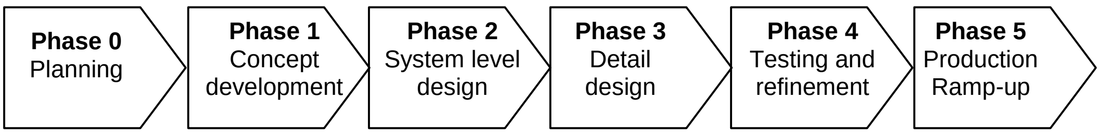

Figure 3.3 – (Ulrich and Eppinger 2004) break down of the NPD process

Lastly, we found a third major research work dealing with NPD which mentions the production ramp-up issue. In (Krishnan and Ulrich 2001), the authors are focusing on NPD major decisions. Ramp-up issue is mentioned as one of the five areas of NPD major decisions (that are concept development, supply chain design, product design, performance testing and validation, and production ramp-up and launch).

As highlighted in the three examples given above, it is the NPD literature that introduces the concept of production ramp-up. Unfortunately, the NPD literature does not go into detail in the ramp-up issue. For example, in their book, (Clark and Wheelwright 1992) detail the content and challenges of most of the steps of their NPD break down, except the ramp-up issue. Likewise, Ulrich and Eppinger only mention the Ramp-up phase in their global description of the NPD process, but do not detail it further. In fact, even though production ramp-up is mentioned by (Krishnan and Ulrich 2001), they acknowledge that NPD literature only lightly focuses on the production ramp-up issue.
In the next section, several existing definitions of the ramp-up phase are given and discussed.

3.2.2 Ramp-up definition

A first definition of the ramp-up phase is given by (Bohn and Terwiesch 1999). Ramp-up is "*the period between completion of development and full capacity utilization*" of the production system (Bohn and Terwiesch 1999). Hence, the ramp-up phase occurs when a new product is introduced in a factory but also when a new process or a new plant starts up (Bohn and Terwiesch 2001; Terwiesch et al. 2001). During this phase, the products which were developed in a small scale, laboratory-like environment will be transferred into a high-volume production environment (Terwiesch and Yi 2004).
The definition given by (Bohn and Terwiesch 1999) is adopted by later studies of the ramp-up issue.

However, three works (Fleischer et al. 2003), (Juerging and Milling 2005) and (Fjällström et al. 2009) interestingly point out the limits of the definition given by (Bohn and Terwiesch 1999). Indeed, the "completion of development" is a very fuzzy boundary. As emphasized by (Fleischer et al. 2003), in reality, product development is not finished at a specific date. There may still be some fine tuning related to product development while the product is already in a production phase (Juerging and Milling 2005). Hence, "start-of-production" (SOP)[6] seems to be a better term to mark the beginning of the ramp-up phase (Fleischer et al. 2003; Fjällström et al. 2009). Other authors argue that a comprehensive understanding of ramp-up should encompass preparatory activities (Meier and Homuth 2006; Winkler et al. 2007). The ramp-up phase begins thus earlier than SOP, right after the end of the prototyping / testing phase.

Once the beginning clarified, the end of production ramp-up is often identified by the satisfaction of initial objectives (such as output volume, cost, or yields). It is stated as: "*capacity and quality targets are attained*" (Almgren 1999c); reaching "*full scale production of*

[6] This term is defined in section 3.2.4.

the whole production system" (Fleischer et al. 2003); "*full volume*" (Haller et al. 2003); "*maximum production rate*" (Carrillo and Franza 2006); "*initial targets, for, e.g. quality, volume, yield, and cost are reached*" (Clark and Wheelwright 1992; Fjällström et al. 2009); "*deliveries are on time, capacity is sufficient, normal efficiency is reached and quality level is acceptable*" (Kontio and Haapasalo 2005); etc.

Figure 3.4 gives a global view of the life-cycle of a product, where the ramp-up phase is illustrated. (Terwiesch et al. 2001) highlight in their study the fundamental difference between time-to-market and time-to-volume: "*the former ends with the beginning of commercial production whereas the latter explicitly includes the period of production ramp-up*".

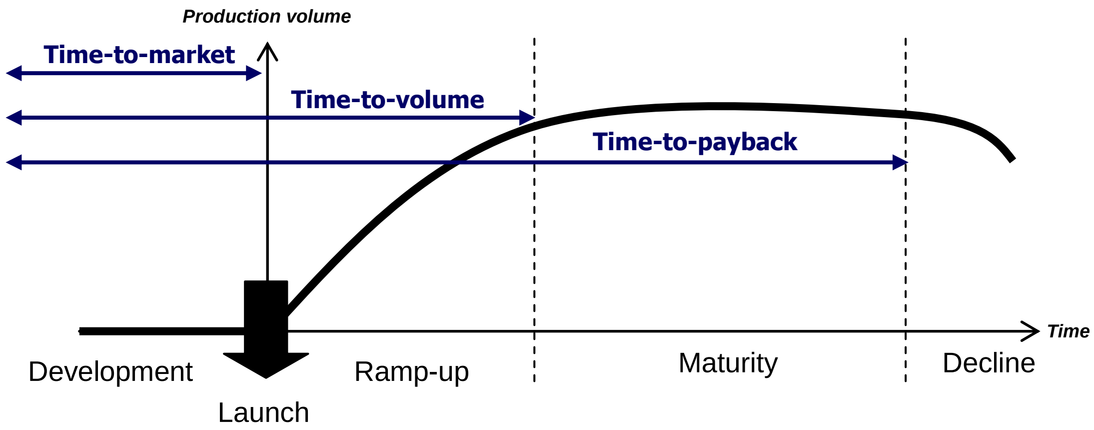

Figure 3.4 – Notions of "time-to-x" as defined by (Terwiesch et al. 2001)

After defining the start and the end points of the ramp-up phase, it is interesting to define which activities compose the ramp-up phase. Details about the breakdowns of the ramp-up phase provided by the literature are given in the next section.

3.2.3 Ramp-up activities

There are several breakdowns of the ramp-up phase proposed by the literature. Ramp-up is divided into sub steps that highlight the different activities to be performed during ramp-up.
For example, (Scholz-Reiter et al. 2007) propose a detailed breakdown of the activities included in the ramp-up phase (see Figure 3.5).

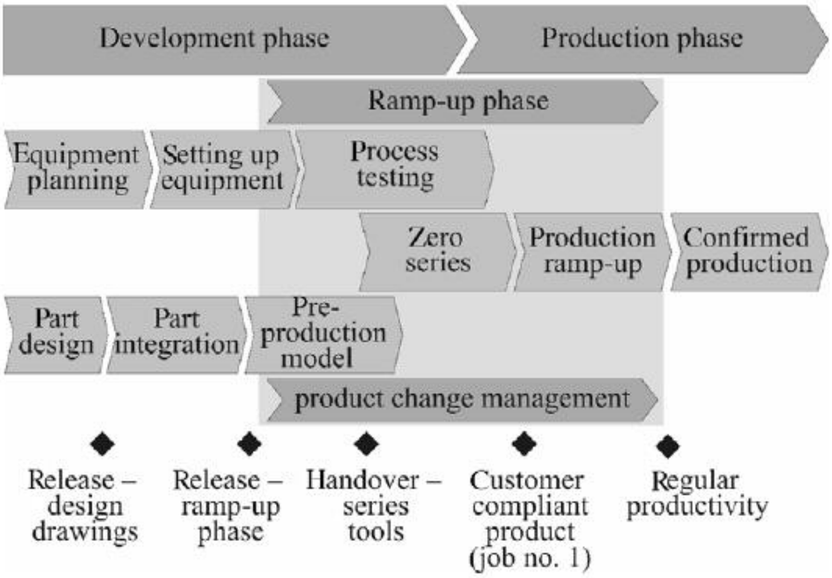

Figure 3.5 – Structure of the ramp-up phase, according to (Scholz-Reiter et al. 2007)

For the authors, the ramp-up phase begins with the assembly of the first pre-production model, which makes the testing of the production process possible. Then zero series are assembled, before the production capacity is gradually accelerated. The authors also highlight in their representation of the ramp-up process the importance of product change management. They picture it as a continuous task during ramp-up.

Another breakdown is proposed by (Winkler et al. 2007). Winkler et al. also suggest including the pre-series and the pre-production run in the ramp-up phase.
In fact, they decompose the production ramp-up phase into two phases (see Figure 3.6):

- The preparation phase, which begins after prototyping and ends with SOP. It includes the pre-series and the pre-production run
- The run-up phase, which begins after SOP and ends when series production begins.

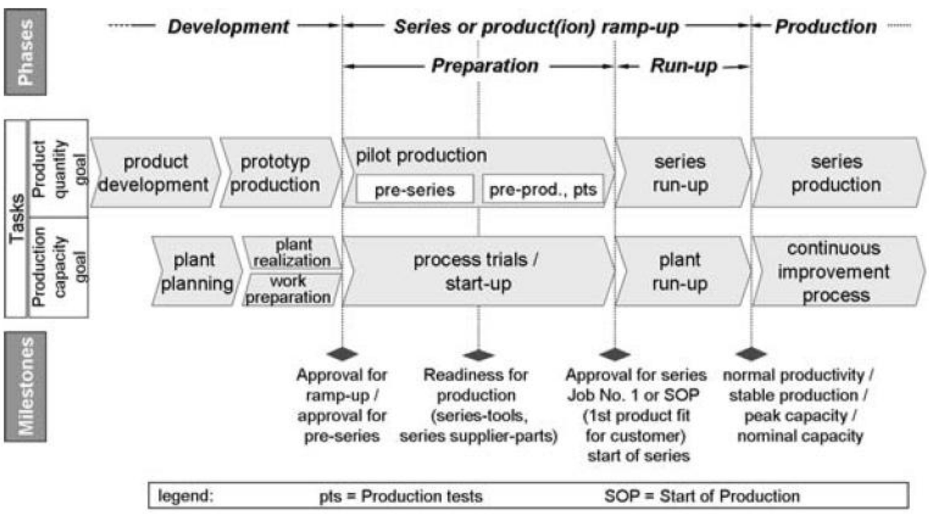

Figure 3.6 – Phases and tasks in the production ramp-up, according to (Winkler et al. 2007)

In fact, (Fleischer et al. 2003) and (Meier and Homuth 2006) also insist on the fact that a comprehensive understanding of the ramp-up phase should encompass preparatory activities(see Figure 3.7). Before the "time-to-volume" phase begins, activities such as change management activities, production system planning, production system setting-up and adaptation should be performed.

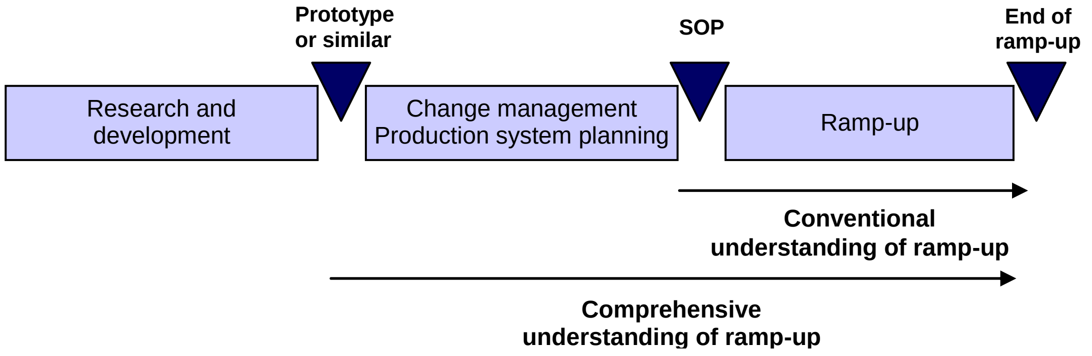

Figure 3.7 – Comprehensive understanding of ramp-up, according to (Meier and Homuth 2006)

The ramp-up literature entails a research work focusing on production ramp-up preparatory activities. (Säfsten et al. 2006b) propose a comprehensive overview of findings concerning preparatory production activities in different research fields. They conclude that preparatory activities can be divided into two types:

- product-related activities (prototyping, DfA/DFM, …)
- process-related preparatory activities (pre-series, pilot series, …)

These activities aim at preparing the product and the production system. They signal a transition from development to production and are spread out in the different phases of the NPD process, as shown in Figure 3.8.

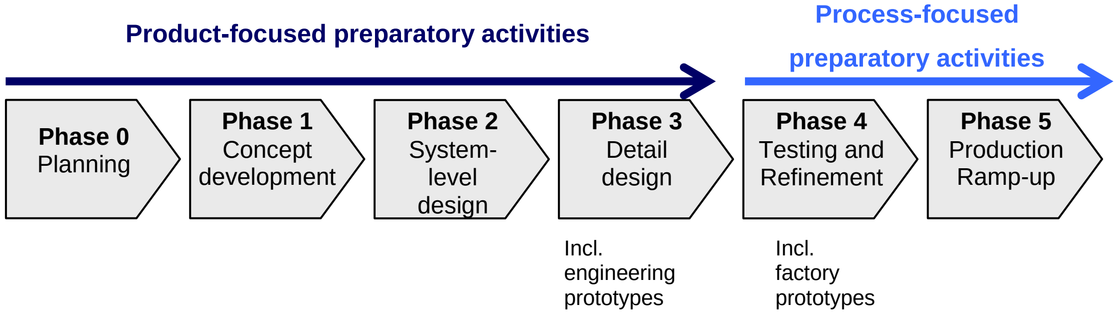

Figure 3.8 – Shift of focus for preparatory activities, adapted from (Säfsten et al. 2006b)

To conclude, several authors argue that ramp-up is not only constituted of the gradual increase of output volume (called "run-up phase" by (Winkler et al. 2007)). A comprehensive decomposition of the ramp-up phase should encompass the necessary preparatory activities before the actual output ramp-up.

We observe that the literature abounds with several terms that are closely related to the ramp-up. Hence, for clarity purposes, the next section provides an overview of the different terms surrounding the production ramp-up issue.

3.2.4 Related terms

In the ramp-up literature, we found a variety of terms that are closely related to the ramp-up issue. Table 3.1 details the different general terms encountered in the ramp-up literature. Table 3.2 presents the "time-to-x" terms (see Figure 3.4). Table 3.3 details the different ramp-up phase we found in the literature. For each term, a definition and the research works mentioning these terms are given.

General terms		
Terminology	**Explanation**	**Cited in**
New product introduction	- "*Co-operative process of combining and integrating the needed organizations, functions and activities cost-efficiently in order to bring the new product from R&D to full-scale manufacturing in a supply chain environment*". - Product development and product launch	(Apilo 2003) (Bowersox et al. 1999)
Product introduction	Part of the product realization process associated with the transfer of a product from product development to serial production Synonym of industrialization	(Terwiesch et al. 2001; Säfsten et al. 2006b; Säfsten et al. 2008a; Säfsten et al. 2008b)
Product launch	Launch of the product on the market, from the marketing and sales point of view	(Di Benedetto 1999; Terwiesch et al. 2001; Winkler et al. 2007)
Production launch	Activities essential to introduce a new product to its target market Synonym of start-of-production	(Bowersox et al. 1999; Di Benedetto 1999).
Start-up	Increase in output of a production system as time passes and production volume is accumulated	(Clawson 1985; Simola et al. 1998; Almgren 1999c; Almgren 1999a; Juerging and Milling 2005; Juerging and Milling 2006; Winkler et al. 2007)
Final verification	Pilot production and production start-up	(Almgren 1999a; Almgren 1999c; Almgren 2000; Säfsten et al. 2006a)

Table 3.1 – Terminology for notions related to the production ramp-up issue

Time-to-X		
Terminology	**Explanation**	**Cited in**
Time-to-market	Development time of a new product	(Almgren 1999c; Terwiesch and Loch 1999; Bohn and Terwiesch 2001; Terwiesch et al. 2001; Terwiesch et al. 2002; Terwiesch and Yi 2004; Juerging and Milling 2005)
Time-to-payback	Time to reach the financial goals initially fixed	(Bohn and Terwiesch 2001)
Time-to-volume	Time to reach full production volume	(Bohn and Terwiesch 2001; Fleischer et al. 2003; Juerging and Milling 2005)

Table 3.2 – Terminology for time-to-X terms

Phases within the ramp-up		
Terminology	**Explanation**	**Cited in**
Pilot production	Production of prototypes or products, not primarily intended for the end customer, at any location. Includes pre series and pre-production run.	(Almgren 1999a; Säfsten et al. 2006a; Winkler et al. 2007; Fjällström et al. 2009)
Pre series	Part of the Preparation phase of ramp-up where products for demonstration or testing are manufactured in close-to-production conditions where the tools and the supply process are tested.	(Winkler et al. 2007)
Pre production run	Part of the Preparation phase of ramp-up where products for demonstration or testing are manufactured in production conditions with series tools and components. Synonym of *preparatory production*	(Winkler et al. 2007) (Säfsten et al. 2006a; Säfsten et al. 2006b)
SOP	Beginning of the first series production (namely, after pilot production and pre series)	(Fleischer et al. 2003; Juerging and Milling 2006; Wolgast and Carlson 2007; Fjällström et al. 2009)
Run-up	Part of the ramp-up phase where volume production begins but with lower output, and quality than mature production	(Winkler et al. 2007)

Table 3.3 – Terminology for the phases of the production ramp-up

The tables presented here are helpful to clarify terms closely related to the ramp-up phase. Indeed, the various published works about production ramp-up are mentioning several different terms. We believe that this emergence of works about ramp-up is related to the importance of the ramp-up phase within the NPD process. Next section identifies the various reasons to focus on the ramp-up issue that are mentioned in the literature.

3.2.5 Reasons to focus on ramp-up

The ramp-up phase appears to be crucial for several reasons.

- **Time:** First entrants on the market can gain monopoly that yields premium prices (Fleischer et al. 2003; Terwiesch and Yi 2004; Carrillo and Franza 2006; Juerging and Milling 2006). There is a direct relationship between the length of the ramp-up phase and the final level of efficiency (Almgren 1999c), and part of the profit can be lost due to a late production launch (Winkler et al. 2007)
- **Complexity:** The growing complexity of products and of the ramp-up phase (Arnold and Floyd 1997; Terwiesch et al. 2001; Apilo 2003; Kontio and Haapasalo 2005; Schuh et al. 2005; Burmer and Görlisch 2006; Juerging and Milling 2006; Pufall et al. 2007) and the constant diversification of product range (Fleischer et al. 2003; Schuh et al. 2005; Winkler et al. 2007) are reasons to focus on the ramp-up issue.
- **Cost:** Development expenses are concentrated around product launch (Terwiesch et al. 2001; Haller et al. 2003), hence, production launch and ramp-up being major cost drivers for the NPD project (Bohn and Terwiesch 2001; Schuh et al. 2005). Furthermore, new products are central to a company's profitability: among the best performing firms in 1997, 49% of sales are derived from new products (Di Benedetto 1999).
- **Context:** the fierce global competition urges companies to launch new products always more often and faster (Almgren 1999c; Kontio and Haapasalo 2005; Fjällström et al. 2009), product lifecycles are always shorter (Arnold and Floyd 1997; Apilo 2003; Fleischer et al. 2003; Haller et al. 2003; Nyhuis and Winkler 2004; Terwiesch and Yi 2004; Schuh et al. 2005; Carrillo and Franza 2006; Meier and Homuth 2006; Winkler et al. 2007), shrinking the market window (Almgren 1999c; Bohn and Terwiesch 2001; Juerging and Milling 2006). Markets are fragmented and customers are sophisticated (Pufall et al. 2007).
- **Strategy:** several authors mention the strategic importance of the success of the ramp-up phase (Nyhuis and Winkler 2004; Kontio and Haapasalo 2005; Schuh et al. 2005; Juerging and Milling 2006).
- **Uncertainty:** Since the product, the production system and the supply chain are new, uncertainty is higher during the ramp-up phase which makes it difficult to manage (Bowersox et al. 1999; Meier and Homuth 2006). Meier and Homuth (2006) mention a survey realized by the Kühne Institute of the St Gallen University concerning automobile suppliers. According to this survey, only 43% of the ramp-ups are

economically and technically successful. 24% have not achieved the desired goals, neither technically nor economically, another 24% are successful economically, but are not satisfying technically and a further 9% have reached the technical goal, but miss the estimated costs. All in all, 57% of the ramp-ups were not successful.

To conclude, ramp-up literature provides several reasons to focus on the ramp-up issue, from the perspective of a company. Indeed, the importance of the ramp-up phase is widely acknowledged. In fact, the ramp-up phase is a very specific phase, compared to other phases of the product life cycle. In order to have a better understanding of the ramp-up phase, the next section describes its most common characteristics.

3.2.6 Characteristics of the ramp-up phase

Ramp-up characteristics that are widely mentioned in the literature are itemized below:

- Low initial level of knowledge about the product and the process (Fleischer et al. 2003; Terwiesch and Yi 2004; Juerging and Milling 2005; Juerging and Milling 2006). Learning gradually takes place (Almgren 1999c; Almgren 2000; Bohn and Terwiesch 2001; Terwiesch and Yi 2004; Van der Merwe 2004) but is difficult (Haller et al. 2003; Säfsten et al. 2008a).
- Low production output (Terwiesch et al. 2001; Fleischer et al. 2003; Haller et al. 2003; Juerging and Milling 2006)
- Higher cycle time (Bohn and Terwiesch 2001; Terwiesch et al. 2001; Apilo 2003; Haller et al. 2003)
- Low production capacities (Bohn and Terwiesch 1999; Bohn and Terwiesch 2001; Fleischer et al. 2003; Juerging and Milling 2006)
- High demand (Bohn and Terwiesch 2001; Terwiesch et al. 2001; Haller et al. 2003)
- High disturbances in process, supply chain or product quality (Almgren 2000; Fleischer et al. 2003; Nyhuis and Winkler 2004; Fjällström et al. 2009)

These different characteristics help to understand the very specific nature of the ramp-up phase.

In the previous sections, we itemize and compare the different definitions and concepts proposed by the ramp-up literature. However, we believe that the industrial context influences the scope of validity of the different concepts presented here. Consequently, the next section proposes a detailed review of the ramp-up literature, where the different research works are clustered according to their industrial context.

3.3 State of the art based on the industrial context

As seen in the previous section, there are several published works that focus specifically on the production ramp-up issue. They provide different definitions, various terms and several different ramp-up characteristics.

In this section the different research works are presented and clustered according to their industrial context. Indeed, most of the studies on production ramp-up are embedded in a specific industrial context. Most of the studies are relying on the industrial context in order to gain insights about the ramp-up phase (e.g. (Terwiesch et al. 2001)'s exploratory study in the hard disk drive industry).
Furthermore, presenting ramp-up literature organized according to the industrial context is interesting for several reasons. First this literature overview provides a general map of ramp-up literature, clustering it in three homogeneous categories. Then, clustering research works according to the industrial context enables results to be linked with their industrial context. Third, it allows the identification of major focuses or major concepts that are emerging within a particular industrial field. Finally, this literature overview makes it possible to identify industrial contexts which are not or very little investigated so far.

Figure 3.9 gives an overview of the major studies realized from the late nineties up to day concerning the ramp-up issue. It organizes the 41 research papers about the production ramp-up, according to their industrial context.

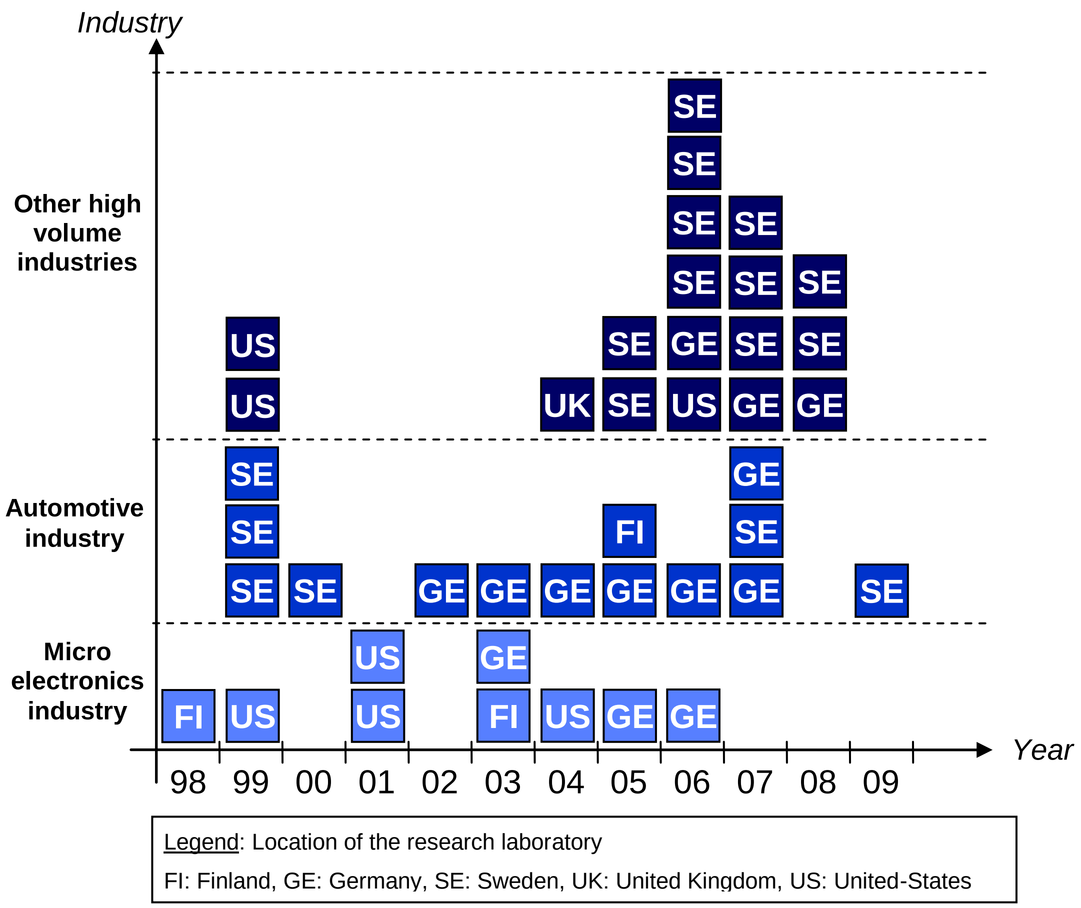

Figure 3.9 – Industrial contexts and origin countries of research works published between 1998 and 2009 concerning ramp-up

The industries that are widely represented in the ramp-up literature are:

- The microelectronics industry, with nine published works, dated from 1998 until 2006
- The automotive industry, with fourteen works, mostly carried out in Germany
- Other high volume industries (outdoor products, industry products, pharmaceutics…), with a pool of research carried out in Sweden in 2006, 2007 and 2008.

3.3.1 Ramp-up in the microelectronics industry

Some pioneering work in ramp-up literature appears in the microelectronics industry dating back to 1998. The major works realized are by (Simola et al. 1998), (Bohn and Terwiesch 1999), (Bohn and Terwiesch 2001), (Terwiesch et al. 2001), (Apilo 2003), (Haller et al. 2003), (Terwiesch and Yi 2004), (Juerging and Milling 2005) and (Burmer and Görlisch 2006). In these studies two points emerge as being major ramp-up performance drivers: yield management and learning.

3.3.1.1 Ramp-up and yield management

Not every unit of material which is launched in the production process does come out of the process with the predefined quality standards. In this case, the product is either reworked or scrapped. In the microelectronics industry, the second solution (i.e. scrapping) surpasses the first one (i.e. rework). Yield is a performance measure which gives the fraction of products which are not scrapped. Yield is hence an important indicator of the maturity of a product and a process in microelectronics industry. For (Apilo 2003), yield is even a mean to define the upper bound of the ramp-up phase: "*when the yield percent achieves a target value, a NPI (New Product Introduction) organization transfers the responsibility for the program to a production organization*". Indeed, yield reflects process maturity and as a result *"an acceptable product yield is a prerequisite for volume production*" (Haller et al., 2003).

The first major work published in the microelectronics industry focusing on the ramp-up phase is by (Bohn and Terwiesch 1999). This is a case study realized in the hard disk drive industry in the USA. The authors investigate the impact of yield losses on the economic performance of a company. In a second case study, (Terwiesch et al. 2001) investigate the evolution of yield and tact time over time, the different activities and the problems encountered (machine breakdown, low yields, supply issues etc.) on an international product transfer and production ramp-up project in hard disk drive industry. They argue that yields are not sufficient to describe the plant's performance. Other losses (rework losses, breakdown of parts and tools, deliberate downtime for calibration, scheduled maintenance or engineering trials) affect the global production cycle time as well. These other losses, as well as yield are highly influenced by the level of knowledge on the products and processes which will be discussed next.

3.3.1.2 Ramp-up and learning

There is a consensus that low yield is related to lack of knowledge and hence learning is a major driver to improve yields. (Bohn and Terwiesch 2001) develop a model to analyze the interactions among capacity utilization, yields, and learning. They model learning as deliberate experiments that decrease production capacity on the short term. They conclude that production ramp-up period suffers from the trade-off between the short-term opportunity cost of capacity and the long term value of learning.

This trade-off between learning (about the process) and making process changes regarding potential financial benefits is studied by (Terwiesch and Yi 2004). The authors demonstrate that the copy-exactly strategy (i.e. delaying process changes to learn) is a good strategy during ramp-up. The "copy-exactly" strategy consists in freezing the process for some period of time, thus allowing no change in the production process. The authors demonstrate that this strategy is optimal if the initial knowledge level is low, the lifecycle is short, demand growth is steep, and learning is difficult. They also assess the performance of the copy-exactly strategy in regards to the production yield. The copy-exactly strategy is compared to a process change strategy (i.e. implementing directly engineering change orders and their resulting process changes) by (Juerging and Milling 2005). They conclude that the more innovative the product is, the more a copy-exactly policy should be favored.

3.3.1.3 Time pressure and ramp-up

Being highly technological, the lifecycle of electronic products are often very short. This results in a time pressure on the release of new products on the market. In a case study (Apilo 2003) investigates how to reduce new product introduction time (which includes the ramp-up time) for electronics manufacturers. The case study is conducted in a context where the NPI tasks are shared among the OEM (original equipment manufacturer) and the CEM (Contract Electronics Manufacturer). The author argues that a successful ramp-up passes by a good communication among actors. The ingredients of a successful ramp-up are given as: (i) a formal and well-understood stage/gate model, (ii) extensive review meetings at every gate, (iii) implication of representatives of all teams, manufacturing and logistics included (iv) planning (v) feedback / lessons-learnt for future projects.

(Simola et al. 1998) also mention too short time dedicated to the ramp-up time (as a result of time pressure) as one of the major problems encountered during ramp-up. Other problems categories they found out in their study are manufacturability, responsibilities, procedural justice and intergroup boundaries.

3.3.2 Ramp-up in the automotive industry

The major research realized on the ramp-up issue in the automotive industry is by (Almgren 1999a), (Almgren 1999b), (Almgren 1999c), (Almgren 2000), (Kuhn et al. 2002), (Fleischer et al. 2003), (Nyhuis and Winkler 2004), (Kontio and Haapasalo 2005), (Schuh et al. 2005), (Juerging and Milling 2006), (Winkler et al. 2007), (Wolgast and Carlson 2007), (Scholz-Reiter et al. 2007) and (Fjällström et al. 2009). Most of these works are conducted in collaboration with German and Swedish car manufacturers.

In the automotive industry, ramp-up is mostly considered as a “project” (Almgren 1999c; Kontio and Haapasalo 2005; Juerging and Milling 2006; Winkler et al. 2007). Therefore, the performance indicators are mostly derived from the classical project performance measures, the “magic triangle” of cost, quality, and time. Unlike the microelectronics industry, in case of quality problems the rework overrules scrapping. Therefore, yield is rarely addressed as a performance measure.

Similar to the microelectronics industry, learning is also considered to have a high impact on the performance of the ramp-up phase, by providing organizational and technical improvements (Almgren 1999c), decreasing production cycle times (Nyhuis and Winkler 2004), increasing cumulative production volume (Juerging and Milling 2006), influencing quality-capability curves and providing price advantages for consumers (Fleischer et al. 2003).

However, the key concepts in the ramp-up literature embedded in the automotive industry are ramp-up key performance indicators (KPI) and the evaluation of ramp-up project complexity.

3.3.2.1 Ramp-up key performance indicators (KPI)

The key performance indicator are resumed by (Juerging and Milling 2006) as follows: *“the objective during the manufacturing start-up is to attain quality and quantity targets with a predetermined production lead time at the lowest possible cost*”.

Under these macro performance indicators, several possible performance measures are mentioned by different researchers. For instance, (Winkler et al. 2007) regroup KPI’s with respect to goals to which they lead: productivity and level of quality serve for effectiveness goal (i.e. best results possible), whereas cost is reflected in efficiency goal (i.e. resource optimization) and length of intervals between milestones of a production ramp-up project will be an indicator on how well the deadline goal is reached.

(Kontio and Haapasalo 2005) argue that the performance indicators to manage the ramp-up phase should be related to the nine competence categories of Project Management, which are: (i) integration management, (ii) scope management, (iii) time management, (iv) cost management, (v) quality management, (vi) human resources management, (vii) communication management, (viii) risk management and (ix) project procurement management.
According to (Scholz-Reiter et al. 2007), ramp-up performance is highly influenced by technical product change management. Decreasing product change lead time will directly enable a decrease of ramp-up total time.

For (Juerging and Milling 2006), there are two major variables that affect the efficiency of the production process: productivity and quality, quality being influenced by four major factors : average skill of the assembly workers, work adequacy, schedule pressure and fatigue.

(Almgren 1999c) selected as relevant the following three indicators: (i) a capacity performance index (ratio between number of produced cars and number of planned cars to produce) (ii) a quality performance index (ratio between number of cars leaving the assembly line without any remark and number of produced cars) and (iii) a cost indicator (measured in terms of extra man-hours to make up for lost capacity, inspection and correction).

Finally, (Almgren 2000) measured production ramp-up performance thanks to two sets of indicators:

- Indicators concerning ramp-up throughput time (namely, time to quality and time to quantity indexes)
- Indicators concerning ramp-up efficiency (namely quantity performance, product conformance, product quality and production efficiency).

3.3.2.2 Classification of ramp-up projects according to their complexity

Another specificity of the automotive industry is that the new product introduction projects do not always concern products which are completely new. The projects may concern completely new products and processes on one extreme or some face-lifting of an old model on the other extreme. The complexity of the ramp-up phase depends on where the ramp-up project is positioned. Indeed, (Almgren 1999a) proposes a framework to classify production ramp-up projects. His framework highlights that two dimensions contribute to the complexity of the ramp-up: the product newness and the production system newness (see Figure 3.10).

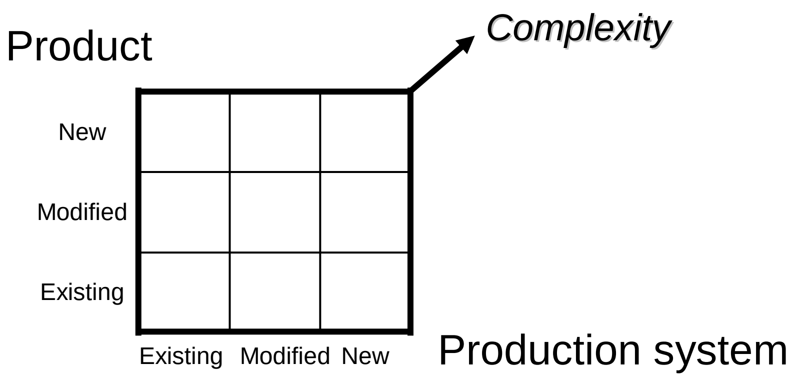

Figure 3.10 – Framework for classifying ramp-up situations from (Almgren 1999a)

This framework is widely used in other research works (notably (Nyhuis and Winkler 2004) and (Säfsten et al. 2006a)) to position the ramp-up situation they were concerned with.

(Juerging and Milling 2006) add a third dimension to Almgren's framework which is the capacity dimension (see Figure 3.11). For (Juerging and Milling 2006) the capacity dimension reflects the means of a company to provide the required manufacturing resources, including services and products by suppliers.

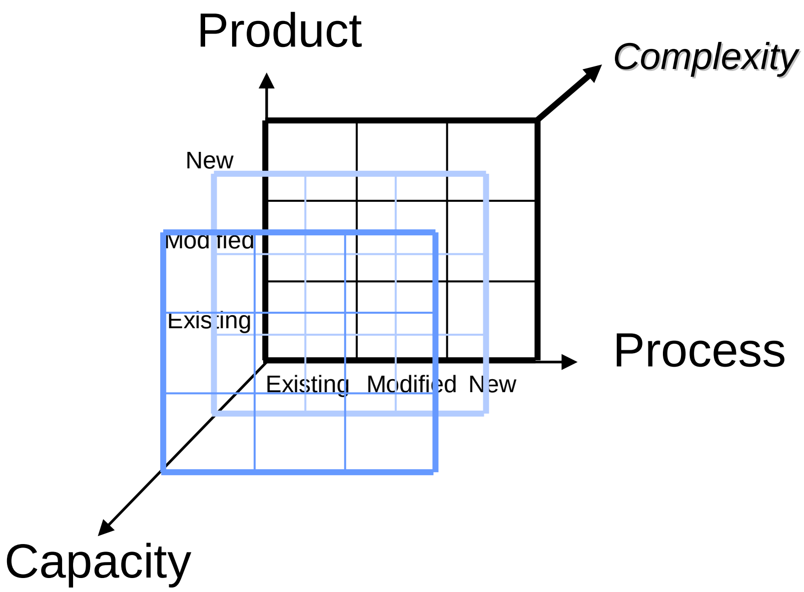

Figure 3.11 – Three dimensions of innovation, adapted from (Juerging and Milling 2006)

3.3.2.3 Managing ramp-up projects in automotive industry

Several different ramp-up management techniques can be observed: some are based on KPI's given above (Almgren 1999c; Fleischer et al. 2003; Juerging and Milling 2006; Winkler et al. 2007); some are based on cause and effects analysis (Nyhuis and Winkler 2004; Winkler et al. 2007); some are related to communication and information exchange during ramp-up (Wolgast and Carlson 2007; Fjällström et al. 2009), some are based on knowledge management (Scholz-Reiter et al. 2007) and one is based on a holistic approach presented by (Schuh et al. 2005).

3.3.3 Ramp-up in other industries

In this section are presented the remaining studies, which are conducted in other industrial contexts. They were mostly conducted in the context of high volume industries. The different research works we identified are the following ones: (Bowersox et al. 1999), (Di Benedetto 1999), (Van der Merwe 2004), (Berg et al. 2005), (Berg and Säfsten 2005), (Berg and Säfsten 2006), (Carrillo and Franza 2006), (Fjällström et al. 2006), (Meier and Homuth 2006), (Säfsten et al. 2006a), (Säfsten et al. 2006b), (Berg 2007a), (Berg 2007b), (Fjällström 2007), (Pufall et al. 2007), (Fransoo et al. 2008), (Säfsten et al. 2008a) and (Säfsten et al. 2008b).

