The transaction costs analysis of the customer-supplier relationships in product development
The case of the car manufacturing industry

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Abstract

The user requirements analysis is an essential part of any automation effort. In this paper we use a methodology for users requirements analysis based on an advanced model, the one of transaction costs analysis, which overcomes the conceptual shortcomings of the data and cybernetic models. The goal of the TIBAS project was to design a multimedia platform for collaboration in product development in the car manufacturing industry. The paper examines how the European automotive industry affects the supplier-manufacturer relationship. We analyse this relationship based on transaction costs economics and on the study of communication breakdowns that affect business transactions. Based on the empirical study, a series of infrastructure services are identified which meet the industrial user requirements.

Keywords

User requirements, transaction cost analysis, multimedia, collaboration, manufacturer, supplier

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The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35357-9_22

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1 INTRODUCTION

Methodologies for user requirements are based on some model of work organisation and information, and ultimately of the rationality of the decision maker who produces, uses and communicates information and knowledge. To be sure, various, alternative models of organisation are available (Ciborra, 1996). Models in good currency are based on the enterprise view of data and the cybernetic view of decision making. Unfortunately, as it has been shown elsewhere both of these models are highly deficient in capturing the essence of the information and decision processes in economic organisations.(Ciborra, 1996). In particular they fail in looking at the organisation as a nexus of contracts between people who have only partially overlapping goals. They do not consider the possibility of gaming behaviour and opportunistic information processing. They fail at including markets as a form of organisation. They have difficulty in coping with the continuous changes the boundaries of the business firm undergoes. In one word, they do not take into account the important results of the economics of organisations as developed originally by the Nobel Prize Ronald Coase (Coase, 1937), subsequently perfectioned by Oliver Williamson (Williamson, 1975) and further applied to the information systems domain (Ciborra, 1996).

This paper, based on a report prepared for the EU research project TIBAS, uses a methodology for users requirements analysis based on a more advanced model, the one of transaction costs analysis, which overcomes the conceptual shortcomings of the data and cybernetic models.

The goal of the TIBAS project was to design a multimedia platform for collaboration in product development in the car manufacturing industry. The transaction costs analysis was carried out by looking at a number of manufacturers such as BMW and Rover and a number of suppliers, such as Siemens AT and IAD. In each case the practices of collaboration around the design of a new product/ component were the focus of analysis. Such practices were analysed both in their daily detail and in the wider framework of the relationship between supplier and customer. A relationship which is information-rich but also made of a mixture of convergent and divergent interests.

The aim of the analysis has been to identify systems requirements not just to make collaboration more efficient "in a vacuum", or to improve joint decision making assuming that there would be full co-operation in all the process stages between supplier and customer. Collaboration and the contractual context in which is embedded were taken always as a (changing) problem, and the introduction and use of new multimedia platforms had to be designed together with a realistic and efficient organisational context. In this respect the transaction costs analysis has proven to be a very useful tool.

The paper examines first the changing context of the European automotive industry and how it affects the supplier-manufacturer relationship. Next, it puts forward the methodology to analyse this relationship based on transaction costs economics and the study of communication breakdowns that affect business transactions. The methodology is applied to the study of major European manufacturers and suppliers, focusing on the main transactions that occur during product development. Based on the empirical study, a series of infrastructure services is identified which meet the industrial user requirements.

The main findings are the following. In the European automotive industry the supplier - manufacturer relationships are changing from being pure market or hierarchical, to a team-like arrangement, following the trend set by the "Japanese model" of car production. Such a transformation entails the creation of a hierarchy of suppliers, the sharp decrease of the number of "first row" suppliers that build complex subsystems, and the more "intimate" relationship between a car manufacturer and its main suppliers.

The new organisation, together with the tighter requirements for flexibility and quality in car production, increases the need for higher levels of co-ordination and integration.

Such needs are currently addressed by a variety of co-ordination and integration mechanisms being set up mostly on an ad hoc basis by manufacturers and suppliers. Guest engineers; internal project leaders; teamwork; collective meetings are being deployed by manufacturers and suppliers, together with the trial of systems such as video-conferencing, EDI and other dedicated electronic links.

This changing industrial landscape and the new experience with network technologies create a favourable environment for more advanced systems, such as the multimedia platforms envisaged by the TIBAS project. Its emerging requirements represent a challenge for the systems designers.

The user requirements suggest first the inclusion on one screen of different streams of information, ranging from CAD data to e-mail, and still and live video images. Second, a user should be able to manipulate such information in an easy way, according to the circumstances dictated by the work flow (e.g. annotate a CAD drawing; partially hide it; show it on video or send it out by fax). Moreover, since there are always multiple actors involved at any moment in the supplier-manufacturer interaction, each of them, manager or technician alike, should be able to access the network from a customised entry point, his or her "adaptive desk". Such a desk should also be able to "remind" the user not only of the typical sets of actions linked to his or her role, but also what needs to be done at the specific point of the ongoing transaction.

Finally, at the centre of the communication network, lies a component database, that works less as a telemarket device and more like a common platform for collaboration between different partners, managers and engineers, who need to share multimedia messages to solve complex problems in a fast and effective way.

