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GLOBALIZATION OF R&D
THE CASE OF PROFESSIONAL GROUPS IN THE CAR INDUSTRY

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ABSTRACT

The globalization of engineering activities is a recent, growing phenomenon (Harfi, Mathieu & Pfister, 2007). It is particularly noteworthy in the car industry, where the question of why and how to go about that globalization is a major challenge for firms (Calabrese, 2001; Sagiyama & Fujimoto, 2000; Miller, 1994). This paper is based on three years of cooperation with a European car manufacturer where we adopted a research-intervention methodology (Hatchuel & David, 2008; Sardas & Lefebvre, 2004). In our exploration of the implications of the creation of a new engineering unit abroad, we have mobilized two analytical models which enable us to understand the large staff turnover observed during the creation of the new unit.

The "internal R&D professional group dynamics" (*"dynamique de metier"*,) (Lefebvre, Roos & Sardas, 2002; Roos, 2006), hereafter referred to simply as the "professional group dynamics", is above all an analytical model in which three interacting sub-dynamics are distinguished: the collective dynamics of expertise (Nonaka & Takeuchi, 1995); the dynamics of roles and their interactions; and the dynamics of collective and individual identities. It is secondly a tool for structuring and management, in so far as it acts primarily on the systems of roles offered to individuals, as well as on the modalities of knowledge management.

In the "global actor dynamic" model (Sardas, 1994), an individual's dynamic is seen as three partial, interlinking dynamics: a cognitive dynamic, a strategic dynamic (Crozier & Friedberg, 1977) and a subjective dynamic (Dejours & Sardas, 2001). This model is designed to diagnose the encounter between an individual and an organization, from a management science point of view.

Our analysis of the firm's first experiments in globalizing its engineering unit shows that the relational deficiencies resulting from actors' games led to blockage in the designers' learning dynamics and caused their dynamic of subjective investment to dwindle. As a result they either became apathetic or they resigned. We can conclude that three conditions are necessary if a designer is to learn: an activity in which new knowledge is acquired; a co-located expert collective that provides the conditions for adequate technical supervision; and the presence of related expertise.

To analyse the subject in depth and to shed light on concrete decisions (how many people were recruited, how many expatriates, etc.), we developed a numeric model for simulating the process of growth and expansion of the competencies of an international engineering unit. This enabled us to assess the time-scale of this process and its sensitivity to staff turnover, which is a major risk in this type of project.

Finally, by reviewing our approach and the models and reasoning applied, we examine the contingency factors of this globalization model.

Keywords: globalization of engineering, internal R&D professional group dynamics, actor dynamics, staff turnover, contingency factors.

INTRODUCTION

General context:

Observers of change in engineering activities have noted two constantly growing phenomena over the past fifteen years (Harfi, Mathieu & Pfister, 2007): both industrialized countries and emergent countries are relying more and more on research and development activities; and this world-wide trend is characterized by increasing globalization of R&D (especially due to multinationals' activities).

These changes are a response to the saturation of markets in developed countries. They confront firms and researchers with two main questions: what impact will the globalization of engineering activities have on the dynamics of design resources, and what models can be used to study this phenomenon?

These questions are particularly salient in the car industry (Humphrey, Lecler & Salerno, 2000). Debate is currently focused on emergent global organizational configurations (concentrated configuration or distributed configuration, Calabrese, 2001; Miller, 1994), but some authors have emphasized the importance of focusing more specifically on the dynamics of manufacturers' resources (Sagiyama & Fujimoto, 2000) and especially of human resources in design, to understand the globalization of engineering activities.

In the broad trends outlined above we have identified a major challenge for all firms: how can R&D resources scattered throughout the world be managed? And, before that, how should R&D resources be distributed? It is the latter question that we will examine here, based on our research-intervention in the Car Body Engineering Department of a large European car manufacturer.

The manufacturer's industrial strategy

The European car manufacturer with which we undertook this intervention has been intensifying its globalization strategy since 2004. This strategy concerns engineering activities and was materialized in the decision to create two units for developing new vehicles: one in Eastern Europe and one in Asia.

In this section we examine the creation of the Eastern European unit. The firm put forward the following arguments to justify its creation of globalized engineering units. First, it argued that products would thus be better suited to their markets, owing to geographic proximity. Second, it maintained that, assuming that skills were equivalent, it would be able to design vehicles that would not be economically viable under different conditions where labour costs were higher.

Research-intervention methodology

The car manufacturer requested the presence of a team of participant researchers (Sardas & Lefebvre, 2004; Hatchuel & David, 2008). This accompaniment lasted for three years, during which the junior researcher was fully immersed in one of the firm's large engineering departments. The results presented here are therefore the fruit of long-term collaboration between the researchers and the firm, following a series of several other common projects over the preceding seven years.

Main organizing principles

The creation of development centres raises the question of the overall structure of an engineering department with units in other countries. The organizational chart drawn up by management shows that the local engineering department in Eastern Europe has to be able to take over the development of a complete vehicle a few months before its style is determined.

In the target organizational chart, the central engineering department is in charge of the preliminary project covering the exploratory phase (consisting in exploring the main hypotheses of services offered to the customer at a set cost) and the preparatory phase (consisting in validating the main lines of the product and process concept). It is at the beginning of the project development, during the general design phase (the objective being to obtain a feasible design, defined with precision), that the project is to be handed over from the central engineering department to the Eastern European development centre.