A series of works have been done by a team of Swedish researchers (Säfsten et al. 2006a; Säfsten et al. 2006b; Fjällström 2007; Säfsten et al. 2008a; Säfsten et al. 2008b), which are conducted in a diverse variety of industries such as the consumer electronics, pharmaceutics, office products, outdoor products, etc. As described below, the findings of the authors are close to the diagnostics made for the electronics and automotive industries which are high volume industries as well.

In (Säfsten et al. 2006a), the authors insist on the fact that a successful ramp-up depends very much on the amount and quality of the preparatory activities performed prior to ramp-up, as well as on the implementation of the appropriate ramp-up strategies. Table 3.4 illustrates the points to consider during the preparatory production phase.

In (Säfsten et al. 2006b), the authors in depth focus on the preparatory activities and present two case studies realized within the same Swedish company, which produces outdoor products. Even though both projects were conducted with the same stage/gate model, the success levels of the projects were not the same. The authors thus conclude that the degree of time pressure, the degree of priority and commitment to the project, the type of project organization and the level of technological uncertainty should also be considered.

Learning during production ramp-up is revisited in (Säfsten et al. 2008a). The authors argue that learning is difficult to plan in an unpredictable environment and they present different types of learning, different learning strategies and different learning methods found in literature. Three case studies illustrate the use of different types of learning. The authors conclude that experience from previous product introductions is not enough and they advise

Aspects to consider
Ramp-up complexity: *product and process newness*
Product / process fit
Product concept
Suppliers
Process / production technology
Role of manufacturing in the company
Organizational support
Engineering deployment and empathy
Formalization: *standards, schedules and plans, mutual adjustment, teams*
Formal stage models
Extensive review meetings at gates
Test and verification
Resources: *time, personnel*
Information, communication, cooperation
Personnel: *education and learning*

Table 3.4 – Aspects to consider before production ramp-up, according to (Säfsten et al. 2006a)

to create opportunities for activities supporting learning by doing (e.g. preseries), learning through experiments (e.g. prototypes) and learning through the use of third party (external expertise).

Finally, in (Säfsten et al. 2008b), the authors tackle the problem solving issue during production ramp-up. A major ramp-up activity is concentrated around the handling of critical events. Säfsten, et al. define four possible types of events and define relevant ways of working (proactive or reactive) and relevant behaviors (skill-based behavior, rule-based behavior or knowledge-based behavior) to resolve the different types of problems.

3.3.4 Conclusion on the existing literature

As depicted in Figure 3.9, most of the existing literature is based on three industrial contexts: the microelectronics, the automotive and other high volume industries. Based on the context, the point of view, the key concepts or the performance measures of ramp-up projects may vary. For instance, "learning" notion which is important in ramp-up projects does not have the same dimension if the industry is labor-intensive or highly automated. Similarly, the work pressure is not the same if the throughput is high (e.g. 1 min 30 seconds per vehicle in an automobile assembly line) or low (e.g. several hours per high voltage switchgear). Therefore a "best practice" in an industrial context is not directly applicable in another industrial context.

Moreover, if the existing literature is placed on a volume-product diversity plane, several blank spaces are identified. Indeed, the industrial context of existing works up to date is high production volume and medium to high diversity product industries (see Figure 3.12). The "low volume" industries area seems to be underresearched and appears thus as an interesting context for new studies on the ramp-up issue.

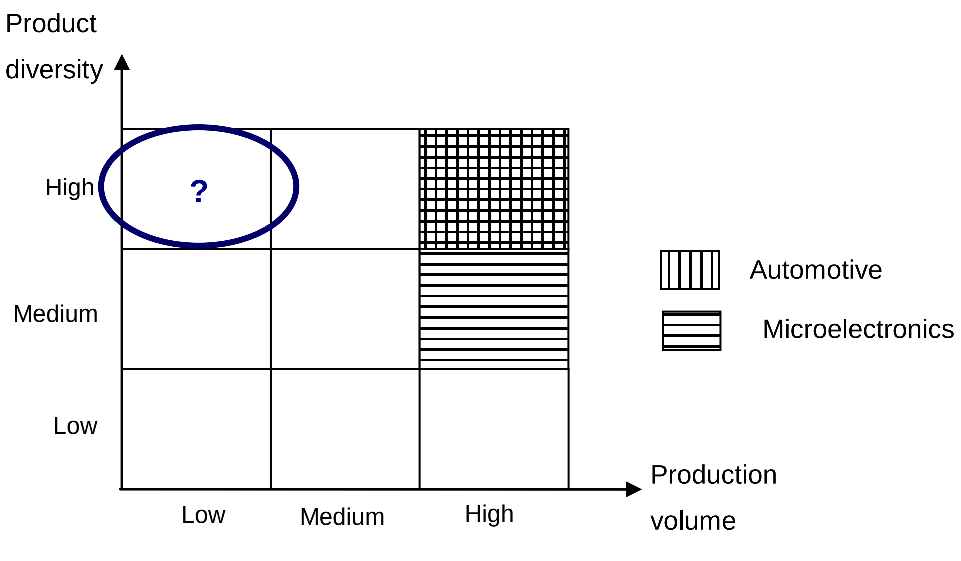

Figure 3.12 – Industrial context of the existing literature

However, we have seen that the industrial context may influence the validity of concepts and approaches of the ramp-up issue. In section 3.5, we will review the major findings of the microelectronics and the automotive industry to discuss their relevance regarding the context of the low volume industry.

Next section provides additional insights about the state of the art regarding the ramp-up issue in proposing three different classifications of the main research works about production ramp-up published between 1998 and 2010.

3.4 Classifications of ramp-up literature

In this section, we propose three different classifications of ramp-up literature. A total of 45 research works are classified:

- The 41 works presented in section 3.1
- Three conference articles and one journal article based on the findings of the research presented here

The aim of these classifications is twofold:

- to propose to future researchers in the field of ramp-up an organized overview of previously published works
- to position the research presented here within the body of ramp-up literature.

3.4.1 Classification according to keywords

The first classification proposed is based on keywords.

3.4.1.1 Methodology

For each article, the five initial proposed keywords of the article are considered. If there were less than five keywords, repeated keywords in the abstract or in the conclusion of the article were chosen. Words that were representative of the subject that the article dealt with were selected. Hence a list of 170 keywords for 34 articles is obtained.

Among the 170 keywords, we deleted:

- Keywords related to the ramp-up terminology because these keywords concern the general issue (namely ramp-up) these works are focusing on.
- Keywords related to the industrial context because section 3.3 already presented a clustering of ramp-up works according to the industrial context.
- Keywords related to company departments because a clustering according to the focus extent is proposed in section 3.4.2
- Keywords related to countries, keywords related to the type of research or to the type of model used, because these keywords didn’t allow knowing exactly the topic focused on in the work

A list of 12 top keywords emerged: yields, learning, strategies, performance, technical changes, (project) management, supply chain, control, problems, knowledge, planning and cooperation. 44 of the 45 articles can be categorized in at least one top term.

3.4.1.2 Classification according to keywords

The classification of the different research papers according to these top terms is shown in Table 3.5.

Yields	(Bohn and Terwiesch 1999) (Burmer and Görlisch 2006)	(Bohn and Terwiesch 2001)	(Haller et al. 2003)
Learning	(Bohn and Terwiesch 2001) (Juerging and Milling 2006)	(Terwiesch and Yi 2004) (Säfsten et al. 2008a)	(Van der Merwe 2004)
Strategies	(Almgren 1999c) (Nyhuis and Winkler 2004) (Berg and Säfsten 2006)	(Bowersox et al. 1999) (Terwiesch and Yi 2004)	(Di Benedetto 1999) (Schuh et al. 2005)
Performance	(Almgren 1999a) (Berg et al. 2005) (Berg 2007a)	(Almgren 1999b) (Berg and Säfsten 2005) (Pufall et al. 2007)	(Van der Merwe 2004) (Säfsten et al. 2006a) (Fransoo et al. 2008)
Technical changes	(Juerging and Milling 2005)	(Juerging and Milling 2006)	(Scholz-Reiter et al. 2007)
(Project) Management	(Di Benedetto 1999) (Meier and Homuth 2006) (Winkler et al. 2007)	(Kontio and Haapasalo 2005) (Säfsten et al. 2006a) (Säfsten et al. 2008b)	(Kuhn et al. 2002) (Säfsten et al. 2006b)
Supply Chain	(Bowersox et al. 1999)	(Meier and Homuth 2006)	(Berg 2007b)
Control	(Fleischer et al. 2003) (Winkler et al. 2007)	(Nyhuis and Winkler 2004)	(Carrillo and Franza 2006)
Problems	(Simola et al. 1998) (Fjällström et al. 2006) (Säfsten et al. 2008b)	(Almgren 2000) (Juerging and Milling 2006) (Fjällström et al. 2009)	(Kuhn et al. 2002) (Fjällström 2007) (Surbier et al. 2009c)
Knowledge	(Carrillo and Franza 2006) (Wolgast and Carlson 2007)	(Fjällström et al. 2006)	(Fjällström 2007)
Planning	(Fleischer et al. 2003) (Meier and Homuth 2006)	(Kontio and Haapasalo 2005) (Fjällström et al. 2009)	
Cooperation	(Apilo 2003) (Surbier et al. 2009a)	(Säfsten et al. 2006b) (Surbier et al. 2009b)	(Säfsten et al. 2008a) (Surbier et al. 2010)
Not classified		(Terwiesch et al. 2001)	

Table 3.5 – Classification according to the keywords

Table 3.5 displays a map of the production ramp-up literature according to the issue focused on by the research article (or research work). This classification could be useful for future researchers in the production ramp-up area in order to:

- have a general view of issues already dealt with by the literature
- find previous research works in the area they are focusing on
- identify blank spaces in the actual ramp-up literature, so as to explore them.

Table 3.5 is for example useful for the research work presented here. Indeed, it lists several previous research works on the “problems” issue and on the “cooperation, coordination and interface” issue, which are the two topics investigated here.

As demonstrated above, the mapping of ramp-up literature according to keywords can bring useful insights for researchers with diverse purposes. General issues dealt with in the literature are identified and holes in the classification can be addressed by future research. Our work is positioned in the “cooperation” area, a very little investigated topic so far.

In the next section, we propose a second classification, which arrays the research papers according to their focus extent within the ramp-up stakeholders.

3.4.2 Classification according to the focus extent

Another possible classification is to evaluate the extent of the papers’ focus area among the stakeholders of the ramp-up phase. According to the literature, usual production ramp-up stakeholders are:

- R&D team
- Production team (spread over one or several production plants)
- Logistics and procurement team
- External suppliers.

Sorting the research papers by extent of focus revealed that an important majority of papers are focused only on production stakeholders. Table 3.6 displays only the research papers with a larger focus than the production stakeholders. In Table 3.6, the extent of the focus is highlighted in blue. For example, (Bowersox et al. 1999) who propose a new logistics strategy for production launch, focus on both the production and the logistics teams. Hence, related cells are colored.

This classification highlights that very few articles consider the suppliers or the whole supply chain when treating the ramp-up issues.

Regarding the research presented here, the classification shown in Table 3.6 helps us to identify the different stakeholders of the production ramp-up phase. These are:

- R&D
- Production
- Logistics
- Suppliers.

	Production	R&D	Logistics	Suppliers	Whole team
(Simola et al. 1998)	■	■			
(Juerging and Milling 2005)	■	■			
(Carrillo and Franza 2006)	■	■			
(Säfsten et al. 2006b)	■	■			
(Scholz-Reiter et al. 2007)	■	■			
(Wolgast and Carlson 2007)	■	■			
(Bohn and Terwiesch 2001)	■	■			
(Bowersox et al. 1999)	■		■		
(Surbier et al. 2009a)	■	■	■		
(Surbier et al. 2009b)	■	■	■		
(Surbier et al. 2010)	■	■	■		
(Berg 2007b)	■			■	
(Schuh et al. 2005)	■			■	
(Apilo 2003)	■	■		■	
(Berg et al. 2005)	■	■		■	
(Berg 2007a)	■	■		■	
(Di Benedetto 1999)	■	■	■	■	■

Table 3.6 – Focus extent of research papers having a larger focus than the production team

In this dissertation, we focus only on internal stakeholders, namely the R&D department, the Production department and the Logistics department. External entities such as external production or suppliers are not taken into consideration.

Both classifications presented in section 3.4.1 and in the previous section help to have an overview of the different published papers dealing with the ramp-up issue. A third overview is proposed in the next section. Indeed, in 2002, Kuhn et al. suggested possible research directions. We classify previously published research works so as to see to what extent these research directions are followed.

3.4.3 Classification according to Kuhn et al.'s 2002

In the German research project "Fast Ramp-ups" mentioned by (Kuhn et al. 2002), the authors outline five research areas:

- Planning, control and organization of ramp-up projects
    - In order to be effective during the production ramp-up phase, methods and tools to support the identification and analysis of disturbances should be developed. Critical events should be forecasted. Actual simulation tools for planning and control should be adapted to the ramp-up situation so as to support decision making. Methods and tools should also be developed so as to identify and calculate ramp-up costs.

- Product change management
    - Research should focus on the consequences of product or product component modifications, so as to decide whether an intended change should be made.
- Ramp-up sturdy production systems
    - Forecasting the behavior of technical processes could enable a decrease of the number and duration of breakdowns and quality problems, a particularly critical issue during ramp-up. Material-flow and quality simulation could be combined. In the case of potential failure with a high impact on the ramp-up project, risk management techniques should be employed.
- Cooperation between the personnel, departments and companies involved in ramp-up
    - The coordination of actors is a major issue during production ramp-up. Partners have to be synchronized thanks to a cooperation reference model. Tools should support structured ways of transferring information and goods to partner. Problem-solving should be a common routine.
- Knowledge management and personnel qualification of the ramp-up personnel
    - Actual ramp-up projects should be able to benefit from the experience of previous ramp-ups. An effective knowledge management system should enable the easy and quick use of knowledge. Human knowledge management is also an important issue: teams of ramp-up specialists could be built and maintained.

The classification of research papers according to the above research directions originally proposed by (Kuhn et al. 2002) is presented in Table 3.7. In this classification, the articles posterior to Kuhn et. al.'s work are highlighted by italic typeface.

Table 3.7 underlines that many studies have been conducted on the planning, controlling and organizational issues throughout the years, including post 2002 period. However, the remaining categories still seem to be open with fewer studies reported.
For the research presented here, this classification stresses the importance of investigating the "cooperation between personnel, department and companies" field of research, which corresponds to our second research question (see section 1.3).

In the previous sections, we provide different overviews of the ramp-up literature. We examined ramp-up definitions, boundaries and characteristics. We propose a state of the art based on the industrial context and different classifications of existing research works focusing on the ramp-up issue. However, in the light of our specific context in Siemens E T HS, we find some limits to some findings. Indeed, in the next section, we discuss the different findings of the ramp-up literature in regard to the context of the low volume industry.

Planning, control and organization		
(Simola et al. 1998)	(Almgren 1999a)	(Almgren 1999b)
(Almgren 1999c)	(Bohn and Terwiesch 1999)	(Bowersox et al. 1999)
(Di Benedetto 1999)	(Bohn and Terwiesch 2001)	(Terwiesch et al. 2001)
(Kuhn et al. 2002)	*(Apilo 2003)*	*(Nyhuis and Winkler 2004)*
(Berg et al. 2005)	*(Berg and Säfsten 2005)*	*(Juerging and Milling 2005)*
(Kontio and Haapasalo 2005)	*(Schuh et al. 2005)*	*(Berg and Säfsten 2006)*
(Carrillo and Franza 2006)	*(Juerging and Milling 2006)*	*(Meier and Homuth 2006)*
(Säfsten et al. 2006b)	*(Berg 2007a)*	*(Berg 2007b)*
(Pufall et al. 2007)	*(Winkler et al. 2007)*	*(Fransoo et al. 2008)*
Product change management		
(Fleischer et al. 2003)	*(Haller et al. 2003)*	*(Burmer and Görlisch 2006)*
(Scholz-Reiter et al. 2007)	*(Wolgast and Carlson 2007)*	
Ramp-up sturdy production systems		
(Kuhn et al. 2002)	*(Haller et al. 2003)*	*(Van der Merwe 2004)*
(Juerging and Milling 2005)	*(Juerging and Milling 2006)*	*(Säfsten et al. 2006a)*
(Säfsten et al. 2006b)	*(Winkler et al. 2007)*	*(Surbier et al. 2009c)*
Cooperation between the personnel, departments and companies involved		
(Kuhn et al. 2002)	*(Surbier et al. 2009a)*	*(Surbier et al. 2009b)*
(Surbier et al. 2010)		
Knowledge management and personnel issues		
(Simola et al. 1998)	*(Terwiesch and Yi 2004)*	*(Burmer and Görlisch 2006)*
(Fjällström et al. 2006)	*(Fjällström 2007)*	*(Winkler et al. 2007)*
(Wolgast and Carlson 2007)	*(Säfsten et al. 2008a)*	*(Säfsten et al. 2008b)*
(Fjällström et al. 2009)		

Table 3.7 – Classification of research papers according to the five action areas identified by the German "Fast Ramp-up" research project

3.5 Discussion regarding the low volume industry context

3.5.1 Ramp-up definition, boundaries and breakdown

We have seen in section 3.2.2 that the mostly accepted definition of ramp-up in the literature is the definition proposed by (Bohn and Terwiesch 1999) where ramp-up is "*the period between completion of development and full capacity utilization*". Thanks to our close relationships with industrial partners, we observed in Siemens that practitioners have difficulties to define the ramp-up in their context. Indeed, ramp-up is a phase difficult to determine because the exact boundaries of the ramp-up phase as defined by (Bohn and Terwiesch 1999) are difficult to identify in low volume industries. This can be explained as follows.

First of all, as pointed out by the literature, the "*completion of development*" is not really relevant as starting point for the ramp-up phase. In reality, development tasks are very often still on-going at SOP. During the XS case study, we observed that numerous engineering changes occurred after SOP. Furthermore, "*completion of development*" appears as a late start for ramp-up since preparatory activities have to be taken into account (Meier and Homuth 2006; Säfsten et al. 2006b; Winkler et al. 2007). During our case studies at Siemens E T HS, we noted that preparatory activities are decisive for ramp-up success. We observe for example during the XS case study that 6 months are dedicated to preparatory activities before SOP. During this period (from November 2007 to April 2008), the whole ramp-up team is involved in several crucial setting-up tasks such as:

- Setting up of physical equipment such as the assembly line, the tooling, as mentioned by (Clawson 1985; Bohn and Terwiesch 2001)
- Setting up of the physical and informational flow
    - Setting-up of the supply chain – mentioned by (Bowersox et al. 1999), (Apilo 2003) and (Meier and Homuth 2006)
    - Setting-up of the physical flow of components
    - Setting-up of the information flow in the ERP
- Setting up of the production process during the pre-production run[7].

Second, *full capacity utilization* appears as a not very relevant endpoint for the ramp-up phase in the low volume industry. Indeed, the high variety of products – which is a characteristic of the low volume industry – implies that very different products are to be manufactured by the company. Major ramp-up difficulties can still appear after the output rate has reached its final target, since a new variant of the product can appear in production one or two years after SOP.

In fact, we had the opportunity to launch an internal investigation on the performance data of previous ramp-up phases at Siemens E T HS (see Appendix I). The investigation was conducted on two ramp-up projects:

- the ramp-up phase of the XJ7 product (SOP in January 2004)
- the ramp-up phase of the XS product (SOP in April 2008).

We were able to retrieve performance data from the company data base about:

- time objectives
- quality objectives
- cost objectives.

[7] See definition section 3.2.4

The XJ7 product was investigated on a period of two years (from January 2004 to January 2006) and the XS project was investigated on a period of one year and two months (from April 2008 to June 2009).
One of the conclusions of this internal investigation is that a long period is necessary for the stabilization of production performance. Practitioners at Siemens E T HS were surprised to observe that the ramp-up period was much longer than they expected (see Figure 8.2, Appendix I). The actual reach of initial targets in cost, time or quality occurs much later than the full capacity utilization of the new production line.

Finally, we observe that Siemens E T HS never realizes pre series[8]. Thanks to the interviews of project ramp-up stakeholders and discussion with key informants in Siemens, we learn that pre-series are not realized for time and cost reasons:

- Pre-series represent an additional duration in the total ramp-up time. Since the shortest ramp-up time is desirable, practitioners are eager to suppress this phase.
- In the low volume industry, the cost of one unit of product is too high for pre-series to be carried out. Too many products cannot be manufactured for testing or demonstration purposes.

Consequently, the prototyping/ testing phase is directly followed by a pre-production run (called SIL in Grenoble, the acronym for the French “Limited Industrial Series”). Then, the output rate is gradually increased (the run-up phase) until reaching full capacity utilization.

To conclude, the following boundaries appear as relevant for the context of the low volume industry:

- The ramp-up phase begins with preparatory production[9] (namely when the first unit of the product is produced in close-to-production conditions). Consequently, we take into consideration the preparation phase of ramp-up, as mentioned in (Winkler et al. 2007) and (Säfsten et al. 2006b)
- The ramp-up phase ends when the initial capacity and quality targets are reached.

Similarly, the end of the NPD process is depicted in this dissertation as shown in Figure 3.13.

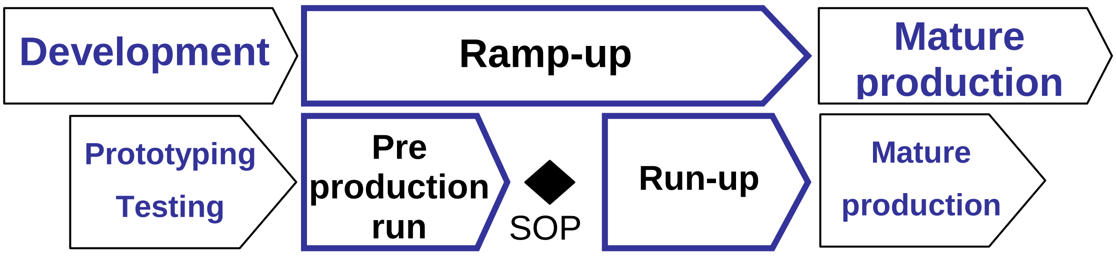

Figure 3.13 – Our process model of the end of the New Product Development process

[8] See definition section 3.2.4
[9] See definition section 3.2.4.

Finally, the research presented here uses the following terms of the ramp-up literature:

- *Pre-production run* (synonymously preparatory production), namely the phase when ramp-up preparatory activities are carried out. At the end of the pre-production run, some products are manufactured in the volume production line, even though they are not intended for the end customer (but for show or final testing purposes).
- *Run-up*, part of the ramp-up phase where output and quality are lower than mature production targets. Output volume is gradually increased until reaching both the initial capacity and quality targets.

3.5.2 Reasons to focus on the ramp-up phase and ramp-up characteristics

The ramp-up literature reports numerous reasons to focus on the ramp-up phase that we cluster in the following categories: Time, Complexity, Context, Strategy and Uncertainty (see section 3.2.5).

At the start of the research project presented here, practitioners at Siemens E T HS mentioned reasons which can be included in the above-given categories (see section 1.2):

- Practitioners at Siemens E T HS mentioned the relationship between ramp-up, time-to-market (**Time**) and profitability (**Cost**).
- They observed that they are facing more and more ramp-up phases (**Context**)
- They acknowledge management difficulties (**Uncertainty**)

In our investigation of performance data of previous ramp-up projects at Siemens E T HS (see Appendix I, section 8.1) we also observe that a long period is necessary to reach cost objectives. It confirms the feeling of practitioners that ramp-up success or failure highly impacts the profitability of the company (**Cost**).

Finally, our observations at Siemens E T HS confirm the different characteristics of the ramp-up phase itemized in the literature:

- We note that the initial level of knowledge concerning a new product is low. Workers in the workshop are very often checking product and assembly documentation. The help of an actor of the R&D department is fundamental during the pre-production run and during the first assemblies.
- We observe both in our investigation of performance data and in our different case studies that the production run-up phase is characterized by lower production output, lower production capacities and higher cycle time. Cycle time was for example multiplied by five during the pre-production run phase of the XS project.
- We thoroughly investigated the numerous disturbances that accompany the ramp-up phase during the SIE case study (see Chapter 4).

3.5.3 Findings of the microelectronics industry

The literature embedded in the microelectronics industry puts a great emphasis on the concepts of yield, learning and time pressure. We would like to discuss here the concept of yield because we believe that in the low volume industry, the notion of yield is not relevant “as is”.

In the microelectronics industry, yield is a major driver for the ramp-up phase. The end of the ramp-up phase can be determined when an acceptable level of yield is attained (Apilo 2003; Haller et al. 2003). Nevertheless, yield cannot be a relevant indicator in the low volume industry. Due to the cost of the final product, there is no scrapping of defective products. Consequently, yield level is always 100%. However, thanks to our investigation, we believe that the concept of yield can be adapted to the context of low volume industry. The equivalent to yield we can find is a combination of:

- The first pass yield, i.e. the percentage of products that are not defective when they are tested for the first time
- The rework time or cost, i.e. an indicator of the effort put to repair defective products.

Research works focusing on the ramp-up issue in the microelectronics industry also focus on learning and time pressure during ramp-up. We observe at Siemens E T HS that these are also relevant issues to consider in the low volume industry:

- We observe learning issues in the SIE case study (see Chapter 4). The lack of knowledge concerning the product or the production process is one of the major difficulties encountered during ramp-up.
- Practitioners at Siemens argue that time-to-volume is critical regarding profitability (see section 1.2). Hence, ramp-up suffers from a great time pressure.

3.5.4 Findings of the automotive industry

The literature embedded in the automotive industry strongly focuses on ramp-up KPI (key performance indicators). We carried out at Siemens E T HS a project of close follow-up of a ramp-up phase using the KPI of the mature phase. Indicators usually used during the mature phase at Siemens E T HS are:

- output indicator (output volume)
- efficiency indicator (performance)
- first pass yield indicator (quality)
- production disturbances (production stability).

We observe that these indicators are not relevant to closely follow-up the ramp-up phase. Indeed, the evolutions of these indicators do not correctly represent the actual progress of the ramp-up phase. We observe several increases and decreases that couldn’t be linked with actual ramp-up difficulties or improvements. Difficulties mentioned by ramp-up actors are not detectable thanks to the indicators.

As a consequence, we agree with research works carried out in the automotive industry: a reflection on KPI is necessary. However, due to time constraints, we weren't able to address the issue of relevant KPI for the ramp-up issue in this study.

In the automotive industrial context, Almgren also proposes a framework to evaluate the complexity of ramp-up projects (Almgren 1999a). His framework has two dimensions – the product newness and the production system newness – and each dimension has three levels: new, modified or existing (see Figure 3.10, p - 38 -). This model can be discussed in the context of the low volume industry. Indeed, the low volume industry is characterized by a very high diversity of manufactured products. For example at Siemens E T HS, the same product type comprises thousands of product variants. Each part of the product can be adapted to customer requirements, leading to a very high number of product variants. As a consequence, we believe that the "modified" level in Almgren's framework cannot be relevant in the low volume industry. "Modified" products (or "modified production system") are part of the daily production and their assembly is not considered as a specific ramp-up project. In the context of the low volume industry, we see consequently only three levels of ramp-up complexity:

- existing product – new production system, such as the start-up of the assembly of an existing product in another location (e.g. the SIE project[10] at Siemens)
- new product – existing production system, such as the introduction of a new subsystem on an existing production line (e.g. the BD project[11])
- new product – new production system (e.g. the XS project[12])

We propose an adaptation of Almgren's framework in the context of the low volume industry as shown in Figure 3.14 . In this dissertation, we will call this model the "complexity matrix".

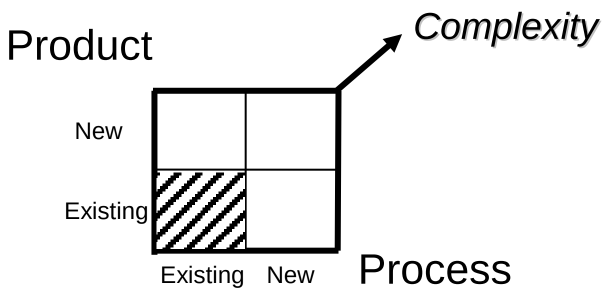

Figure 3.14 – Complexity matrix for ramp-up situations in the context of the low volume industry, adapted from (Almgren 1999a)

[10] See section 2.2.3.1 for details
[11] See section 2.2.3.1 for details
[12] See section 2.2.3.1 for details

3.6 Conclusion

In this chapter, we aim at establishing a state of the art regarding the ramp-up issue and to discuss existing results in regard to the context of the low volume industry, the context of the industrial partners of the research presented here.

Concerning the state of the art on the ramp-up issue, we propose different perspectives on the 41 research works focusing on the ramp-up issue that we found in the literature.

First, we observe that there is no general consensus on general concepts such as ramp-up definition, ramp-up characteristics or ramp-up activities, yet. For example, there are several on-going discussions about the start and the end points of the ramp-up phase. Another interesting issue is whether or not preparatory activities must be encompassed in the ramp-up phase. Similarly, there is a variety of terms related to the ramp-up notion.

Thanks to our state of the art that clusters ramp-up works according to their industrial context, we notice that all the previous research concerning ramp-up was carried out in an industrial context of mass production (microelectronics, automotive industry, consumer goods…). Hence, examining the ramp-up issue in the context of the low volume industry constitutes a breakthrough in ramp-up literature.

Due to its specificities, we find that several concepts of the previously published ramp-up literature are not relevant in the context of the low volume industry. Yield for example is not a relevant performance indicator (contrarily as in the microelectronics industry) since no product is scrapped. Therefore, we adapt several concepts and frameworks to the low volume industrial context (such as Almgren's framework for ramp-up complexity or Winkler et al.'s breakdown structure of the ramp-up phase). These adapted results will be a help for investigating ramp-up projects in the low volume industry. Next chapter presents our first investigation carried out during the ramp-up phase of a Siemens E T HS project, the SIE project. We examine ramp-up problems to gain insights from practice and for both practitioners and researchers.

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CHAPTER 4 RAMP-UP PROBLEMS

Chapter outline:

This chapter introduces our exploratory study, realized in Siemens E T HS. This exploratory study aimed at investigating the ramp-up period of a product, which was transferred from one production plant (Berlin) to another production plant (Grenoble).

Typical ramp-up problems were researched by listing all the problems that occurred during the ramp-up phase. Two different classifications of these problems are proposed, leading to problem categories. A risk assessment analysis of major problems completes the investigation.

The conclusions of this research are twofold: human resource management is key during production ramp-up and coordination and information exchange issues are the most problematic issues.

4.1 Introduction

The first case study realized in the dissertation here was performed on a project of Siemens E T HS[13], called here the “SIE project”.

4.1.1 Goals of the first case study

An important topic in ramp-up management is the handling of ramp-up problems. The earliest study related to ramp-up problems is by (Clawson 1985). In his article of the Harvard Business Review, Clawson highlights that a start-up situation is very different from mature production and that a lot of problems can be expected during ramp-up. As we have seen in section 3.2.6, high uncertainty is one of the characteristics of the ramp-up phase. Therefore, the ramp-up production environment is subject to problems, disturbances or discrepancies more often than the mature production. One of the most important activities of ramp-up phase is “*discovering and removing "bugs", problems, and missed opportunities*” (Terwiesch et al. 2001). If not taken care of, the occurred problems may cause delays in the project of a new product, resulting in major loss of profits.

In literature, there are several case studies on the ramp-up phase several of which have been the main source in identifying typical problems encountered during ramp-up (Simola et al. 1998; Bohn and Terwiesch 2001; Kuhn et al. 2002; Fleischer et al. 2003; Haller et al. 2003; Carrillo and Franza 2006). Some articles specifically focus on the type of problems that can occur (Almgren 1999c; Nyhuis and Winkler 2004; Van der Merwe 2004; Meier and Homuth 2006; Säfsten et al. 2008b; Fjällström et al. 2009). To provide a more comprehensive view of these problems, the above authors propose different problem categories. (Almgren 1999a) for example, suggests a categorization based on four main sources of disturbances: product

[13] See definition 1.2

concept, material supply, production technology, and personnel. (Van der Merwe 2004) proposes a similar categorization. (Simola et al. 1998) regroup problems in four categories: manufacturability and quick ramp-up, lack of clarity of responsibilities, procedural justice (i.e. implication of all actors in decision making) and intergroup boundaries.
However, most of the studies on ramp-up problems found in the literature are carried out in the high volume industry and more specifically, the automotive industry. Are encountered problems the same in the low volume industry[14]? The exploration of ramp-up problems in the low volume industrial context appears as a promising research area.

As our involvement in Siemens E T HS began, we had the opportunity to carry out a field study during one project, the SIE project. Both researchers and practitioners were interested by the potential results of such study. Hence, the findings of the SIE case study presented in this chapter aim at answering our first research question:

(RQ1) What are the typical problems encountered during a ramp-up situation in a low volume industry?

This research question has three sub-questions:

(RQ1.1) Can we establish typical problem types?
(RQ1.2) Within the identified problems, which issues are the most crucial ones?
(RQ1.3) Are the encountered problems similar in other industrial contexts?

We expect several benefits from the investigation of ramp-up problems in the low volume industry. First, identifying different problems which occur during the ramp-up phase could enable industrials of the low volume industry to benefit from experience-based knowledge for a better handling of these problems or future probable ones. Second, from a research point of view, identifying major problem types during ramp-up could allow us to compare them to other findings from other industrial contexts and either validate previously published results or establish new results.

4.1.2 The SIE project

The SIE project was carried out in the Grenoble plant of Siemens E T HS between July 2006 and July 2007. Its aim was to transfer the production of the SIE product from the Berlin plant to the Grenoble plant. Indeed, before April 2007, the SIE product was only produced at two locations: in Berlin, Germany and in Shanghai, China. In order to increase the global production capacity, the Grenoble plant was qualified to be a new production site for the SIE product.
The transfer project was decomposed in several steps (see Figure 4.1). The ramp-up process breakdown shown in Figure 4.1 is the breakdown introduced in section 3.5.1.

[14] A definition of "low volume industry" is given in section 1.2

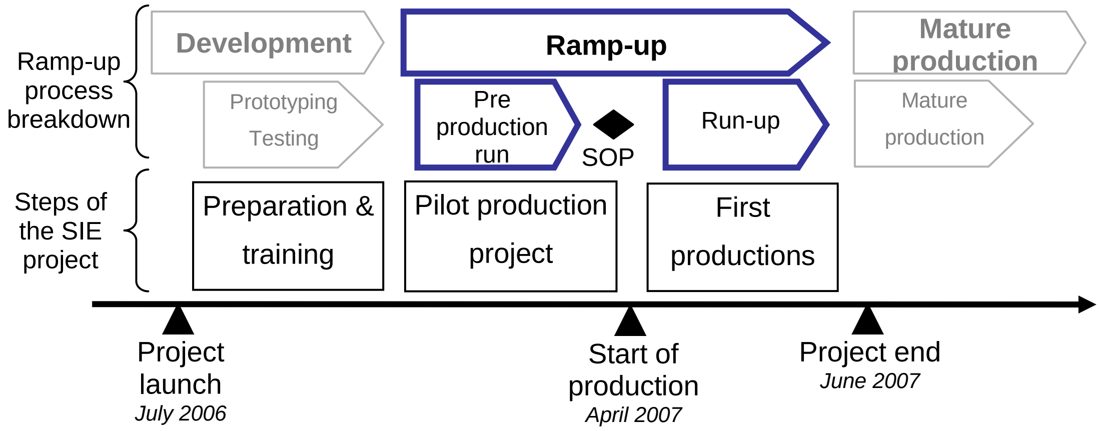

Figure 4.1 – Schedule of the SIE transfer project

When the project was launched, in July 2006, a phase of preparation and training began. Training of upstream and downstream order execution actors was organized at the Berlin plant by Berlin actors. Then a pre-production run was carried out in March 2007, in order to:

- check the set-up of physical flow of components
- check the series tools, i.e. tools used for series production
- finalize the training of workers

The pre-production run consisted in the assembly of one SIE bay. Then, start of production was scheduled for April 2007. After SOP[15], bays were manufactured for customers. The global product introduction project ended in June 2007, after the production of two customer projects (i.e. a total of nine bays). As a consequence, the ramp-up phase was considered to be over in June 2007.

A first specific characteristic of the SIE project is that it is a production transfer project. That is to say, the product was designed long before its transfer to the Grenoble plant. Production facilities already produced the SIE product before April 2007 (namely the Berlin and the Shanghai plants). The production transfer was organized between a senior plant (the Berlin factory) and a junior plant (the Grenoble factory). The senior plant had a past manufacturing experience of eight years (production began early 1999). It also had the experience of an international production transfer, since the same kind of project had been carried out to duplicate the production in China in 2001.

Another very specific characteristic of the SIE project is the way components were supplied. In fact, during ramp-up, several supply sources were used so as to manufacture the SIE bays in Grenoble (the junior plant):

[15] Start-of-production, see section 3.2.2.

- Some components were sent by the senior plant. Since the SIE product was new to the Grenoble plant, Grenoble suppliers had to be qualified[16] before being allowed to supply parts, so as to ensure the product quality. Thus, to start production in Grenoble faster whilst ensuring the quality of components, part of the components for the assembly in Grenoble was procured by the senior plant and sent to the junior plant in crates. This component flow from the senior plant in Berlin to the junior plant in Grenoble was the main supply source during the run-up phase. Further in this chapter, we name these components the "senior plant supplies".
- Some components were supplied by the suppliers of the junior plant that were gradually qualified. The objective was that parts sent by the senior plant are progressively replaced by parts supplied directly by the junior plant via its suppliers (see Figure 4.2). Further in this chapter, we name these components the "junior plant supplies".
- Fastenings were provided by a supplier of the senior plant. The orders were issued by an actor of the senior plant. The supplier was then delivering the order of fastenings to the junior plant. There was one delivery per customer project. This mode of external order / direct delivery was new for the junior plant, which used to procure its fastenings by itself.