2 ORGANIZATIONAL AND TECHNOLOGICAL TRENDS

The supplier/car-manufacturer relationship is, in Europe, in an exciting state of transition. The challenge that major car manufacturers are facing in order to stay competitive, is how to adopt in a creative fashion the Japanese model, or in other words, how to move from the prevailing "Fordist" model of car manufacturing towards a European version of the "Toyota" model.

Three major phenomena are sweeping the industry:

- A sharp decrease in vertical integration of car manufacturers. This manifests itself as a transfer from "make" to "buy"; from two-party transactions to teamwork; from catalogue buying at arms length to co-operation and profit sharing.
- A rearrangement of suppliers taking into account greater diversity of business relationships, company sizes, and geographical locations.
- The establishment of longer term, non-market relationships uniting a co-operative circle of major suppliers to deliver the main components of the car. (see Figures 1 and 2).

	From a clear-cut division of labour...	...to a hybrid arrangement
Organisation	- Large and multi-layer hierarchy and a highly dispersed market of relatively small suppliers	- Leaner car manufacturer surrounded by a hierarchy of suppliers. The inner circle of suppliers has long term, team-like relationships with the central firm
Information System	- MIS, databases, departmental systems tendering process with the suppliers	- EDI, horizontal networks and direct links with the suppliers

Figure 1: Evolution of the supplier - car manufacturer relationship.

Let us examine this industrial landscape in more detail, to set the context for the more detailed user requirements analysis.

Phase 0 All-in-house	**Phase 1** Hierarchy+market	**Phase 2 - Today** Leaner firm + hierarchy of suppliers	**Phase 3 - Future** Teams of teams (?)
Ford's River Rouge Plant (Detroit)	American and European plants up to the 80's	Toyota and other Japanese, US and European plants	
Organisation:			
All hierarchy no market	Hierarchy + many suppliers	Hierarchy + few large suppliers + many sub suppliers	Flexible manufacturing systems managed by teams Product development teams
Bureaucratic procedures for co-ordination	Bureaucratic procedures and tendering process	Selection of suppliers	...
Problems:			
Departmentalisation Slow response time High over head No control of cost	Departmentalisation Quality High Purchasing overhead	Complex interfirm and cross functional co-ordination	Redesign of information systems to make them groupware applications more than MIS

Figure 2: The evolution of the car industry organisation.

2.1 Basic trends

European car manufacturers are responding to the Japanese challenge by adopting and adapting the Japanese model of car production. The so called "Toyota model" has emerged as the one with highest productivity, both compared to US and European manufacturers (Womack, Jones and Ross, 1991).

We found different European companies actually moving in the direction of "Toyotism", and abandoning the prevailing "Fordist" model.

The reasons for such a dramatic shift are the ones of efficiency, quality and time. Such issues are not new. They always lied at the centre of car manufacturing. What is interesting here is the re-invention that the Japanese did of these three concepts and the novel solutions that they have been able to offer. After the fact, such solutions though developed on an ad hoc basis, have proven to be superior to the conventional ones.

1. The "lean factory" is the Japanese answer to the efficiency problem. Search for efficiency in the Fordist production system was concerned with exploiting single machines and workers. The Japanese are concerned, instead, about minimising the "work in process" and the "free time", that is any slack that hides in production. For example, techniques, such as Just in Time, are aimed at restructuring the whole production flow so as to eliminate stocks. Or, the layout of the machines is such that a worker can intervene on a whole set of machines, to optimise the overall production rate of a complex line, rather than the job at an individual machine.

Note how the new style of work organisation is based on a revolution in the way information flows. The Fordist model centralised all information and knowledge. The Japanese model relies, through the "kanban" system, on a decentralised information management: at the limit, the assembly worker has the right to stop the line, and in any case the whole production system when working smoothly is able to take care of itself, without the need of a centralised planning function. (the principle of "autonomy", introduced by the chief Toyota engineer, Ohno prescribes that the production flow be able to progress autonomously)

Note further, that the concept of the "lean factory" goes hand in hand with the growing role played by outside suppliers. In Japan the degree of vertical integration is low compared to the one prevailing in the US or in Europe (30% compared to 50%). (See Figure 3). Suppliers do not only deliver standardised parts from catalogues, but also complete subsystems that integrate various technologies. The product development activity, ranging from the initial design to the execution of detailed drawings is also contracted out (see below).

Products			**Suppliers**
Traded products	30,5%	26,5%	General suppliers
		23%	Normal suppliers
		15%	First order suppliers
Ordered products	43,0%	9%	
			Associated partners
Internal production	26,5%		

(from Coriat, 1991)

Figure 3: The "Lean Factory".

Subcontracting is due to various reasons: standardisation of the parts; degree of criticality for a specific manufacturer; access to highly specialised workforce; need of a more flexible management of the human resources; capacity problems etc.

Whatever the reason, however, having to rely on a dispersed set of suppliers and at the same time wanting to achieve efficiency, quality and integration of the final product, poses more complex problems of co-ordination across multiple, semi-autonomous or totally autonomous organisations. The Japanese have been able to enact more flexible and effective forms of co-ordination through a new array of "integration mechanisms" both inside and outside the firm.