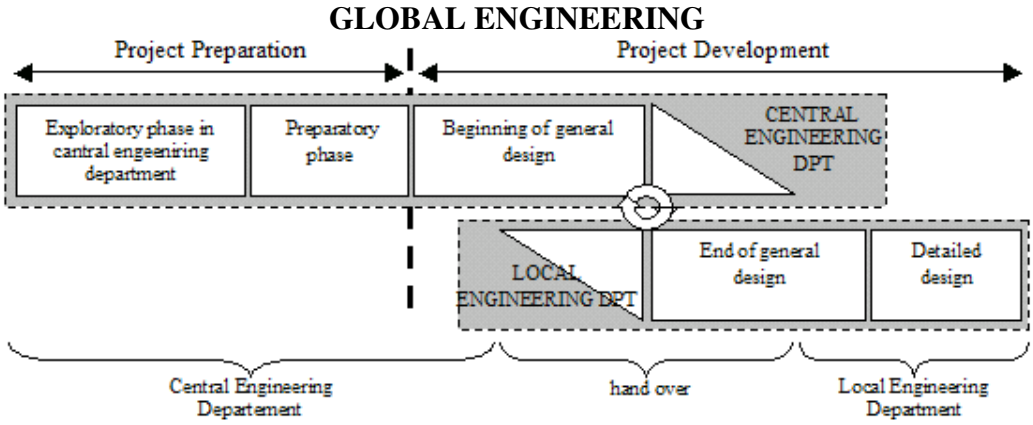


Figure 1: Main organizing principles

Main questions posed by the project of globalizing engineering activities

On the basis of this scenario, it was necessary to define the types and quantities of human resources required by the Eastern European development centre. It was also necessary to be able to determine how the growing competencies of this development centre would be accompanied ("missionaries" devoted to a vehicle project or expatriates devoted to training and supervising local resources; quantity and characteristics of the supervisors; nature, quantity and rhythm of recruitment; modes of training of new recruits, etc.), and what the time-scale of the process would be (number of years needed to attain certain numbers of employees and sufficient autonomy).

QUALIFICATION OF THE RESEARCH QUESTION AND ANALYTICAL MODEL

Qualification of the research question and analytical model: How can a subsidiary engineering unit be created from a central parent unit?

In this paper we explore the implications of the creation of a new engineering unit abroad. In the case of the Eastern European unit, it is possible, on the scale of that unit, to consider the creation as a process of filiation designed to reproduce certain design capacities and to make them autonomous, without at that stage challenging the structuring and dynamics of the design resources at the parent company (central engineering).

Although we cannot analyse this point within the scope of this paper, we wish to point out that the filiation process has feedback effects on the mother company, and that these warrant closer attention. The central engineering unit in the firm studied here is itself undergoing a process of change which is necessary if it is to act as a "teacher" for the newly-created units. For an all-encompassing view of the changes triggered by the globalization of engineering activities, we need to reason in terms of the global dynamic of the internal R&D professionals' resources spread between the central engineering unit and all the units abroad.

Once the goals of the project to set up an engineering unit have been clarified, the firm has to create and facilitate the local development of the required "professional group dynamics". We now wish to show that the globalization project needs to be thought of in

terms of the creation of "professional group dynamics". For this purpose we will use the *"dynamique de metier"* (what we have called "professional groups dynamic") model proposed by Lefebvre, Roos & Sardas (2002), Roos (2006) and Acquier & Eyherabide (2005).

The "professional group dynamic" model as a framework of analysis

This model is above all a framework of analysis for the functioning of a profession within a firm. We will analyse:

- Knowledge dynamics: how is knowledge produced and distributed? How is it transmitted within the collective? How vital are these knowledge dynamics? (Argyris & Schön, 1978; Nonaka & Takeuchi, 1995)
- The dynamics of roles and their interactions: what are the different roles actually and how are they differentiated? What is the nature of their interactions?
- The dynamics of identities: to what extent is the collective's identity recognized within the organization? How does this collective identity serve to support the construction of individual identities (Sainsaulieu, 1977; Dubar, 1994)? What are the various individual career paths and do these paths form the basis for the construction of identities? Finally, how is the collective dynamic based on the identity dynamics of certain individuals who constitute the "mainstays of the profession".

The professional group dynamic as an object of structuring and management

As the professional group dynamic becomes an object of structuring and management[1], it is possible to act on the redefinition of the system of roles proposed, of possible careers, and of fields of knowledge, and on the modalities of knowledge management (roles dedicated or not, knowledge-management tools, creation and leadership of communities of practice or of expertise in areas of knowledge). These different organizational and management actions aim to generate a new professional group dynamic that meets the challenge of performance and is sustainable for individuals.

In former studies the professional group dynamics model concerned the reorientation of the dynamics of changing design professions. In the present case the aim was initially not to transform these professions (that happened afterwards, as a consequence), but to enable them to produce a new entity (and then others) in other countries. In this sense it implied the creation of new professional group dynamics, so that the new delocalized unit could be set up by the central engineering department. The project to create an engineering unit in Eastern Europe should therefore be seen as an experiment that needed to be managed.