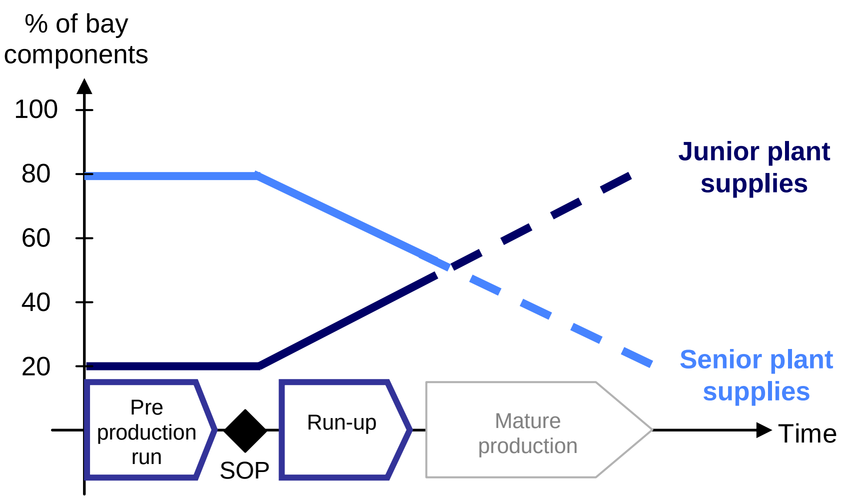

Figure 4.2 – Evolution of supply sources over time during the SIE project

The SIE project was the first project that gathered together actors from the Berlin and the Grenoble plants. Despite some difficulties (such as the language barrier between French and German, understanding problems, trust problems between actors of the two plants), the SIE project was considered a success, since it resulted in qualifying Grenoble as a new production plant for the SIE product.

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[16] Supplier qualification is the process of establishing a relationship with a supplier. The major aspect to consider in this process is to check that the supplier respects Siemens quality standards.

In the next section, we address the fact that the SIE project is a transfer project and detail the consequences for our investigation.

4.1.3 A transfer project as a specific ramp-up situation

In this dissertation, we consider the SIE production transfer project as a production ramp-up situation, as (Terwiesch et al. 2001) did in their study of a ramp-up situation in the hard disk drives industry. Indeed, the SIE project has the same characteristics as the different characteristics of the ramp-up situation itemized in section 3.2.6:

- Low initial knowledge about the product and the process: Even though the senior plant had experience concerning the product and the process; these are totally new for the junior plant. Gradual learning took place for the actors of the junior plant, thanks to regular contacts (notably business trips and trainings) between the two plants.
- Low production output and higher cycle time than in mature production conditions: Within the frame of the SIE project, the production output objective was reduced compared to the existing standards in the senior plant. The target output was divided by four during the ramp-up period in Grenoble. Likewise, the cycle time was higher during the ramp-up period in the SIE project.
- High demand: The incentives for the SIE transfer project were indeed an increasing demand on the SIE product from the market. There were high expectations on the Grenoble plant, since the Siemens group wanted to increase its market share on the market of SIE-like circuit breakers.
- High disturbances in the process, supply chain or product quality: These disturbances were both expected and noticed during the SIE project. Disturbances were expected on the supply chain, since a new supply chain was set up for the junior plant, in order to purchase the required parts for the SIE product. Disturbances in the process were expected: the production and order processes of the SIE product came from a different production policy and were totally new for the junior plant. Disturbances in the supply chain, the process and product quality were noticed and classified for it was the primary objective of the field study.

We recall the framework adapted from (Almgren 1999a) to evaluate the complexity of ramp-up projects (see section 3.3.5.2, Chapter 3). Almgren specifies that product and process “newness” should be evaluated from the point of view of the manufacturing plant experiencing the ramp-up situation. For example, “*a new product is a product not previously manufactured in a plant (however, it may have been manufactured elsewhere and transferred to a new plant)*”. According to Almgren’s definition, the ramp-up situation of the SIE project is characterized by:

- A new product, since the SIE product hadn’t been produced in the Grenoble plant before April 2007.

- A new production process, since the SIE project required new machinery, new equipment, a new layout in the manufacturing area and new supply flows.

Hence, the SIE project is classified as a very complex ramp-up project (see Figure 4.3).

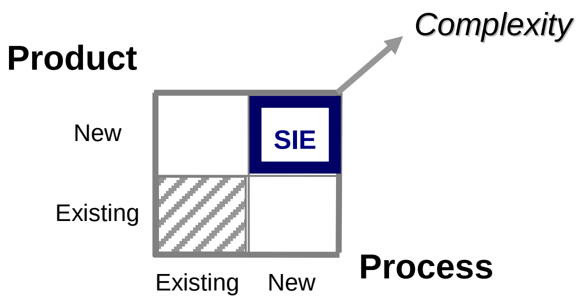

Figure 4.3 – Position of the SIE project on the complexity matrix (adapted from (Almgren 1999a))

Nevertheless, we expect the following differences between the SIE project and a ramp-up situation in the context of a newly designed product:

- In a transfer project, product data is already mature. There are far less engineering changes, design glitches, or product maturity problems which are topics acknowledged as very problematic in numerous previous ramp-up studies (Almgren 1999a; Scholz-Reiter et al. 2007; Wolgast and Carlson 2007).
- In the case of a transfer, the "new" production system of the junior plant can be in large parts copied on the existing production system of the senior plant. So the flow and the set-up are new for the workers but they can be more quickly effective thanks to the training of workers of the senior plant.

4.2 Methodological approach

The involvement of the main researcher in the SIE project on an operational position enabled us to collect data all along the production transfer project. In this section, we detail our data collection method and our data validation steps for the investigation of the SIE project. We also clarify our "problem approach": we give our definition of a problem and explain how to identify "problem statements" within our collected data.

4.2.1 Case study approach – data collection and validation

The methodological approach chosen for the investigation of the SIE project is the case study approach (see section 2.2). The main researcher of this dissertation was operationally involved in the project team between February 2007 and June 2007. Her involvement implied cross functional responsibilities. We recall that her position corresponds to a "complete participant" status, according to (Junker 2004) (see section 2.2.3.2). A summary of the main characteristics of the investigation of the SIE project is given in Table 4.1.

<u>**SIE project investigation**</u>
15 interviewees
32 interviews
21 weeks of involvement
47 meetings attended
1 meeting with project actors to carry out the FMEA[17] analysis
2 factory tours
<u>Other collected data:</u> - Minutes of meetings - Lists of components on Excel sheets: missing components, required components, specific components… - Versions of exchanged documents such as drawings, requirements, "to do" lists… - Bills of material, part descriptions and supplier descriptions in the ERP[18] system - Etc.
Feedback to interviewees: September 14th, 2007
Feedback to the steering committee: February 6th, 2008
Internal report of 66 pages, issued September 14th, 2007

Table 4.1 – Characteristics of the investigation of the SIE project

Most of the data were collected thanks to her involvement in the project.

(i) **Research notes** were taken daily, with the main goal of describing without judgment what was happening. Facts and majors events were noted down in a field research notebook.

(ii) During her involvement, the main researcher had **informal conversations** with the actors of the SIE project. These informal conversations were helpful to understand the context of the project, its major stakes and to investigate further unclear issues.

(iii) As a member of the project team, the main researcher also had the opportunity during the five months of her involvement to **attend meetings** and be the witness of different events related to the progress of the SIE project. Notes about the meetings, the participants and the discussions were added in the field research notebook.

(iv) On an ad-hoc basis, **unstructured[19] interviews** were also conducted in order to validate or to investigate further aspects of the direct observation. In these

[17] Failure Mode and Effects Analysis, see section 4.3.2.1
[18] See glossary of acronyms
[19] Unstructured interviews are interviews that tend to be informal, bordering on conversations. The interviewee is answering open-ended questions.

interviews, the main researcher looked for multiple viewpoints of the same event, taking into account the opinions and positions of the different stakeholders of the project. All the main actors of the project (including the project manager) were interviewed at least once, and other actors close to the project (from other departments of the company for example) were also consulted.

(v) Beyond the interviews and personal involvement, meaningful data were also collected from **observations**, **factory tours** (in Grenoble and in Berlin), **organizational data** on the company's intranet and various archival sources to provide a more complete picture of the context of the SIE project.

Finally, after the case study investigation, the researcher presented her findings to the SIE project actors and to key partners in the company (organized in a steering committee, see section 2.2.2) for validation (see Table 4.1). Both case study data and findings were thoroughly examined and then validated by the actors of Siemens E T HS.

For the investigation of the SIE project, we decided to have a "problem approach", that is to say that we look for "problem statements" in the collected data. We clarify in the next section the definition of a problem and describe how we identify problem statements within the collected data.

4.2.2 Collection of problem statements

To list the problems encountered during the ramp-up phase of the SIE project, "problem statements" have to be extracted from field notes, interviews and observations. Hence, an exact definition of "what a problem is" is necessary. This focus on the exact definition of a problem is important for the transparency of the field study. We define exactly what a problem is in section 4.2.2.1. Once identified, problem should also be thoroughly described to enable an exact determination of its nature (Büyükdamgaci 2003). For that purpose, we outline our method to identify problem and to establish problem statements in section 4.2.2.2.

4.2.2.1 Problem definition

According to Smith (Smith 1988), there are three necessary conditions for the existence of a problem:

- The existence of a gap between a desired state and the reality (Jonassen 2000).
- The existence of a certain difficulty. "Where there is no difficulty, there is no problem" (Polya 1962). The difficulty lies in solving the difference between the current state and the desired state.
- The problem should be important enough for the solver-to-be to be eager to spend energy in solving it. "If no one perceives an unknown, there is no perceived problem" (Jonassen 2000).

These three conditions are summarized in the following definition (Smith 1989): "A problem is an undesirable situation that is significant to and may be solvable by some agent, although probably with some difficulty".

Once its existence acknowledged, a problem should be carefully described. Actually, having a precise description of a problem is really useful for two major reasons:

- Since it has no physical existence, describing a problem is the first necessary step in order to seize the problem. For Smith (Smith 1989), problem definition is the first step of problem solving.
- A thorough description is helpful to grasp the exact nature of a problem and to view the desired state the solver-to-be wants to reach. Problem definition is thus the "best defense against Type III Error, solving the wrong problem" (Smith 1989).

In the next section, we propose a method to describe problems and thus identify problem statements within the data collected in the field.

4.2.2.2 Problem approach

Problem definition and problem description are two key issues in a problem approach of the ramp-up situation. Here, we detail the way to describe problems that we used during our investigation of the SIE project. Our method is derived from the 5W method. The "5W" is a well-known method to describe a situation. This method aims at describing five attributes of a situation:

- who is concerned,
- what it is about (topic),
- when it happened (time),
- where it happened (place),
- why it happened (causes)

However, the 5W method is not "as is" relevant for describing a problem. Indeed, as it is said in the definition of what a problem is, a problem is not really a "situation". It is a gap between two situations (Smith 1988), a difference between a current state and a goal state. Furthermore, for some problems, it is very difficult to define its exact time or place. For example, which time and place can be attributed to a communication problem between two project stakeholders? Consequently, we propose to slightly adapt the "5W" method to suit our purpose of "problem description". We propose a method which is a modified version of "5W": in our study, a problem statement is composed of the description of:

- who is concerned (same as 5W method);
- where the problem lays, i.e. the description of "the gap" (to this end, we describe both the actual and the desired situation)
- why the problem occur, that is to say what the possible causes of the problem are (same as 5W method)

Based on the above method, we have identified and established a list of 107 statements of problems encountered during the transfer project under study. Some of these problem statements are given in Appendix II (see section 8.2).

4.3 Problem classifications

After the identification of the 107 problem statements, our goal is to classify them so as to build homogeneous classes of problems from which "problem types" could be extracted and thus knowledge gained about typical critical issues during ramp-up in a low volume industry.
An important point about classifying problems is that the method employed to classify has a great influence on the result. The classes (and thus the problem types) found are totally linked to the way the problem statements are ordered. Finding criteria to dispatch problems in one category or the other is very crucial. In this section, we will propose two different classifications of our set of 107 problem statements: a resource-based classification and a cause-based classification.

4.3.1 Resource-based problem classification

The first method employed to classify the 107 problem statements is similar to the one presented by (Harper and Rainer 2000) for classifying problem statements in the technology transfer area. The aim of their study was to develop a classification method for problem statements in technology transfer assistance requests. To create a logical classification (easy to understand and easy to use), the authors state several guidelines to follow. Their most important guideline is to determine top-level categories by a problem attribute present in each problem statement. In their study, they identified the "physical or non-physical resource" as a general attribute of the collected problem statements. The key point of the classification methodology presented by (Harper and Rainer 2000) is that it leads to a self-constructed classification (see the algorithm in Appendix III, see section 8.3). Problem categories emerge as problems are classified.
Following the guidelines defined by (Harper and Rainer 2000) leads to the classification of the 107 collected problem statements illustrated in Figure 4.4. We call this classification the resource-based classification.

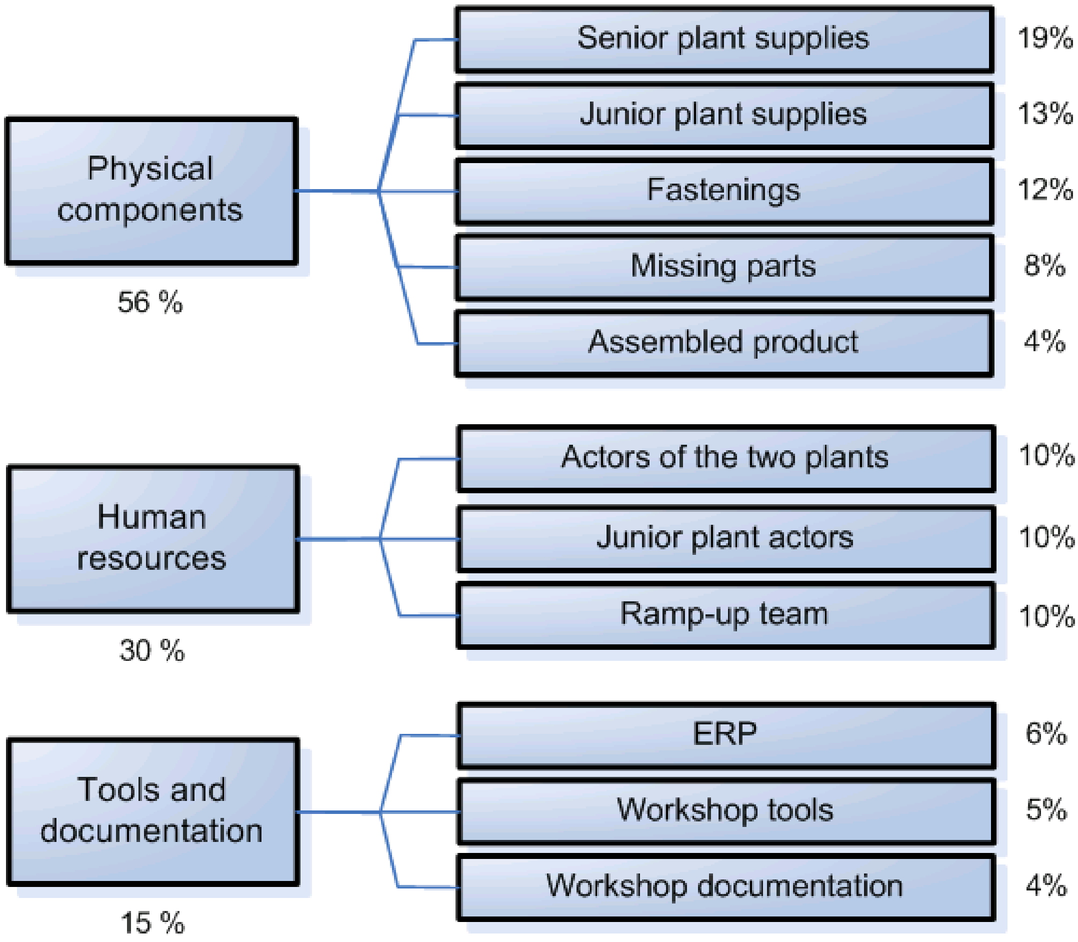

Figure 4.4 – First classification of the 107 problem statements – the resource-based classification

Harper and Rainer's guidelines lead to three top-level categories: Physical Components, Human Resources and Tools and Documentation.

The first category, the "Physical Components" category, gathers problems focusing on a part of the product. For example, the problem statement number 11 (see Appendix II, section 8.2) concerns the supply of fastenings (a physical component of the bay) and thus it belongs to the "Physical Components" top-level category.

The second top-level category assembles problems focusing on human resources. Problems concerning coordination or motivation of the different actors involved in the project belong to this category. Problem statement number 20 for example (see Appendix II, section 8.2) refers to the overload of two project actors of the junior and the senior plants: it is ordered in the "Human Resources" category.

The last top-level category contains problem statements focusing on a tool or a document used by project actors. For example, the problem statement number 2 (see Appendix II, section 8.2) is about the handling of the ERP: it belongs to the "Tools and Documentation" category.

The top-level categories are divided into second-level categories, which detail the resource focused on in the problem.

Five second-level categories are extracted from the "Physical Components" top-level category:

- The "**Senior plant supplies**" category, where problems concerning the components shipped from the senior plant to the junior plant are listed (see section 4.1.2)
- The "**Junior plant supplies**", which contains problems regarding the parts supplied directly by the junior plant via its suppliers (see section 4.1.2)
- The "**Fastenings**" category, with the problem statements focusing on fastenings. For example, problem statement number 11 (see Appendix II, section 8.2) belongs to this category.
- The "**Missing parts**" category, including problems in regard to part that were missing during the assembly
- The "**Assembled product**" category, which gathers together problems concerning the final product (its shipment, its transportation…)

The "Human Resources" top-level category is divided into three second-level categories:

- The "**Actors of the two plants**" category, including problems that concerned actors of both the senior and the junior plants. Problem statement number 20 (see Appendix II, section 8.2) for example is ordered in this category.
- The "**Junior plant actors**" category, which contains problems encountered by project actors of the junior plant only (coordination problems between departments …).
- The "**Ramp-up team**" category, including problems that concerned only members of the ramp-up team (motivation problems, workload problems…).

Three second-level categories are included in "Tools and Documentation":

- The "**ERP**" category, with problems referring to the ERP system (access problems, no dedicated interface…)
- The "**Workshop tools**" category: several tools were missing or unsuitable when the production began.
- The "**Workshop documentation**" category, gathering difficulties regarding production documents (access problems to the assembly instructions, to product BOM …)

The final result is that the resource-based classification presented in Figure 4.4 highlights 11 problem categories (in bold in the precedent paragraph). These problem categories correspond to eleven different problem types that were encountered during the SIE project. The percentage of problem statement of each top-level and second-level category is given in brackets (see Figure 4.4). We conclude that two major resources concerned by ramp-up difficulties are components – from all the different supply sources – and human resources. Indeed, among the biggest top-level category ("Physical Components" – 56% of the problem statements) secondary supply processes are the source of a higher amount of problems than the principal supply flow: the senior plant supplies (which corresponds to the principal supply flow during the ramp-up phase, see section 4.1.2) caused 19% of the problems while the “junior plant supplies” and the “Fastenings” categories total up 25% of the problem statements. The resource-based classification emphasizes the importance of secondary supply processes. There are several different sources of supply and each one can be problematic in its own way. Furthermore, the “Human resources” problem category represents 30% of the stated problems. It is unexpected that human resources are concerned by such an amount of problems. It stresses the importance of human resources during a ramp-up project.

The resource-based classification in Figure 4.4 displays percentages for problem type, that is to say an insight about the total amount of problem statements in each problem category. However, no further analysis is made on the real impact of each disturbance on the ramp-up phase, since each one has the same weight (1/107). As a result, we propose a further analysis to understand the relative importance of each problem and to measure its impact on the ramp-up process. In the next section, we detail the risk analysis we conducted to evaluate the impact of each problem on the ramp-up situation.

4.3.2 Risk analysis

In this section, we propose to evaluate the impact of problems using the risk assessment procedure of the FMEA (Failure Mode and Effects Analysis).

4.3.2.1 FMEA approach

The FMEA method is a tool for systematic analysis of potential failures of a product, a process or an installation. This method is used to find and evaluate the criticality of failure modes. Thanks to FMEA risk assessment approach, the failure modes are ranked by importance. Then, actions about the most critical failure modes are determined so as to reduce their related risks (MIL-STD-1629A 1980).

Risk assessment is done in calculating the Risk Priority Number (RPN) of each failure mode. RPN refers to the multiplication of Severity (the outcome of a failure), Probability (the chance of a failure) and Detection (the chance a failure is not detected by internal actors or customers).

The risk assessment approach of the FMEA tool was chosen to assess the impact of encountered problems on the ramp-up phase because we believe that this approach is very interesting. The decomposition of the risk of a problem into severity, probability and detection is an interesting approach of the different aspects of a problem impact. We think that the Risk Priority Number of a problem is proportional to his impact on the ramp-up phase.

Further, we chose the FMEA tool among other impact evaluation tools in this case study because it is a widely known tool within the companies. Indeed, several field studies about Total Quality Management mentions the widespread use of FMEA in companies (Tari and Sabater 2004; Herron and Braiden 2006; Karim et al. 2008). FMEA is also used in different research works with different purposes, such as for example, the improvement of ERP introduction (Lin et al. 2006) or improvement of the reliability of customer order fulfillment (Turner et al. 2002). Finally, the concept and rationale of the FMEA tool are known by the SIE project actors, an element which facilitates its utilization in the context of this case study.

4.3.2.2 Methodology

The set of problem statements concerned by the risk analysis was reduced to 46 statements for two reasons. First, for practical reasons, the 107 statements could not be taken into account. Indeed, we aim at having a precise and relevant assessment of each criterion (severity, occurrence and detection) of each problem statement. Hence, we decide to select a smaller set of problem statements to perform the FMEA analysis. Second, one of the conclusions of the resource-based classification is that different sources of supply exist and each one can cause problems during the ramp-up phase. It appears interesting to focus on the relative importance, and similarly the impact on ramp-up, of these different sources of supply. Therefore, we choose problem statements that are related to the different sources of supply. In fact, the risk assessment analysis (based on FMEA criteria) is constructed for the following problem statements:

- Senior plant supplies
- Junior plant supplies
- Fastenings

These three problem categories represent 46 problem statements – 43% of the total amount of problem statements. They are the three biggest problem categories of the resource-based classification in terms of amount of problem statements.

In our field study, the assessment of the chosen problem statements was realized by the actors who participated in the production ramp-up project. Each actor of the SIE project was given the 46 problem statements. A recall of the principles of the FMEA assessment tool was given. Then each project actor was asked to fill in its assessment (level of probability, level of severity and level of detection) of each problem statement based on experience and project knowledge. The result presented is the mean of the obtained values, except for criterion values with a standard deviation bigger than 1,5. For the latter, a group value was agreed on by the SIE project actors during a group meeting (see Table 4.1).

The results and the final ranking were presented to and validated by both the SIE project participants and key stakeholders of Siemens E T HS[20] (see Table 4.1).

4.3.2.3 FMEA ranking

The risk assessment of the set of 46 problem statements of the resource-based classification leads to a final ranking. Only top ten problems are shown in Table 4.2.

[20] Members of the steering committee of this research, see section 2.2.3

Problem Statement Category (Harper and Rainer's classification's)	Problem statement number	**Probability** 1=low 5= high	**Severity** 1=low 5= high	**Detection** 1 = easy 5= hard	**Risk Priority Number**
Fastenings	**11**	5	5	5	125
Fastenings	**58**	5	5	4	100
Fastenings	**65**	5	5	4	100
Fastenings	**92**	5	4	5	100
Senior plant supplies	**100**	5	4	5	100
Fastenings	**51**	4	5	4	80
Fastenings	**26**	5	4	4	80
Fastenings	**96**	5	4	4	80
Fastenings	**54**	5	3	5	75
Senior plant supplies	**104**	3	5	5	75

Table 4.2 – Top ten of the problem impact ranking according to FMEA risk analysis

The conclusion of the risk analysis and the ranking shown in Table 4.2 is that out of all the components (and their different flows) the problems having a higher risk priority number are problems encountered on fastenings. We can deduce from this that these problems are the most critical problems encountered. Fastenings seem to be very insignificant components (“only bolts and nuts”) and yet they have been the origins of the most impacting problems.

Next section introduces the second classification of our set of 107 problem statements, which aims at compensating the first classification’s shortcomings.

4.3.3 Cause-based problem classification

Harper and Rainer’s classification method, which leads to the resource-based classification shown in, has several advantages. First of all in this classification each problem can be stored in a unique category because only one resource is focused in each problem statement and the clustered problems share the same problematic resource. Thus there is no hesitation about where to classify a problem statement. Secondly, the guidelines provided by (Harper and Rainer 2000) procure a very effective way of bracketing problem statements. The obtained classification is very intuitive. However the classification shown in Figure 4.4 also has downsides. Trying to classify more problems could lead to a substantial increase of problem categories. Moreover, this classification doesn’t highlight the main reasons or causes of the problem. This is a downside regarding problem solving. For example, if two different components are concerned by the same kind of problem (i.e. a unique cause led to these two problems), the two corresponding problem statements won’t be stored in the same problem category, because the resource focused on is not the same. In the resource-based classification presented in Figure 4.4, the problem types are homogeneous regarding the resource focused on but not regarding the origin of the problem. Therefore, in this section, we propose another classification method, focusing on the principal cause of the problem.

For the 107 problem statements, the main problem sources given in the problem statements were gathered. Three main sources were identifiable: (i) knowledge & information; (ii) cooperation and (iii) human resources management. Refining these causes (into second-level categories) leads to slightly different classification (see Figure 4.5) which entails nine problem categories.

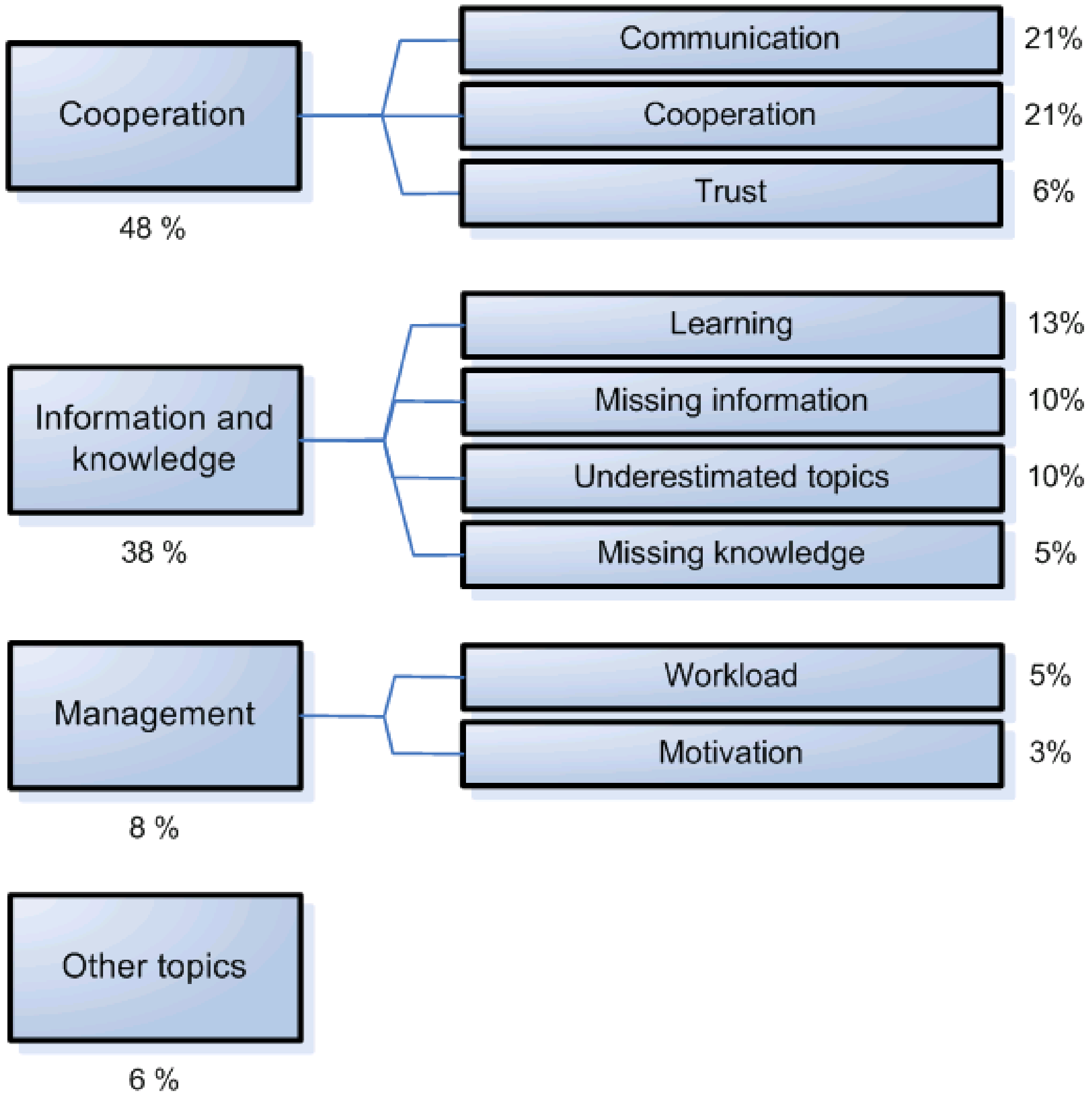

Figure 4.5 - Second classification of the 107 problem statements – the cause-based classification

In this classification, called the cause-based classification, the clustered problems share the same origin.

The nine final problem types (in bold) are described hereafter:

- The “**Communication**” category, which includes problem statements mentioning a communication problem as their main origin. For example, problem statement number 104 refers to a supply problem regarding senior plant supplies, which was caused by a lack of communication between the senior and the junior plant (see Appendix II, section 8.2).

- The “**Cooperation**” category gathers together problems which are caused by a failure in cooperation between project actors. For example, problem statement number 9 report a marking error on the senior plant supplies that led to a wrong storage (see Appendix II, section 8.2). It originated in a cooperation problem between the junior plant and the senior plant: project actors didn’t succeed into labeling the supplies correctly.
- The “**Trust**” category, where problems rooted in a lack of trust between project actors are clustered. Problem statement number 36 for example reports the difficulty for the junior plant to order to the senior plant a missing component (see Appendix II, section 8.2). This problem is due to lack of trust of the senior plant actors in the word of junior plant actors.
- The “**Learning**” category, where are ordered problem statements which focus on difficulties rooted in the gradual learning of the junior plant. For example, problem statement number 85 is about the problematic shipping of additional material that has to be sent with the bay to the customer (see Appendix II, section 8.2). It is due to the time needed by the junior plant for gaining experience about this topic.
- The “**Missing information**” category, which includes problem statements mentioning difficulties caused by an access problem to information, a lack of information to perform a task…
- The “**Underestimated topics**” category, gathering together problem statements regarding difficulties encountered by project actors because they underestimated the importance of some topics (fastenings for example, see in Appendix II, section 8.2, problem statement number 58 about the late delivery of fastenings).
- The “**Missing knowledge**” category, where are clustered problems rooted in a lack of knowledge or difficulties in sharing knowledge between the junior and the senior plant. For example, problem statement 26 is about the sharing of knowledge needed for identifying fastenings (see Appendix II, section 8.2).
- The “**Workload**” category, where are ordered problem statements which mention difficulties due to the workload of ramp-up actors.
- The “**Motivation**” category, which includes problem statements referring to the difficulties that are caused by the lack of motivation of project actors.

Six problem statements couldn’t fit into any of the nine above-mentioned categories. They are gathered together in the “**Other topics**” category.

To conclude, the cause-based classification highlights that most of the ramp-up difficulties have cooperation or information exchange as origin.

In the next section, we conclude on our investigation on ramp-up problems carried out during the SIE project at Siemens E T HS. We present practical implications of our findings for our industrial partners and the conclusion for the research presented here.

4.4 Conclusions on the problem approach

In this section, we present the concrete proposals we make to our industrial partners at Siemens E T HS Grenoble, regarding the findings of our investigation of problems during the ramp-up phase. Indeed, we recall that the research presented here aims at creating new actionable knowledge for practitioners. Then we conclude on our findings from a research point of view.

4.4.1 Conclusion for practitioners

There are several practical implications from the findings presented in the previous sections. Indeed, the resource-based classification highlights that problems concerning components or human resources total up more than 80% of the problems encountered during ramp-up. The risk analysis performed on supply problems demonstrates that every source of supply can be problematic, even small sources (such as the provision of fastenings). Lastly, the cause-based classification stresses that more than 85% of the problems originate in information exchange or cooperation difficulties. Considering these results, we proposed four measures to our partners at Siemens E T HS.

First of all, to overcome difficulties concerning components (56% of the problem statements), we propose that the supply chain coordination on a global point of view is taken care of in next up-coming projects. For this purpose, we suggest that a dedicated actor is appointed in future ramp-up projects. S/He will be responsible of supply flows set-up and of ensuring the action coordination all along the supply chain.

Second, to overcome difficulties concerning fastenings (problems identified as having the greater impact on the ramp-up phase), we propose to reinforce the supply of fastenings. We suggest that the relationship with the supplier becomes tighter. We advise that a dedicated resource from the Purchasing department is appointed as major contact person for the fastening supplier and for project actors within Siemens.

Third, the resource-based classification outline that difficulties also arise from tools, such as the ERP system for example. We suggest that future ramp-up project managers are aware of the importance of tools. This topic must be especially considered in future projects, to reduce difficulties concerning tools and to improve information exchange and coordination thanks to these tools.

Lastly, to overcome information exchange and coordination difficulties, we propose that ramp-up projects are always managed by a dedicated ramp-up team. It was the case on the SIE project and we believe that it contributed to the final success of this project. We suggest that a dedicated office is attributed to the team and that regular meetings are organized for the involved stakeholders of the project. Indeed, dedicated actors gathered together in the same office can easily share information and perform tasks together. Moreover, regular meetings with involved stakeholders can improve information exchange and coordination during the project.

These four propositions of organizational changes were implemented in the following ramp-up projects of the Grenoble plant of Siemens E T HS (on the XS and the BD project, notably). Feedback on the effectiveness of these proposed practical measures is given in Chapter 7.

4.4.2 Conclusion for researchers

The research on ramp-up problems in the low volume industry presented in this chapter aims at answering our first research question:

(RQ1) What are the typical problems encountered during a ramp-up situation in a low volume industry?

Our goal is to establish typical problem types, to identify the most crucial problems and to compare our findings to other industrial contexts.

4.4.2.1 Typical problem types and most crucial problems

Thanks to the resource-based classification (see Figure 4.4) and the cause-based classification (see Figure 4.5), we identify two sets of typical problem types of the ramp-up phase in the low volume industry.

Resource concerned	**Problem origin**
Senior plant supplies	Communication
Junior plant supplies	Cooperation
Fastenings	Trust
Missing parts	Learning
Assembled product	Missing information
Actors of the two plants	Underestimated topics
Junior plant actors	Missing knowledge
Ramp-up team	Workload
ERP	Motivation
Workshop tools	
Workshop documentation	

Table 4.3 – Typical problem types in the low volume industry

Furthermore, the risk analysis performed on 46 problem statements of the resource-based classification (see section 4.3.1) leads to the conclusion that supply appear as being the most crucial issue during ramp-up situation, especially supply of components of secondary importance to the product. Supply difficulties that have the greater impact on the ramp-up phase are encountered on minor parts. Hence, a special attention should be paid to each part of the global supply chain and not only to the principal materials flow. In addition, this result points out that the piloting methods which are convenient for a mature product are not necessarily relevant for the production ramp-up. Typically, for a mature product, the principal materials flow which encloses the type A parts are controlled with full attention, while type C parts (like fastenings in the SIE project) receive minor attention. Consequently, we believe that the classical production control methods are not completely suitable for an effective follow-up of the production ramp-up, a belief supported by literature (Nyhuis and Winkler 2004; Meier and Homuth 2006)

Moreover, we believe that this result is typical of the context of the case study namely the low volume industry. In fact, several cases have been conducted in the microelectronics industry (see section 3.3.1). In the microelectronics industry supply isn't the major issue since a product isn't made of numerous components. The focus is for the most part laid on the efficiency of the production process (yields). In the automotive industry, supply also is outlined as being a problem category. However, we couldn't find any classification that detailed further the different supply problems. Besides, we think that supply problems may be handled differently in the automotive industry, due to the high power of automotive OEM[21] on their suppliers. In his case study, (Almgren 1999a) describes "*frequent delivery of small quantities of materials*" (p. 82), "*just-in-time*" supply (p. 58). These are not supply methods that can be used in low volume industry, due to the low power OEM has regarding their suppliers. As a consequence, supply problems may be more problematic in the case of low volume industries than in the case of the automotive industry.

4.4.2.2 Comparison with other industrial contexts

Our findings are similar to other findings of the ramp-up literature derived from high volume industrial contexts.

The problem types established thanks to the resource-based classification are very comparable to the "sources of disturbances" found by (Almgren 1999a) (see Table 4.4) in the context of the automotive industry.

Indeed, Almgren's "*Material flow*" category is similar to the "Physical Components" top-level category of the resource-based classification: it includes problems concerning quality, availability of different components of the product. Almgren's source of disturbance called "*Work organization*" is close to our "Human Resources" category of the Resource-based classification: it comprises problems related to the management, the definition of responsibilities… Finally, Almgren's "*Production technology*" category is similar to our "*Tools and Documentation*" category (problems concerning adequacy of tools, availability of workshop tools…).

[21] Original Equipment Manufacturer, see section ACRONYMS.

Source of disturbance
I. Product concept
II. Materials flow
III. Production technology
IV. Work organization

Table 4.4 – Disturbance sources, according to (Almgren 1999a)

The only difference between Almgren's list and the resource-based classification is Almgren's "*Product concept*" source of disturbance. Indeed, such disturbances are not encountered in the SIE project, since the product is mature in terms of design (the SIE project is a transfer project, see section 4.1.3).

The resource-based classification presented in Figure 4.4 can also be compared to (Fjällström et al. 2009)'s classification. In their case study realized at a Swedish automotive company, the authors propose six problem types:

- process
- suppliers / supply
- product / quality
- equipment / technique
- personnel / education
- organization

Similarities can be found:

- between "*suppliers / supply*", "*product / quality*" and the "*Physical Components*" category of the resource-based classification
- between "*personnel / education*" and the "*Human Resources*" category of the resource-based classification
- between "*equipment / technique*" and the "*Tools and Documentation*" category of the resource-based classification

We conclude that, with respect to the resource concerned, problem types are similar in the low volume industry and in other high volume industries. However, there is no possibility of comparison on the relative importance of these different problem types since we found no other studies giving the same statistical metrics. As explained in the previous section, we believe that supply problems are more crucial in the low volume industries, due to its specificities (high amount of parts, low power of OEM regarding their suppliers).

As for the problem types identified thanks to the cause-based classification, we find similarities with other research works, notably mentioning "information exchange" or "cooperation" problems. For example, in their case study within small and medium-sized enterprises of diverse high volume industries in Germany, (Meier and Homuth 2006) classified the “failures, inconsistencies and problems” into five problem areas, two of them being “Information and communication” and “Cooperation in the network”. (Nyhuis and Winkler 2004) also classified problems into seven categories, according to the “causes of problem encountered during ramp-up”. The authors also mention “cooperation” as a cause of problems encountered during ramp-up. Consequently, our cause-based classification validates previous findings in confirming that cooperation and information exchange are major issues during the ramp-up phase.