2. Attention to detail is the strongest drive to obtain high levels of quality in the manufacturing process and in the product. Various techniques, such as the quality circles, or statistical methods to measure defects, are employed at all levels in the manufacturing process. The Toyota model differs from the Fordist because it tries to build quality "into" the product at each stage, from product conception to final assembly, and not measure it and intervene after the fact.

Note that the Japanese attention to quality is based, once again, on a different style of information management. Data about quality is collected at each production stage and immediately fed back to the workers, who discuss such data and engage in immediate problem solving. Like for the case of the "kanban", information management is mostly generated and handled bottom-up in the organisation and supports local and team, as opposed to hierarchical, problem solving.

3. The final trend regards timing and speed, innovation and flexibility. Competition based on price and performance is shifting to a competition based on level of quality and rate of innovation. This requires a shorter product life cycle, and especially a shorter product development cycle. Rate of innovation is bound to increase, too.(see Figure 4)

	Japanese producers	American producers	European volume	European specialists
Average engineering hours per new car (millions)	1,7	3,1	2,9	3,1
Average development time per new car (month)	46,2	60,4	57,3	59,9
Number of employees in project team	485	903	904	904
Supplier share of engineering	***51%***	***14%***	***37%***	***32%***

Figure 4: International comparison of development time and resources (from Womack *et al.*, 1991).

The new scenario requires a much quicker transfer of information between the different departments engaged in launching a new car. Collaborative design and simultaneous engineering are the work methods emerging in product development to address the new requirements.

The intertwining of these trends make the design and construction of the car a "new job", that requires a new organisation of work and above all a different way of managing information throughout the entire process.

To the extent to which higher levels of quality and flexibility are required, the job of designing and building the car becomes more complex. The higher complexity needs an overall work organisation that is highly tightened together. The old functional organisation is too departmentalised, slow and scarcely integrated to cope with the new complex job.

As a consequence, European manufacturers have implemented a series of organisational reforms aiming at increasing the levels of coupling between the various production phases, departments, work units inside and outside the firm.

These reforms include both organisational and information technology means, or "integration mechanisms". Examples are: teams arrangements (like in the quality circles); matrix forms of organisation; project or product leaders; liaison roles across departments or with suppliers; more sophisticated Management Information Systems; EDI; video-conferencing, etc.

2.2 Trends in Product Development

Clark and Fujimoto (Clark & Fujimoto, 1990) conclude that car companies that are able to consistently develop successful products are producing in fact "integrated products", and are themselves coherent and integrated in both strategic and day-to-day activities.

For example, when Mazda put racy, four-wheel steering in a conservative family car, potential customers felt the mismatch. The cause of the mismatch? Most likely, the conception of the car: the engineers in proposing an advanced technical innovation and the sales and marketing people did not talk to each other enough to perceive the potential mismatch. Honda, on the other hand, put a similarly performing system in a sporty two-door coupe that matched consumers' ideas about the innovative technology: that was a success.

In the shift from competition based on price to other, more subtle features, it becomes of paramount importance that the final customer perceives no mismatches between the various features of the product, such as design, image, quality, fit, performance and price. In other words, what matters is "product integrity", i.e. the fact that all the performance and quality features of the car are valued as an integrated whole by the customer and convince him/her to buy it.

Clark and Fujimoto have found a strict correlation between the integrity of the final product and the level of integration of the organisation that conceives and manufactures it.

Information is the main factor that supports integration. Consider how a new car starts and ends. Though the car is a tangible artefact that the customer will see in a showroom and subsequently will drive, the car does begin as a piece of information, as an idea. During product development, that idea is implemented in progressively more detailed and concrete forms: ideas turn into designs, designs into drawings, drawings into CAD blueprints, CAD blueprints into prototypes and so on until the finished car emerges from the factory. The process of developing and building new cars depends as much on the flow of information as it does on the flow of materials.

Today product development faces the following challenges. On the one hand, product integrity gets defined during product development. Hence, the product development organisation needs to be highly integrated. On the other, shorter life cycle and a more prominent role of innovation, make product development a more intense, flexible and faster activity. At the same time, product development is being increasingly contracted out.

In product development, then, we can identify the same challenge already described in more general terms above: how to reach simultaneously higher integration through a dispersed organisation.

In this respect, consider two vignettes of product development. Once, proprietary innovation, quality and cost savings were achieved by relying on a highly vertically integrated functional organisation. The drawbacks were slow response time; long development cycles; bureaucratic departmentalisation that reflected itself in mismatches in the product; high fixed administrative costs; scarce flexibility in managing and motivating large design departments. The nice thing about it was that co-ordination was simple, since it could rely on bureaucratic procedures linking activities carried out "under one roof".

Today, precisely for the reasons mentioned above, development is carried out partially outside the scope of the car manufacturer by a few independent or semi-independent suppliers, and, at the same time, the need for integration, innovation and flexibility is even higher than before. Unfortunately, the traditional functional organisation cannot play an overarching role in this new situation: it is too slow, and vertically integrated.