The project to globalize engineering activities, seen as an experiment that brings problems to the fore

Without explicitly considering the globalization project as an experiment, the European car manufacturer made an experimental approach possible, mainly by requesting the collaboration of a team of participant researchers. Two and a half years after the beginning of the project to create an engineering unit in Eastern Europe, the recognition of the experimental nature of the project proved to be relevant: in certain professions the staff turnover was huge (up to two-thirds of the employees in a profession), which called into question the feasibility of the globalization project. The causes for these resignations had to be analysed and understood.

[1] This is an important result of the "rationalization of design and recomposition of designers' professional dynamics" programme supported by the Ministry of Research under the "Work" programme. The profession thus becomes an object of rationalization whereas until recently the project was the main object of rationalization in R&D.

Interpretation of the problems encountered, using the global actor dynamic model

We are now going to examine the causes for such a high staff turnover by analysing a profession in the Eastern European unit: product calculation.

In this analysis we apply the global actor dynamic model (Sardas, 1994) in which an individual's dynamic is conceived of as three interlinking partial dynamics: a cognitive dynamic, a strategic dynamic (Crozier & Friedbert, 1977), and a subjective dynamic (Dejours, 1990; Sardas, 2001). This model is designed to synthetically diagnose the encounter between the individual and the organization from the management science point of view: to what extent can the individual fulfil the role offered by the organization? – whether individual refers to a single person or a generic category of actors. In this sense, the approach is situated on an individual scale but takes into account interactions with other actors, essentially by considering the dynamics of work collectives and professional group collectives (which links it to the professional group dynamic presented above). This diagnosis should serve to explain the causes of the difficulties experienced by designers, or to anticipate them in the framework of an ex ante analysis of the real functioning of an organizational scenario. The global actor dynamic is thus an analytical tool for understanding questions of performance and the implications of occupational health.

ANALYSIS OF EXPERIMENT CONCERNING THE CALCULATORS' PROFESSION IN THE EASTERN EUROPEAN ENGINEERING UNIT, USING THE IDENTITY DYNAMICS MODEL

Our aim is to understand the causes of the very high staff turnover during the first experiment in forming a team of "calculators". For this purpose we will first briefly present the characteristics of the profession.

Characteristics of the calculators' profession in Eastern Europe

After analysing the activity in cooperation with the profession expert of the central engineering department, the calculator's work can be characterized by four levels of competencies. These levels can be linked to the roles and modes of transmission of knowledge, as shown in the following table.

<table>
<tr><th>Competency level</th><th>Place of knowledge transmission</th><th>Mode of knowledge transmission</th><th>Role</th></tr>
<tr><td>Level 1: basic functioning of numeric tools and theoretical background</td><td rowspan="2">Common knowledge, dispensed outside the firm (in universities, schools, etc.)</td><td>Learning in class and through case studies</td><td>Apprentice</td></tr>
<tr><td>Level 2: analysis of a given service (being capable of choosing a model, making it "work", and analysing the results in terms of a service)</td><td rowspan="3">Learning-by-doing and under the supervision of an experienced person within the profession or through interaction between senior peers within the profession</td><td>Junior

Senior</td></tr>
<tr><td>Level 3: calculating the proportions of a car body (being capable of taking into account the different services and constraints of other occupations)</td><td rowspan="2">Knowledge particular to a firm, created and transmitted by the profession</td><td>Project expert</td></tr>
<tr><td>Level 4: Innovating on the models and supporting the project experts where necessary; being in charge of capitalizing on knowledge and of the professional group dynamics through the roles offered to individuals</td><td>Learning through interaction between peers within the profession and through interaction with the technical managers of related occupations</td><td>Profession expert</td></tr>
</table>

Figure2: Level and transmission of competencies in calculation

This synthesis will enable us to analyse the global actor dynamics of the calculators' profession.

Expected results of the attempt to create a professional team of calculators in Eastern Europe

People with professional experience are difficult to find in the Eastern European job market. In our case study a PhD with partial experience in calculation models was trained in specific skills relative to the car body, for an 18-month period in 2004, at the central engineering department. He then had to train new recruits and was himself supervised for a year by a project expert "missionary" from the central engineering department. After this period he trained new recruits alone, with distance support from the central engineering department. The activities entrusted to the Eastern European structure dimensioning team were of the service analysis type (level 2) and had to be controlled from the central engineering department by a project expert.

Analysis of the real functioning of the calculation team in Eastern Europe: the sequence of causes leading to resignations

In this section we present the synthesis of our analyses, based on in-depth interviews with the actors concerned (on site and at the central engineering department), and on our participation in various work sessions or teleconferences between the managers concerned.

- The cognitive dimension: blockage in the learning dynamic

The new recruits were technically unable to do the job. They felt that local management and distance management by the central engineering department were insufficient. The training load had been under-estimated and there were too many new recruits. Some noted the local manager's lack of knowledge, especially on technical aspects relative to analytical activities and on the load that such activities represented. We can see that the cognitive dynamic for a generic actor in calculation was blocked, and that this blockage cannot be dissociated from the strategic dimension.

- The strategic dimension: a deficiency of relations necessary for learning

Strategic relations between the project representative at the central engineering department and the local Eastern European team:

Leadership of the delegated activity in Romania was entrusted to a level-4 engineer from the central engineering department, who had to report on the quality of R&D work with very short notice. Relations between this engineer and the Eastern European team were initially supposed to be a partnership; however, through the strategic play of the different actors, they turned into principal/sub-contractor relations, where results took precedence over learning.