In fact, this is also supported by experience of practitioners at Siemens E T HS. To their opinion, cooperation and information exchange difficulties are at the heart of reduced effectiveness in ramp-up situations. Consequently, we propose to go further into detail about the cooperation and information exchange issues. The next chapter presents the interface model and the analysis grids focusing on the project interfaces that were developed to study in depth the interactions between project actors, so as to improve cooperation and information exchange.

CHAPTER 5 INTERFACE APPROACH

Chapter outline:

This chapter presents the interface model and the auditing tool we designed so as to investigate actors' interactions during ramp-up. Several incentives, in the literature or in the industrial context of Siemens, urge to investigate further information exchange and cooperation problems at the interface between ramp-up actors. The interface model proposed here is built on previous models and concepts found in the literature. It aims at describing interface characteristics with a set of meaningful concepts (about the dynamics of information or the impact of information for example). The interface model is used to develop an auditing tool (composed of two evaluation grids and a summary diagram) so that interface can be investigated with practical and concrete tools and evaluation rules in a field study

5.1 Introduction

In a first case study carried out at Siemens E T HS, major problems encountered during a ramp-up situation in a low volume industry context were outlined. The investigation carried out on the SIE project highlights that cooperation and information exchange between project actors are critical issues during ramp-up. Indeed, cooperation is essential to ramp-up projects (Juerging and Milling 2005; Säfsten et al. 2008a) and is often mentioned in the literature as being an important source of disturbance and a hindrance to production ramp-up success (Langowitz 1987; Simola et al. 1998; Säfsten et al. 2006b). This results in a deep interest, from both academics and practitioners' sides, for investigating further cooperation and information exchange problems between project actors in ramp-up situations.

The concept of interface is an interesting concept to investigate cooperation and information exchange in a complex situation with numerous actors. In the research presented here, the concept of "interface" is defined according to the management science literature. Interface is the collection of links and interactions existing at the boundary of different industrial functions that support communication and coordination. The concept of interface was not – to the best of our knowledge – more deeply investigated in the case of production ramp-up situation. We see there an interesting opportunity. As a consequence, the research presented here aims at answering our second research question:

(RQ 2) How can we characterize the interface situation between project actors during ramp-up?

To characterize interface situation, we look for a model that would enable the characterization of exchanged information between ramp-up actors. The model should enable the depiction of information flows. It should focus on actors involved in the ramp-up and make it possible to investigate characteristics of the exchanged information in terms of dynamic, structure …

This chapter is structured as follows. Section 5.1.1 and section 5.1.2 detail the literature and field incentives that led to the investigation of this particular topic. Then section 5.2 presents several models we found in the literature that could describe information exchange or cooperation mechanisms between actors. In section 5.3, we present the interface model we propose here, based on existing concepts and models of the literature. Finally, section 5.4 describes the auditing tool we design, based on our interface model.

5.1.1 Literature incentives

To our mind, the literature provides three incentives to investigate the issue of cooperation and information exchange during ramp-up.

First of all, cooperation and information problems are often reported by field studies about the ramp-up phase. One of (Nyhuis and Winkler 2004)'s category of problems encountered during ramp-up in the automotive industry is "cooperation and communication". Similarly, (Säfsten et al. 2006a) mention that "*people as success factor*", including problem issues such as "*cooperation, information, conflicts/cultural differences*", is an important aspect affecting the ramp-up phase. (Apilo 2003) defines ramp-up as "a co-operative process". In her study, she aims at improving the "*co-operative effectiveness and efficiency*" between OEMs and CEMs. The maturity of information can play an important role in production ramp-up difficulties: (Säfsten, et al. 2006a) noticed disturbances due to "*continuous engineering changes*", which is an insight of non mature product information and (Scholz-Reiter, et al. 2007) describe "*situations of diffuse fuzzy states of information*" that disturbed the production ramp-up phase and mention numerous ramp-up problems concerning the communication between employees of different disciplines. For (Apilo 2003), communication between cross-functional teams is a success factor of ramp-ups in the electronics industry.

Second, problems at "the interface" or at the "boundaries" of teams or actors are often reported during production ramp-up. (Säfsten, et al. 2006a) investigate the impact of preparatory activities on ramp-up success and point out the criticality of communication problems between departments involved in the New Product Development (NPD) project. (Simola et al. 1998) focused on the disturbances encountered during a specific NPD project and its production ramp-up stages and argue that the main reason for difficulties during the ramp-up can be found in the "*co-ordination and communication processes, i.e. the intergroup boundaries*[22]". (Scholz-Reiter et al. 2007) who have investigated the issue of technical product changes mention "*complications at the interface between product development and production*". During production ramp-up, one of the major interfaces is the R&D (Research & Development) – Production (or manufacturing) interface. Two papers specifically investigated this R&D – Production interface:

- Adler proposed a taxonomy of coordination mechanisms for the "design/manufacturing interface" throughout NPD (Adler 1995).

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[22] Intergroup boundaries refer to the interactions between two project groups, here the R&D group and the Production group.

- Vandevelde and Van Dierdonck identified five major barriers to design/manufacturing integration: personality differences, cultural differences, language barriers, organizational barrier and physical barrier (Vandevelde and Van Dierdonck 2003). They advise to promote design-manufacturing communication and collaboration and to provide actors more opportunities to interact.

Third, ramp-up is considered in the literature as a “transfer”, i.e. transitory phase requiring cooperation and information exchange for its knowledge transfer. As a matter of fact, there are two aspects of transfer within a ramp-up project:

- The transfer of the ownership of the NPD project and consequently of the project responsibilities (Meier and Homuth 2006). Around SOP, the project is transferred from the design team to the production team – i.e. from the R&D department to the Production department (Langowitz 1987; Säfsten et al. 2008a).
- The physical transfer of design results from a laboratory-like environment into series production (Langowitz 1987; Juerging and Milling 2005; Säfsten et al. 2006a). Consequently, the issue of the manufacturability of the product is often raised (Langowitz 1987).

These two transfer aspects require a close cooperation between ramp-up teams and call for an intense information exchange between ramp-up stakeholders. As a result, the issue of project interface seems particularly promising in order to go into detail about the cooperation and information exchange between project actors during ramp-up.

5.1.2 Field incentives

Additionally to the three incentives provided by literature, there are also practical reasons (i.e. from our industrial context) that urge upon investigating further cooperation and information exchange via the analysis of project interfaces.

First of all, practitioners at Siemens E T HS reported that numerous actors are involved during production ramp-up. A production ramp-up project impacts all company departments: R&D, Production but also Procurement, Quality, Warehouse (see section 2.1.1). Different tasks to perform are split up into work packages. Since project actors have to meet a common goal and that activities are very often interrelated, they have to develop “interfaces” between their teams. They have to achieve coordinated tasks, to perform cooperative work and above all to exchange information. A thorough analysis of the project interfaces should bring a lot of insights about how the project actors interacted in order to succeed in ramp-up projects.

Second, the conclusion of our second classification of ramp-up problems (see section 4.3.3) is that cooperation and information exchange issues are critical issues during ramp-up.

As a consequence, investigating project interfaces to clarify cooperation and information exchange problems between ramp-up actors seems also interesting from practitioners’ point of view.

Lastly, our first investigation on production ramp-up problems (see section 4.3.1) pointed out that human resources were a capital resource and that supply problems were numerous.

These results advocate examining the specific production / procurement interface, from the point of view of exchange between project actors.

Once the issues to investigate identified, and the different reasons for this choice detailed, the next topic to be tackled is the approach taken to investigate cooperation and information exchange at the interfaces between projects actors.

5.2 Model for investigating cooperation and information flows

Several models exist to investigate interface situation and information flows. In the following sections, we detail four models found in the literature. We looked into domains such as management, supply chain management and operations management.

5.2.1 The activity model

A first model is available in the management literature: the activity model. A first step towards the final framework of the activity model was developed by (Vygotsky 1962) a Russian psychologist, which introduces a third element (the artefact) in the interaction between a subject and an object (Perrin 2008). This triangular model was enriched by (Leontiev 1981) and then (Engström 2000) to become the activity model.
The activity model articulates a subject and an object in depicting the mediating artefacts, the rules, the community and the work division (see Figure 2.1).

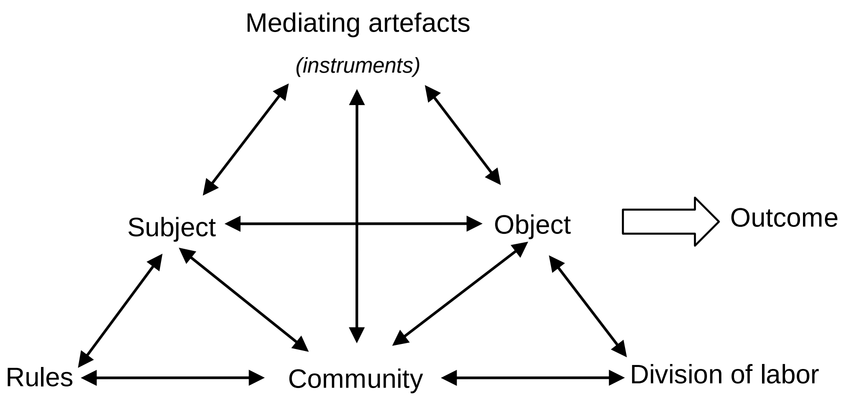


Figure 5.1 – Activity model, adapted from (Engström 2000)

However, this framework only takes into consideration one subject and one object. It does not take into consideration several stakeholders. As a consequence, it is not convenient to describe an interface situation in our context.

5.2.2 The information flows analysis framework

Another model is presented by (Forza and Salvador 2001). The authors present a framework for the analysis of information flows in operations management.

They decompose processes of manufacturing firms into three broad processes:

- The physical transformation process
- The logistics process
- The product development process.

They divide the possible information flows into three types of flows:

- Horizontal flow – internal communication crossing hierarchy lines
- Vertical flow – superior/subordinate communication
- External flow – firm/supplier and firm/customer communication.

Their framework for analyzing information flows is shown in Figure 5.2.

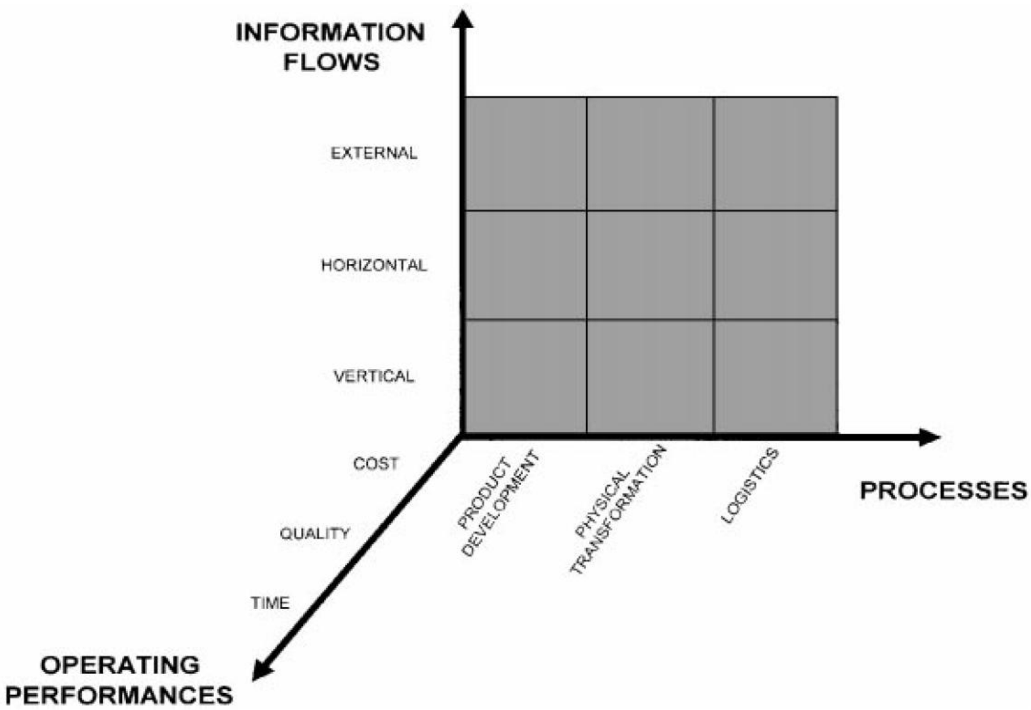


Figure 5.2 – Framework for the analysis of information flows, according to (Forza and Salvador 2001)

According to the authors, the framework can be used by practitioners as a tool for addressing in a comprehensive way the problem of information delivery and exchange in a manufacturing firm. It can be applied regardless of the communication media adopted.

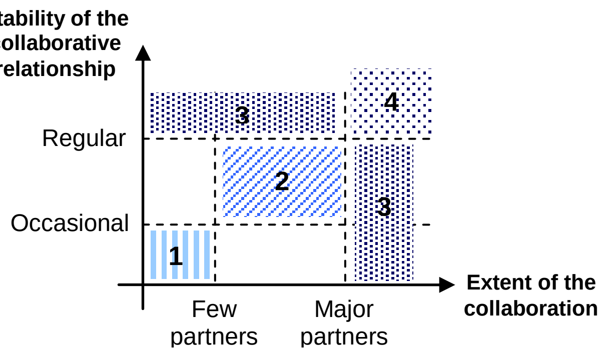
Unfortunately, the framework presented by (Forza and Salvador 2001) does not distinguish between formal and informal information flows. Moreover, it doesn't go very much into details: once categorized in one of the nine boxes, no further detail is given about the information exchange. Furthermore, it is a framework for analysis; it gives little insights about how to improve information exchange. Users are not displayed.

5.2.3 The collaborative situations' grid

A third model is presented by (Gruat La Forme et al. 2007). They propose a multi-dimensional grid to characterize the collaborative situation of a company within its supply chain (called here the collaborative situations' grid). The authors define a company's "collaborative situation" by the information exchange (internally and externally) and the activity integration of a company with its partners in its supply chain. The goal of their three-dimensional grid is to make it possible for a firm to identify its collaborative profile around eleven processes of the supply chain management and establish a first analysis regarding the coherence of collaborative practices at the strategic, tactical and operational levels.

The first axis of the collaborative situations' grid is composed of the 11 processes – extracted from a literature review – that cover all the activities of the supply chain. The second axis corresponds to the strategic, tactical or operational levels, each one divided into "proactive behavior" or "reactive behavior". The third axis defines four progress levels, according to the stability and the collaboration area.

As a consequence, a company using (Gruat La Forme et al. 2007)'s model should define for each of the 11 supply chain processes (first axis, see Table 5.1), at the strategic, the tactical and the operational levels and for both its proactive and reactive behaviors (second axis, see Table 5.1) where it stands on the stability / collaboration extent matrix (see Table 5.1).

<table>
<tr><td></td><td colspan="7">Second axis</td></tr>
<tr><td rowspan="7">First axis</td><td rowspan="2">Supply chain processes</td><td colspan="2">Strategic level</td><td colspan="2">Tactical level</td><td colspan="2">Operational level</td></tr>
<tr><td>Proactive behavior</td><td>Reactive behavior</td><td>Proactive behavior</td><td>Reactive behavior</td><td>Proactive behavior</td><td>Reactive behavior</td></tr>
<tr><td>Process 1</td><td>Collaborative situation</td><td>Collaborative situation</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>Process 2</td><td>Collaborative situation</td><td colspan="5" rowspan="4">For each collaborative situation, four possible maturity levels:


Maturity / collaboration extent matrix</td></tr>
<tr><td>Process 3</td><td>…</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>Process 11</td><td>…</td></tr>
</table>

Table 5.1 – Architecture of the collaborative situations' grid (from (Gruat La Forme et al. 2007))

The model proposed by (Gruat La Forme et al. 2007) could be adapted to our context. We could replace the eleven supply chain management processes by ramp-up processes. Furthermore, we want to investigate information exchange and cooperation problems within the boundaries of the company: we could adapt the maturity / collaboration extent matrix so that only intern stakeholders are considered.

However, the collaborative situations' grid does not focus on the characterization of information flows. This model doesn't provide insights about characteristics of the exchanged information or about means used by actors so as to exchange information. We look for a model that could make it possible to describe more precisely the links between teams involved in the information exchange.

5.2.4 The project actors interface model

(Koike et al. 2005) define the concept of the interface among project actors using five fundamental elements (see Figure 5.3):

- The interface actors
- The intermediary objects (artefacts or objects)
- The tools
- The procedures and rules
- The interface space and time.

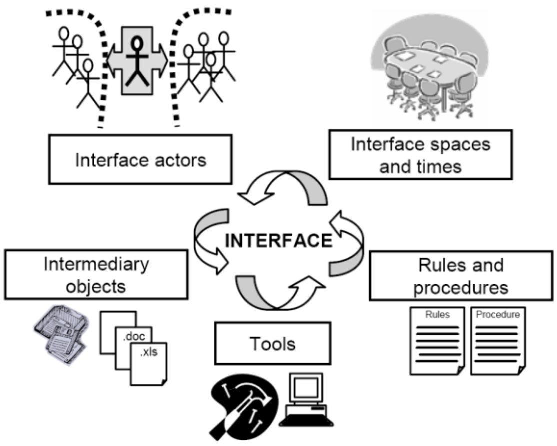


Figure 5.3 – The five fundamental elements of an interface, adapted from (Koike et al. 2005)

Interface actors are persons in charge of articulating the interface. Their role is to be a mediator, a link between the two groups of actors or the two industrial functions that composes the interface.

The concept of **intermediary object** was first presented by Jeantet and Vinck (Jeantet and Vinck 1995). The authors call "intermediary objects" (IO) items that are used or created during the design process. Intermediary objects are for example bills of material, component drawings or product prototypes. Jeantet and Vinck explain that these items have two utilizations. First, they are a way for actors to exchange information. However, the authors also insist on the second utilization of IO: these objects also represent the coordination that exists among their users.

The **tools** are essential in a project to help the information exchange as well as the work break down. Several different tools are often at the project stakeholders' disposal such as PLM (Product Lifecycle Management), ERP (Enterprise Resource Planning), and MS Office software.

The **rules and procedures** of an interface define how to design and coordinate the information flows and activity execution. For example, defining the participants of a project structures the information dissemination within the project.

Interface spaces and times are moments and places where stakeholders can interact during the project. They are dedicated moments and places to create or use intermediary objects. The interface times could be either synchronous (such as project status meetings) or asynchronous (such as e-mail exchanges).

To conclude, an interface can be considered either on a static point of view – trying to describe the fundamental elements of the interface – or on a dynamic point of view – trying to identify the different information flows that compose the information exchange between the project actors and their characteristics.

The five fundamental elements of an interface given by (Koike et al. 2005) are useful to describe the core elements of an interface but do not give insights about the dynamic aspects of an interface and the different characteristics of the exchanged information. In fact, the most important aspect of an interface is the characteristics of exchanged information, notably the dynamics of information.

5.2.5 Conclusion

In the previous sections, four models for describing interfaces and information exchange are introduced .We give in Table 5.2 a summary overview of these models found in the literature. Advantages and drawbacks of each model are given, as well as arguments that motivated our choice.

Each model has flaws in order to depict precisely the characteristics of project actors' interfaces. Consequently, since none of the models found in the literature fitted exactly our purposes, we designed an auditing tool inspired from the five fundamental elements of an interface illustrated by (Koike et al. 2005). The fundamental elements of an interface given by Koike et al. are complemented by other interesting concepts of the literature. The aim is to characterize the information exchange that occurs among the different stakeholders interface but also to capture the dynamic aspect of the interface situation.

Model	Short description	Advantages	Drawbacks
Activity model	Description of mediating artefacts, rules, community and work division between a subject and an object.	Thorough description of every element of an activity, including the subject environment (community).	Concentrated on one subject. Analysis on multiple actors too time-consuming.
Information flow analysis framework	Focus on information flows, processes and operating performance.	Precise map of information flow and their characteristics.	No focus on actors, only considers information exchange.
Collaborative situations' grid	Three-dimensional grid to identify a company's collaborative profile around 11 processes of the supply chain management.	Thorough description of four maturity levels for each collaborative situation, for each SCM process, from the strategic to the operational level.	No details on the characteristics of the exchanged information or on the means used to exchange information.
Project actors interface model	Interface model with five distinctive elements.	Consideration of actors, information flows and context.	No insights on information dynamics (information maturity, evolution…).

Table 5.2 – The different approaches found in the literature

5.3 Proposed interface model

The interface model proposed here is built from the interface model proposed by (Koike et al. 2005), which is completed with other literature concepts so as to take into account the characteristics of exchanged information, notably information dynamics. Indeed, information dynamics and hence information maturity are also very critical challenges during production ramp-up. Indeed, when the ramp-up phase begins, the design of the product may not be completely finished. There may still be some fine tuning related to product development while the product is already in a production phase (Juerging and Milling 2005). Several authors also witness the importance of technical engineering changes during ramp-up (Scholz-Reiter et al. 2007; Wolgast and Carlson 2007). As a result, actors of the ramp-up phase have to exchange immature information. Very often, information evolves very quickly, requiring a very close cooperation between actors.

As a result, our purpose is to design a model so as to be able to investigate project interfaces in an industrial context, a model that helps describing the interface mechanisms and evaluating if its different characteristics are coherent.

We propose the interface model shown in Figure 5.4.

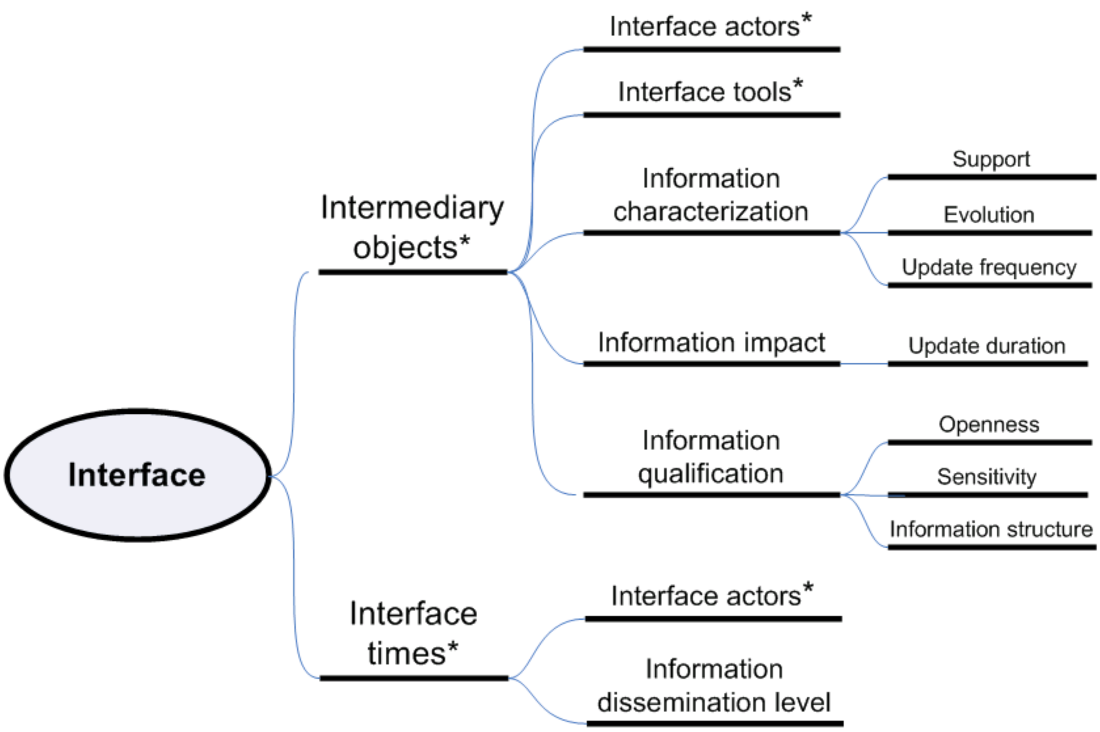


Figure 5.4 – The proposed interface model to investigate cooperation and information exchange in an industrial context

This model entails four out of the five fundamental elements composing an interface according to Koike (Koike et al. 2005):

- the interface actors (as crucial pivot between teams)
- the intermediary objects (as support for the information exchange)
- the interface tools
- the interface times (as times for the exchange and the dissemination of information).

In Figure 5.4, we highlight them with an asterisk *.

In the proposed interface model, the different elements taken from the model of (Koike et al. 2005) are not on the same level. Indeed, our model lays a special emphasis on two elements: the intermediary objects and the interface times. We put an emphasis on interface objects and interface times because, first of all, they are elements of an interface that are easily retrievable from a field study. Second, analyzing intermediary objects or interface times also enables the identification of interface actors or tools.

We also note that the “rules and procedure” element of Koike’s model is not directly part of our model. A first reason is that it is very difficult to capture “as is” during field investigation. Second, we also believe that most of the rules and procedures are implicitly embedded in intermediary objects or interface times. For example, intermediary objects are often created or used according to a special procedure.

The additional elements of our model are concepts useful to describe different information characteristics that play an important role in the information exchange. In Figure 5.5, these elements are organized according to the framework given by (Grebici 2007). Indeed, Grebici proposes a model in order to arrange the different characteristics of exchanged information – from the information source to the information users. For this purpose, she decomposes the information exchange into two steps:

- a first information characterization step, performed by the information source
- an information qualification step, performed by the information users.

Within each step, there are different concepts that are helpful to characterize information.

The eight concepts we use in our model are the following ones (they are marked by a **(*)** in Figure 5.5):

- three concepts for information characterization
  - **information support**
  - concepts to evaluate information dynamics: **information evolution** and **information update frequency**
- a concept for the impact of information on the source: **information update duration**
- three concepts for information qualification
  - concepts referring to the use of information: the **openness**, **information sensitivity**, **information structure**
- a concept related to the dissemination of information: the **information dissemination levels**.

These different concepts are explained in the next sections.

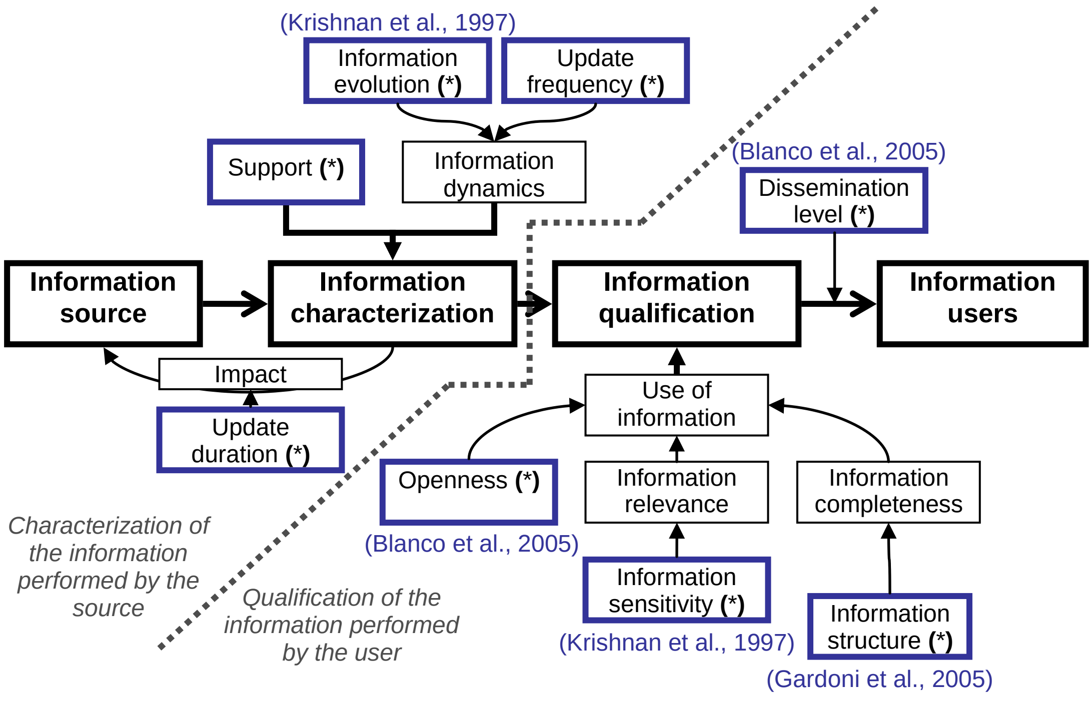


Figure 5.5 – Concepts to characterize exchanged information (framework adapted from (Grebici 2007))

5.3.1 Concepts for information characterization

The first step of information exchange is information characterization by the information source (Grebici 2007). Information being intangible (i.e. immaterial), the information source has to choose a **support** to carry his information. In this dissertation, we consider that Intermediary Objects (see section 5.2.4) are the support of exchanged information but these intermediary objects can be of different types: a sheet of paper, a software file, data in the company's ERP… As a consequence, the concept of "information support" refers to the type of Intermediary Object used to exchange information.

The information source is also responsible for updating the information. As a consequence, his/her action on the information influences the dynamics of information. We selected two concepts to evaluate the dynamics of information: information update frequency and information evolution.

The **update frequency** is an interesting indicator of the information dynamics. Indeed, the more frequent the changes are, the more dynamic the information is. It is also a very practical concept, easily retrievable from field experience or thanks to stakeholder interviews.

Information evolution is a concept introduced by (Krishnan et al. 1997). Krishnan et al. propose a model which focuses on exchanged information in overlapped design activities.

They take the example of two activities, the upstream activity and the downstream activity. The information exchanged between these activities is the output of the upstream activity and the input of the downstream activity. If the activities are performed sequentially (see Figure 5.6), the only information exchange takes place at the end of the upstream activity.

But if the activities are overlapped (see Figure 5.6), a preliminary exchange of information takes place, so that the downstream activity can begin earlier than sequential case. In the case of overlapping activities, the information exchanged is not necessarily finalized.

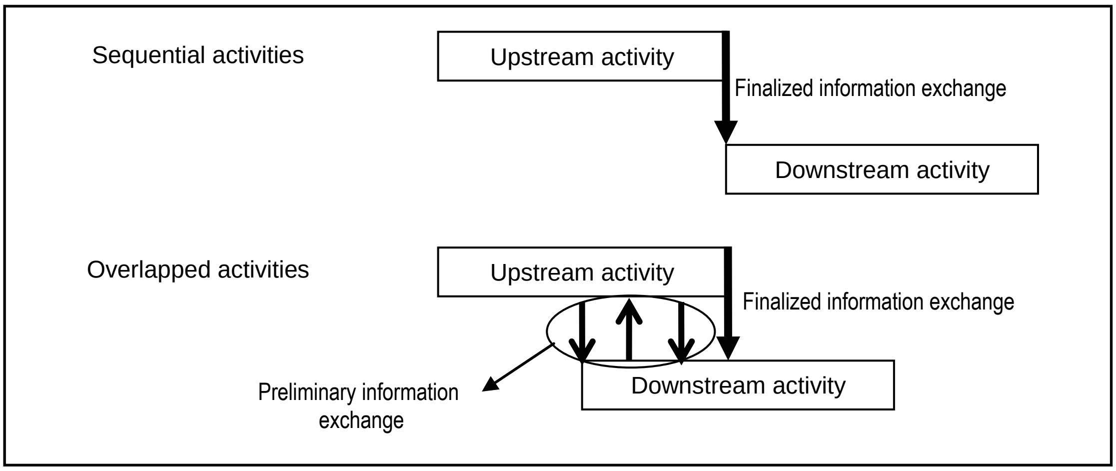


Figure 5.6 – Information exchange in sequential and overlapped activities

This is why (Krishnan et al. 1997) focus on two important properties of exchanged information:

- the degree of evolution of information
- the sensitivity of downstream activities (see further section 5.3.3.2)

The **degree of evolution** is valuated by a function that can be understood as the convergence of information towards its final value. It can be either fast or slow (see Figure 5.7). Information with a fast evolution will quickly approach its final value. Only minor changes will occur after the first delivery of the information. For example, in a printing machine development project, it is very likely that the approximate size of the future product is known quite precisely before the design's total completion. This information has a fast evolution.

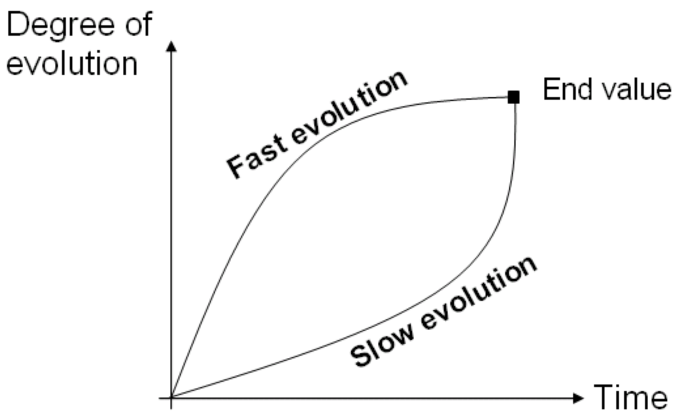


Figure 5.7 – (Krishnan et al. 1997)'s evolution extreme values

Another interesting aspect to investigate the characteristics of information is the impact of information. In the next section, two concepts to grasp and evaluate the impact of information are described.

5.3.2 Concept for the impact of information

(Grebici 2007) outlines in her model (p. 141) that information exchange should be considered from two points of view of the information source and the information user. Indeed, she outlines the importance of considering the impact of information on both sides of the information exchange. As a consequence, in the proposed model shown in Figure 5.4, we use a concept found in the literature in order to take into account the impact on the source of the information: the **information update duration**, which refers to the necessary time the information source needs to issue a modification. The update duration of information can be very variable: information is automatically updated in an ERP system for example, whereas a thorough analysis of several different information sources (Excel-files, Access data bases …) can require days of work for an actor. As a consequence, update duration appears as an interesting characteristic of an intermediary object, in order to evaluate the effort required by an update for the information source. This concept is interesting to couple with information dynamics criteria. For instance, we logically expect to observe a fast-evolving information accompanied by a high update frequency.

5.3.3 Concepts for information qualification

Information qualification is the second step of information exchange in (Grebici 2007)'s decomposition (see Figure 5.5). Different concepts characterize the use of the information by the information users. In our interface model, we selected three concepts: the information openness, the information sensitivity and the information structure.

5.3.3.1 Openness

The **openness** concept refers to the interaction level that is fostered by the exchanged information. Indeed, (Blanco et al. 2007) identify two types of supports for exchanged information: open or closed intermediary objects. An object which cannot be modified by its users is a closed object whereas an object which is a support for negotiation and interaction is an open object. Hence, the closed or open characteristic directly depends on the degree of freedom that is left to the users of the object. This concept is interesting to determine the influence of the different users on the content of the object and if the exchanged information is more dedicated to negotiation or to prescription.

5.3.3.2 Information sensitivity

Information sensitivity is the second concept developed by (Krishnan et al. 1997) concerning the exchange of information in overlapped activities.

The sensitivity of downstream activities represents the impact of the changes on information on the downstream activities, i.e. the information user. It is valuated by the necessary rework within the downstream activities. That is to say that if a change in the output information given by the upstream activity implies a huge rework (re-doing of some tasks to take into account the information evolution) for the downstream activity, then the information generated by the upstream activity will be qualified as information with a high sensitivity. We will only focus on the extreme values, determining if the downstream activity has either a high or a low sensitivity (see Figure 5.8). The design of the printing machine's cover is for example a very sensitive downstream activity. Any changes of the internal components' design or assembly will affect the cover design. If a designer decides to change one of the internal components, the cover designer has to do his job all over again. The rework cost for this downstream activity is high. This is why the information exchange about the design of internal components of a printing machine is an information with "high sensitivity".

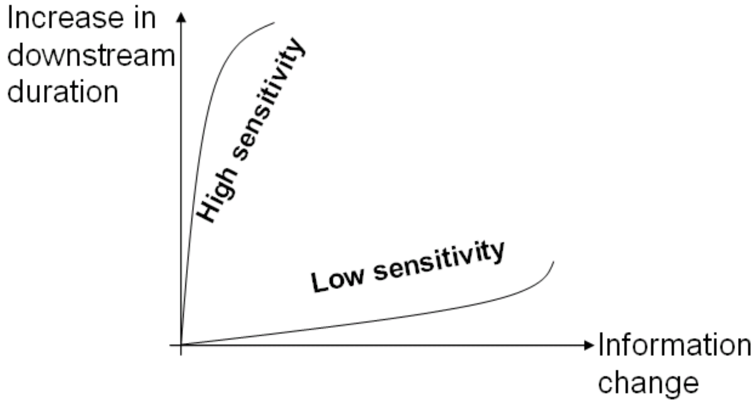


Figure 5.8 – (Krishnan et al. 1997)'s sensitivity extreme values

This concept is really useful to evaluate whether information exchanged has a great impact on downstream activities, i.e. on information users. In this dissertation, we name "**critical information**" information that has a strong impact on downstream activities (or information users). This information is critical because:

- it is necessary for downstream activities to be performed
- any change in the information requires a high rework in downstream activities. Rework could lead to necessary additional time for the performing of the downstream activities. The total lead time of the ramp-up phase can be impacted.

As a consequence, critical information will be characterized in our model by a "high sensitivity" value for the information sensitivity concept and a high number of information users (the more users, the more probable an impact on ramp-up lead time).

5.3.3.3 Information structure

The concept of **information structure** is outlined by (Gardoni et al. 2005). The authors develop this concept to evaluate elements of context attached to the information for interpretation purposes. They identify three degrees of information structure:

- Structured Information (SI): Structured Information's content and form are strongly regulated and fixed through rules and procedures. For example, a design drawing is an IO with Structured Information: all the information enclosed in the drawing sheet is mandatory and thoroughly predefined by official company rules.
- Semi-structured information (SSI): The content and the form of Semi-Structured Information can only be partially shaped by the company's official rules. For example, minutes of meeting are always handed out following the same frame but the content is always various. SSI could be either very explicit or totally meaningless for external actors, depending on their personal knowledge.
- Non Structured Information (NSI): the information enclosed in the IO is very little formalized. Context elements are the bare minimum for the information receiver to understand.

This information characteristic is noteworthy since it is very easily identifiable during field investigation. It also sheds a very interesting light on the quality of the exchanged information (whether contextual elements are given or if the data is more or less rough) and on the relationship between information source and information users (the exchange of Non-Structured Information for example means that information source and information users should share a common knowledge).

The last element of our interface model is related to the dissemination of information: the information dissemination levels. This concept is useful in our case to determine the extent of the collaboration for each interface time.