Consider, then, the second vignette of modern product development. The old mix of co-ordination/integration mechanisms represented by a large and deep hierarchy cum market relationships, surrounded by a myriad of suppliers providing only the most standardised components, is superseded by a new organisational mix, that we may call of lean, flexible co-ordination. This entails the lean product development, carried out internally, of the most crucial subsystems only(these critical subsystems vary from manufacturer to manufacturer, and they may vary for the same manufacturer as different competitive necessities appear): it can be the engine; or the car concept design, or the car body. This internal development is carried out by highly integrated teams, and not by separate functional departments. Each team has a project leader with some degree of authority in cutting across functional lines. Next, there is a small circle of key suppliers who work in close contact with the development units, usually in a way closer to a team arrangement, than a pure market relationship. The relationship with the supplier is in itself a mix of various co-ordination mechanisms: it is in part at arm's length, since the supplier at some point signs a market contract; it is hierarchical, since suppliers are organised hierarchically in respect to the car manufacturer; and on a team basis both in the day-to-day work, and in the long term partnership that is established between the car manufacturer and its key system suppliers.

During product development, thus, the work is carried out by a multiplicity of units, both inside and outside the car manufacturer: these units tend to work as a "team of teams", and not as the traditional bureaucracy.

Still, by looking carefully at the nature of relationships that hold together such a "team of teams", we find a variety of co-ordination mechanisms being deployed, sometimes on an ad hoc basis. In the relationship between two designers located at the supplier and car manufacturer site, we may observe <u>three main co-ordination mechanisms</u>, often working at the same time:

- <u>market</u>: where the buy and sale of a service prevails, with all the concerns about security; deadlines; price and explicit, detailed contract language;

- hierarchy: the outside supplier may de facto works as an employee or internal department of the main car company, and has limited choice but in following the company procedures;

- team: the two organisations collaborate in order to get the job done, solving problems jointly as members of the same team, sharing the same values and goals.

Note that the intertwining of these mechanisms is of paramount importance for the system designer, since the way information flows across these different relationships may differ drastically. Thus, for example,

- in a market relationship: very little information needs to circulate: design is carried out completely at the supplier site; the car manufacturer provides the initial specs, and then commercial and administrative data need to flow (EDI would suffice). Access to internal databases and mainframes is usually denied;

- in a hierarchical context, the supplier needs a more intimate knowledge of the car manufacturer procedures: its CAD system can well be the same, "imposed" by the car manufacturer. Also the supplier may have the only choice to comply strictly with the car manufacturer's administrative and work procedures. Access to internal databases is carefully monitored and regulated;

- in a team, open informal communication prevails: the larger the bandwidth, the better; access to the manufacturer's databases is open to the supplier.

2.3 Integration mechanisms in product development

Usually, the basic scenario, where a car manufacturer needs a part, consults a catalogue, or asks a supplier to provide or design the part etc., implicitly assumes that the transactions would take place through a series of clear cut organisational settings. Inside the car manufacturer there is a clear definition of responsibilities between Purchasing, Design and Production functions, while with the supplier a sharp in - sharp out market relationship would obtain.

What we found by looking actual business practices is that the picture is much more blurred than the one presented by the basic scenario: roles are "fuzzier" and transactions are "messier". By closely studying how transactions are carried out, we have discovered that the "messiness" can be analysed by referring to a finite number of supplementary integration mechanisms, deployed in order to carry out complex and uncertain transactions in a more efficient way than the one allowed by the pure co-ordination mechanisms of the market and hierarchy.

The integration mechanisms we found can be short-listed, according to their level of sophistication and complexity:

- temporary liaison roles;
- frequent meetings (of various sizes: from a few individuals to more than a hundred people);
- fixed liaison roles, both by the car manufacturer or the supplier (guest engineer; site engineer etc.);
- product manager (roles inside the functional hierarchy that lead product or part development, such as the "systems engineer", or the "module leader");
- task forces (temporary, cross-functional and interorganisational work groups set up to solve a problem);
- teams (more stable, cross-functional and inter-organisational work groups that attend to the whole development of a subsystem or the entire car);
- matrix (forms of cross-responsibility between functional departments and product lines).

	Internal	**External**
Individual	Liaison Role Product Manager	Liaison Role (guest engineers)
Collective	Task forces Teams Matrix Meetings	Meetings Task forces Teams

Figure 5: A typology of the integration mechanisms.

Figure 5 classifies the integration mechanisms according to two axes: internal vs. external; and individual vs. collective.

Figure 6 spells out where these mechanisms are usually found and to what form of hybrid organisation they tend to lead up to.

Finally, Figure 7 suggests the role that IT can play in supporting such integration mechanisms.

Integration Mechanism	Context where it is applied (main co-ordination mechanisms)		New hybrid arrangement
	Internal	*External*	
Temporary liaison roles	Between departments of hierarchy	Across the market relationship	Introduces horizontal communication and co-ordination links in the hierarchy and across the market
	"	"	
Fixed liaison roles	"	–	
Product manager			
Task force	"	"	Introduces team elements in the hierarchy and the market
Team	"	"	
Matrix	"	–	

Figure 6: The deployment of the main integration mechanisms.