Strategic relations between the representative of the profession at central level and the local Eastern European team:

Support for the local Eastern European teams by managers at central level was complicated due to under-estimation of the need for supervision and to competition (in terms of demand for supervision) between the Eastern European team and the Asian team. The profession expert at central level in charge of distance technical supervision favoured the Asian team as its technical level was higher. This made supervision of that team more attractive than supervision of the Eastern European team, which was consequently neglected.

Strategic relations between the local manager and the local team of calculators:

Technical support by the local manager was inadequate due to a lack of technical competencies but also to a vertical, top-down conception of authority stemming from the principles of the former authoritarian and bureaucratic regime of this Eastern European dictatorship (he had had positions in the former state hierarchy). Without a peer in his own profession, he was unable to learn. Several members of his team therefore gradually became more skilled in the activity than he was, without being able to influence his management choices, especially the management of the workload in terms of quantity and difficulty. This manager found himself in a tricky position where he preferred to avoid refusing activities delegated by the central unit. He felt that doing so would have been an acknowledgement of his own and his team's technical shortcomings.

Strategic relations between the local HR manager and the local calculation team:

The local human resource managers did not recognize the complexity of the activity and failed to differentiate, in terms of salary and role, between calculation and the archiving of technical data (a very simple job). Moreover, this HR actor attributed more value to manufacturing than to R&D (his value criterion was the number of cars produced).

- The subjective dimension: from a deficit of "external recognition" to a deficit of "internal recognition":

The fact that the quality of the calculation team's work in Eastern Europe was deemed to be poor, was naturally a negative reflection on the local calculators who were sometimes considered as incompetent. This negative image was compounded by the lack of recognition by the local HR manager. Faced with the lack of "external recognition" (which appeared in the strategic dimension), the way in which the Eastern European calculators considered themselves was important because it was what motivated their decision to resign rather than fighting for recognition.

To sum up, we can synthesize the causal chain leading to the resignations as follows:

Relational deficiencies resulting from strategic dynamics➔ Blockage of cognitive dynamic ➔ Dwindling of the subjective investment dynamic ➔ resignation or apathy

Lessons learned

On the basis of the above analysis (of the encounter between the role and environment offered by the organization, on the one hand, and the individual's capacities for learning and his/her strategic resources and subjective expectations, on the other) we can carry out an organizational diagnosis of the real functioning of the organization. This diagnosis, concerning the calculators' profession, reveals a key issue to consider as regards the question of the creation of a subsidiary engineering unit. This issue pertains to individuals' conditions of integration and learning.

We established the general relevance of this result by studying two other engineering activities, and showed that there are three conditions on which an individual can learn: 1) an activity that is conducive to learning; 2) a co-located professional collective which provides adequate conditions for technical supervision; and 3) other elements concerning the work collective (presence of other related professions and other functions). The analysis of these conditions enabled us to produce initial knowledge on the firm's globalization of its engineering department and thus to answer the following questions mentioned in the introduction: what type and quantity of human resources should be recruited? How many

expatriates should be sent to the local unit? What should the expatriates' role be? On what criteria should they be selected? What activity should be delegated to the local unit? Finally, how do the answers to these questions evolve over time?

MODELLING AND SIMULATION OF THE DYNAMICS OF THE BIRTH OF AN ENGINEERING UNIT ABROAD

Modelling

Based on our findings, we propose a model of the conditions that need to be met for individuals to be integrated and to learn.

Structuring of the professional groups according to level of competencies

This model segments the type of activity by profession and structures each profession into five levels of competency, based on the complexity of the design (a study of each of these professions showed that this generic segmentation was robust). In the diagram below each circle represents a level of competence.

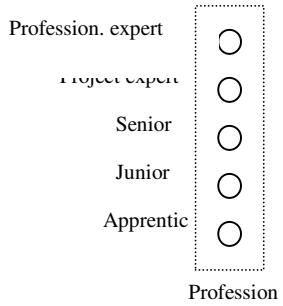


Figure 3: Structuring of a profession according to level of competence

The conditions of an individual's progression: intra- and inter-professional work collective

For each competency level we model the work collective needed for an individual to progress technically, as well as the competencies that he or she would be required to have. For example, as the diagram below shows, a project expert (level 4 in terms of competencies) needs a profession expert (level 5 in terms of competencies) for technical support within his or her own profession, as well as one of the project experts from a related profession (level 4 in terms of competencies) in order to progress technically in his or her own field and do his or her job (here, we have taken a case where only one related profession is necessary).

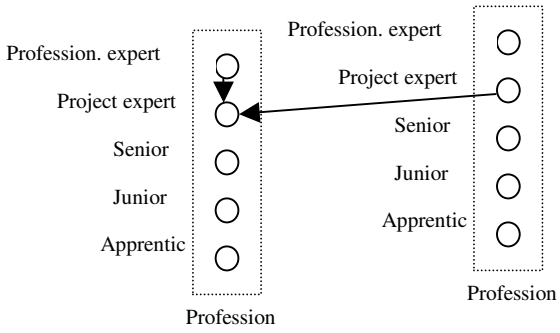


Figure 4: The work collective, conditions on which an individual progresses

The links between the circles represents the presence of other competencies (in terms of level of expertise) that allow for learning to take place. The project expert in calculation had to go through the levels of Apprentice, Junior and finally Senior before attaining the project expert level.