5.3.4 Concept for information dissemination

(Blanco et al. 2007) argue that four levels of **information dissemination** can be distinguished in collaborative design activities:

- The “Public workspace”, where the official deliverables are published. This place is also for external communication with suppliers or customers. In general, the exchanged information in the public workspace is extremely formalized. Information disseminated within the “public workspace” is for example posted information on a display panel or an e-mail sent to the whole company.
- The “Project workspace” concerns the sharing of information within the project team. This level is still influenced by the company formalization of information. Information disseminated within the “project workspace” is for example a document saved on the project SharePoint (only project actors have access to the project SharePoint) or information discussed at a project meeting.
- The “Proximity workspace” corresponds to the information producer’s personal network. The invited actors accepted in the information producer’s proximity workspace compose a “friendly” assistance for sharing information. Information disseminated within the “proximity workspace” is for example information discussed in a phone-call or during small talk between two actors. It could also be a file sent by e-mail by an actor to a selected set of other actors.
- The “Private workspace”: in this level, the information producer arranges his personal data, which he doesn’t want to share. Information of the private workspace can be for example an actor’s notebook or files saved on the personal computer of an actor.

In our interface model, we extend this concept from design process field to the information exchanged during the ramp-up phase. The first three levels of information dissemination are valuable to distinguish the different interface times, focusing on their influence within the project area. Indeed, the private workspace isn’t relevant in our context, since the information kept in the private workspace isn’t shared as is with any of the other interface actors.

5.3.5 Conclusion

Other concepts are available in the literature in order to investigate further characteristics of exchanged information (see Figure 5.9) but only the above cited criteria were selected (marked by a **(*)** in Figure 5.9). Indeed, we aim at selecting the concepts that are easily usable during field investigation. This aspect is major for us because we aim at investigating real cases. The other concepts are hardly usable during field investigation: they are either too complex to retrieve or too hard to evaluate during field investigation.

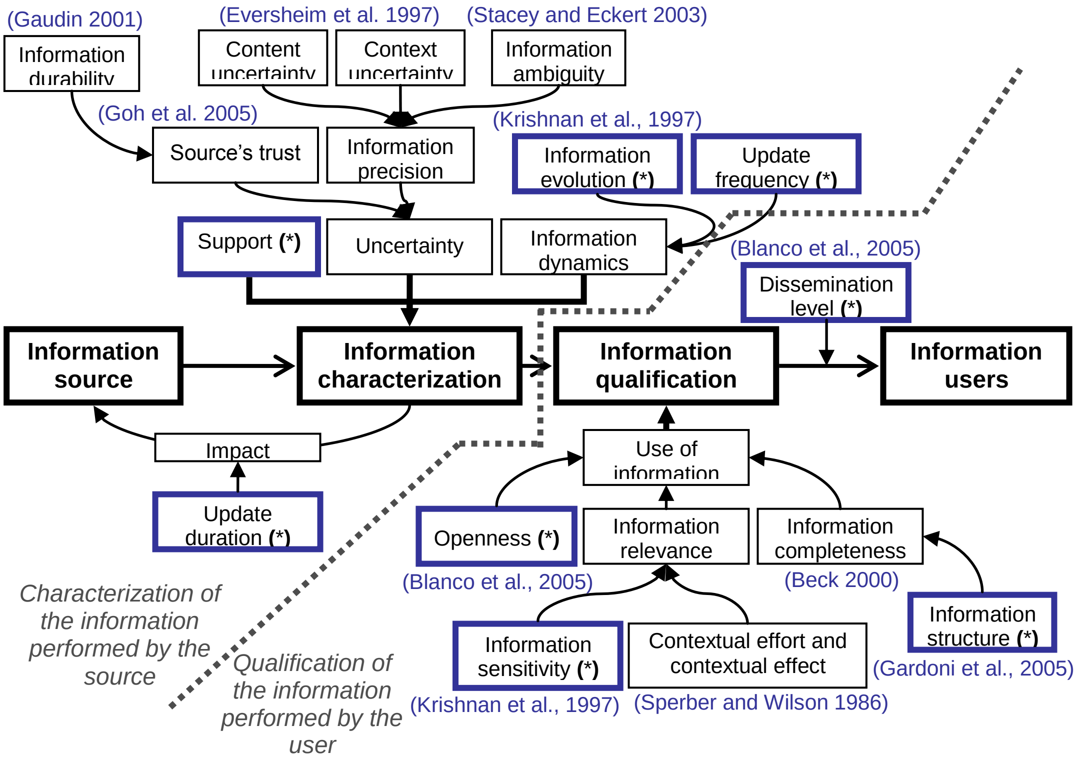


Figure 5.9 – Different concepts to characterize information, adapted from (Grebici 2007)

For example, source's trust refers to the characterization of the discrepancy between the intention of the information source and the actual information. For example, a designer of a R&D department wants to design a new component. The model of his component that he will create may be different from its original idea because the designer lacks knowledge or competencies regarding the computer-aided-design tool he is using. The trust of the user characterizes the discrepancy between the original idea of the information source and the actual information and the discrepancy between the purpose of the data provided and the reliability of it that the user attributes on behalf of a judgment on the provider. This concept is very interesting but very difficult to valuate during field investigation.

Furthermore, we believe that the chosen concepts for our interface model provide a good overview of information characteristics. The concepts chosen aim at providing a global but precise picture of the characteristics of exchanged information in the interfaces between ramp-up actors. They enable the identification of any misalignment or incoherence between characteristics of an interface. For instance, we logically expect to observe a fast-evolving information accompanied by a high update frequency. A high update duration accompanied by a high update frequency denotes a problem. Indeed, the impact of the update of the information on the information source is high (high update duration). But the information must be updated regularly. It means that the activities of the information source are highly impacted by the update of this information.

Based on the new interface model proposed above, auditing tools are developed as actionable tools that can be operative in conducting a field study. These tools are presented in the next section.

5.4 Auditing tools

As the interface model proposed in Figure 5.4, the auditing tools proposed here put a major highlight on the intermediary objects (as support for the information exchange) and the interface spaces (as spaces for the exchange and the dissemination of information). The auditing tools are composed of three tools: two grids and one summary diagram.

- The first grid named the IO (Intermediary Object) grid investigates the different characteristics of exchanged information and project structure through the listing of the project intermediary objects.
- The second grid, named the SIT grid, investigates via the synchronous interface times the major information flows.
- The summary diagram details the main interfaces of the project, showing their different information flows and their fundamental elements supporting the interfaces.

This auditing tool aims at:

- identifying the major information flows between project actors (i.e. the information flows at the interface between project teams)
- identifying where and how critical information is exchanged
- identifying misalignments thanks to information characteristics, in order to explain encountered problems during the ramp-up phase. The characteristics of exchanged information can also be helpful to design appropriate solutions to avoid problems in future ramp-up phase.

We recall that we define critical information here as information having a strong impact on downstream activities (or information users), hence possibly leading to a delay in ramp-up lead time.

5.4.1 The IO grid

The IO grid has the objective of investigating the characteristics of exchanged information in order to shed a light on cooperation mechanisms and project structure. The IO grid lists the different intermediary objects that are created during the project, since intermediary objects support the information exchange.

5.4.1.1 IO grid structure

In the IO grid, an intermediary object is characterized by the following attributes:

- the name of the object
- a short description of the object
- who is the person in charge of the IO (in charge of creation of the object and its updates)
- who are the users of the IO (groups of actors interested by the information enclosed in the IO, who need it for performing their tasks)
- concepts for information characterization (notably for characterizing the dynamics of information):
    - The support of the IO (whether it is an object on paper, a software file, data in the ERP, etc.)
    - The information evolution to describe the velocity with which the information will reach its final value (Krishnan et al. 1997)
    - The update frequency to evaluate how often the information changes
- concepts qualifying the impact of information
    - The IO update duration to evaluate the load for the person in charge of the information release to update the information
- concepts related to the information qualification
    - The openness to evaluate if the information can be changed after its release by the information source so as to determine whether the object is more a support for negotiation or for prescription.
    - The information sensitivity to evaluate the impact of information changes on information users (downstream tasks)
    - The structure of the information enclosed in the IO
        - Structured information (SI), Semi-structured Information (SSI) or Non-Structured information (NSI) (see section 5.3.3.3).

All these information characteristics allow a precise picture to be made of the information exchanged between stakeholders of the ramp-up phase. The proposed frame for the IO grid is presented in Table 5.3.

Filling in the IO grid leads to a first analysis of the information exchange. Identifying the person in charge and the users of IO helps identifying the major information flows at the interface between project teams.

Moreover, the IO grid reveals which objects enclose critical information that is exchanged between project actors. We name in this dissertation "**critical IO**" the intermediary objects having the following characteristics:

- they entail critical information (high sensitivity information with numerous users)
- they are open objects (information users can influence information enclosed in the objects)

	Intermediary object	Description	Person in charge	Users	Support	Structure	Update frequency	Evolution	Openness	Sensitivity	Update duration
1	Name of the object	Description of the object	Project actor	Project actors	Software, paper…	SI, SSI or NSI[23]	High, Average, Low	Slow, Fast	Open, Closed	Low, High	In hours or days
2	…	…	…	…	⋮	⋮	⋮	⋮	⋮	⋮	⋮
3	…	…	…	…	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 5.3 – Analysis of the project intermediary objects – the IO grid

The critical IO are the intermediary objects that are the most important in the cooperation mechanism at the interface between project actors. They are the objects that must be focused on.

5.4.1.2 Criteria evaluation

Operational measures are then necessary to evaluate the value of different criteria of the IO grid in an industrial context. For this purpose, several practical evaluation rules are established, so as to be able to valuate the concepts chosen. These rules were established during a group meeting with the project stakeholders of the first case study (see section 6.2.2). The same rules are applied in each case study.

(i) About the **update frequency** criteria, the following categories were chosen:
   - High update frequency, if the IO was updated more than 10 times during the investigation period[24]. For example, our first investigation period lasted 19 weeks. More than 10 updates mean an update at least every two weeks.
   - Average update frequency, if the IO was updated between 4 and 9 times (i.e. in our first case study at least once a month)
   - Low update frequency, if the IO was updated 3 times or less.

(ii) Concerning the **update duration**, it was evaluated roughly in days or hours by the person in charge of the IO.

(iii) Regarding the **modification** criteria, the rule was the following one: either the content of the IO was modifiable by the users and the object was open, or the content was definitely fixed by the person in charge of the IO and the object was closed.

[23] See glossary for acronyms
[24] In our second case study (investigation of the GE project), the investigation period was only two weeks. As a consequence, we extended the period considered to the whole run-up phase (i.e. four months), a period equivalent to the investigation periods in the first and the third case studies (the XS and BD projects, see Chapter 6).

(iv) As for the **information structure** of the IO, the below rules were established:
- if the IO was an official object of the manufacturing plant (official document, official content of the ERP…), the IO information was considered as "Structured Information"
- if the IO information was referenced (for example, Excel-sheet columns with titles broadly known by the plant's actors) and if the document was shared by various actors without needing to be further explained or translated, the IO information was considered as "Semi-Structured Information"
- if the IO information was almost raw information (raw data) with no special layout and the person in charge of the IO is almost the only one to understand the information, then it was considered as "Non-Structured Information"

(v) About the **information sensitivity**, the criteria given were the following ones:
- High sensitivity of the IO information meant that a change in IO information had a direct impact in the final delivery of the first customer product. Indeed, in the low volume industry, the time constraint is really important[25] (Jina et al. 1997).
- Average sensitivity of the IO information meant that an information change implied rework for some activities and thus an additional cost but no delay for the final delivery of the first customer project
- Low sensitivity meant that the global impact (in the project duration or project cost) was not significant.

(vi) And finally, with respect to the **information evolution** criterion:
- either the updates were mainly at the end of the IO life-cycle (slow evolution)
- either the updates were mainly close to the first release date of the IO (fast evolution).

The IO grid enables the identification of how information is exchanged between project actors. It describes which supports are used to exchange information and gives an overview of information characteristics. However, the IO grid fails at identifying "when" information is exchanged. Indeed, as outlined by (Koike et al. 2005), a fundamental element of an interface is the interface times. In order to investigate when and with whom information is actually exchanged, we designed the "SIT tool", the second item of our auditing tool, which will be explained next.

5.4.2 The SIT grid

The second diagnosis tool, which we will name the SIT (synchronous interface times) grid, consists in listing the synchronous interface times occurring during the production launch of the project. Synchronous interface times are times when project actors are exchanging

[25] See section 1.2

information synchronously. There are the meetings, phone calls, encounters that are happening during the project and that are used for information exchange and cooperation by project actors.

5.4.2.1 SIT grid structure

Interface times are precious times, where information is exchanged and/or diffused, where IO are created and/or used. In the SIT grid, the team responsible for the interface time is also registered, as well as the participants.

The number of meetings held during the project is given, as well as the indication of whether the meeting was specifically held during the project or part of the normal functioning of the organization.

The SIT grid also makes the identification of information flows possible thanks to the concept of information dissemination (see section 5.3.4).

As a second part of the auditing tool, the SIT grid illustrated in Table 5.4 is proposed.

	Meeting(s)	Description	Person in charge	Participants	Number of meetings	Project specific	Public workspace	Project workspace	Proximity workspace
1	Name	Description of the purpose of the meeting	Project actor	Project actors		Yes or No	To tick		
2	…	…	…	…	…	…			
3	…	…	…	…	…	…			

Table 5.4 – Investigation of the synchronous interface times – the SIT grid

5.4.2.2 Criteria evaluation

In order to determine whether the gathering took place in public, project or proximity workspace, the following rule was designed during a group meeting held for the filling of the grid during our first case study (see section 6.2.2). The same rule is applied in each case study.

- If participants external to the ramp-up project team participated in the meeting, then its information dissemination level is the public workspace.
- if the gathering concerned only actors of the ramp-up project team and that it was a formal meeting (officially set in the actors Outlook™ schedule) then its information dissemination level is the project workspace
- if the gathering concerned actors of the ramp-up project team and if it was an informal gathering (not scheduled in the participants' Outlook™ calendar), then its information dissemination level is the proximity workspace

All the SIT belonging to public and project workspaces are formal meetings. They are officially scheduled, most of them lead to a minutes of meeting sheet which is disseminated to at least

all of the meeting participants. On the contrary, the gatherings that belong to the proximity workspace are more informal meetings. They are spontaneous and unrehearsed visits.
This spontaneous meetings are the most difficult to identify during field investigation. This is why unstructured interviews of project actors are very important. We notably asked actors which tasks they performed during the ramp-up phase and which information they needed for performing these tasks. Then, when we enquire on the source of the information and how the actor got the information, we sometimes discover the existence of spontaneous meetings or phone calls.

The IO grid and the SIT grid are tables that list objects and meetings that are crucial for project actors to exchange information. However, these tools are not visual. A visual tool could speak more for itself in order to depict information flows. Consequently, we design a third tool which summarizes and highlights the information collected in the IO grid and the SIT grid. This third item of our auditing tool, the summary diagram, is detailed in the next section.

5.4.3 The summary diagram

The summary diagram is a graphical representation of the project's interfaces and the information flows. It encapsulates the information collected in the grids, displaying for each major project interface its principal characteristics:

- The information flows
- The potential interface actor. The interface actors are depicted in the dotted line boxes. The principal information exchanges are depicted with big black arrows. The cipher on the arrow designates to which interface the information flow belongs.
- The amount of intermediary objects that participated to the information exchange within this interface (the interface stakeholders have to be in charge of the IO or users of the information)
- The tools (if the information exchange is mostly supported by a tool). For example, the ERP system is very often used to exchange information: if most of the information exchange within the interface is done via the ERP system, the ERP is the "tool" of the interface.
- The amount of synchronous interface times (the interface stakeholders have to be participants of the SIT).

The summary diagram is an effective way to visualize the different information exchanges and the structure of the project interfaces (see Figure 5.10).

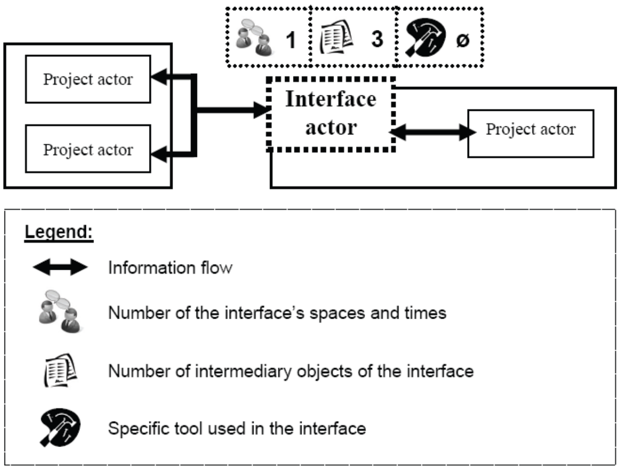


Figure 5.10 : The summary diagram

5.5 Conclusion

In this chapter is presented the interface model that was designed in order to investigate the characteristics of interfaces between actors during the ramp-up phase. The model is built on existing models and concepts of the literature that are chosen for their relevance and easiness of implementation on a case study. Out of this interface model is developed an auditing tool, composed of three different elements: two grids and a summary diagram. This operational tool and their several practical evaluation rules enable the investigation of interfaces in ramp-up projects and shed an interesting light on cooperation and information exchange mechanisms. This auditing tool also enables to identify misalignments in the characteristics of exchanged information, giving possible explanations for encountered cooperation or information exchange problems. The identification of weaknesses in the information flows lead to improvement propositions that will help future ramp-up projects to avoid previous mistakes and thus be possibly more successful.

In the next chapter are presented three cases studies where the auditing tool is used, so as to draw valuable conclusions for both academicians and practitioners.

CHAPTER 6 THREE CASE STUDIES ON PROJECT INTERFACES

Chapter outline:

This chapter presents the case studies realized at Siemens E T HS in order to investigate further cooperation and information exchange in ramp-up situation. The audits of three different complex ramp-up situations and their results are presented separately. The results of these audits, as well as their comparisons, are both valuable from a practical and an academic point of view.

6.1 Introduction

In the research presented here, project interfaces are investigated in order to improve cooperation and information flows between actors in the ramp-up phase. The investigation is carried out thanks to the auditing tool presented in Chapter 5. The analysis of actors' interfaces, their characteristics, and their structure help identifying possible causes of cooperation and information exchange problems.

As a result, our aim is to answer the following research question:

(RQ 2) How can we characterize the interface situation during ramp-up?

This research question can be divided into two sub-questions:

(RQ2.1) Where are the major interfaces and how is information exchanged? (RQ2.2) Can we draw actionable conclusions to improve future ramp-up situations from the analysis of the interfaces?

To answer these questions, we designed three case studies. Each case study was carried out in a different project of Siemens E T HS but at different stages of the ramp-up process (see Figure 6.1).

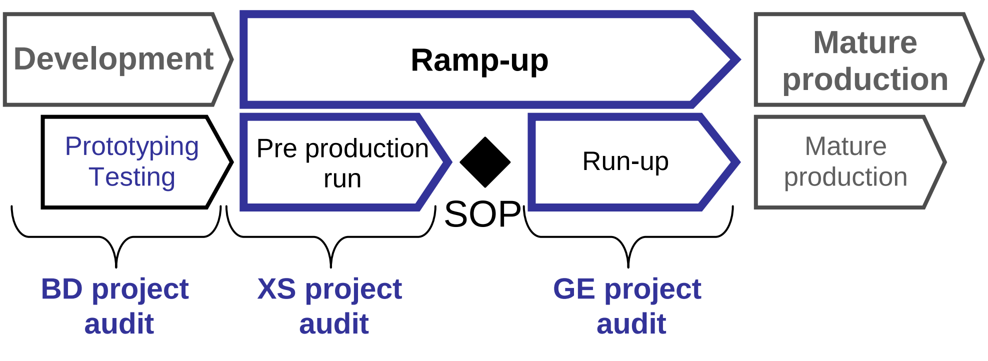


Figure 6.1 – The different audit period of the three case studies

Two cases, the XS project and the BD project, were located at the Grenoble plant of Siemens and the GE project was located in Berlin. In the case studies, several types of investigation were carried out, from interviews to operational involvement in the project (see line "status of the researcher" in Table 6.1). As a consequence, the investigation duration varies between a few weeks and several months.

	Project XS	Project GE	Project BD
Project start - end	Nov. 2004 – Dec. 2008	Mar. 2006 – May 2009	Jul. 2008 – Apr. 2010
Type of project	New product	New product	New sub-system
Investigation time interval	Nov. 2007 to Apr. 2008	Oct. to Nov. 2008	Oct. 2009 to Jan. 2010
Status of the project	Preproduction run	Run-up	Prototyping / Testing
Status of the researcher	Participant as Observer[26]	Observer as Participant[26]	Participant as Observer
Location	Grenoble (FR)	Berlin (DE)	Grenoble (FR)
Main data source	Involvement + regular unstructured interviews[27]	Structured interviews[28] + E-mail questionnaire	Involvement + Regular unstructured interviews[27]

Table 6.1 – Characteristics of the three case studies

The three case studies are presented one after another in the next sections. For each case, a case description is provided, as well as a thorough description of the case study protocol.

6.2 The XS Project

6.2.1 XS Project Case description

The first project under study was the project of the introduction of the new XS switchgear in production, at the manufacturing plant of Grenoble. The New Product Development project began in November 2004 and ended in December 2008.

The scope of the case study was the final assembly of the XS switchgear on the manual assembly line of the Grenoble plant. There were six major departments (hence six actors groups) involved in this project:

- the Grenoble Production department
- the Grenoble R&D department (named R&D G hereafter)
- the Berlin R&D department (named R&D B hereafter)

[26] See definition section 2.2.2.
[27] Unstructured interviews are interviews that tend to be informal, bordering on conversations. The interviewee is answering open-ended questions.
[28] Structured interviews are more formalized interviews with a structured interview protocol. The interviewee is answering a precise questionnaire.

- the Grenoble Purchasing department
- the Grenoble Procurement department
- the Grenoble Quality department

An organizational chart of the XS ramp-up team is given in Appendix IV (see section 8.4).

In the XS project, both the product and the production system were new for the Grenoble plant. Indeed, the XS product was developed by Berlin and Grenoble R&D departments and the production line was started from scratch at Grenoble. As a consequence, in our framework adapted from (Almgren 1999a), the complexity matrix, the XS project is located on the upper right box, which means that this project was a very complex ramp-up situation (see Figure 6.2).

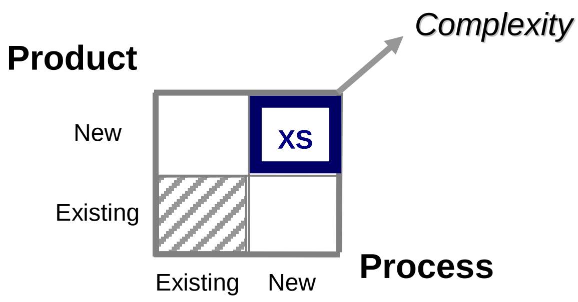


Figure 6.2 – Position of the XS project on the complexity matrix

6.2.2 Case study protocol

The audit of the XS project was realized from February 2007 until June 2007, which corresponds to the pre-production run phase of the XS project (i.e. after prototyping and testing and until SOP, Start-of-Production) as shown in Figure 6.3.

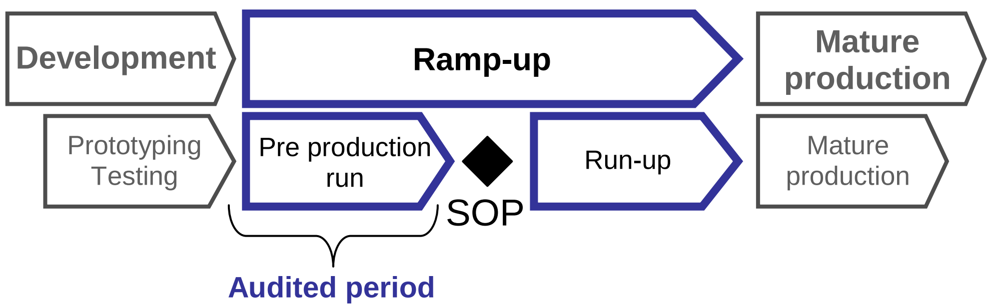


Figure 6.3 – Phase of the XS project by the time of the audit

The position adopted by the researcher was the "Participant as Observer" position, enabling a deep understanding of the progress of the project (Junker 2004). The main researcher was involved 19 weeks in this project as supply chain coordinator and was responsible of project life during the ramp-up phase (i.e. project planning, project meetings etc.). Her role involved relationships and daily exchanges with all actors involved in the ramp-up project. As "Participant as Observer", the status of the researcher was made explicit enabling **23 interviews** to be carried out to complete or validate the findings. As a result, case data was both collected through participation in the project and unstructured interviews of **13 different project actors** (Project Managers, Department Managers, Work Package Managers…). The aim was to look for multiple viewpoints.

The aim of the 23 interviews (10 actors were interviewed twice and three actors were interviewed only once) was to have a better understanding of the progress and the difficulties of each group of actors. A **collective work session**, with five key actors during two meetings, enabled the filling of the grids of the auditing tools. Each key actor was first asked for the intermediary objects he or she used or the meetings he or she participated to. The answers were completed with findings from field notes. This meeting was also used so as to design evaluation rules for the concepts of the grids[29]. Once the different items of the grids identified, their different criteria and their operational rules were explained by the interviewees during the second meeting. The five actors were then asked to fill the grids they were given with their estimated value of each concept. The results presented here are average values of all the answers collected. These results were **fed back to the interviewees for a final validation** at the end of the main researcher's involvement (May 2008).

XS project investigation
13 interviewees
23 interviews
19 weeks of involvement
39 meetings attended
2 meetings of 5 key respondents to fill the grids
2 factory tours
Other collected data: - Follow-up Excel-list of component qualification - Versions of exchanged documents such as drawings, follow-up sheets … - Customer bills of material in the ERP system - Etc.
Feedback to interviewees: May 7th, 2008
Feedback to the steering committee: June 12th, 2008
Internal report of 56 pages, issued May 30th, 2008

Table 6.2 – Characteristics of the investigation of the XS project

Other sources were used to collect data (the company's intranet, for shared files; the ERP system, for information; etc.) to validate or complete insights from the interviews or group meetings.

[29] The practical evaluation rules presented section 5.4.1.2 and section 5.4.2.2 were designed during the first meeting.

Finally, **field notes** were recorded during the whole investigation duration.
A summary of the characteristics of the XS project investigation is given in Table 6.2.

6.2.3 Results and analysis

6.2.3.1 Major difficulties of the XS project

Thanks to the involvement of the major researcher and the interviews of project participants, two major difficulties encountered by the project were outlined.
First of all, major procurement problems were encountered on parts that had been developed by the Berlin R&D team (Problem XS1). At SOP, about 80% of the missing parts were parts developed by Berlin. Indeed, the Purchasing team complained that information about newly created components in Berlin came very late, so that they lacked time to set up their procurement. Other project teams reported communication problems with the Berlin R&D team (Problem XS2).
Secondly, several project actors complained about their difficulty in following up the Purchasing team activities and tasks dispatch (Problem XS3). The composition of the Purchasing team evolved during the progress of the XS project. New resources were continuously involved in the project. This constant change in the stakeholders of the Purchasing team led to a certain opacity regarding Purchasing work.

In general, the XS project's pre-production phase was considered by project actors as not very successful. Development and procurement tasks were not finished at SOP which led to a lot of problems (missing parts, wrong parts …) during the run-up phase of the XS project. The start of the pre-production phase was delayed because of procurement issues and it lasted two weeks more than forecasted, because of procurement and assembly problems.

The problems encountered by the XS project are coherent with the classifications of ramp-up problems presented in section 4.3.1 and section 4.3.3. Table 6.3 shows in which problem types of the resource-based classification and the cause-based classification the problems encountered by the XS project are clustered. For example, Problem XS1, regarding missing components at SOP can be clustered in the "Missing components" problem type of the resource-based classification presented in section 4.3.1 and in the "Cooperation" problem type of the cause-based classification presented in section 4.3.3.

	Resource-based classification	Cause-based classification
Problem XS1	Missing components	Cooperation
Problem XS2	Actors of the two plants	Communication
Problem XS3	Actors of the Grenoble plant	Cooperation

Table 6.3 – Problem types of the problems encountered during the XS ramp-up phase

6.2.3.2 XS project's IO Grid

The IO grid[30] realized during the XS project is given in Table 6.4.

	Intermediary object	**Description**	**Person in charge**	**Users**	**Support**	**Structure**	**Update frequency**	**Evolution**	**Openness**	**Sensitivity**	**Update duration**
1	**R&D Critical Components follow-up list**	References of components that are difficult to supply from the R&D point of view.	Local R&D PM (R&D G)	R&D G team Purch. NP team	MSExcel file	NSI[31]	Average	Fast	Closed	High	1 hour
2	**R&D Bills of Materials**	Bills of materials entailing only technical information	R&D G R&D B	Production	PLM software	SI[32]	Low	Fast	Closed	High	1,5 hours
3	**R&D parts and subassemblies drawings**	Drawings of the parts and the subassemblies of the new product	R&D G R&D B	All	PLM software	SI	Low	Fast	Closed	High	4 hours
4	**Production bills of materials**	Bills of materials with all the necessary production information	Production PM (Production)	All excepted R&D G and R&D B	ERP software	SI	Low	Fast	Closed	High	4 hours
5	**Purchasing follow-up list**	References of the components to be qualified.	Purch. NP team	Sourcing coordinator (Production)	Paper	NSI	Average	Slow	Closed	High	2 hours
6	**Long lead-time components list**	References of components with a lead time higher than fours months.	Sourcing coordinator (Production)	Production team R&D G Purch. NP team Procurement	MSExcel file	SSI[33]	Average	Slow	Open	High	2 hours
7	**"Samples tests" components follow-up list**	References concerned by samples tests	Component quality inspection (Quality)	R&D G Purch. NP team	MSExcel file	SSI	High	Slow	Open	High	6 hours
8	**Components-to-buy list**	References of the first production components	Production PM (Production)	Production team R&D G Purch. NP team Proc. NP team	MSExcel file	SSI	High	Slow	Open	High	9 hours
9	**Minutes of the project workpackages meetings**	Minutes of coordination meeting with all the project workpackage managers	Sourcing coordinator (Production)	Production Purch. NP team R&D G Proc. NP team	MSExcel file	SSI	High	Slow	Closed	Average	2 hours

Table 6.4 – IO grid of the XS project

30 See definition section 5.4.1
31 See glossary for acronyms
32 See glossary for acronyms
33 See glossary for acronyms

Based on the IO grid of the XS project, we make the following remarks.

First of all, almost all IO listed in this grid carry “high sensitivity information”. High sensitive information means that users of the information are highly impacted by any change of this information (see section 5.3.3.2), i.e. the information is crucial for their work. In fact, the exchange of high sensitive information plays a key role in the cooperation process. As a consequence, the objects listed in Table 6.4 are very important objects for collaboration between project actors, even though the list might not be exhaustive.

Secondly, it emerges that the Purchasing department is mostly mentioned as “user” of the IO (IO no.1-4 and IO no. 6-9) and only once as a “person in charge of the IO” (IO no.5). The Purchasing department being only “user” of IO seems to reveal that it had a “passive attitude” toward the information exchange.

On a third point, R&D B is only listed twice as user and person in charge of IO (IO no.2 and IO no.3). It shows a light implication of the Berlin R&D department in the information exchange during the pre-production run phase of the XS project.

IO no. 6, 7 and 8 are open objects shared by many different users which entail very sensitive information. As a result, these IO are critical IO (see definition section 5.4.1.1) identified thanks to the IO grid.

Among these three IO, we note that IO no. 8, the “Components-to-buy list” has misaligned characteristics. Indeed, it has a high update frequency, and the biggest update duration of the IO grid. This misalignment presumably led to difficulties in the information exchange.

6.2.3.3 SIT grid

The SIT grid[34] realized during the XS project is depicted below (see Table 6.5).

Most of the SIT of the XS project presented in Table 6.5 are project specific and belong to the “project” or the “proximity” information dissemination level.

The SIT grid presented in Table 6.5 highlights that major actors of the ramp-up phase (i.e. Production, R&D and Purchasing) are well represented as “person in charge” or “participants”. However, additional groups of actors also appear, such as Procurement, Quality and Factory Management.

Then, it is noteworthy that a vast part of the project coordination was organized within small groups of actors. Only few meetings to support project-wide coordination were officially scheduled (SIT no.1-2, for a total of 15 meetings) while numerous formal and informal meetings took place locally between two to three actors’ groups (SIT no.8-12, for a total of 80 meetings).

The SIT also highlights the light involvement of the R&D B, the Berlin R&D department in the meetings. This group of actors does not appear in the SIT grid beyond the “public workspace” i.e. it is not involved in any “project workspace” or “proximity workspace” meeting.

[34] See definition section 5.4.2.

	Meeting(s)	Description	Person in charge	Participants	Number of meetings	Project specific	Public workspace	Project workspace	Proximity workspace
1	**Project Status Meetings**	Official project status meetings to review the project progress	Production PM (Production)	R&D G, R&D B Purchasing Procurement Quality	3	Yes	X		
2	**Supplier visits**	Visit in order to discuss parts' qualification	Purch. NP Team (Purchasing)	Procurement R&D G Quality	10	No	X		
3	**Project Milestones Meetings**	Gathering to focus on important deadlines of the project	Production PM (Production)	Production team R&D G, R&D B Purchasing Procurement Quality	2	Yes	X		
4	**Project follow-up meetings**	Review of workpackages' progress and problem solving	Sourcing coordinator (Production)	R&D G Purchasing Procurement Quality	11	Yes		X	
5	**Component qualification meetings**	Weekly review of newly created parts	Local R&D PM (R&D G)	Purchasing	8	Yes		X	
6	**Component supply meetings**	Appointments to discuss the progress of parts supply	Production PM (Production)	Production team Purch. NP team Proc. NP team	20	Yes		X	
7	**Purchasing department meetings**	Regular meetings to review general part supply and common problems	Purchasing	Procurement	12	No		X	
8	**Purchasing information visits**	Review of parts' qualification and problems	Purch. NP Team (Purchasing)	Quality	7	Yes			X
9	**Technical information gathering**	Information gathering to gain knowledge about the new product (structure, parts, etc.)	Production engineering (Production)	R&D G	22	Yes			X
10	**Supply information gathering**	Information gathering to gain knowledge about the progress of the components qualification	Sourcing coordinator (Production)	R&D G Purch. NP team Proc. NP team	19	Yes			X
11	**Information visits**	Information gathering to gain knowledge about the progress of parts' qualification	Local R&D PM (R&D G)	Purch. NP team	17	Yes			X
12	**Qualification information gathering**	Information gathering to gain knowledge about the progress of parts' qualification	Proc. NP team	Purch. NP team	15	Yes			X

Table 6.5 – SIT grid of the XS project

Finally, the SIT grid helps to identify the intense collaboration around the Purchasing team. Indeed, the Purchasing department is involved in almost all the meetings and gatherings that are listed in the SIT grid (all except SIT no.9) and at the "proximity workspace" level, a total of 51 meetings (SIT no.10-12) involve Purchasing.

6.2.3.4 Summary diagram

The summary diagram depicted in Figure 6.4 shows that a lot of actors and departments are involved in the ramp-up project. A total of six actors groups are involved in the main information flows. They are all concerned by the exchange of sensitive information.

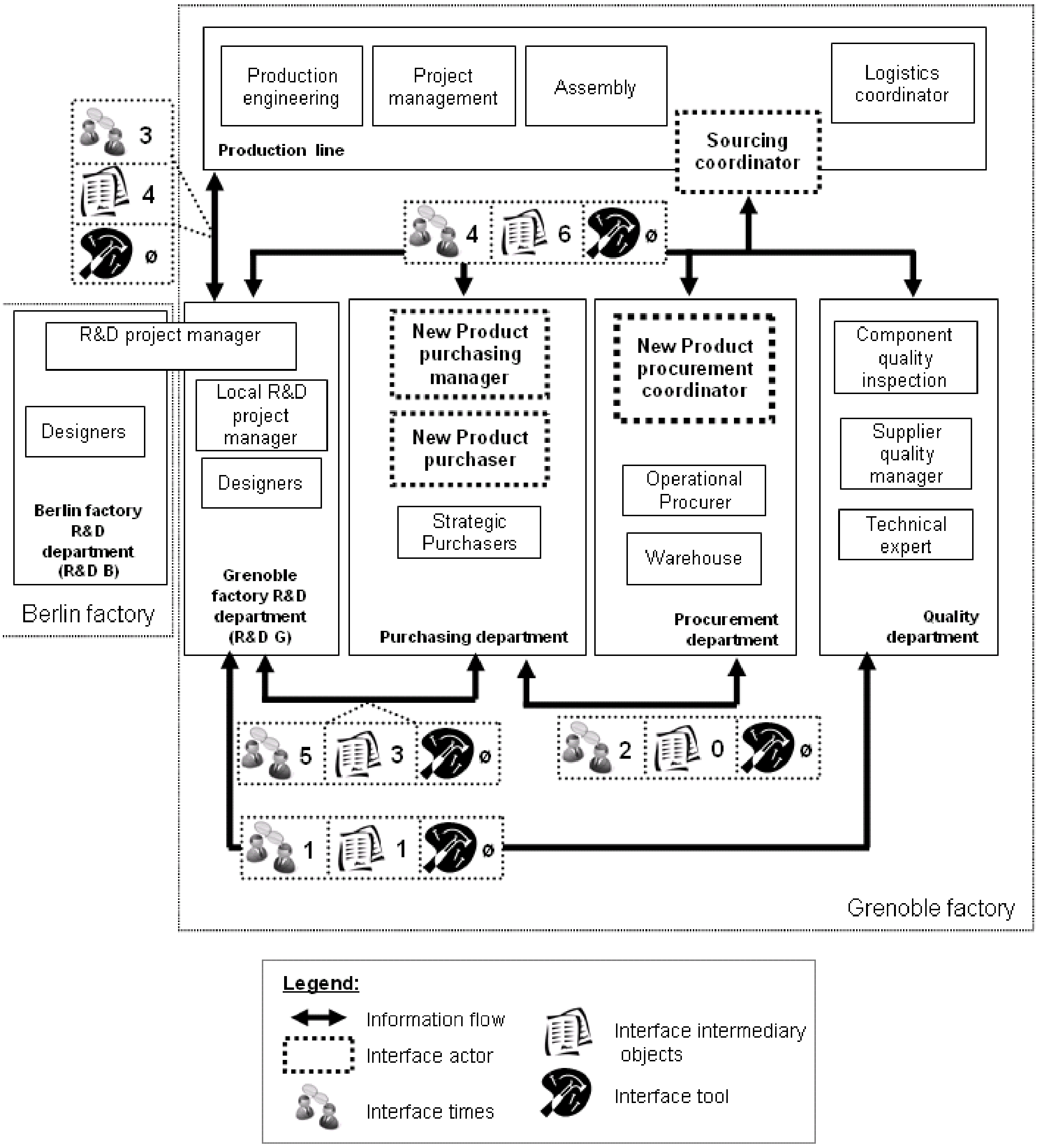


Figure 6.4 – Summary diagram of the XS project case study

The summary diagram depicted in Figure 6.4 highlights where the interface actors are. In the XS project, the three interface actors outlined by the summary diagram belong to the Production – Purchasing/Procurement interface. No other interface actor supports the other interfaces.