3 TRANSACTION COSTS ANALYSIS METHODOLOGY

The basic aim of the TIBAS project was to develop an application experiment for manufacturers, suppliers and designers in order to shorten the decision making process and reduce design process time. More specifically, the project was aimed at developing a single multi-media database with marketing data, technical product specifications and commercial product specifications, the so-called "telemarket", or electronic commerce; (Ciborra, 1996) and at developing tools for co-operative design in a distributed environment.

The preliminary steps for the car manufacturer to consult its supplier's database for technical information about available components (marketing data sheets, technical specifications of the product, and commercial information) involve consultation and acquisition of many different types of data which come in various formats.

Decision making typically requires:

- numerous meetings until a good technical understanding of the demand is reached;
- information exchange mainly done by mail or travel.

Integration Mechanism	IT support		Expected Impacts	
	Internal	*External*	*Internal*	*External*
Temporary liaison roles	e-mail	Satellite office	More efficient horizontal links	Tighter link with the home base
Fixed liaison roles	e-mail			
Product manager	Management tools Structured e-mail	Structured e-mail	More effective hierarchical planning	Better co-ordination with subcontractors
Task force	Groupware for synchronous and asynchronous meetings	same	More effective teamwork	Better teamwork
Team	"	"	More effective teamwork	Better teamwork
Matrix	E-mail Management tools	_	Better communicatio n between functions and product area	

Figure 7: IT and the integration mechanisms.

Both the duration and the quality of the specifications of the product to be developed by the supplier are negatively affected by numerous meetings, iterations of electronic interaction and lack of accuracy and efficiency.

In sum, even though design engineers are provided with the most sophisticated CAD systems and workstations, they lack the associated communication facilities that would significantly enhance their level of efficiency.

3.1 A Basic Application Scenario

In order to be more specific about the interactions during the product development process, consider a generic scenario concerning the relationship between supplier and customer. The scenario involves two actors: a car equipment supplier (CS) (covering both suppliers of parts for the general automotive market and suppliers of contracted design work) and a car maker design engineer (CM), and it covers both electronic commerce and collaborative design.(see Figure 8)

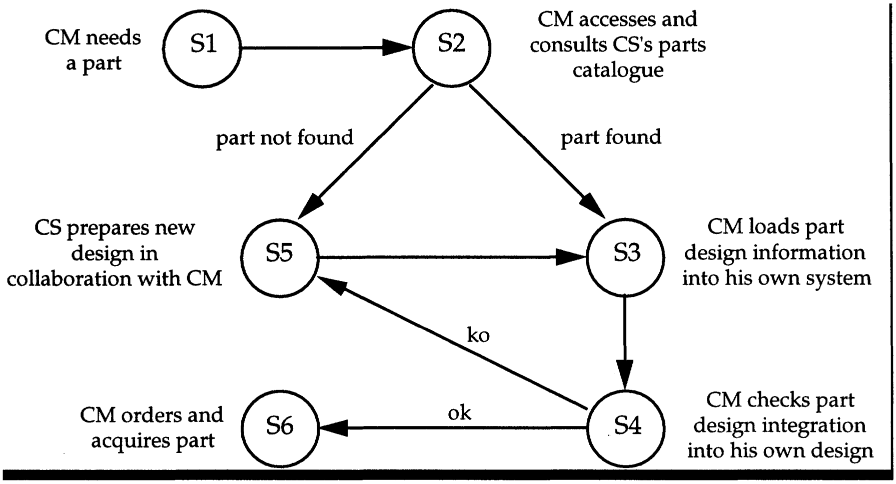

Figure 8: The basic application scenario.

The "Toyota model" of lean production indicates that being able to manage the suppliers is the other side of a lean internal assembling process. Japanese manufacturers seem to be more effective in managing the procurement of more components and sub-systems, by employing less people in the purchasing departments, reaching far higher levels of quality and flexibility, and harnessing the whole supply chain to the pace of just-in-time. They achieve all this not through IT, but through subtle and effective organisational arrangements, where the processing of information plays a key role.

In Europe a thorough understanding is needed of the organisational nature of the supplier-manufacturer relationship in order to re-engineer it through the deployment of IT. We need to focus on the context of the information exchange, asking "why" a given exchange takes place, before jumping to the "how".

The supplier - manufacturer relationship is a contractual one, where information and knowledge are distributed asymmetrically; where negotiation and bargaining go hand in hand with co-operation; where innovation can be jointly generated and shared; where trust can play a decisive factor in making this relationship more efficient; where the contractual arrangement chosen to govern the relationship has a direct impact on the performance of the players, and where, finally, the information infrastructure plays a determining role in affecting the knowledge asymmetries; the degree of control and trust; the levels of learning and innovation.

3.2 Transaction costs framework

The transaction costs methodology analyses the organisational contexts of the communication needs from a contractual perspective. Specifically, it distinguishes a range of components of varying degrees of complexity, that may involve different contractual arrangements. It looks at any of these relationships as a negotiated co-ordination problem, where communication has both a co-operation and a bargaining content. It does not ignore the structural as well as the subjective reasons why a certain relationship should be designed more as a market or as a team, and will recommend systems specifications that are in line with the most suitable contractual context.