The partial architecture of learning links can then be represented by the diagram below which shows interactions between professions. The numbers on the links indicate the

supervisory capacity required for the profession specialities (vertical; supervision of 1 to "x" individuals from the level beneath) and the needs for inter-professional presence (horizontal). Note that, for the sake of confidentiality, the numbers in this paper are only examples.
As regards the professions, represented vertically, we have given two numbers (a minimum and a maximum) at each competency level, for an individual's supervisory capacity (essential parameter representing the number of individuals of a lower level whose upper level can simultaneously serve as supervisors). This parameter is then modulated in relation to the project load weighing at a particular point in time on an individual with that competency level (rate of activity).

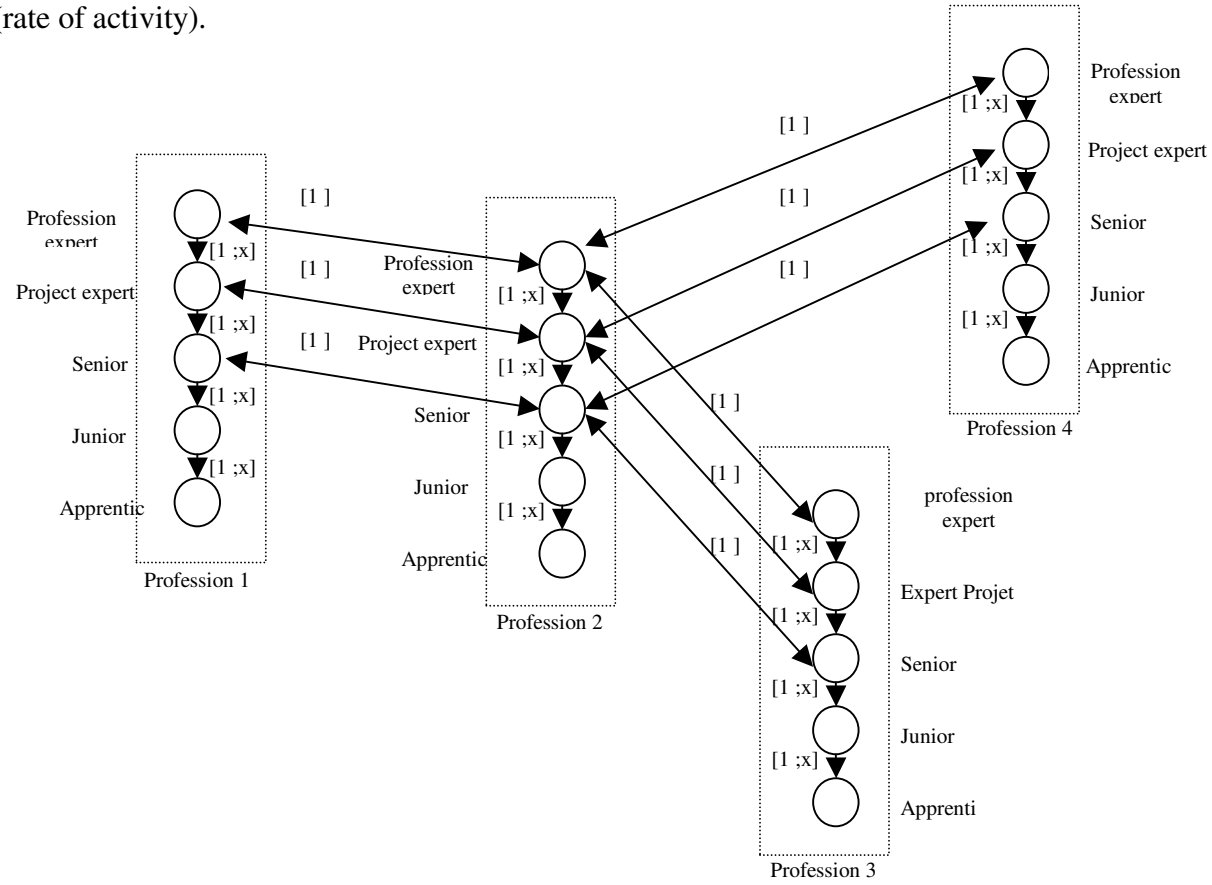


Figure 5: Architecture of the learning links and conditions of learning

The time-scale of individual learning

On the basis of our analysis of careers at the central engineering department we have specified the average time needed for an individual to progress, when all the conditions for integration and learning are met. Our results are consistent with the analyses of Pelz & Andrews (1976). For the sake of confidentiality, we reason here in terms of time units.