The summary diagram also enables the identification of major interfaces. These are:

- The Production – Purchasing/Procurement interface
- The R&D – Purchasing interface
- The R&D – Production interface (which is supported by two parallel information flows)

Lastly, the summary diagram, in detailing the structure of each interface, describes the use (or absence of use) of tools for information exchange in the interface. We can see on Figure 6.4 that during the XS project no specific tool was used for ramp-up actors to exchange information or to foster cooperation.

6.2.4 Conclusions on the XS project case study for the industrial partners

From the audit of the XS project, we can drawn three conclusions and propose several improvement solutions to Siemens practitioners.

First of all, exchanged objects should be taken care and supported by project management and plant management. Indeed, the diagnosis shows that the identified objects are an important way for project actors to exchange critical (sensitive) information. For example, our first improvement proposition for industrials is to secure the “Components-to-buy-list” (IO no.8, see Table 6.4) in future ramp-up situations. This object has been identified as a critical object. Besides, it played an important role in the progress of procurement tasks. It was this list that guided project actors’ effort in setting up the procurement of parts. IO no. 8 was a key object during the project for information exchange and coordination of procurement tasks. And yet, the XS project suffered from a lot of procurement difficulties at SOP (see section 6.2.3.1). We believe that modifying the characteristics of this object will help future ramp-up project to be more successful in setting-up part procurement. In fact, several improvement possibilities are entailed in the diagnosis of the IO grid. Indeed, the IO grid shows that the information of IO no.8 isn’t totally formalized. It is only semi-structured. Moreover, IO no.8 is an open object (modifiable by users) used by numerous actors within the project. We propose to define via an official procedure what should exactly be the content and the frame of such an object, so as to avoid some interpretation mistakes noticed during the lifetime of the IO. Besides, the “update duration” characteristic of the IO grid signals that it was extremely absorbing for the person in charge of it to update this list, even though it needed to be updated frequently (every week). Another improvement suggestion is to facilitate the creation and the update of this list (which could be automatically generated via the ERP for example), here again to improve the information exchange and thus the collaboration around this IO. It will lead to a decrease of the amount of problems related to procurement tasks.

Second, we propose to strengthen the position of the Purchasing department in future Ramp-up projects. Indeed, thanks to the IO and the SIT grids, the Purchasing department was identified as rather being in the background during ramp-up. For example, we noticed from our involvement in the XS project that the “components-to-buy” list (IO no.8, Table 6.4) emerged from a need of the Production team to have a clearer view of the progress in purchasing activities. It corresponds to the problem encountered by the project team to follow-up Purchasing activities (see section 6.2.3.1). To solve this problem so as to ramp up more efficiently, we propose that additional resources and means are given to the Purchasing group. We proposed to Siemens practitioners that the position of New Product Purchaser is to be strengthened, and that this actor is to be involved earlier in the R&D project so as to smooth his workload.

Lastly, the SIT grid draws attention to the fact that most of the collaboration between actors seemed to be localized and are between small groups of actors. This conclusion shed a very interesting light on the communication problems observed between the Berlin R&D team and the other teams during the XS project (see section 6.2.3.1). As the R&D B team was located in another plant of Siemens than all the other teams, the information exchange was more difficult and hence poorer. Furthermore, there wasn’t any alternative tool to overcome bi-localization (as highlighted by the audit). This led to a very light collaboration between the R&D B teams and the other ones and hence difficulties in the achievement of common activities. To solve this problem in future comparable ramp-up situations, we propose to encourage information exchange between all the teams involved in the project. Information exchange at a project dissemination level should be encouraged by project management. Several dedicated meetings could be for example scheduled during the ramp-up phase. Tools should also support the information exchange. A common tool must be dedicated to the exchange of information.

6.3 The GE project

6.3.1 GE project case description

The second project under study is the project of the introduction of the new GE switchgear in production, at the Berlin manufacturing plant of Siemens E T HS. This New Product Development project lasted from March 2006 until May 2009.

The scope of our case study is the final assembly of the GE switchgear product on the manual assembly line in Berlin. The level of analysis chosen is still project actors’ groups, defined according to departmental organization. In the GE project, a total of four departments participated to the ramp-up project:

- the Production department
- the R&D department
- the Purchasing department
- the Prefabrication department

An organizational chart of the GE ramp-up team is given in Appendix V, see section 8.5.

In the GE project, the product was new to the Production department: indeed, it has been developed by the R&D center. The new GE product required a new production system. As a consequence, the GE project is located on the upper row and the right column of our complexity matrix (see Figure 6.5), which means that the GE project is a very complex ramp-up situation.

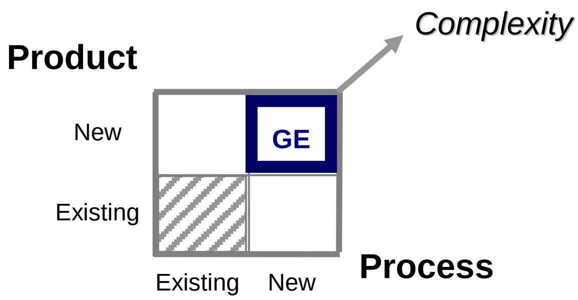


Figure 6.5 – Complexity of the GE project (framework adapted from (Almgren 1999a))

6.3.2 Case study protocol

The audit of the GE project was carried out between October and November 2008. By that time, the GE project was in its "Run-up period" (see Figure 6.6).

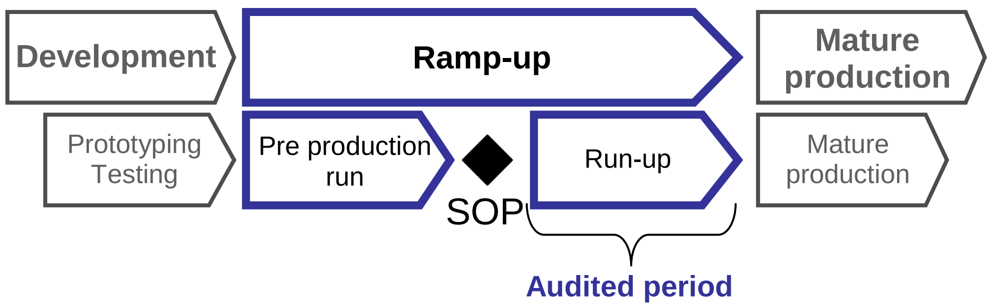


Figure 6.6 – Phase of the GE project by the time of the audit

The position adopted by the main researcher was the "Observer as Participant" position, i.e. a position that allows an external audit to be carried out. The main researcher realized only interviews and hadn't any practical involvement in the GE project.

In fact, the main researcher realized **two series of interviews** of the major stakeholders of the GE ramp-up project.

The goal of the **first row of interviews** was to acquire general knowledge about the NPD project under study, i.e. the GE project and about the Berlin factory (its organization, its general processes, etc.). Eleven stakeholders of the ramp-up project (from the Production, the R&D and the Purchasing departments) were asked about their experience of the GE project in unstructured interviews with open-ended questions. Other sources of information (factory tour, internal documentation …) completed the overview of the project context and the project progress.

The goal of the **second row of interviews** was to acquire knowledge about the actual functioning of the interfaces of the GE project. The goal was to identify how and where information was exchanged. 12 project stakeholders were interviewed; since a new stakeholder had been identified during the first row of interviews (a project actor from the Purchasing department). These interviews were structured interviews (see Appendix VI, section 8.6). A document explaining the goal of the interviews and giving explanations about our interface model was sent previous to the participants. After collecting all required information to establish a preliminary list of the intermediary objects and the interface times of the projects, an **e-mail questionnaire** was sent so that actors can fill up the IO grid and the SIT grid. This questionnaire included explanations about our interface model, the interface characteristics chosen, how they were to be evaluated etc. (see Appendix VII, section 8.7). The document was once again explained at the beginning of the interviews and the interviewees were asked to fill the grid (if they had not done it before). The results presented here are average values of collected answers. The results were fed back to interviewees for a final validation. The main researcher had also the opportunity to participate to **two project meetings** (as a silent observer) that were held during the time of her investigation.
Finally, case data and results of the investigation on the GE project were **fed back to the interviewees and to key partners** in the company for validation.

A summary of the characteristics of the GE project investigation is given in Table 6.6.

GE project investigation
12 interviewees
16 interviews
2 weeks of investigation at the manufacturing plant
2 meetings attended
9 meetings of 12 key respondents to fill the grids
1 factory tours
Other collected data: - Description of the official NPD process - Versions or screenshots of exchanged documents such as Excel-files, databases… - Minutes of meetings - Presentation of meetings - Etc.
Feedback to interviewees: January 11th, 2010
Feedback to the steering committee: January 15th, 2009
Internal report of 62 pages, issued June 15th, 2009

Table 6.6 – Characteristics of the investigation of the GE project

6.3.3 Results and analysis

6.3.3.1 Major difficulties of the GE project

Our interviews allowed us to distinguish two key issues that disrupted the progress of the GE project during its run-up phase:

(i) The postponement of the end of the run-up phase, which correspond to the official handover of the project from the R&D team to the Production department (Problem GE1).

Indeed, as manufacturing began, some development tasks were still on-going. This created perturbations and additional difficulties for the whole project team.

(ii) Communication and cooperation problems between the R&D department and the Production department (Problem GE2).

The Production department actors reported that they encountered several difficulties during the run-up phase of the project because the R&D department didn't sufficiently take into account their requirements during the development phase. On the other hand, the R&D department complained about too vague specifications and too many additional requests scattered in time from the Production department team, which increased the duration and the complexity of the development phase and other project phases.

No other significant communication or information exchange difficulties were mentioned by the different project actors. However, interviews with ramp-up actors revealed that they felt a little bit "helpless" at the beginning of the project, due to the lack of specific tools and specific instructions for the ramp-up phase management (Problem GE3). They reported that they had to "create" themselves several means to cooperate (meetings or shared documents). They regretted that these tools were not defined by company rules and that they had not been given prior to the beginning of the ramp-up phase.

The problems encountered by the GE project are coherent with the classifications of ramp-up problems presented in section 4.3.1 and section 4.3.3. Table 6.7 shows in which problem types of the resource-based classification and the cause-based classification the problems encountered by the GE project are clustered.

	Resource-based classification	Cause-based classification
Problem GE1	Components	Cooperation
Problem GE2	Actors of the R&D and the Production department	Communication
Problem GE3	Tools	Management

Table 6.7 – Problem types of the problems encountered during the GE ramp-up phase

6.3.3.2 GE project's IO grid

The IO grid realized during the investigation of the GE project is shown in Table 6.8.

	Intermediary object	Description	Person in charge	Users	Support	Structure	Update frequency	Evolution	Openness	Sensitivity	Update duration
1	**Drawings and BOM[35]s**	Drawings and BOMs of the GE product	R&D	Production Purchasing	PLM software	SI[36]	High	Fast	Closed	High	5 hours
2	**Project folder**	Official documentation for assembly	Customer PM (Production)	Assembly (Production)	Paper	SI	Average	Fast	Closed	Average	8 hours
3	**Production schedule**	Planning of the customers orders	Customer PM (Production)	Assembly (Production) Material scheduler (Production)	ERP software	SI	Average	Fast	Closed	High	4 hours
4	**3D design models**	CAD models of product subassemblies	R&D	Production	CAD software	SI	Low	Slow	Closed	High	8 hours
5	**Assembly problems data base**	Data base of problems encountered in the shop floor	Customer PM (Production)	All	MSAccess file	SSI[37]	Average	Slow	Open	Average	3 hours
6	**Work and test instructions**	Assembly and test procedures for the shop floor	R&D	Production Eng. (Production)	MSWord file	SI	Average	Slow	Closed	Average	3 hours
7	**Customer order BOM**	Bill of material of the ordered customized products	Production Eng. (Production)	Material scheduler Assembly (Production) Material planner (Purchasing)	ERP software	SI	High	Fast	Closed	High	4 hours
8	**SAP program**	Dynamic list of material new to the ERP system	Customer PM (Production)	Material planner (Purchasing)	ERP software	SI	High	Slow	Closed	High	1 hour
9	**Minutes of preparation meetings**	List of problematic issues encountered during ramp-up	Customer PM (Production)	All	MSWord file	SSI	High	Slow	Open	High	3 hours
10	**Drafts**	Raw drawings representing a future equipment or product subassembly	R&D	Customer PM Assembly (Production)	Paper or CAD[38] software	NSI[39]	Low	Fast	Closed	Average	4 hours

Table 6.8 – IO grid for the GE project

[35] See glossary of acronyms
[36] See glossary of acronyms
[37] See glossary of acronyms
[38] See glossary of acronyms
[39] See glossary of acronyms

Several conclusions can be drawn from the analysis of the IO grid presented au-dessus.
First of all, the objects listed in the IO grid enclose sensitive or very sensitive information. Since the list presented might not be exhaustive, this characteristic shows that the listed objects are at least part of the most important ones for the project.
Second, most of the intermediary objects of the IO grid are closed and structured objects. The significant structuring of objects comes from the use of several company-wide tools such as ERP, PLM or CAD software systems as support of the intermediary objects. We notice that objects supported by these tools are mostly fast evolving objects (IO no.1,2, 7, 10) but with a significant update duration (4 to 8 hours).
Third, the most critical IO appears to be IO no. 9, “Minutes of preparation meetings”. Indeed, this IO encloses critical information and is open to modifications by its numerous users. Furthermore, its evolution is slow, enabling late crucial modifications.
Finally, the IO grid highlights that R&D and Production are the two main sources of information in the ramp-up of the GE project. In fact, no other actor is “person in charge” of the objects listed in Table 6.8. Purchasing is cited as “user” of half of the IO itemized in the IO grid (IO no. 1, 5, 7-9) and no other actor of the company is explicitly cited in the IO grid.

6.3.3.3 SIT grid

The SIT grid of the GE project shown in Table 6.9 highlights that a lot of interface times that occurred during the GE project were project specific meetings. This confirms that ramp-up situation is a very specific situation, where a lot of actors have to exchange information. From our interviews with ramp-up actors, we learned that many meetings listed in the SIT grid were created specifically for this project and hadn’t existed before.
Second, in the SIT grid, all ramp-up actors depicted in Appendix V (see section 8.5) are present. An important part of the company actors are indeed still involved in the run-up phase of ramp-up.

However, we notice that the main actors are the R&D and the Production departments: they are the only actors involved in 9 SIT out of 11. As a result, Purchasing is only lightly involved, mostly as participant of meetings itemized in the SIT grid in Table 6.9.
Lastly, the SIT grid shows that, in the case of the GE project, most of the meetings are happening at a “project” level, concerning information dissemination level.

	Meeting(s)	Description	Person in charge	Participants	Number of meetings	Project specific	Public workspace	Project workspace	Proximity workspace
1	**Milestones reviews**	Official project status meetings to review the project progress	R&D PM (R&D)	Assembly (Production)	8	Yes	X		
2	**Procurement - Material scheduling meetings**	Coordination meetings between Procurement and the Material scheduler	Purchasing	Material scheduler (Production)	4	No	X		
3	**Material scheduling-Assembly meeting**	Review of on-going production projects and their problems	Customer PM (Production)	Material scheduler Assembly (Production)	17	No		X	
4	**Production - R&D meetings**	Presentation and discussion of different product subassemblies under development	R&D PM (R&D)	R&D team Assembly Production engineering Customer PM (Production)	8	Yes		X	
5	**Meetings for preparation of material**	Preparation of the first projects and discussion of the problems encountered	Customer PM (Production)	Assembly Material scheduler (Production) R&D Material planner (Purchasing)	20	Yes		X	
6	**R&D back-up**	Techncial support from the R&D department to realize the first customer projects	R&D team	Production Engineering (Production)	2	Yes		X	
7	**Problem sovling meetings**	Unscheduled meetings, dedicated to the immediate solving of important problems	Customer PM (Production)	R&D PM Assembly (Production)	5	Yes		X	
8	**On the spot meetings**	Targeted appointments to find short-term solutions to assembly problems	Assembly	Customer PM (Production) R&D PM (R&D)	8	Yes		X	
9	**Informal exchanges to solve problems**	Unscheduled meetings, phone calls or casual discussions	Customer PM (Production)	R&D PM (R&D)	40	Yes		X	
10	**Informal exchanges to solve problems**	Unscheduled meetings, phone calls or casual discussions	Assembly (Production)	R&D PM (R&D)	30	Yes		X	
11	**Informal exchanges to solve problems**	Unscheduled meetings, phone calls or casual discussions	Customer PM (Production)	Material scheduler (Production)	20	Yes			X

Table 6.9 – SIT grid for the GE project

6.3.3.4 Summary diagram

The summary diagram realized during the audit of the GE project is shown in Figure 6.7.

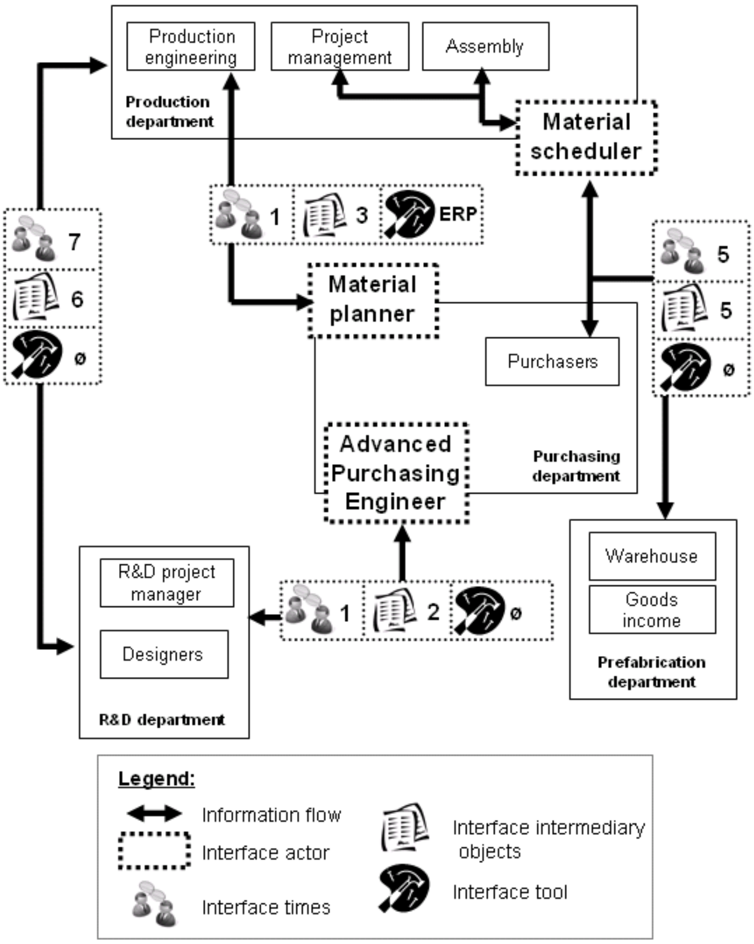


Figure 6.7 – Summary diagram of the GE project

First of all, thanks to the summary diagram, three interface actors have been identified: the Material Planner, the Berlin Advanced Purchasing Engineer and the Material Scheduler (from the Production department). The Material Planner supports the Production – Purchasing interface, which is also supported by a company-wide tool, the ERP system. The Berlin Advanced Purchasing Engineer is at the interface between the Purchasing department and the R&D department. The Material Planner is responsible for the interface between Production and part procurement stakeholders, namely the Purchasing and the Prefabrication departments.

Second, the Production – R&D interface is one of the most concentrated interfaces in IO and SIT. The summary diagram highlights that no specific interface actors and no specific tool are supporting this interface. Furthermore, the interviewees reported still a lot of communication and cooperation problems between the production and the R&D teams (see section 6.3.3.1). The other very dense interface is the one supported by the Material Planner, namely the Production – Purchasing/Prefabrication interface.

Lastly, only the ERP system is mentioned as a tool supporting a specific interface (in Figure 6.7, the Production – Purchasing interface). Other tools do not appear as specifically dedicated to the support of information exchange in other project interfaces.

In the next section, the conclusions of the audit of the GE project are presented.

6.3.4 Conclusions of the GE project for the industrial partners

Auditing the GE project, we are able to outline three improvement propositions.

A first improvement proposition concerns the Berlin Advanced Purchasing Engineer. In the Berlin organization, this role has recently been set-up in the organization of NPD projects. The Berlin Advanced Purchasing Engineer's role is to support the R&D – Purchasing interface, being involved very early in the R&D project. He enables a smooth cooperation between the R&D department and the Purchasing department. Indeed, during the interviews of the GE project participants, no major component procurement problem due to a lack of information exchange was reported (see section 6.3.3.1). As a result, we defend that this is a positive and efficient result of the appointment of a special interface actor to support the R&D – Purchasing interface. We recall that this position has been lacking in the XS project which suffered from many procurement problems. Thus, we propose to systematically appoint an Advanced Purchasing Engineer in future ramp-up projects and to assure that he is involved as early as possible in the R&D project.

Second, we argue that another interface actor can be useful to improve and smooth the information exchange in the Production – R&D interface. Indeed, the delay problem of the run-up phase is mostly due to a lack of efficiency in the Production – R&D interface. Both Production and R&D actors reported communication and cooperation problems (see section 6.3.3.1). Moreover, the Production actors complained that no tool or system was available to foster the information exchange between R&D and Production. As a consequence, the actors created many IO and organized many SIT information exchange. We argue that an interface actor, responsible for the information exchange between the departments could allow a decrease in the amount of participants to meetings and the number of necessary IO and SIT. Namely, different systems are possible to dedicate a resource to the interface between the Production and the R&D department. Either project actors could rotate: for example, a member of the Production engineering team and a member of the R&D team could temporarily switch places. The job roles are comparable and they could become key respondents for the cooperation between the two departments. Another system is to dedicate a single resource (from one or the other department) to be the unique interface actor.

Finally, the IO and the SIT grid outline the different means (intermediary objects and meetings) that were created especially for the GE project. Interviews with ramp-up actors revealed that they felt a little bit "helpless" at the beginning of the project, due to the lack of specific tools and specific instructions for the ramp-up phase (see section 6.3.3.1). To our mind, efficient tools used during the GE project (such as the preparation meetings or the problem data base) should be formalized within Siemens E T HS as the toolbox for future ramp-up situations. It could allow future ramp-up project managers to benefit from the experience of the GE project.

6.4 The BD project

6.4.1 BD Project Case description

This project involves the introduction of a new switchgear subsystem, the BD system, in production, at the manufacturing plant of Berlin. The New Product Development project, managed entirely by the Grenoble R&D team, began in July 2008 and ended in April 2010.
The scope of the case study is the end of the development phase of the BD subsystem, at the Grenoble R&D department. There were six major departments (hence six actors' group) involved in this project:

- the Grenoble R&D department
- the Berlin Production department
- the Berlin Marketing department
- the Grenoble Quality department
- the Grenoble Purchasing department
- the Berlin Purchasing department

An organizational chart of the BD ramp-up team is given in Appendix IX (see section 8.9).
In the BD case, we note that two Purchasing departments were involved. Indeed, the split-up of the NPD project over two countries and two plants (namely the development phase in Grenoble and the production phase in Berlin) led to the split-up of procurement tasks. On the one hand, the development tasks were performed by the R&D department of Grenoble. Hence, the Purchasing department of Grenoble was in charge of procuring parts for prototypes and test objects. On the other hand, the Berlin plant was responsible for production. Hence, the Berlin Purchasing department was involved in the project to set up the procurement of series parts.

Regarding ramp-up project complexity, the BD project is a less complex ramp-up situation since the production system wasn't started from scratch. Indeed, in the BD project, the product is new to the Berlin Production department: it has been developed by the Grenoble R&D center. However, the production of the new BD subsystem has been directly introduced on the existing production line of the product enclosing the new BD subsystem. As a consequence, the BD project is located on the upper row but the left column on our complexity matrix (adapted from (Almgren 1999a)'s framework, see Figure 6.8), which means that the BD project is a less complex ramp-up situation than the XS project, for example.

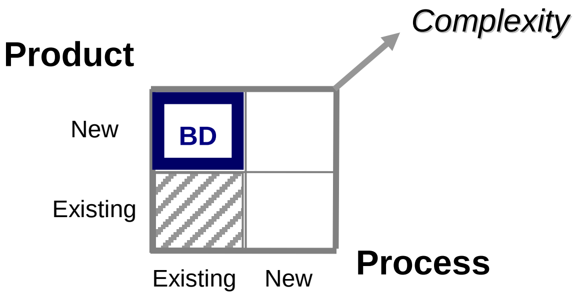


Figure 6.8 – Complexity of the BD project (framework adapted from (Almgren 1999a))

6.4.2 Case study protocol

The audit of the BD project was carried out between October 2009 and January 2010. By that time, the BD project was in its "Prototyping/Testing" phase, just before the actual beginning of the ramp-up phase (see Figure 6.9).

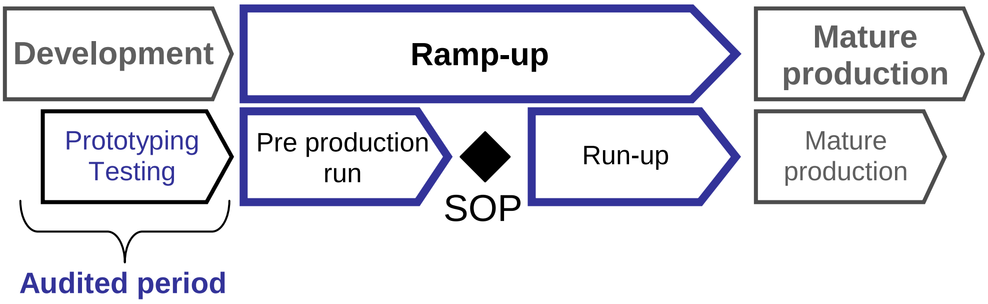


Figure 6.9 –: Phase of the BD project by the time of the audit

The position adopted by the main researcher was the "Participant as Observer" position, i.e. a position where the main researcher was actually involved in the project, even though her status of research wasn't hidden. Her role was to ensure the part qualification and a smooth ramp-up at the Berlin factory. This role implied weekly exchanges with the actors involved in the BD project. The main researcher also realized interviews with the project key actors and kept a field notebook during the whole duration of her involvement.

Case data was collected through **participation in the project** and **interviews** with the main project actors (Project Manager, Advanced Purchasing Engineers, Production Engineer…) and field observation. The aim was to look for multiple viewpoints.

Project actors' interviews also enabled the filling of the grids of the auditing tools. Each key actor was asked for the intermediary objects he or she used or the meetings he or she participated to. The answers were completed with findings from field notes.

Once different items of the grids identified, their criteria and the operational rules were explained to interviewees. They were then asked to fill the grids they were given with their estimated value of each concept. The results presented in the IO and the SIT grids are average values of all the answers collected. These results were **fed back to the interviewees** for a final validation.

Finally, case data and results of the investigation were **fed back to key partners** in the company (organized in a steering committee of the research presented here) for validation.
A summary of the characteristics of the BD project investigation is given in Table 6.10.

BD project investigation
5 interviewees
10 interviews
12 weeks of involvement
7 meetings attended
10 interviews of 5 key respondents to fill the grids
Other collected data: - Follow-up Excel-list of component qualification - Versions of exchanged documents such as drawings, follow-up sheets … - Etc.
Feedback to interviewees: November 23rd , 2009
Feedback to the steering committee: January 12th, 2010
Internal report of 28 pages, issued March 5th, 2010

Table 6.10 – Characteristics of the investigation of the BD project

6.4.3 Results and analysis

6.4.3.1 Major difficulties of the BD project

The major difficulty encountered during the prototyping / testing phase of the BD project was the fact that the Development phase of the BD project took place in Grenoble while its ramp-up phase occurred in Berlin (Problem BD1). The actors of the BD project had to overcome the distance problems, the language barriers and the difference between the two organizations. During his interviews, the R&D project manager admitted that he lacked knowledge and information about how the manufacturing plant was working in Berlin (Problem BD2). Thus it was more difficult for him to have a clear view of the needs of the Production team. He acknowledged that he had to put in place very regular net meetings so as to exchange information and cooperate with his colleagues from Berlin (Problem BD3).
Otherwise, the prototyping / testing phase of the BD project was considered as successful, since no major problem was observed at the beginning of the ramp-up phase. The feedback from the Production stakeholders was very good. They decided to skip the pre-production run and directly start the production in manufacturing a product for the end customer. However, this production is to occur at the Berlin plant more than six months after the official end of the prototyping/testing phase. As a consequence, we lack feedback about the first assemblies of BD product in the Production line at the Berlin factory.

The problems encountered by the BD project are again coherent with the classifications of ramp-up problems presented in section 4.3.1 and section 4.3.3. Table 6.11 shows in which problem types of the resource-based classification and the cause-based classification the problems encountered by the BD project are clustered.

	Resource-based classification	Cause-based classification
Problem BD1	Actors of the R&D and the Production department	Cooperation
Problem BD2	Actors of the R&D and the Production department	Missing knowledge
Problem BD3	Tools	Management

Table 6.11 – Problem types of the problems encountered during the BD ramp-up phase

6.4.3.2 IO grid

Based on the IO grid for the audit of the BD project shown in Table 6.12, we can make the following remarks.

First of all, a majority of IO listed in Table 6.12 are “semi-structured” objects (10 IO out of 13). They are mostly supported by MS Excel.

Second, the IO grid outlines that only a small amount of actors are really highly involved in the information exchange. Indeed, the production department is only lightly involved through one contact person of the production engineering team and the Quality and the Marketing departments are only cited once. The source of information is mostly the R&D department (8 IO out of 9) and users are from the Grenoble and Berlin Purchasing departments (6 out of 10).

Third, the IO grid presented in Table 6.12 entails atypical objects:

- Several objects of the grid are characterized as “low sensitivity” objects, which hasn’t been the case in the two other cases studies
- IO no. 4, Screenshots, is an intermediary object without possible update. As a consequence, it has no update frequency and no update duration. It is impossible to evaluate its evolution and its sensitivity, since these criteria are related to a modification of the information enclosed in the IO.

To conclude the analysis of the IO grid of the BD project, no object listed in Table 6.12 is a critical IO. Indeed, all the objects have only few users. Nevertheless, IO no. 6 appeared to be a key object for coordination between actors by the time of the audit of the project. Indeed, we noted from the interviews realized with the project actors that this object was central.

	Intermediary object	Description	Person in charge	Users	Support	Structure	Update frequency	Evolution	Openness	Sensitivity	Update duration
1	**Drawings**	Drawings of the different components and subassemblies of the final product	R&D	Advanced Purch. Engineer (Purchasing Gre.)	PLM software	SI	Average	Fast	Closed	High	8 hours
2	**R&D BOM**	List of all the sub-assemblies and components of the product	R&D	R&D	MS Excel file	SSI	Average	Fast	Closed	High	1,5 hour
3	**Production BOM**	Description of the composition of production sub-assemblies	R&D	Advanced Purch. Engineer (Purchasing Gre.)	PLM software	SI	Low	Fast	Closed	Low	8 hours
4	**Drawing screenshots**	Screenshot of a drawing which is not official	R&D	Advanced Purch. Engineer (Purchasing Gre.)	Acrobat PDF file	SSI	No update	No update	Closed	No update	No update
5	**Review Checklist**	List of all the open topics and risk issues reviewed at a milestone review	R&D	Production Purchasing Gre.	MS Excel file	SI	Low	Slow	Closed	High	4,5 hours
6	**Minutes of weekly meeting**	List of the items discussed during the weekly meeting	R&D	All	MS Word file	SSI	High	Slow	Closed	High	1 hour
7	**Folder per component**	Folder including documents concerning the qualification of components	Advanced Purch. Engineer (Purchasing Gre.)	R&D	Intranet	SSI	High	Fast	Open	High	1 hour
8	**Request-for-Quotation Follow-up**	Follow-up list of the Advanced Purchasing Engineer	Advanced Purch. Engineer (Purchasing Gre.)	R&D	MS Excel file	SSI	High	Slow	Open	Low	1 hour
9	**Team workload**	Tasks in process within the R&D team	R&D PM (R&D)	R&D	MS Excel file	SSI	High	Slow	Open	High	3 hours
10	**DFM[40] Guidelines**	List of all the DFM Guidelines to take into account	Production	R&D Production	MS Excel file	SSI	Low	Fast	Open	Low	4 hours
11	**Test planning**	Planning of the different development and type tests	R&D PM (R&D)	R&D Advanced Purch. Engineer (Purchasing Gre.)	MS Excel file	SSI	Average	Fast	Closed	High	1 hour
12	**Sample request follow-up**	Follow-up of the samples asked to suppliers	Advanced Purch. Engineer (Purchasing Gre.)	R&D PM (R&D)	MS Excel file	SSI	High	Fast	Open	High	1 hour
13	**Sample reports' list**	List of all the sample reports	Quality	R&D Advanced Purch. Engineer (Purchasing Gre.)	MS Excel file	SSI	High	Slow	Open	Low	1 hour

Table 6.12 – IO grid of the BD project

[40] See glossary of acronyms

6.4.3.3 SIT grid

The SIT grid realized during the audit of the BD project in July 2009 is shown in Table 6.13.

	Meeting(s)	Description	Person in charge	Participants	Number of meetings	Project specific	Public workspace	Project workspace	Proximity workspace
1	**Milestones reviews**	Official reviews of the Siemens New Product Development process	R&D PM (R&D)	All	8	Yes	X		
2	**Weekly net meeting**	Follow-up of the progress of the R&D project and information exchange	R&D PM (R&D)	Advanced Purch. Eng. (Purchasing Gre.) Advanced Purch. Eng. (Purchasing Ber.) Production engineering (Production)	48	Yes		X	
3	**Dedicated meetings NP Purchaser - R&D**	Focused discussions about new parts' qualification	R&D PM (R&D)	Advanced Purch. Eng. (Purchasing Gre.)	20	Yes		X	
4	**Phone calls**	Focused discussions about new parts' qualification	R&D PM (R&D)	Advanced Purch. Eng. (Purchasing Gre.)	40	Yes		X	
5	**Weekly follow-up of the prototype components supply**	Follow-up of the prototype parts' procurement	R&D PM (R&D)	Advanced Purch. Eng. (Purchasing Gre.) Advanced Purch. Eng. (Purchasing Ber.)	6	Yes		X	
6	**Information exchange with Production meetings**	Discussion of necessary documents and information for the Production	R&D PM (R&D)	Production engineering (Production)	17	Yes		X	
7	**DFM[41] Reviews**	Review of the different guidelines to take into account	Production engineering (Production)	R&D PM (R&D)	2	Yes		X	
8	**Design follow-up**	Follow-up of the design progress	R&D PM (R&D)	R&D	20	Yes			X
9	**Architecture follow-up**	Follow-up of product architecture	R&D PM (R&D)	R&D	15	Yes			X

Table 6.13 – SIT grid of the BD project

We can draw three conclusions from the SIT grid shown in Table 6.13.

First of all, the major actor of the BD project by the time of the audit is the R&D department. R&D is a stakeholder in all the meetings listed in the SIT grid. The R&D team is an important source of information and a very dynamic actor in the project: it is the organizer of 7 meetings (out of 9).

Second of all, the SIT grid of the BD project sheds a light highlights the intense exchanges between R&D and Purchasing:

- Three SIT are entirely dedicated to the coordination between the R&D team and the Grenoble Advanced Purchasing Engineer (SIT nos. 3, 4, 5). Moreover, these SIT have a noteworthy high amount of meetings compared to other SIT.

[41] Design for Manufacturing

- Grenoble Advanced Purchasing Engineer and R&D also have two additional opportunities to discuss issues: during weekly net meeting (SIT no.2) at a project level, and during Milestone reviews (SIT no. 1) at a public level.

Finally, Production is involved in a very light way: we can notice only information exchange concerning the preparation of production launch at R&D request (SIT no. 6) and concerning the Design-for-Manufacturing approach (SIT no. 7). This is certainly related to the status of the project by the time of the audit. The BD project was at a very early stage (actually, before the beginning of ramp-up, at the “Prototyping/Testing” stage) during the realization of the case study.

6.4.3.4 Summary diagram

Figure 6.10 shows the summary diagram realized for the audit of the BD project.

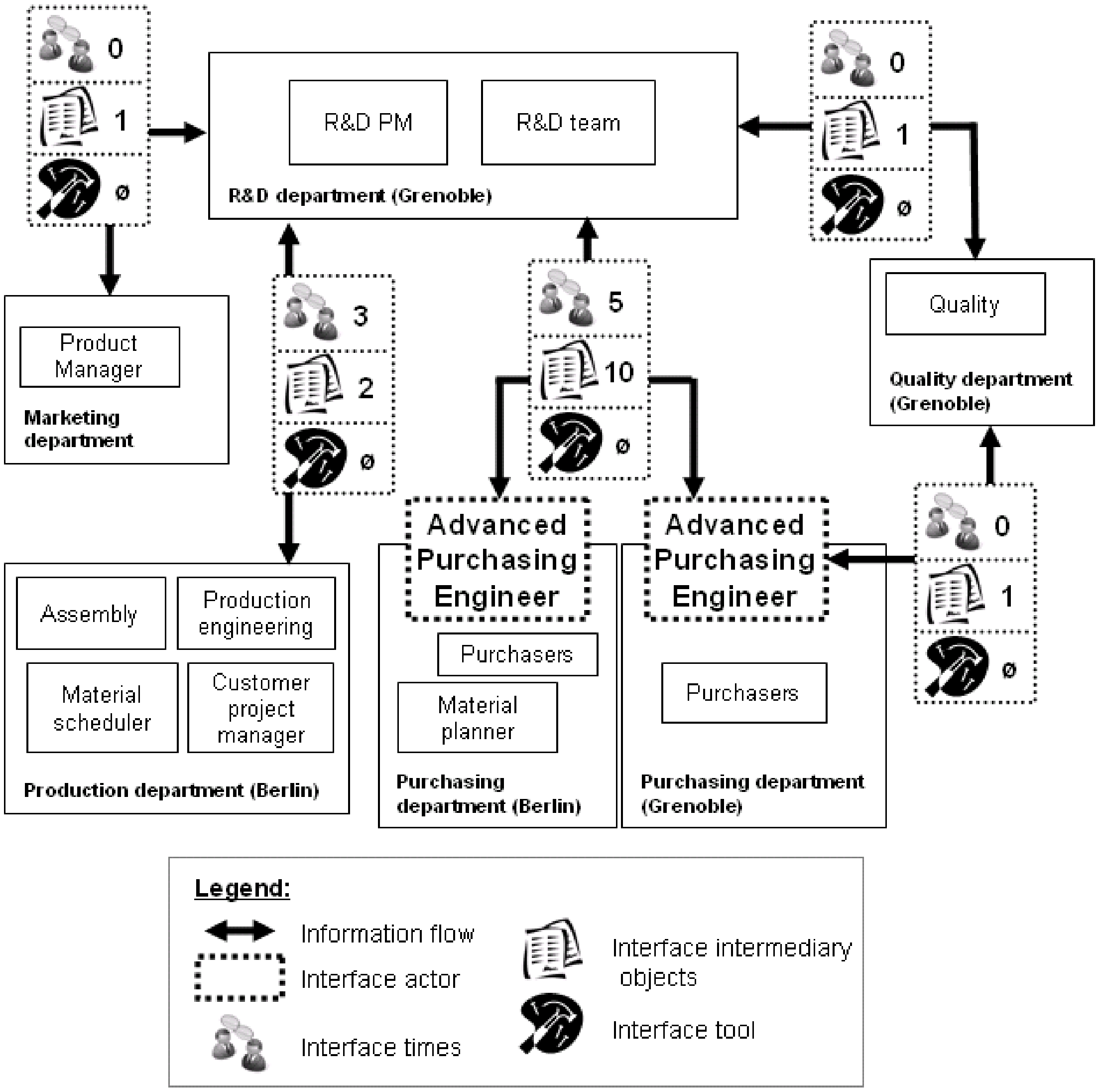


Figure 6.10 – Summary diagram for the BD project

First of all, the most important interface is the interface between the R&D team and the Purchasing teams (Purchasing Grenoble and Purchasing Berlin). 10 IO and 5 SIT are necessary between these actors to continuously exchange information.