The first idea of the analysis framework is that the manufacturer–supplier relations vary from an organisational point of view over a broad spectrum depending upon many factors, such as:

- frequency of the relationship;
- experience/mutual knowledge;
- complexity/uncertainty of the service/product supplied/requested;
- degree of goal congruence between the parties;
- number of suppliers/manufacturers involved;
- information/communication barriers;
- norms and regulations.

The second general hypothesis is that for each combination of factors there is a limited number of efficient ways to arrange the relationship. A third hypothesis is that IT by affecting co-ordination costs is an important element in designing the most efficient relationship.

Factors are also interlinked indicating what particular class of arrangements is best suited to meet a particular set of circumstances. More precisely, for complex products and services a "closer" relationship is required, while for standardised items a more arm's length would do. A "closer" relationship means more intense co-ordination/integration in order for the parties to adapt to the changing specifications of the service/product while it is designed, engineered, manufactured, delivered and assembled into the final product. "Closeness" is required to enhance mutual control during contract implementation between parties who cannot be assumed to be fully co-operative.

Ideally, a very close relationship would consist in working like a **team**, with no conflict of interests, maximum levels of trust and no fear of opportunistic behaviour. In reality, such a team arrangement may be not always enacted with a given partner. If there is large number of potential partners, then it may be possible to choose the most suitable team-mate. When the number of partners is limited, however, one may have to work with partners one can trust to a certain extent only.

Such a common situation can be dealt with by adopting an appropriate contractual arrangement to govern the relationship supported by a suitable information infrastructure. The purpose of the contract is to indicate how the parties ought to behave during the delivery of the product/service and the related processes. The contractual arrangement specifies the terms of exchange, the obligations of the parties, the adaptations required if circumstances change and the reciprocal responsibilities if one party fails to comply. It also specifies bodies, both internal and external to the relationship, which are entitled to monitor and govern the execution and modification of the contract.

To be sure, a contract is a piece of paper, or a handshake, that can be made effective only if supported by an appropriate information infrastructure, which allows parties or external bodies to monitor circumstances, the way the contract is carried out, and modifications are implemented. Without an information infrastructure one has to rely on trust and perfect goal congruence between the parties.

At the other extreme, the product/service exchanged can be highly standardised and available from many suppliers: this is a situation where one can rely on the **market** and the price system to get what one needs. In that case the exchange is a pure market transaction concerning a commodity. The "invisible hand" of competition takes care of weeding out those parties that cheat on price, delivery dates or quality.

Note, however, that deciding whether a service or product is standardised (and thus one can rely on an arm's length relationship), or complex (a team arrangement is required in this case), or variations thereof, cannot be done once for all. For example, to achieve high quality levels for an ordinary component, a manufacturer may be keen in establishing a very close relationship with one or more suppliers in order to raise the product quality. Such higher levels of quality may in fact transform that standardised product in a more complex one, which would require, according to our framework, a closer relationship.

In sum, the first set of general hypotheses suggests that a supplier–manufacturer relationship can be viewed as a bundle, or "package" of items:

- the object (product or service) of the transaction;
- the type of contract that regulates the transaction;
- the organisational arrangement (a team, a market, a hierarchical relationship) that governs the execution and completion of the contract, and sets the contexts for its further modifications and renewal;
- the information infrastructure;
- the parties involved, their goals in engaging the transaction;
- the broader context where the transaction occurs (number of players; public bodies emanating, enforcing and policing regulations and norms; state of the technology).

When suggesting and designing a new information infrastructure, one should design the related package that can be supported by that specific infrastructure. The notions of "telemarket" or "collaborative design" contained in the TIBAS project should be understood not just as suggesting a specific technological solution, but as composite bundles to be applied to manufacturer - supplier transactions that vary in their degree of complexity.

Next, from a **process** perspective the supplier-manufacturer relationship can be articulated in a sequence of steps (seen from the point of view of the manufacturer): search of supplier using contacts, data sheets, (on-line) parts catalogue, etc.

- supplier assessment: technical competence, production capabilities, commercial relations, competitive position, financial reliability, etc. The aim is to find out if the supplier is reliable for becoming part of a total quality system and/or supplying just-in-time;
- supplier homologation: if the assessment is successful, the supplier is allowed to supply components;
- the manufacturer gives component specifications to the supplier; this can be done in two different ways:
    - the car manufacturer gives a detailed design of the component, and the supplier manufactures it;
    - the manufacturer gives the functional specifications of the desired component, and the supplier designs and manufactures it;
- contract negotiation: specs, price, delivery time, penalties, etc.;
- design: information exchange to face problems, surprises, etc.;
- production: information exchange to face problems such as defective parts, delays in delivery, variations in quantity desired, etc.;
- exchange of feedback information to improve the product design, the engineering, the manufacturing process, etc.

What it takes to carry out this process, in terms of human resources, information handling and overhead is called transaction costs. IT can be applied to decrease such costs in a variety of contexts, depending upon the complexity and uncertainty of the transactions.