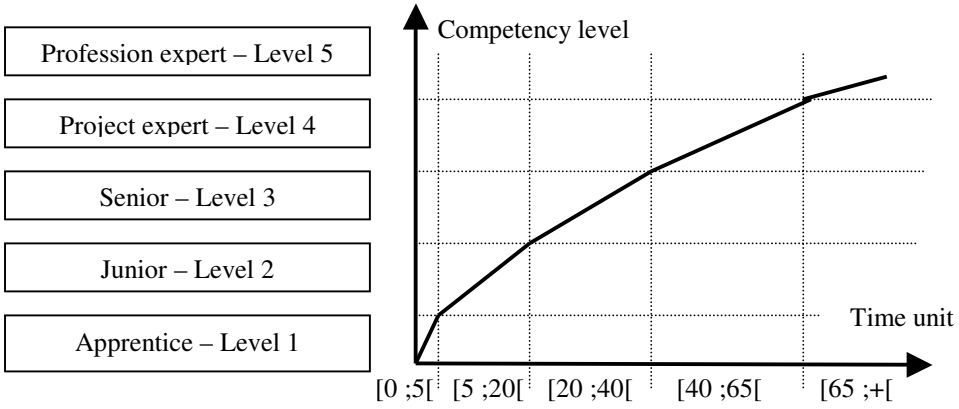


Figure 6: Average time needed for an individual to progress

Simulation of the process of creation of an engineering unit

This modelling enables us to simulate the dynamics of an engineering unit (in the framework of relatively stable design activities). It serves to estimate, in relation to the number of expatriates in each profession speciality, and in relation to the actual learning of resources and the turnover, the number of new recruits that can be integrated over a certain period of time. It also allows us to determine the time required for the engineering unit to be able to perform major activities of increasing complexity.

To characterize an engineering unit's complexity, we distinguish four levels of decreasing complexity: A, B, C and D. When there are only apprentices and juniors the engineering unit can perform only support activities (qualified as level D). When there is at least one senior in each speciality, the engineering unit can perform slight adjustments on existing products (level C). When there is at least one project expert in each of the profession specialities, the support unit can develop a vehicle for which 65% of the design has already been specified – assuming that this specification has been done according to the rules of the art (level B). Finally, when there is a profession expert in each speciality, the unit is able to develop an entire car (level A).

If the model is applied to four professions with some expatriates for each of them, in a country that has no designer with professional experience in the areas concerned, the simulation enables us to estimate the progression represented by the graph below. This simulation indicates the number of time units necessary to master the basic design levels (level C in 20 time units) and the more complex ones (level B in 40 time units and A in 65 time units). It also indicates the sustainable growth in terms of staff numbers (growth relative to the technical supervisory capacities of the local employees and expatriates). For example, it is possible here to have 600 individuals after about 75 time units. The blue peaks on the graph indicate the number and timing of new recruitments.

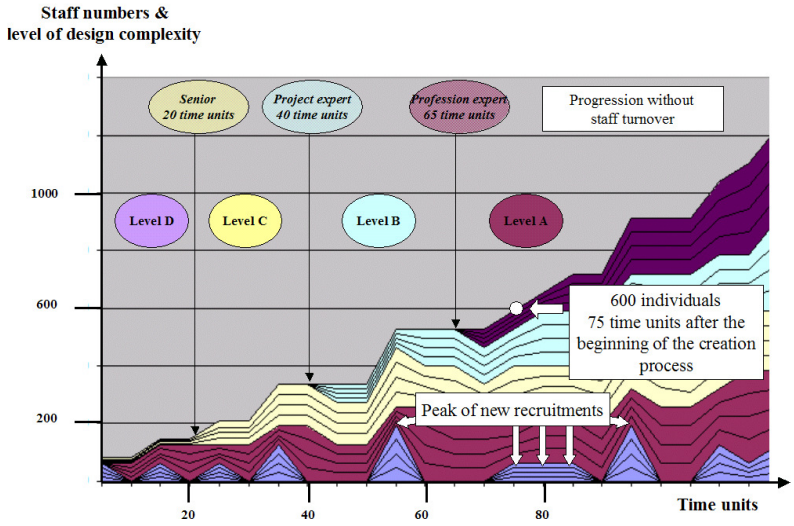


Figure 7: Simulation of the creation process without staff turnover

It is possible to parametrize a level of turnover to estimate its impact on the progression of an engineering unit abroad. The diagram below represents the progression of the same situation as in the one above, but with a staff turnover of 10%. We see that with 75 time units, a staff of only 500 can be attained, against 600 in the situation without turnover, and that it takes 15 additional time units to reach the highest level (level A).

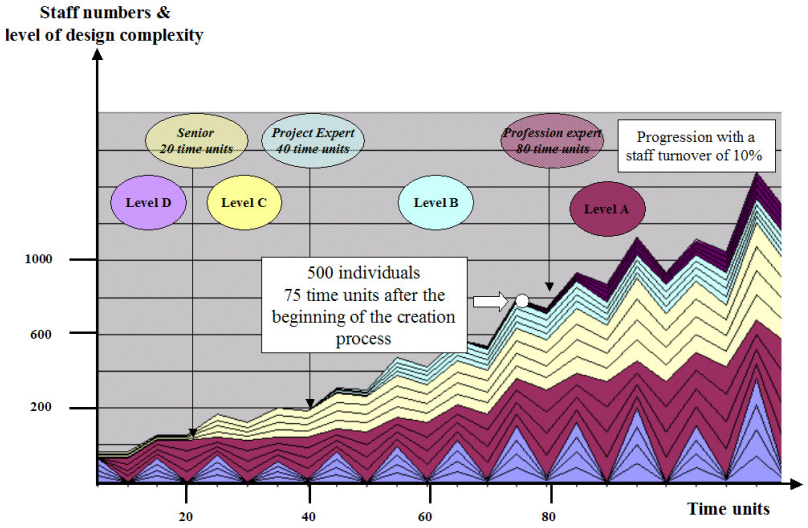


Figure 8: Simulation of the creation process with a staff turnover of 10%

This simulation enables us to revise the principles and process of creation of engineering units abroad, and to propose a new way of characterizing the globalization of engineering activities which is coherent with the characteristics and general particularities outlined in the first part. It enables us to focus not only on the external aspect of the phenomenon but also on the firm's internal considerations.