Second, the summary diagram highlights the “interface role” of the Berlin Advanced Purchasing Engineer and the Grenoble Advanced Purchasing Engineer. They are interface actors, ensuring that the information issued by the R&D department flows in the Purchasing department. In the BD case, two Purchasing departments were involved. Indeed, the Grenoble Purchasing department was responsible for the procurement of parts for prototypes and test objects (see section 6.4.1). As far as the plant of Grenoble is concerned, a special emphasis was put on the role of the Advanced Purchasing Engineer as a result of our conclusions of the case study of the XS project.

Lastly, we can see on the summary diagram that other departments (such as Production, Marketing or Quality) are only linked to the R&D department through a very light interface.

6.4.4 Conclusions of the BD project for the industrial partners

Thanks to the different diagnosis tools, we can draw several conclusions from the GE study and propose improvement solutions.

First of all, the IO grid highlights the numerous Excel-files used as intermediary objects. To our mind, many of them should be incorporated in a computer system, such as for example IO no. 8 (Request-for-Quotation follow-up) and IO no. 12 (Sample request follow-up). In the case of the BD project, no major problem happened because of these files but we observed (in the XS project case study for example) that Excel-files shared by many users as cooperation tool increase the risk of errors. The Excel-files such as IO no. 8 or IO no. 12 are built thanks to information retrieved from the ERP. A customized program in the ERP would decrease the risk of errors and avoid necessary manual updates. Furthermore, Siemens E T HS also uses a workflow system which can support collaborative tasks and which is more reliable for processes (such as Request for Quotation or Sample request) that require the involvement of many different actors.

Second, the IO grid and project actors’ interviews highlight the collaboration that takes place around IO no. 6 (Minutes of weekly net meetings). This IO is coupled with an important SIT, highlighted also by the SIT grid: the SIT no. 2 (Weekly net meetings). Both of these elements are at the core of the cooperation between the R&D department and the other major stakeholders of the project (Purchasing and Production). Interviews with project actors revealed that these were meetings and objects specifically created for the BD project. We propose that these elements are systematically integrated in future projects. Indeed, it seems to us that the success of the BD project is linked to the means that project actors developed in order to exchange information and cooperate.

Third, the SIT grid highlighted that the DFM approach allows the Production department to be involved earlier in a R&D project. Thanks to this approach (composed of DFM guidelines, IO no. 10 and DFM meetings, SIT no. 7), Production department can play its role in influencing design. This certainly improves the handover of the R&D project to Production at the start of production ramp-up. This also improves the manufacturability of the product. We proposed to the R&D team to initiate the ramp-up phase with a thorough presentation of the R&D project (the new elements) to whole Production team. This meeting was held and we could report that very interesting questions were raised and that the Production team seemed to easily accept the new product as is.

Finally, the summary diagram highlights the key role of the Berlin Advanced Purchasing Engineer and Grenoble Advanced Purchasing Engineer in R&D projects. We stress that to our mind, this job role has to be maintained in all future R&D projects. Indeed, the Advanced Purchasing Engineer is a very useful interface actor. He is responsible for parts procurement and he makes sure that procurement is set up for the start of production. Having only one key respondent concerning procurement issues is very useful for Production and R&D. In fact, we noted during the XS project case study that having many different Purchasing contacts leads to a feeling of opacity for other project actors. It seems to us that the success of the BD project concerning the procurement of parts (whether for prototypes or for series production) is related to the presence of Advanced Purchasing Engineers.

Three different case studies were realized at three different steps of the NPD process but within the same company. Crossing the results of the three case studies brings very interesting results, presented in the next section. Next section also presents our general conclusions.

6.5 Case comparison

In this research work, we realized three case studies within the same company but

(i) on different projects
(ii) at different stages within the NPD process and
(iii) occurring at different locations.

It enables the identification of very interesting common points and differences.

6.5.1 Key actors' groups and major information flows

Key actors' groups vary according to the cases. Comparing them in a chronologically order from the NPD process point of view, the three case studies outline that:

- In early phases of the NPD project (at the Prototyping and testing stages) the R&D is the key actor. Most of the coordination is done around the R&D department, with a huge information flow in the direction of the Purchasing department. R&D department has a high level of initiative. Other departments are very lightly involved.
- When the ramp-up phase starts, with the pre-production run, key actors groups are still R&D and Purchasing, but Production heavily steps in the project. The next milestone, SOP, represents the official handover of the project from R&D to production so the Production department has a high level of initiative. Other actors

(Quality department, operational procurement, etc.) gradually step in the project. Information flows become denser than at the previous stage: more actors are involved, more information is exchanged.

- When the run-up phase starts, Production and R&D stay the key actors' groups and other departments gradually step out of the project.

6.5.2 Key interface actors

Key interface actors only slightly vary from one case to another and are very comparable.

An interface actor is often present in the Production team (the Sourcing Coordinator in the XS project, the Material Scheduler in the GE project).

An interface actor is always representing the Purchasing department in the NPD project, at all stages of the project progress. This interface actor was called "Grenoble Advanced Purchasing Engineer" in Grenoble and "Berlin Advanced Purchasing Engineer" in Berlin, but their role and tasks are basically the same. They appear in each case study, depending on where the supply chain had to be started.

Surprisingly, even though R&D is also a key actor at different phases of the NPD process under study, no interface actor was identified. Most of the initiative and information come from the R&D project manager. Of course, part of the role of the R&D project manager is to be an interface towards other departments but it is only part of his role. We observed that the R&D project manager is a lot occupied with the internal coordination of R&D tasks, with planning and R&D project global follow-up (cost, time, efficiency). Even though DFM is a help to integrate Production requirements to the general requirements of the Development phase, we noted that R&D actors are very little "customer-oriented". It is therefore harder for them to fully take on the role of interface between R&D and Production.

6.5.3 Interface structure

There are differences among the cases concerning the interface structure. In the XS case, the interfaces were mostly structured thanks to IO and SIT with very dense interfaces. On the contrary, in another very dynamic phase (the run-up phase), the GE project exhibits very structured information thanks to the use of several company-wide tools. Interface actors are deeply rooted in the organization and are fully playing their role of "information relay".

6.5.4 Information dissemination level

In both the GE and the BD projects, most of the information is disseminated at a "project" level. It shows that local project coordination is a very important mechanism for the information exchange. Furthermore, this result is interestingly different from the results found in the SIT grid of the XS case, where information was exchanged at a proximity level. The proximity level for information exchange in the XS project is surprising, since the XS project had an international dimension. Indeed, part of the R&D team was located in Berlin, Germany when the rest of the project was carried out by the Grenoble plant. However, project actors' interviews revealed that the cooperation between Grenoble and Berlin actors was not a success during the XS project. We believe that the information dissemination level is a good indicator of the success probability of international projects.

6.5.5 Sensitivity of information exchanged

In the XS and GE project, only “highly sensitive” information was exchanged (at least only “high sensitivity” IO were mentioned). However, in the BD case, “low sensitivity” objects were mentioned in the IO grid. “Low sensitivity” objects are the Production BOM (IO no. 3) and the sample reports’ list. Comparing with XS and GE case studies, advanced in the NPD process, these “low sensitivity” objects are likely to become “high sensitivity” objects afterwards in the project. For example, production BOM has a low sensitivity in the early phases of a R&D project and becomes a crucial document when the project is handed over to Production. Sensitivity of objects is subject to changes, according to the progress of the project. We argue that sensitivity varies according to the relevance of the object for its users. During early phases, the production BOM has a low sensitivity because it is not yet relevant for information users such as the Production department. When it comes to ramp-up phase, the sensitivity of production BOM increases and becomes a high sensitivity because Production is actually using this object and this information.

6.6 Conclusion

In the investigation presented in this chapter, our aim is to answer the following research question:

(RQ 2) How can we characterize the interface situation during ramp-up?

This research question can be divided into two sub-questions:

(RQ2.1) Where are the major interfaces and how is information exchanged? (RQ2.2) Can we draw actionable conclusions to improve future ramp-up situations from the analysis of the interfaces?

Thanks to the auditing tool designed in Chapter 5, we are able to investigate on-going ramp-up projects. Thanks to three case studies, we were able to demonstrate that the auditing tool we designed enables the identification of major interfaces and major information flows during ramp-up in a NPD project (see Table 6.14). Thanks to the analysis of intermediary objects and interface times, the major information flows are outlined, enabling the identification of where and how critical information is exchanged. We are also able to evaluate different characteristics of the interface situation (namely information dynamics, information support, information dissemination level…).

We explain in section 6.5.1 that the major interfaces are mostly between the three key actors of the ramp-up phase: the Production department, the R&D department and the Purchasing department. Depending on the phase of the ramp-up phase, the major interfaces are either (see Table 6.14):

- between the trio Production – R&D – Purchasing, during the pre-production run phase
- only between Production and R&D and between Production and Purchasing, during the run-up phase.

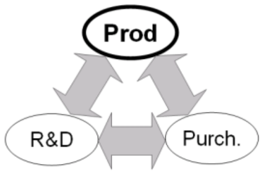
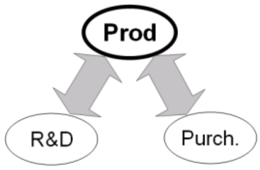
Aspect	BD case study	XS case study	GE case study
Phase of the NPD process	Prototyping / Testing (Development)	Pre-production run (Ramp-up)	Run-up (Ramp-up)
Leading actor	R&D	Production	Production
Key interfaces			
Interface structure	Light (few IO and SIT)	Dense in IO and SIT	Dense in tools and interface actors
Information sensitivity	Average and high	Only high	Only high

Table 6.14 – Brief summary of the results of the three case studies

We argue that the important involvement of the Purchasing department is linked to the industrial context of the case studies, namely the low volume industry. Indeed, as mentioned in section 4.4.2.1, supply problems may be more problematic in the case of low volume industries than in the case of the other industries; due to the relatively low power final manufacturers have on their suppliers.

We were able to identify the major information flows. Information is exchanged thanks to objects, mostly supported by software and mostly created especially for the ramp-up phase. Here again, we believe that this result is linked to the specific characteristics of the low volume industry. Companies of the low volume industry are less used to face ramp-up phases. As a consequence, they have not developed specific tools to manage the ramp-up phase.

Finally, in the different cases, we were able to draw valuable conclusions on an operational level in order to improve future ramp-up situations at Siemens E T HS. The different practical implications and improvement solutions proposed to our key partners at Siemens E T HS were implemented. We for example advised after the XS project case study to reinforce the

Purchasing position: it was done for the BD case, for example, where the Advanced Purchasing Engineer was fully dedicated to the BD project. It allowed the BD project to be successful regarding the procurement of components.

Our last chapter aims at summing-up the different results presented in this thesis and discuss their expected validity.

CHAPTER 7 CONCLUSIONS

Chapter outline:

In this chapter, we discuss the aspects of validity and generalizability of the research presented here. We also conclude on the findings and give possible future research tracks within the ramp-up literature.

7.1 Discussions on research validity and generalizability

As exposed in section 2.3, the validity of case research is evaluated thanks to the following concepts:

(1) Sampling
(2) Reliability
(3) Construct validity
(4) Internal validity
(5) External validity (generalizability)

We discuss these concepts in regard to the dissertation presented here in the following sections.

7.1.1 Sampling

Thanks to the CIFRE agreement elaborated for this study (see section 1.2), we were able to have access to the NPD projects carried out by Siemens E T HS. All our case studies have been carried out for Siemens E T HS projects, namely the SIE project, the XS project, the BD project and the GE project. We were also able to access data concerning the XJ7 project and the XS project (see Appendix I, section 8.1). Hence, we were able to observe a variety of different projects. However, all these projects had the same context. As a result, the effect of the industrial context is the same on the results of the different case studies. The validity of our results in other industrial contexts is to be confirmed.

For our first exploratory purposes, the SIE case study was chosen as an exemplary case. The aim was to examine a typical case of production ramp-up situation in the context of a low volume industry, so as to draw conclusions with relative generalizability. The SIE project was mostly a unique "*opportunity for unusual research access*" (Yin 2009). The fact that the SIE project is a "transfer" project (and not the launch in production of a completely new product) is a positive aspect for studying problems. Indeed, no disturbance is to be expected from design problems. Nevertheless, a possible drawback of the SIE case study is to miss a part of very problematic issues (i.e. disturbances due to design changes). We weren't able to evaluate the possible impact of these problems on the ramp-up phase, and whether the occurrence of this type of problems strongly modifies our results.

The next three case studies (that concerned the XS, the GE and the BD projects) were three additional opportunities at Siemens E T HS to study NPD projects at a stage close to SOP. Due to investigation opportunities, the case studies are spread along the NPD process:

- we investigated the BD project during its “prototyping / testing” phase
- we investigated the XS project during its pre-production phase
- we investigated the BD project during its run-up phase.

As a consequence, the XS and the GE project were audited exactly during the ramp-up process. Similarities in the results of their investigation can be expected to be typical of the ramp-up phase. Similarly, dissimilarities between the results of the XS (or the GE) case study and the BD case study can outline typical differences between the ramp-up phase and other phases of the lifecycle of a product.

7.1.2 Reliability

Another issue to evaluate research validity is to consider research reliability. To enhance research reliability, a case study protocol, explaining the instruments and rules followed to carry out the case study should be documented (Stuart et al. 2002; Yin 2009). Furthermore, the steps of the research should be clearly itemized and described (Yin 2009). All along the research presented here, we try to depict our protocol in the clearest possible way. For example, the followed rules to obtain the classifications in section 4.3.1 and section 4.3.3 are stated and explained. To help future researchers in comparing their results with ours, we also give a detailed description of each case study (sections 4.1.2, 6.2.1, 6.3.1 and 6.4.1) and of the general context of our research (section 1.2). We hope that a prospective researcher would find in all this enough material to either perform similar investigations on other case studies or compare his results to ours.

7.1.3 Construct validity

A third issue to consider in order to evaluate the validity of a research work is the construct validity. Advices are to use multiple source of evidence to study the same phenomenon (data triangulation) and to have key informants review the draft case study report.

Since this research was carried out thanks to industrial partners, we organized regular feedback to key informants at Siemens E T HS. Furthermore, some of these key informants were included in the steering committee of our research project. They reviewed our case data and findings every six months during the three years of our research project.

In addition, during case studies, we try to look for different sources of data to avoid bias (see Table 4.1, Table 6.2, Table 6.6 and Table 6.10). In case studies of the SIE, the XS and the BD projects, data was collected both by observations of the main researcher during her involvement in the project and by interviews. Case data and results were presented to the interviewees, so that any difference with their feeling on the situation could be cleared. We also tried to get quantitative elements to confirm our findings but we encountered several difficulties.

A first difficulty is that performance during ramp-up is difficult to define and it is influenced by a variety of factors (Pufall et al. 2007).

Second, we observed that during ramp-up, the performance indicators were not set-up yet. Indeed, objectives that are set are those of the mature production phase. Since the actual performance was way below this objective, the actual performance is not recorded. As a consequence, it was impossible to capitalize on previous experiences.

Third, we observed that the performance data that was recorded by the company is not always relevant. Indeed, we observed during our investigation on performance data (see Appendix I) that the recorded information was not relevant enough to analyze ramp-up situations after the event. For example, important variations were noted in production quality. After the event, no further data was available in the system of the company to explain these variations. Problems occurred during the ramp-up phase but no further information was available on these problems so as to capitalize experience. We had similar observations during the follow-up of another ramp-up project in Siemens E T HS. The progress and difficulties of the ramp-up were not depicted by the performance indicators that were monitored. Additional information (such as context information for example) was necessary to manage properly the ramp-up phase.

Finally, projects are unique settings. Their success or failure might not be caused by one single criterion or event. Direct relationships between the progress of the project and its success are difficult to establish.

7.1.4 Internal validity

Three approaches were adopted so as to enhance the internal validity of our findings. First, we compared the results of our investigation with existing literature when it was available. However, we encountered several difficulties. First of all, many studies do not give insights on their (possible) industrial context, which might influence the results. Second, the issue of ramp-up has been studied from very different points of view. We were able to find different problem classifications that we compared to our findings (see section 4.4.2.2). However, to the best of our knowledge, there is no previous study of project interfaces during ramp-up and no previous research about ramp-up carried out in the low volume industry. As a consequence, our findings are hardly comparable to findings of previous studies. Future similar studies (either focusing on the ramp-up situation in the low volume or on ramp-up interfaces) could be helpful to validate the findings presented here.

Nevertheless, to overcome this lack of reference and enhance the internal validity of our findings, we presented and discussed them both with co-researchers at the G-SCOP laboratory and in international conferences. The discussions with fellow researchers were very helpful to outline the importance of our industrial context and to have a better knowledge of the actual topics investigated in the research on the ramp-up issue.

7.1.5 External validity

The last issue to address to evaluate the research validity is the external validity. Advice is given to select the case based on theoretical sampling. As explained in section 7.1.1, we note that the case studies we carried out at Siemens E T HS are spread out along the process breakdown of the ramp-up phase. Indeed, the investigation on the BD project occurred during its prototyping/testing phase, while the investigation of both the XS and the GE projects occurred during their ramp-up phase. We believe that these similarities and differences are helpful to outline typical aspects of the ramp-up phase.

Then, the possible effects of industry, organization, size, manufacturing processes and inter-organizational issues should be considered. The effect of industry was taken into account in two ways:

- we selected cases within the same industry, so as to reduce the influence of industry on our findings
- we compared our results to fundamentally different industries, so as to see to which extent the industry could possibly influence results

However, these possible effects are harder to outline, due to the lack of previous research on the issues we investigated and within the context we had.

7.2 Major contributions

In this section, we return to the major results obtained in the research work presented here. We first address our contribution regarding ramp-up literature. Then we discuss the relevance of the auditing tool proposed here (see Chapter 5 and Chapter 6). Finally, we highlight the major findings of this dissertation regarding the issue of ramp-up in the low volume industry.

7.2.1 Contribution regarding ramp-up literature

Regarding the ramp-up literature, we proposed several contributions in the research presented here. We would like to highlight four of them.

Fist of all, we propose in section 3.3 a thorough state of the art regarding ramp-up literature. Section 3.4 entails several detailed mapping of the literature. We think that these contributions could be very helpful for future researchers interested by the ramp-up issue. Prospective researchers can gain from our literature study a good overview of existing articles on a specific question. Moreover, we are able to identify thanks to our mapping interesting issues that have not yet been studied. Issues such as cooperation and information exchange or supply chain management are interesting tracks for future research on ramp-up.

Secondly, the work presented here contributed to ramp-up literature in investigating an area that was not explored yet, i.e. the issue of cooperation and information exchange during ramp-up. Ramp-up literature evokes this issue as central but no previous study focused on possible solutions to this problem. We propose here an auditing tool that enables the analysis of information exchange and cooperation problems during the ramp-up phase.

Third, regarding the specific issue of ramp-up problems, our classifications in section 3.4 confirms the results of previously published case study. These classifications also validate that same kind of problems are encountered in high volume industries as well. However, a difference may come from the importance of each of the problem types (i.e. the priority of each problem type). This potential difference couldn't be observed since no statistical data was available in the previous classifications.

Finally, we outlined in section 3.5 some limits of previous findings of the ramp-up literature in regard to our industrial context. We highlighted that:

- The performance indicator based on "yields" was not relevant in every industrial context
- (Almgren 1999a)'s framework had to be adapted (the "modified" level is not relevant for the low volume industry). We therefore propose the "complexity matrix" for classifying ramp-up projects of the low volume industry (see Figure 7.1).
- A new process break down structure is necessary, since companies of the low volume industry do not realize preseries and have to carry out major preparation activities before actually ramping-up.

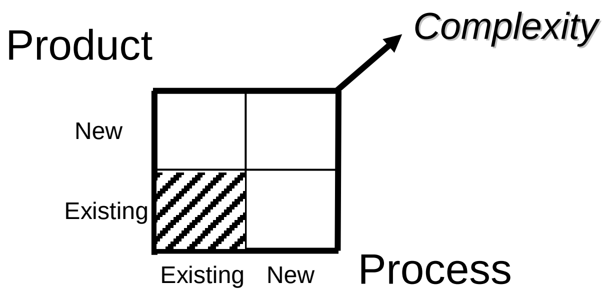


Figure 7.1 – Complexity matrix for ramp-up situations in the context of the low volume industry, adapted from (Almgren 1999a)

7.2.2 Relevance of the auditing tool

We introduce in section 5.4 an auditing tool which aims at analyzing project interfaces so that information exchange and cooperation problems can be solved.

We see three main strengths to this tool.

First of all, the auditing tool presented in section 5.4 makes it possible to carry out a deep analysis of project interfaces. Thanks to the auditing tool, an investigator can identify the major actors that are involved in the information exchange and the critical objects that enable the information exchange. Thanks to the different concepts used, the analysis provided by the auditing tool outlines how dynamic the exchanged information is and what are the characteristics of the exchanged information.

Secondly, the auditing tool is design so as to be practical and possibly used during field investigation. This tool was first used on a case study where the main researcher was deeply involved in the industrial project (the XS project, see section 6.2.2) but in a second case study, only two weeks of investigation were necessary to carry out the analysis of the project (the GE project, see section 6.3.2). The grids are easily filled by the interviewees, once the concepts and evaluation rules explained. As a consequence, we defend that this tool could be directly used by practitioners without great difficulty.

Finally, we argue that the auditing tool presented here is not limited to the analysis of ramp-up situations. It may be used in any other complex situation with many actors. Indeed, the concepts used are not directly related to the ramp-up phase and may be relevant in other projects with multiple actors.

However, the auditing tool presented here also has two drawbacks.

A first drawback of the auditing tool presented here is that this tool allows only an analysis of a ramp-up situation after the event. The analysis proposed by this auditing tool only proposes improvement solutions for future ramp-ups, based on problems already encountered by the project team. Except for previously encountered problems, this tool doesn't make it possible to foresee possible problems or misalignments in the characteristics of the information exchange.

Second, the tool presented in this dissertation focuses on existing objects and meetings that support the information exchange. Difficulties during the ramp-up phase could also arise from the lack of objects or meetings to support information exchange or cooperation between actors. The tool presented here doesn't take into account potential requirements that are not fulfilled by existing objects and meetings.

7.2.3 Contribution concerning the ramp-up phase

In this section, we stress the major contributions of the work presented in this dissertation regarding the initial research questions, i.e. regarding the issue of problems and the issue of project interfaces during ramp-up in the low volume industry.

7.2.3.1 Ramp-up problems

The investigation carried out on the SIE project (presented in section 4.3) enabled us to establish typical problem types of a ramp-up situation in the low volume industry. We conclude that these problems are similar to problems encountered in other industries, such as the high volume industry. Besides, the case studies that were carried out in Siemens after the SIE project investigation (namely the investigation of the XS project, the GE project and the BD project) validated further these results. Problems encountered during these ramp-up phases can be ordered in the problem categories we find.

However, an interesting result presented in section 4.4 is that the issue of supplying components (i.e. component procurement) is certainly more crucial in the context of the low volume industry. We see at least three reasons explaining the complexity of procurement in the case of the low volume industry.

First of all, companies operating in the low volume industry have a very high variety of products in their product portfolio. As a consequence, several variants of each component have to be supplied. It renders the issue of setting-up the supply chain for the new product more complex.

Secondly, in the case of low volume industry, due to the low output per year, final manufacturers may have a lack of power on their suppliers. For example, due to the very limited amount of components ordered by Siemens E T HS, suppliers of casted parts may not consider their deliveries for Siemens E T HS of utmost importance.

Finally, low volume industries very often manufacture high technological products with very high standards in terms of quality. This additional feature brings a lot of potential problems for procurement of newly designed components. We noted for example in Siemens E T HS that several sets of sample parts and long discussions between Siemens and their suppliers were necessary to qualify complex parts, such as casted parts or insulating parts.

7.2.3.2 Structure of the ramp-up in the low volume industry

Regarding the issue of the structure of the ramp-up in the low volume industry, our investigations presented here led to the conclusion that companies of the low volume industry may not realize pre series. We see three reasons that incite on skipping the pre series phase:

- Time constraints. As in other industries, companies of the low volume industry need to reach the mature production phase of new product as soon as possible.
- Product variety. It is difficult to design relevant pre series due to the very high variety of possible products.
- High product cost. In the low volume industry, products are high technological products, partly designed for a unique customer. As a consequence, product cost is very high, which makes it more difficult to find a second utilization to products manufactured during the preseries.

As a consequence, the structure breakdown of the ramp-up phase has to be adapted and tasks performed during the pre series phase are performed either during the prototyping / testing phase at the end of the Development phase or during the pre production run.

Thanks to our observations at Siemens E T HS, we are able to outline several consequences of skipping the phase of pre series:

- The capacity of the production line is not tested before the run-up phase. (Almgren 1999b) for example advocate that performing preseries on the production line at full-speed allows the anticipation of difficulties. He argues that some problems can be only seen at full-speed. Not doing preseries burdens the run-up phase with additional difficulties that would have been detected during preseries (such as bottleneck step or lack of tool to maintain the production line capacity).

- The preseries phase is useful to test series tools. We noted at Siemens E T HS that since the preseries phase was skipped, a lot of problems were encountered on assembly tools during the run-up phase.
- The preseries phase is also an opportunity to test the supply process of series components. We noted in our first classification of problems (see 4.3.1) that many problems encountered concerned supplies. Skipping the preseries phase leads to additional problems during the run-up phase concerning the supply of components. Besides, these problems have to be solved during the manufacturing of customer products.
- Similarly, the gradual learning of the manufacturing process occurs during the manufacturing of customer projects. At start-of-production, the performance is even lower, since no preparation occurred beforehand.
- Finally, skipping the preseries phase leads to a kind of “bullwhip effect” (i.e. vicious circle). Problems pile up since the whole process is tested at the same time (from component supply to end-product shipment). The ramp-up team is overloaded and works in a fire-fighting mode.

As a consequence, even though there are several good reasons to skip the preseries phase during ramp-up in the low volume industry, we argue that companies should consider more carefully the issue of whether or not to carry out preseries. We advocate that possible time and cost gains due to skipping the preseries phase should be weighted carefully against possible difficulties triggered by the lack of testing of the production line. We think that if there is a great uncertainty on the functioning of the procurement system or on the actual capacity of the production line, costs of unused products can be less important than the cost of dealing and solving difficulties during the run-up phase (where products are manufactured for the final customer). An evaluation of cost in the ramp up phase could make it possible to demonstrate the economic return of a preseries’ phase.

7.2.3.3 Interface characterization

About interface characterization, we proposed in section 5.3 an interface model that enables the identification of several characteristics of information exchanged within project actors’ interfaces.

We would like to outline here that our investigation led to the conclusion that several factors influence the type of interface that is needed during ramp-up in the low volume industry. We identified four factors:

- The level of trust within the ramp-up team.
- The use of tools during ramp-up.
- Similarities in the process of departments involved in the ramp-up project.
- The international dimension of the ramp-up project (if applicable).

The level of trust within the ramp-up team is an important factor to consider because it influences the information dissemination level. In both the GE and the BD projects, most of the information is disseminated at a “project” level. However, in the XS project where we noted a lack of trust between the project actors, the information dissemination level is the “proximity level”. Most of the information is exchanged with people that the information source trusts, keeping out of the information flow actors that are not trusted. As a consequence, in ramp-up situation where actors may not trust each other, we advise to provide actors with tools, intermediary objects and interface times that compel them to exchange information at the project level. It will insure that no actor is kept out of the flow of crucial information, which could lead to additional communication and cooperation problems. For example, in the XS project, the fact that actors of the Berlin R&D department were kept out of the information flow led to procurement difficulties on components they had designed at the start of production.
As a consequence, we argue that the consequences of a lack of trust between actors of the ramp-up can be very important in terms of costs. A communication problem can lead to a missing component for the assembly of a customer project and to a delay in the delivery of the product to the final customer. Hence, if lack of trust is foreseen for a project, we advocate that project interfaces are structured as depicted in Figure 7.2. Indeed, interface actors on both sides could ensure that information is exchanged. They could act as spokesperson for their team or department in meetings, ensuring thus a successful cooperation. If interface actors cannot be dedicated, top managers of the company should at least provide the ramp-up team an important amount of interface times (x, in Figure 7.2) so as to encourage and foster information exchange and cooperation between teams.

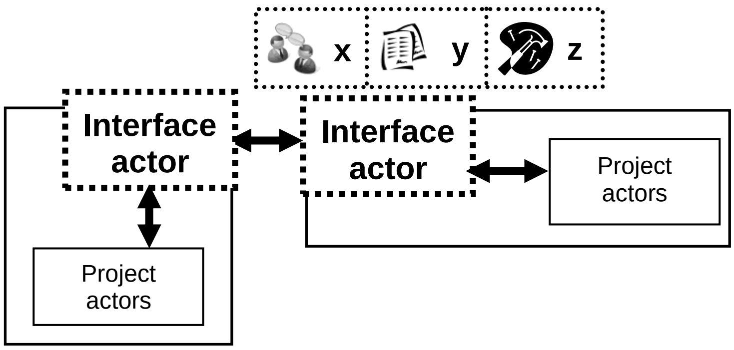


Figure 7.2 – Proposed interface structure in the case of a lack of trust within the ramp-up team

A second factor that influences the required structure of an interface is the use of tools. Indeed, we noted that the mastery of tools influences the structure of objects that are exchanged at the interfaces between project actors. In the XS and the BD projects, most of the objects were supported by MS Office software (such as MSWord or MSExcel). Highly sensitive information was consequently semi-structured. On the GE project, objects were mostly supported by company-wide tools and thus entailed structured information. Indeed, the

GE project was carried out by the Berlin unit, the historical factory. They have a deep experience with their ERP and PLM systems, enabling the support of crucial information exchanged by these tools and thus, improving information structuring level. On the contrary, the XS and BD project, carried out by the Grenoble unit, which was only integrated by the Siemens group some years ago, did certainly suffer from the lack of master of the company-wide tools by Grenoble actors.

As a result, we argue that the level of structure of objects proposed to support the information exchange within project interfaces during the ramp-up phase should be adapted to the level of use and mastery of tools provided by the company.

A third influencing factor is the differences in the NPD processes used by the departments or companies involved in the ramp-up phase. Indeed, we noted differences in the NPD process used by the actors of the Grenoble factory and the one used by the actors of the Berlin factory. This observation was first surprising because both belong to the Siemens Company, which provide the same NPD process breakdown and the same organization structure to each of its factories. Nevertheless, we believe that even if factories are given the same general process, several external factors (such as past history of the factory, tasks dispatch or the building layout) will influence their local interpretation of the general process. We for example observed in Siemens E T HS that even if both the Berlin and the Grenoble factories had the same general process for new product development, the local interpretation was different. Teams are not organized exactly the same way (even if the departments are the same). Tasks are distributed not in the same way. These differences lead to additional problems in the information exchange and the cooperation between actors. They should thus be taken into account in order to avoid problems during the ramp-up phase.

As a consequence, we believe that a reciprocal learning should be encouraged by top management and should be enabled by the structure of ramp-up project interfaces. The ramp-up phase should be prepared. An opportunity has to be given to the team to clarify its process.

The last influencing factor we noted during our investigation at Siemens E T HS is the international dimension of the project. Indeed, ramp-up projects that are carried out by teams of different nationalities face specific communication and cooperation problems. Even though cooperation and information exchange problems were mentioned in the three case studies of the XS, the GE and the BD projects, we believe that these difficulties are more complicated to overcome when actors aren't sharing the same language and the same culture. This is an additional difficulty to the existing discrepancies due to the different departments and technical background of actors involved in ramp-up projects. This observation is coherent with the analysis carried out by (Vandevelde and Van Dierdonck 2003). They noted that the cooperation between manufacturing and design has to overcome several barriers, such as cultural, organizational and language barriers.

The four aspects underlined above question the strategy of multinational companies to split up the phases of a product life cycle over different units in different countries. Indeed, if a product is designed in a factory and then its production is located in another factory, several factors mentioned here above can be encountered during the ramp-up phase. Level of trust within the ramp-up team can be low, the tools and processes used different and the companies involved can be of different countries. These aspects make more complex the ramp-up phase, leading to additional difficulties and hence additional costs.

7.3 Perspectives

7.3.1 Short term perspectives

Given the research work presented here, we are able to outline several short term perspectives.

First of all, regarding the issue of problems encountered during the ramp-up phase in the low volume industry, further research in this area could bring useful complementary insights to our first findings. Indeed, our investigation protocol could be used on a similar case and enhance the generalizability of our findings. A similar case study could be performed in another company of the low volume industry. For example, Siemens Healthcare, which manufactures MRI devices for hospitals, could provide an interesting environment. We also know in the area of Grenoble a company which develops and manufactures advanced infrared detectors for military, space and commercial applications and which could be another interesting setting for a further case study on ramp-up problems in the low volume industry.

Furthermore, we lacked studies of ramp-up problems in other industries than the low volume industry that display the repartition and the importance of the different problem types. Indeed, comparing our problem repartition to other similar findings could bring interesting results.

Secondly, regarding the auditing tool proposed in this dissertation, we think that some improvements could be carried out on the short term:

- The auditing tool could be used in a broader context, encompassing the company's suppliers and customers. Very interesting insights should come from the taking into account of the whole supply chain. Indeed, we strongly believe that coordination and information exchange problems also happen at the interfaces between a company and its suppliers.
- The auditing tools presented here could be completed in taking into account other criteria. A potential lack to be filled is notably the "uncertainty" criteria (see Figure 5.9). Our interface model didn't include concepts that enable to evaluate the uncertainty of the information source on the information he releases.
- The auditing tool and notably the IO grid could be completed in taking into account the requirement of information users. Indeed, the IO grid only takes into account existing information flows and existing intermediary objects. It does not look at possible lacks in the information flows. In analyzing which information the different

ramp-up actors really require (which content, which format…) further difficulties in the information exchange could be solved.

The short term perspectives presented can be performed either to improve the scope of the auditing tool presented here or to improve the validity of the findings presented here. The next section proposed long-term perspectives.

7.3.2 Long term perspectives

There are several possible tracks for further research.
First of all, further investigation on project interfaces should aim at building a piloting tool that enables the management of the ramp-up phase. In this research, we designed an auditing tool, which enable the analysis of a project at different time points during its progress. However, literature on the ramp-up phase stresses the lack of relevant management tools customized to fit the challenges of the ramp-up period. As a consequence, we see as an interesting track for future research to propose a piloting tool, based on the auditing tool proposed here. The piloting tool should both evaluate the situation and give instructions to reach the initially fixed goal. For this purpose, our auditing tool could be used as a first building block of the piloting tool, in order to evaluate the situation. Then attention should be paid to concepts outlined in section 7.2.3.3 (the lack of trust, the international dimension of the project, the mastery of tools and the different processes used by departments involved in the ramp-up phase) so as to design a relevant interface structure. Finally, another important building block for a piloting tool is to build a set of relevant KPI for the ramp-up phase. Besides, key performance measures of the ramp-up period is an issue already rather well investigated, that is to say several research results are available in the literature.

Secondly, we believe that further insights could be brought on the interface design during the ramp-up phase. In fact, the work presented here lacks of quantitative elements. We see as an interesting opportunity to investigate the influence of interface design on ramp-up performance. Particularly, it could be interesting to evaluate the benefits brought by interface actors (their exact influence on the information exchange). Indeed, dedicating an interface actor so as to ensure the information exchange is costly for companies. They are rather unwilling to dedicate an additional human resource. Investigating the exact benefits in terms of performance and cost of interface actors could be an interesting quantitative extension to the work presented in this dissertation.

Lastly, we concluded from our problem classification that component supply is of an especially crucial importance in ramp-up situation in the context of low volume industry. Due to the lack of research investigation on supply chain issues during ramp-up, we believe that there is a wide research potential in this direction. Besides, the issue of supply quite underresearched in the ramp-up literature, as shown by our classifications of ramp-up literature in section 3.4. As outlined by the classification by focus extent shown in section 3.4.2, further research could focus on the whole supply chain involved in the ramp-up phase, so as to gain more insights on the supply issue during ramp-up. (Meier and Homuth 2006) notably examine ramp-up management in SME networks but additional contributions to this field of research would be valuable for the ramp-up literature. Thanks to the research presented in this dissertation, we see several possible ways to investigate supply chain issues.

First of all, as presented in section 7.3.1, cooperation and information exchange problem within the supply chain could be investigated thanks to the auditing tool presented in this dissertation. Indeed, these tools could be used to analyze the interfaces between a company and other partners of its supply chain (suppliers and customers).

Secondly, the level of maturity of the collaboration of a firm within its supply chain during ramp-up could also be analyzed thanks to the collaborative situations' grid presented in section 5.2.3.

Lastly, future research could build management tools so as to evaluate the maturity of the supply chain that is being set-up during the ramp-up phase, in order to identify possible weaknesses and anticipate problems.

7.4 Conclusion

In this chapter, we discussed the different concepts to evaluate the validity and the generalizability of the research presented in this dissertation. We provided elements and arguments so that external researchers can trust the findings presented here.

Then we summed up the major contributions of our research on problem and interface characterization during ramp-up in the low volume industry.

Finally we proposed several short-term and long-term perspectives to the research presented here.