From a **structural perspective**, the following points can be highlighted:

- any supplier-manufacturer relationship can be seen as a *network of exchanges* among units;
- a *unit* is a phase in the value chain of the manufacturer and in the value chain of the supplier; in the case of small supplier companies where more than one function in the value chain is done by the same person/office, we consider that person/office as a unit;
- the *type of component* affects the intensity and contractual arrangement of the exchanges; components can be classified according to complexity: at one extreme of the spectrum we have very standardised parts that can be simply selected from a catalogue (e.g. a screw), at the other end we have parts which involve unpredictable designs and require close interaction among CS and CM (e.g. a die cast plastic component);
- the transactions involve various units both within and outside a single manufacturer or supplier.

The number, intensity and types of transactions among units of two companies will vary on a wide spectrum; different classes of supplier-manufacturer relationships could be highlighted by different patterns of connecting lines in graphs like this:

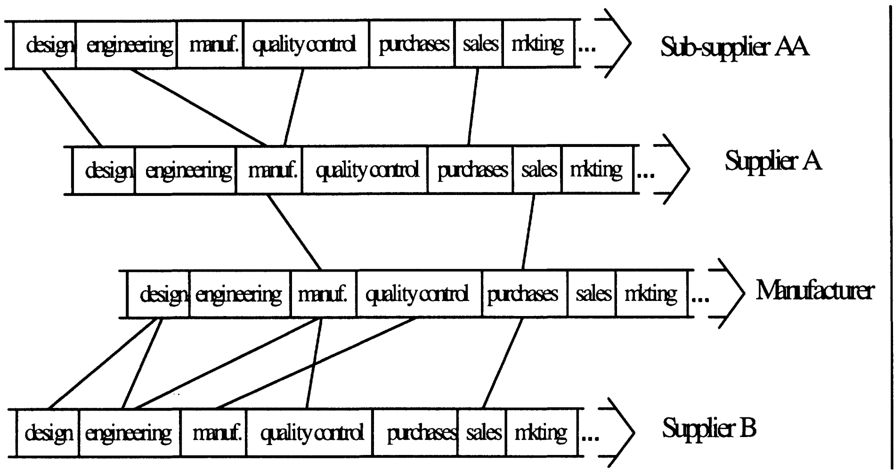

Figure 9: Different patterns of transactions.

When looking more closely at the supplier-manufacturer relationships, one has to consider the organisational arrangements within each company: whether there is a project leader who co-ordinates the relationship and acts as an interface, whether the design unit includes two separate sub-units for mechanical and electronic design, whether there is a specialist from the supplier working at the car maker's site, whether there is a cross-company design team co-operating to solve a difficult problem, and so on. Different arrangements can be shown by graphs like this:

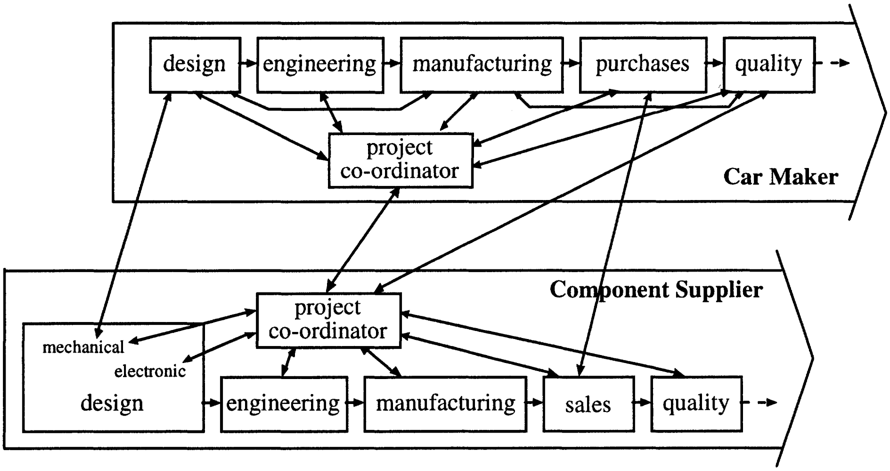

Figure 10: Alternative transactions arrangements.

3.3 Analysis of breakdowns

An effective way to analyse a supplier–manufacturer relationship and the backbone information system it may require, is to analyse its behaviour both under normal circumstances (those for which it has been designed) and under stress, when breakdowns occur that cause strain in the relationship, minor and major modifications and most probably the deployment of a surplus of co-ordination and information resources.

Such a "stress analysis" provides intelligence on the resilience and efficiency of the original relationship design, its domain of applicability, and the new emerging arrangements and their relevant information systems, people apply in order to "rescue" the relationship in the face of unexpected circumstances. (Winograd, Flores, 1987) This in turn points to the user information needs in a broad range of contingencies and allows to design a more efficient and effective "bundle", including an appropriate contractual arrangement with a viable information system.