Proposed principles for the globalization of engineering activities

The modelling and simulation described above enables us to propose new management knowledge concerning the process of globalization of engineering activities. They enable us to discuss the main questions usually posed, such as the choice of location, the number of expatriates, the duration of expatriations, the quantitative progression of resources, the qualitative maturity of engineering units, etc.
It shifts the usual approach to the globalization of engineering activities, from outside the organization to the inside. The analysis in the first part of this paper shows the relationship between staff turnover and the organization in place. On the basis of two performance criteria (the increase of staff and the level of complexity of the engineering activities that can be achieved), our model shows the link between performance and turnover.

The performance of a design collective can be characterized by two variables: the size of the collective, and the complexity of the design work that it is capable of performing.

As regards the size of the design collective, the above simulations show the dual impact of turnover. For example: 60 time units after the beginning of the creation process, without turnover we obtain a design collective of 500 individuals. With a turnover of 10%, 60 time units after the beginning of the creation process we obtain a design collective of about 300 individuals. 10% of the turnover reduces the size of the collective by 40%, 60 time units after the beginning of the creation process.

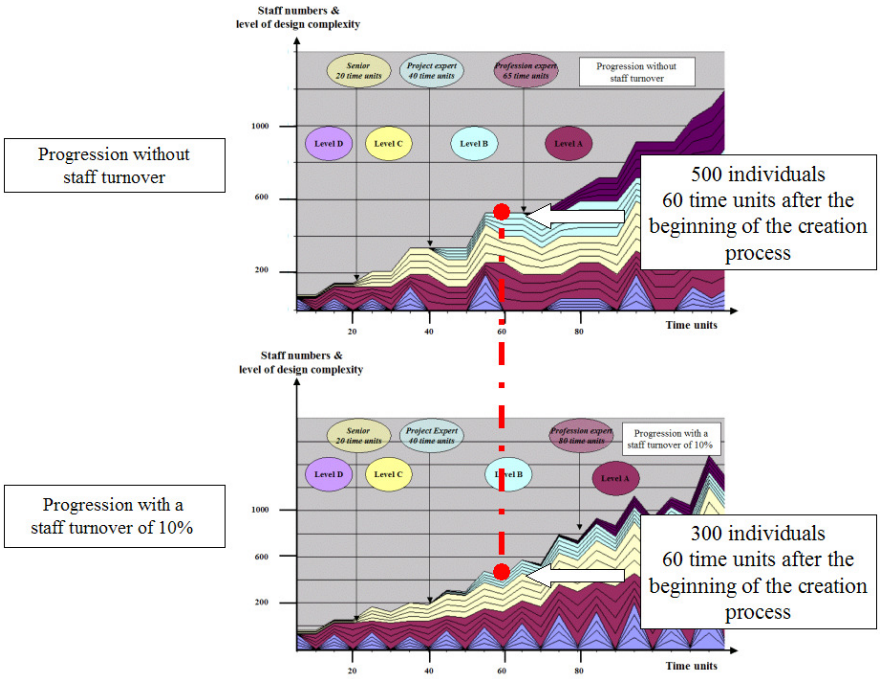


Figure 9: Impact of staff turnover on the creation process

The impact of staff turnover on the design collective is explained in terms of two effects. The direct effect of the turnover reduces the size of the collective by 10% every year, but these resignations should be compensated for by new ad hoc recruitment. This is where we will also have an indirect effect of which the mechanism is as follows: by losing 10% of the staff every year, there is a loss of individuals (direct effect) but also of a capacity for technical supervision. It is therefore not necessarily possible to offset resignations by recruiting new staff (in the model we saturate the capacities for supervision). The more turnover affects resources with a high level of competency, the greater the indirect effect will be because they are the ones who have the training capacity.

In the above example we used different levels of turnover, combined with 60 time units after the beginning of the process. We can also consider the impact of turnover at other stages of the creation process (at 20 or 40 time units, for instance).

To obtain a synthetic representation of the impact of turnover at a specific stage in the creation process, we proceed as follows. The above examples of numbers will serve to explain the construction of the graph below. The size of the collective, 60 time units after the beginning of the creation unit, without turnover, was 500 individuals. This will be our base (500 => 100; see point X). With 10% of turnover the size of the collective 60 time units after the beginning of the process of creating the unit is about 300 (thus 60% of our base of 500, point Y).