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CHAPTER 8 APPENDIX

8.1 Appendix I – Extract of the internal report on the investigation on performance data

We wanted to investigate previous ramp-up projects of the Grenoble Siemens plant. Indeed several authors highlighted the importance from learning from previous ramp-up projects.
Within the experience of the Grenoble plant of Siemens, we identified four previous ramp-up projects:

- the ramp-up of the new XJ7 product
- the ramp-up phase of the transfer project of the SIE production from the Berlin plant to the Grenoble plant
- the ramp-up of the new XS product
- the ramp-up of the output raise project of the DQ product.

Due to time constraints, we decided to only focus our analysis on two products. To make a choice, we classified the different ramp-up projects in a product / process newness matrix.
We obtained the matrix shown in Figure 6.8.

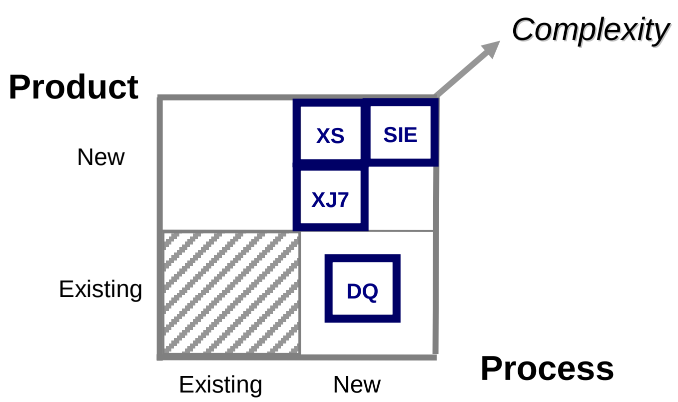

Figure 8.1 - Complexity matrix of the ramp-up projects of the Grenoble plant

We chose among the “new/new” projects, i.e. the XJ7 ramp-up project and the XS ramp-up project.
Indeed, they were the most interesting, since both of them were highly complex.
They were also complementary, given that the XJ7 ramp-up project is an older project (2004) and the XJ ramp-up project is the most recent project (Apr. 2008).

For each of these two projects, we investigated Siemens intranet to find indicators that could reflect the progress of the ramp-up phase.

The ramp-up phase is often considered as a project. The ramp-up phase is piloted thanks to a project management model, with stages and gates. A focused team is often created (according to a matrix organization) to deal with ramp-up issues. As a result, ramp-up performance is measured as project performance, according to the "magic triangle" aspects, i.e. cost, quality and time. Thus, we decided to look for indicators that reflected the cost, quality and time aspects of the ramp-up projects.

[…]

XJ7 quality rate

Figure 8.2 – Evolution of the XJ7 quality rate over time[42]

We observe that the quality rate of the XJ7 is not stabilized after the end of the ramp-up phase.

[…]

XS cost

Figure 8.3 – Evolution of the XS cost over time[43]

[42] Scales on X and Y axis are omitted to respect confidentiality.

This “screenshot” reflects the evolution of the XS cost after the ramp-up period. We can see that several dots on the figure are not better than the objective.

[…]

8.2 Appendix II – Problem statements

Problem statement number 2

Who: Procurement, Logistics coordinator

Gap description: The junior plant’s ERP tool wasn’t designed to fit the new product’s process. It required a lot of manual operations from the logistic coordinator. No information was available in the ERP system for the procurement team.

Causes: The supply process of the transferred product is really different from the existing one in the junior plant. Furthermore the ERP tool of the junior plant is ageing and no customization is possible.

Problem statement number 9

Who: Junior plan, senior plant

Gap description: There was a marking error on the crates of the senior plant supplies. As a consequence, they were not stored where they should have been and the production actors had difficulties to find them in the warehouse.

Causes: Problem in the cooperation between the junior and the senior plant.

Problem statement number 11

Who: Procurement, Assembly, Berlin fastening supplier

Gap description: No fastenings were available when the assembly in the junior plant has started. The supply of the fastenings was supposed to be done by the senior plant’s supplier. However, the junior factory and the supplier didn’t come to an agreement by the time the production began in the junior plant.

Causes: No emphasis was laid on the fastenings and the agreement with the supplier. The delivery time of fastenings was also underestimated.

Problem statement number 20

Who: Project team of the senior and the junior plant

Gap description: Communication problems exist between the senior and the junior plant. Information is not reaching targeted people.

Causes: It was decided that every communication should go through two contact persons, each in one plant. This organization not only overloaded the two contact persons but also created discontinuities in the information transfer.

---

[43] Scales on X and Y axis are omitted to respect confidentiality.

Problem statement number 26

Who: Logistics, Production

Gap description: When fastenings were delivered, the different boxes were not labeled. We couldn't identify the fastenings because:

- the box weren't labeled with the Siemens reference numbers
- nobody had the required experience or the knowledge regarding Siemens reference numbers for fastenings

Causes: Lack of knowledge concerning Siemens reference numbers for fastenings.

Problem statement number 36

Who: Junior plant, senior plant

Gap description: The order of missing components is difficult. More than 2 weeks and 9 e-mails were necessary to order a missing component. At first, the reference number wasn't right, then it was the reference of a sub-assembly … The senior plant is not willing to send components before it is sure that the component is actually missing.

Causes: there is a lack of trust from the senior plant into the word of actors of the junior plant. Errors generated this lack of trust, magnified by the distance.

Problem statement number 51

Who: Senior plant, PM of junior plant

Gap description: Fastenings are missing because the supplier underestimated the actual need in fastenings in his forecasts. Both the junior plant and the senior plant are impacted: projects cannot be assembled.

Causes: Bad forecast from the supplier.

Problem statement number 54

Who: Production at the junior plant

Gap description: Fastenings were wrongly identified on the shop floor. A pin was labeled with the reference number of a screw

Causes: Lack of knowledge regarding fastenings and their Siemens reference number. An error of label or storage is not detected.

Problem statement number 58

Who: Production at the junior plant

Gap description: The delivery of fastenings was not on time for the production of the second customer project. The actor responsible of the order of fastenings forgot to do it on time and the delivery could only be late.

Causes: The actor responsible of the order of fastenings underestimated this topic and focused only on the delivery of other components. He issued his order too late, thinking it wouldn't be a problem.

Problem statement number 65

Who: Junior plant, PM at the senior plant

Gap description: Delivery problem concerning fastenings for the first customer project.

Causes: The actor responsible for the order of fastenings lacked experience in this matter. He underestimated the difficulty of this delivery.

Problem statement number 85

Who: Junior plant

Gap description: The issue of shipping additional material with the bay was not anticipated. It had to be solved very quickly. The project actors are only operating on fire-fighting mode.

Causes: The junior plant actors lacked experience in this issue. Its existence was not foreseen and when the issue was raised, the actors of the junior plant encountered several difficulties because they had never dealt with this issue before.

Problem statement number 92

Who: Junior plant

Gap description: A misunderstanding happened about the delivery of fastenings for the third customer project. The junior plant was expecting the delivery and the senior plant assumed that the delivery had occurred.

Causes: Lack of communication of the junior plant. They didn't ask the senior plant about the delivery of fastenings.

Problem statement number 96

Who: Logistics, Production

Gap description: When fastenings were delivered for the third customer project, the different boxes were once again not labeled. The junior plant still encountered difficulties in identifying the different fastenings and labeling them with the right Siemens reference number.

Causes: On-going learning concerning Siemens reference numbers for fastenings.

Problem statement number 100

Who: Production

Gap description: Components for different customer projects are put together next to each other on the shop floor. Wrong components are picked by the workers and missing components are identified very late.

Causes: Lack of knowledge of the workers for identifying the right component for the right customer project.

Problem statement number 104

Who: Junior plant

Gap description: The order of senior plant supplies was not updated by the PM of the junior plant. The final delivery of senior plant supplies entailed wrong components.
Causes: Lack of communication between the junior and the senior plant.

8.3 Appendix III – Algorithm of Harper and Rainert's guidelines

For n problem statements (X_1….X_n), each one has a resource R it focuses on so a set of resources (R_1….R_n).
We create a table C (1; n), to store the problem types
For each resource R_i, if it doesn't appear in the table yet, it is put in the first free box of the table C.
You have to review all the resources R_i.
At the end, your table C lists the different problem types.

8.4 Appendix VI – Organizational chart of the XS ramp-up team

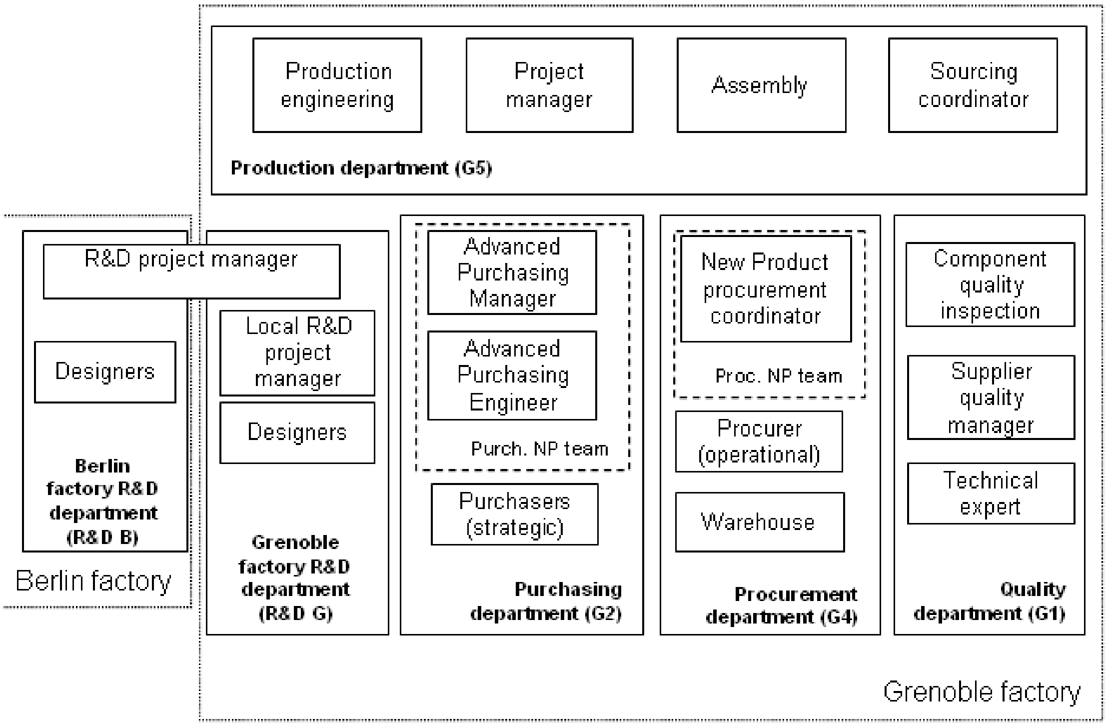

Figure 8.4 - Organizational chart of the XS project team

The XS product is developed jointly by the Grenoble and the Berlin R&D department under the responsibility of a Berlin R&D project manager. Other actors of the project are from the Grenoble factory:

- G5, one of the Grenoble production departments, responsible for series production.
- G2, the Purchasing department, responsible for supply chain set-up and parts procurement.

- G4, the Procurement department, responsible for stocks and operational procurement.
- G1, the Quality department, responsible for inspection of part quality and validation of suppliers' quality.

8.5 Appendix V – Organizational chart of the GE ramp-up team

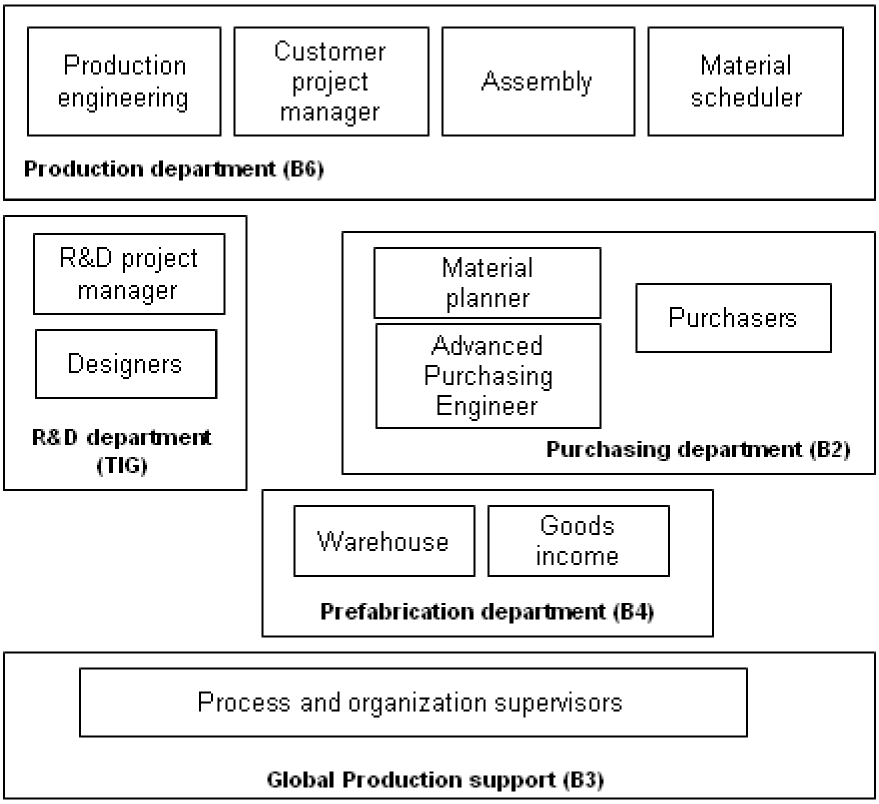

Figure 8.5 - Organizational chart of the GE project team

The GE project was carried out only at the Berlin plant of Siemens E T HS. The actors involved belonged to five different departments:

- TIG (Technology Innovation Grenoble), the R&D center of the Berlin plant.
- B2, the Purchasing department, responsible for supply chain set-up and parts procurement.
- B4, the Procurement department, responsible for stocks.
- B3, the Global Production Support, responsible for continuous improvement approaches (such as Design for Manufacturing, DFM).

8.6 Appendix VI – Structured interviews of the GE project actors

The interviewees were asked the following questions (in German):

1. Projekt organization
    a. Allgemein : wieviel Teams waren in den Projekt?
    b. Ihre Team
        i. Wieviel Leute ?
        ii. Welche Kompetenz ?
        iii. Welche Aufgabebereich ?
2. Ihre Aufgabe
    a. Wann in den Projektlauf?
    b. Mit wem ?
3. Die Schnistellen
    a. Mit wem haben Sie gearbeitet?
    b. Sie brauchen Information von wem?
    c. Wo finden Sie diese Information? Können Sie mir zeigen?
    d. Wer hat diese Information?
    e. Welche Info-Art?
        i. Lastenheft
        ii. Pflichtenheft
        iii. DFM-Rechtlinien
        iv. Projektvertrag?
        v. Montagekonzept
        vi. Vorschriften? (versand, verpackung...)
        vii. Anweisungen?
        viii. Prozesse?
        ix. Zeichungen, Stücklisten?
        x. Dokumenten auf ein Netz? Netz für das Projekt?
    f. Gespräche: haben Gespräche mit den Leuten gehabt, die Information für Sie hatten oder die Information von Sie brauchten? Nur reviews Meetings? Haben Sie zu diese Meilsteinenreviews mitgemacht?
        i. Wann ?
        ii. Wieviel ?
        iii. Wie lange ?
        iv. Mit wem?
4. Messung
    a. Wie haben Sie Ihre Arbeit/ Ihre Fortschritte gemessen?

8.7 Appendix VII – Document for preparation of the interviews

1. Einführung :

Was mich interessiert ist das Beispiel von der GE Einführungsprojekt. Ich würde gerne die Projektschnittstellen scharfstellen. Ich würde gern wissen, wie diese Schnittstellen funktioniert haben, wie das Projekt konkret gelaufen ist.

2. Schnittstellen:

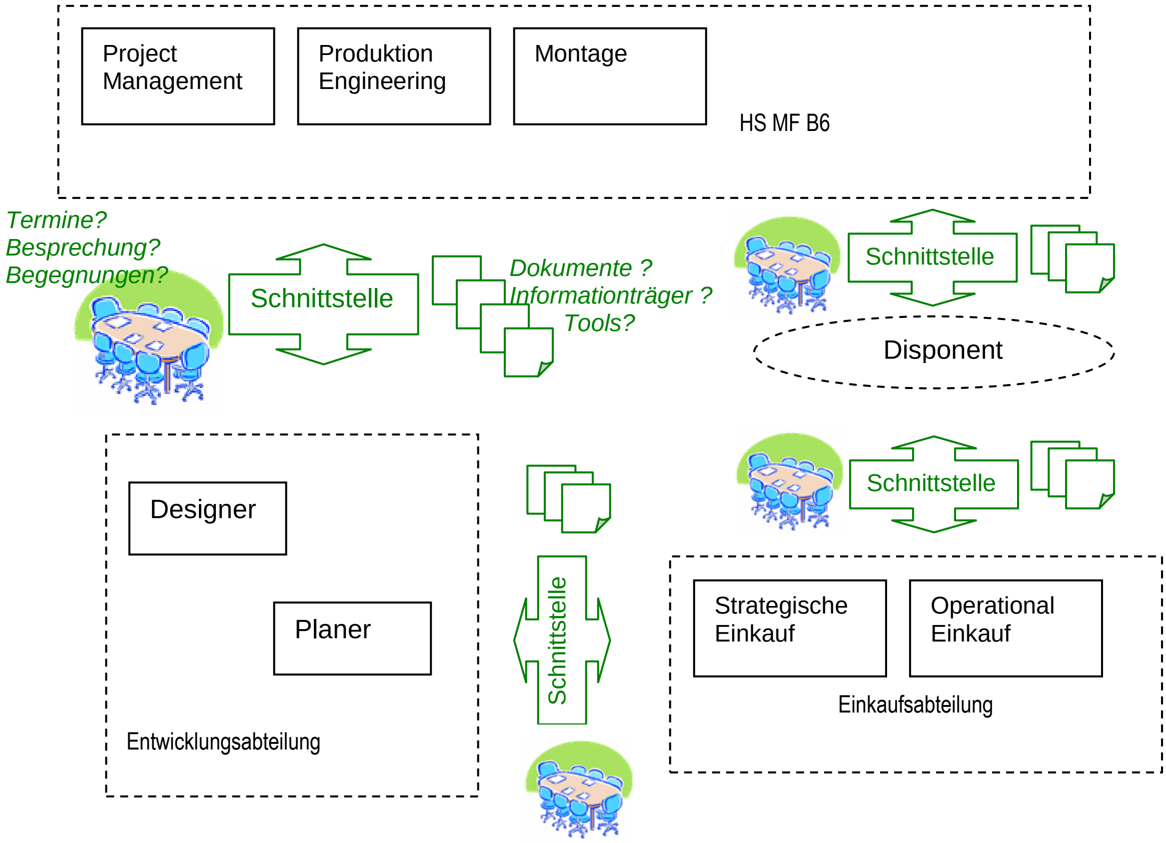

Figure 8.6 – Projekt teams und ihre Schnittstellen

Sind Sie mit diesem Bild einverstanden?

Können Sie dieses Bild weiterfüllen? (Namen den Dokumenten, weitere Schnittstellen? Andere Akteure?)

3. Weitere Fragen, um die Interview vorzubereiten:

1/ Wann hat Ihre Arbeit für das GE Einführungsprojekt angefangen? (Monat + Jahr) Wann fängt Ihre Arbeit in der Projektprozess an ?

2/ Wieviel Personen würden in Ihre Team notwendig? Ist diese Nummer gleichbleibend durch das Projektsablauf?

3/ Welche Aufgabe haben Sie vollgebracht ? (3 zu 5 Hauptthemen)

4/ Welche Information brauchten Sie von wem, zur Erfüllung Ihrer Aufgabe? (3 zu 5 Hauptinformation, mit der Informationquelle)

5/ Wie haben Sie diese Information bekommen? Welche Informationsträger (aus einem Dokument (.xls, .msp), E-Mail, Information aus einem Tool (SAP, PLM), auf ein Netz?)? Können Sie mir zeigen, wo Sie die Information finden könnte? Können Sie mir die Dokumente zeigen, die für Sie nützlich waren (sind)?

6/ Zu welchem Termine / Besprechungen / Begegnungen haben Sie mitgemacht?

Herzlichen Dank.

8.8 Appendix VIII – E-mail questionnaire

1. Introduction

This interview complement's goal is to collect your opinion about the description of the interfaces of the GE qualification project. This interview complement focuses on two specific aspects of the interfaces[44]:

- the intermediary object (items used or created in order to exchange information)
- the interface spaces and times (moment and places where project actors can interact)

We will present you the two grids we established (based on our interviews) about the intermediary objects and the interface spaces and times of the GE qualification project.
We'd like you to fill in these grids with some criteria that we'll describe to you.

2. Intermediary objects of the GE qualification project

Thanks to the interviews, we realized a list of the intermediary objects used during the GE qualification project.
The intermediary objects list is organized as follows (see Figure 8.7 down below):

- name of the intermediary object (in English and in German) and its description
- person responsible for the object (i.e. the creator of the object and the person who updates the information contained in the object)
- the users of the object (i.e. the project actors who need the information contained in the object)

[44] For a deeper description of what an interface is, please see Annex 1

- the support of the IO (whether it is a MS Word document, an Excel sheet or an object of SAP)

Intermediary object	Vermittelndes Objekt	Description	Person in charge of the IO	Users of the IO	Support
Drawings and BOMs	Zeichungen und Produkt Stücklisten	Drawings of the equipment's parts. Bills of material of all the possible subassemblies that could compose an equipment.	R&D team	Customer PM Primary Eng. Assembly Proc. / Purch	PLM
Project BOM	Aufragsstücklisten	Bill of material of the customer project. Implemented in SAP	Primary Engineering	Material scheduler Material planner Production	SAP
Project folder	Auftragsordner	Folder with all the official project documentation for the assembly (HZ drawings, HSA lists, SOBs…)	Customer PM	Assembly	Paper
Scheduling in SAP	SAP Auftragsplannung	Planning of the customer projects in SAP	Customer PM	Assembly	SAP
Information gathered by the ZMAN dialog box of SAP	ZMAN Dialogfenster in SAP	List of all the material that is part of a customer project BOM and which hasn't been ever ordered before	*Customer PM* (contact person in case of problem)	Material planner	SAP
Work instructions Test instructions	Arbeitsanweisungen und Prüfanweisungen	Information about the product, about the way you have to test it	R&D team	Assembly	Paper
CAD models	CAD Modelle	3 dimension models of subassemblies	R&D team	R&D team Assembly Customer PM	CAD Software
Access data base of assembly problems	Access Datenbank der Montageproblemen	Access data base containing all the problem that are encountered by the production line in the realization of a customer project.	Customer PM	All	Access
Minutes of the "material preparation for first projects" meetings	Protokoll den Besprechungen "Status Materialbereitstellung für Erstprojekte 8DN9-6"	Word document which lists all the problems encountered during the first customer projects, that are typical of an introduction problem. With a responsible, an appearance date, …	Customer PM	All	MS Word
Drafts	Entürfe	Raw drawings (hand-made) representing what an equipment or a subassembly will look like	R&D team	R&D team Assembly Customer PM	Paper or CAD software

Figure 8.7 – List of the intermediary objects of the GE qualification project

In appendix, you can find the German equivalent of the English project actors' names.

3. Additional criteria – it's your turn to fill in the grid!

However, there are some other criteria that can characterize an intermediary object, such as:

- its update frequency
- its update duration
- its sensitivity and evolution (see explanations below)

a. Sensitivity of an intermediary object:

Sensitivity (Krishnan et al. 1997) characterizes the information exchanged between an upstream activity A for which the piece of information is an output (see Figure 8.8) and overlapped downstream activities (for which the piece of information is an input).

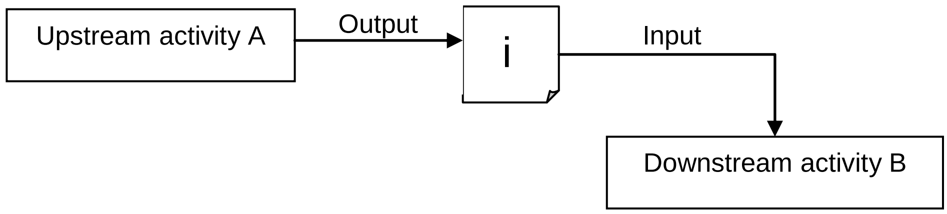

Figure 8.8 – Exchange of information between an upstream activity and a downstream activity

A piece of information is very sensitive if its modification will have serious impacts on the downstream activity. On the contrary, information with a low sensitivity will not have a high impact on the downstream activity.

b. Evolution of an intermediary object:

The information evolution is a concept to evaluate with which tendency the information is reaching its final value. A piece of information with a fast evolution will quickly reach its final value and thus only have small-scale changes. On the contrary, a slow evolution piece of information will not approach its final value until the very end of its evolution.

The aim of this document is that you complete the Figure 8.9 regarding the following criteria

- update frequency
- update duration
- sensitivity
- evolution

About the **update frequency criteria**, you'll have three choices:

- ***high*** update frequency if the information was updated more than 10 times in the life-time of the object
- ***average*** update frequency if the information was updated between 4 and 9 times
- ***low*** update frequency if the information was updated less than 3 times

About the **update duration**, please fill the box with your appraisal of the average necessary time in hours for the person in charge of the object for updating the information contained in the object

	Intermediary object	Vermittelndes Objekt	Update frequency	Update duration	Sensitivity	Evolution
1	**Drawings and BOMs**	**Zeichungen und Produkt Stücklisten**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
2	**Project BOM**	**Aufragsstücklisten**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
3	**Project folder**	**Auftragsordner**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
4	**Scheduling in SAP**	**SAP Auftragsplannung**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
5	**Information gathered by the ZMAN dialog box of SAP**	**ZMAN Dialogfenster in SAP**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
6	**Work instructions Test instructions**	**Arbeitsanweisungen und Prüfanweisungen**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
7	**CAD models**	**CAD Modelle**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
8	**Access data base of assembly problems**	**Access Datenbank der Montageproblemen**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
9	**Minutes of the "material preparation for first projects" meetings**	**Protokoll den Besprechungen "Status Materialbereitstellung für Erstprojekte GE"**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast
10	**Drafts**	**Entürfe**	☐ high ☐ average ☐ low	hours	☐ high ☐ average ☐ low	☐ slow ☐ fast

Figure 8.9 – Intermediary objects' list to fill in with your personal appraisal

In our case of a new product introduction project, the **information sensitivity** is evaluated with respect to the project lead time and the project cost:

- ***High*** sensitivity of the IO information means that a change in IO information has a direct impact in the project lead time (i.e. the final delivery date of the first customer product).

- ***Average*** sensitivity of the IO information means that an information change implies rework for some activities and thus an additional cost but no delay in the project lead time.
- ***Low*** sensitivity means that the global impact (in the project lead time or project cost) of the information change isn't significant with respect to the project lead time and the project cost.

About the **information evolution**, the criterion chosen is the time occurrence of the update in the lifecycle of the IO:

- Either the updates were in a majority at the end of the object life-cycle (***slow*** evolution).
- Or the updates were in a majority close to the first release date of the object (***fast*** evolution).

Please, fill in the Figure 8.9 above with your evaluation of the above mentioned criteria.

4. List of the GE project interface spaces and times

Thanks to the interviews, we also realized a list of the interface spaces and times of the GE qualification project.
The interface spaces and times are the different synchronous interface times (such as meetings, occasional encounters, phone calls…) occurring during the GE introduction project.

We listed the interface spaces and times, describing them as follows (see Figure 8.10 down below):

- The name of the interface space or time (in English and in German) and a short description
- the name of the team responsible for the interface time
- the different participants

In annex, you can find the German equivalent of the English project actors' names.

	Meeting(s)/ Information Gathering(s)	Termine / Besprechungen	Description	Person in charge	Actors
1	**Milestones reviews**	**Meilsteine Reviews**	Official meetings of the Siemens process, corresponding to crucial steps in the progress of a product development project. The M300 is for example the official handover of the project from the R&D to the production department	R&D PM	R&D PM (2) Prod. WP manager (1) Prod. Dep. Manager R&D dep. manager
2	**Material scheduling-Assembly meeting (Dispo-Montage runde)**	**Disposition-Montage Runde**	Presentation of the actual stand of the on-going production projects Review of the encountered problems (thanks an Access database)	Customer PM	Material scheduler (4) Assembly managers (5) Customer PM (2)
3	**Production - R&D meetings**	**Termine bei der Entwicklung**	Presentation of different modules under development by the R&D. Discussion of the different technical solutions with the production line	R&D PM	R&D team Assembly managers (2), Prod. WP manager (1) Primary Engineering
4	**Status meeting for preparation of material for first project**	**Besprechung "Status Materialbereitstellung für Erstprojekte**	Preparation of the first projects (components availability, technical problems) and discussion of the problems encountered during the assembly of the first customer projects (long-term solutions)	Customer PM	R&D PM (2) Material schedulers (4) Material planer (1) Assembly managers (2) Primary Engineering
5	**R&D back-up**	**Unterstützung von der Entwicklung**	Techncial support from the R&D department to the Primary Engineering in order to realize the	R&D team	Primary Engineering
6	**Problem sovling meetings**	**Ungeplannte Besprechungen für die Lösung dringenden Problemen**	Unscheduled meetings, dedicated to the immediate solving of important problems	Customer PM	R&D PM (2) Assembly managers (2), Prod. Dep. Manager R&D dep. Manager
7	**On the spot meetings**	**Vor-ort Termine währen der Montage des erstes Projekts Butovo**	Dedicated meeting that happened in the assembly hall, in order to find a short-term solution to the problems encountered during the assembly of the first customer projects	Customer PM	R&D PM (2) Customer PM (1) Assembly managers (2)
8	**Purchasing/procurement - Material scheduling meetings**	**Monatliche Disposition - Einkauf Termine**	Normal functionning meetings for the Purchasing/Procurement department and the material scheduling team to exchange information	Proc./Purch	Proc./Purch Material schedulers
9	**Informal exchanges to solve problems**	**Informelle Kontakte Projektleitung - Entwicklung**	Gathering, phone calls, unscheduled discussions	Customer PM	Customer PM R&D PM
10	**Informal exchanges to solve problems**	**Informelle Kontakte Montage - Entwicklung**	Gathering, phone calls, unscheduled discussions	Assembly manager	Assembly manager R&D PM
11	**Informal exchanges to solve problems**	**Informelle Kontakte Produktion - Disposition**	Gathering, phone calls, unscheduled discussions	Customer PM	Customer PM Material scheduler

Figure 8.10 – Interface spaces and times list for the GE introduction project

5. Additional criteria – it's your turn to fill in the grid!

However, there are some other criteria that can characterize an intermediary object, such as:

- its frequency (total amount of meetings)
- its level of information exchange (see explanation below)

a. Information exchange level

The interface spaces and times grid also concentrates on the identification of information flows in utilizing the concept developed by Blanco et al. (Blanco et al. 2007), to determine at which level the information is exchanged. Blanco et al. defined three levels of information diffusion in collaborative activities:

	Meeting(s)/ Information Gathering(s)	Termine / Besprechungen	Frequency (Total number of meetings)	Information diffusion level
1	**Milestones reviews**	**Meilsteine Reviews**	meetings	☐ public ☐ project ☐ proximity
2	**Material scheduling-Assembly meeting**	**Disposition-Montage Runde**	meetings	☐ public ☐ project ☐ proximity
3	**Production - R&D meetings**	**Termine bei der Entwicklung**	meetings	☐ public ☐ project ☐ proximity
4	**Status meeting for preparation of material for first project GE**	**Besprechung "Status Materialbereitstellung für Erstprojekte GE"**	meetings	☐ public ☐ project ☐ proximity
5	**R&D back-up**	**Unterstützung von der Entwicklung**	meetings	☐ public ☐ project ☐ proximity
6	**Problem sovling meetings**	**Ungeplannte Besprechungen für die Lösung dringenden Problemen**	meetings	☐ public ☐ project ☐ proximity
7	**On the spot meetings**	**Vor-ort Termine währen der Montage des erstes Projekts Butovo**	meetings	☐ public ☐ project ☐ proximity
8	**Purchasing/ procurement - Material scheduling meetings**	**Monatliche Disposition - Einkauf Termine**	meetings	☐ public ☐ project ☐ proximity
9	**Informal exchanges to solve problems**	**Informelle Kontakte Projektleitung - Entwicklung**	meetings	☐ public ☐ project ☐ proximity
10	**Informal exchanges to solve problems**	**Informelle Kontakte Montage - Entwicklung**	meetings	☐ public ☐ project ☐ proximity
11	**Informal exchanges to solve problems**	**Informelle Kontakte Produktion - Disposition**	meetings	☐ public ☐ project ☐ proximity

Figure 8.11 – Interface spaces and times' list to fill in with your personal appraisal

- The **public workspace**: it is in the public workspace that official deliverables are published. It is also the place for external communication with suppliers or customers. In general, the information exchanged in the public workspace is extremely formalized.

- The **project workspace**: this intermediary level concerns the sharing of information within the project team. This level is still influenced by the company formalization of information (and by project's role segmentation)
- The **proximity workspace**: this level corresponds to the information producers' personal network. The invited actors accepted in the information producer's proximity workspace compose a "friendly" assistance for the share of information.

The aim of this document is that you complete the Figure 8.11 above regarding the following criteria

- meeting frequency
- meeting's level of information diffusion

Please, fill in the Figure 8.11 above with your evaluation of the above mentioned criteria.

6. Conclusion

We'd like to thank you for your participation. The global results of my stay of November in Berlin will be presented in both a report that I will hand out after gathering together your answers.

Thank you very much again.

7. Annex

English	Deutsch
Assembly	Montageleute
Assembly managers	Montage Teamleiter / Montage leiter
Customer PM	Produktionsprojektleiter
Material planner	Planner
Material scheduler	Disponent
Primary Engineering	Primary Engineering
Proc./Purch	Einkaufsabteilung
Prod. Department manager	Produktionslinie Leiter
Production work package manager	Arbeitspakete Produktion Vertreter
R&D department manager	Entwicklungsleiter
R&D PM	Entwicklungsprojektleiter
R&D team	Entwicklungsteam

8.9 Appendix IX – Structure of the BD ramp-up team

The BD project was carried out at the Grenoble and the Berlin plants of Siemens E T HS (see Figure 8.12). The actors involved belonged to six different departments:

- The R&D department of the Grenoble plant.
- The Purchasing department of the Grenoble plant, responsible for the procurement of development and test parts
- The Quality department of the Grenoble plant
- The Purchasing department of the Berlin plant, responsible for supply chain set-up and series parts procurement.
- Berlin Production department
- The Marketing department.

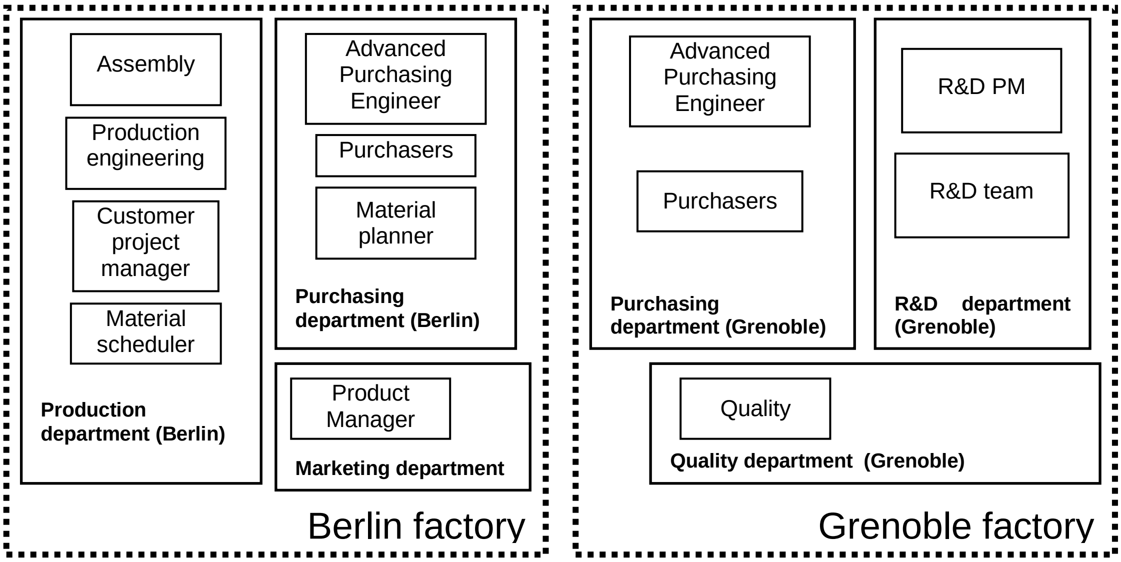

Figure 8.12 - Organizational chart of the GE project team

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PROBLEM AND INTERFACE CHARACTERIZATION DURING RAMP-UP IN THE LOW VOLUME INDUSTRY

Résumé :

Dans cette thèse, nous nous intéressons à la phase de montée en cadence dans le contexte de l'industrie de faible volume. Nos travaux se fondent sur des études de cas réalisées à Siemens E T HS, une entreprise produisant des disjoncteurs haute tension. Nous nous sommes tout d'abord intéressé aux problèmes rencontrés lors de la phase de montée en cadence car leur gestion est une activité majeure pendant cette phase. Nous avons établi des problèmes types. En parallèle, nous avons réalisé un état de l'art complet sur la question de la montée en cadence afin d'établir une cartographie de la littérature existante. Enfin, nous nous sommes concentrés sur les problèmes d'échange d'information et de coopération en examinant les interfaces, c'est-à-dire les liens et interactions existantes aux frontières entre différentes fonctions industrielles. Nous proposons un nouveau modèle d'interface ainsi qu'un outil d'audit que nous avons utilisé sur trois études de cas, ce qui nous permet de tirer des conclusions tant d'un point de vue pratique pour nos partenaires industriels que d'un point de vue académique.

Mots-clés: Lancement de produit, Industrie de faible volume, Problème, Interface, Coordination.

Abstract:

In this dissertation, we address the issue of production ramp-up in the context of the low volume industry. This dissertation builds upon case studies carried out at Siemens E T HS, a company manufacturing high voltage switchgear. We first focused on the problems encountered during the ramp-up phase, since fire-fighting (i.e. problem handling) is a major activity during ramp-up. We identified problem types. Meanwhile, we realized a thorough state regarding the ramp-up issue, so as to provide a “map” of the existing literature. Finally, we focused on information exchange and cooperation problems. The approach taken is to focus on “interfaces”, i.e. the links and interactions existing at the boundary of different industrial functions. We propose a new interface model and the corresponding auditing tool. The auditing tool was used on three different case studies. We draw valuable conclusions for our industrial partners but also outlined interesting results from a research point of view.

Keywords: Ramp-up, Low volume industry, Problem, Interface, Coordination.