More precisely, one can identify the following steps:

- analysis of the present relationship and its main dimensions (object, frequency, type of contract, number of players, organisational arrangement, direct labour involved, overhead, information system - structure and cost);
- mapping the extant relationship. Usually, a relationship can be decomposed in a network of sublinks between various units of the supplier and manufacturer. The analysis above should be specified for each of the main sublinks;
- an evaluation can be made at this point of the adequacy of the existing information system to support the relationship. A first set of user requirements can be thus identified;

- analysis of breakdowns. For each relationship a limited number of breakdowns is analysed that lead to major problems (i.e. that generate extra transaction costs). A series of questions is asked to this effect.
  - What is the nature of the breakdown?
  - What are its impacts and economic consequences?
  - Who perceives it?
  - Who intervenes to solve it?
  - In what way?
  - How is the original contract modified?
  - At what cost?
  - What information is used and produced during the event?
  - Which new links and contracts are set up by the parties?
  - How are litigations negotiated?
- a second map of the new network of linkages emerging to cope with the breakdown can be drawn. What are the contractual arrangements that characterise this new network? What is their stability and what their ad hoc information systems? Is this new network efficient?

This analysis helps to identify the user requirements during stress situations; and to evaluate if this new bundle is efficient and effective and how it can be supported by information technology. Furthermore, by analysing the ramifications of breakdowns one can find clues about the flexibility and the hidden costs of the "normal relationship"; and alternative bundles to better cope with normal and stress situations, thanks to a more sophisticated information infrastructure.

4 RESULTS AND CONCLUSIONS

The new scenario envisaged by the TIBAS project shows a new, "hybrid" from of organisation links car manufacturers and suppliers in ways to achieve higher levels of product integrity. This organisational scenario is characterised not by one single company, nor by many small firms operating on a perfect market. It is characterised by a complex web of interdependent, semi-autonomous production units of various sizes and specialisation.

Specifically, an organisational mix composed of a central company (the car manufacturer), much leaner, more nimble and flexible which acts as an intelligent middleman and co-ordinator between a circle of systems suppliers. Outside this "solar system" and linked to the main suppliers there is a constellation of a relatively large number of smaller suppliers.

Inside the central firm, there is the need for a communication medium which can support tighter co-ordination of activities and functions such as purchasing, quality control, design, and production. An information infrastructure supports the co-ordination within the central company via improved horizontal links. Additionally, the various transactional modes (commercial, technical, teamwork) of the central company need to be extended by IT to interconnect the suppliers and sub suppliers.

During the field study it has been found out that not only the nature of the division of labour between suppliers and car manufacturers is undergoing a deep transformation, but also the style and the content of communication are changing. For example, in- house product development design work is beginning to be replaced with joint car-manufacturer/supplier collaboration. This requires more intensive styles of communication (hence the explosion of communication needs). Where the "make" approach used to prevail (i.e., large internal design departments leading to in-house fabrication), now a growing use of the "buy" approach is the norm (i.e., flexible as-needed subcontracting for either or both the design and the fabrication). The "buy" approach has become attractive as the complexity of component parts increases: car-manufacturer/supplier teamwork can bring more expertise to bear on problems in a cost-effective way. A communication infrastructure must accommodate the different, and sometimes conflicting styles of transactions: open and collective, but also commercial and "at arm's length".

The key feature of an effective information infrastructure is to address such a simultaneous concurrence of needs. Thus, a flexible negotiation support system should be closely linked to an electronic collaborative environment in order to help solve emerging design problems in a multi-organisational, cross-functional, and interdisciplinary way.

The infrastructure integrates effectively on the same platform the following types of information:

- commercial as well as technical;
- model-based as well as planar image based;
- still images as well as motion video;
- design drawings and data as well as product testing data and analysis;
- asynchronous as well as synchronous messages;
- prose as well as voice;
- archival as well as real-time;
- company internal (private) as well as external (public).

A multifaceted ("hybrid") electronic infrastructure is not only difficult to design and implement; it could also be difficult to use and navigate to access all the options for interaction. To help manage this necessary complexity and versatility, the system needs to provide intelligent aids for its use. In particular, one can think of a reconfigurable desktop which provides the proper support for specific styles of use contingent upon the work circumstances. The adaptive desktop should not only present the most suitable subset of commands and menus for the work situation, it should also have enough "depth" to permit the easy retrieval of contextual information linked to the task at hand, be it commercial or technical in nature.

Furthermore, the study suggests that any new information infrastructure, even highly sophisticated, would not fundamentally alter the overall pattern of hybrid organisation today deployed to manage and carry out the supplier-car manufacturer relationship. In other words, it is expected that any system, whatever the special services it is going to provide the users with, will not allow a radical change of socio-technical integrating mechanisms, but may alter the mix used to solve a given problem. Thus, the TIBAS system is designed to fully support the whole variety of integration mechanisms, and improve both their efficiency and effectiveness.

A final research issue is whether the new infrastructure should be open on the plethora of less sophisticated technologies, such as the fax, the telephone, the overhead projector, the heterogeneous e-mail environments, databases etc. that characterise any present, and future, work environment in the car industry. In other words, should the infrastructure be an "hybrid media" system, that is isomorphic with the "dirty" and "messy" patterns of work organisation one can observe in the everyday interaction between suppliers and car manufacturers; or, should it be built assuming a totally new, ideal environment? Evidence obtained with the application of the transaction costs methodology points towards the former solution.

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