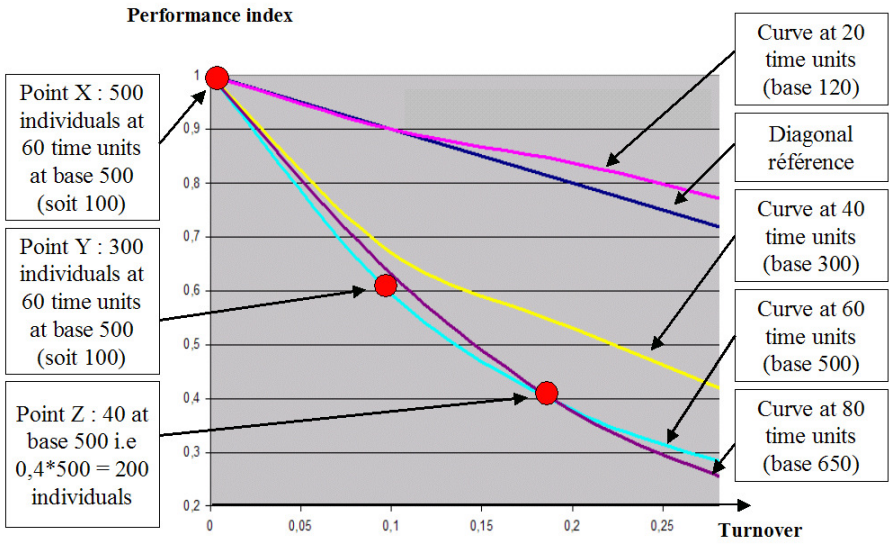


Figure 10: Representation of the impact of staff turnover on the size of the design collective

Had we done the exercise with a 20% turnover, 60 time units after the beginning of the creation process, we would have obtained point Z (40% of our base of 500, which is 0.4* 500 = 200 individuals).
It is thus possible to represent the impact of turnover for each year of the creation process. On the graph we have represented the curves at 20, 40, 60 and 80 time-year units. Each curve is characterized by its own base, shown on the progression graph below, without turnover. The convexity (to be related to the descending diagonal) shows the more than proportional impact of turnover.

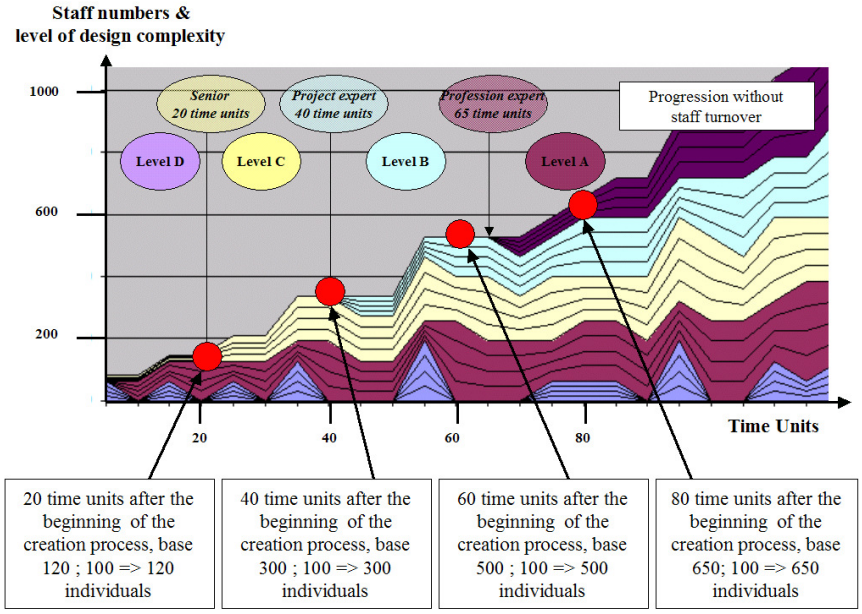


Figure 11: Explication of baseline (without turnover)

As regards the complexity of the design work that can be carried out in the engineering unit abroad, the above simulations enable us to define the four main levels of complexity (D, C, B, A) described above. These levels necessitate a learning period (65 time units to attain level A without turnover – point A0), which increases in line with the turnover (80 time units to reach level A with 10% of turnover – point A10). It is then possible to link

the time needed to attain the main levels of complexity to the rate of turnover. This is represented in the diagram below (the curves represent the boundaries between one level of complexity and the next, and areas between the curves represent the zones in which a certain level of design complexity can be achieved).

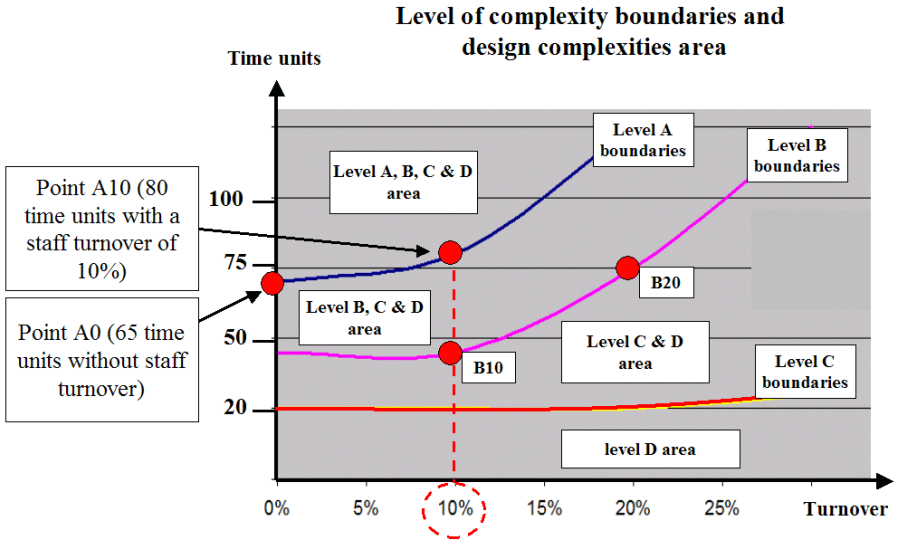


Figure 12: Representation of the impact of turnover on the complexity of the design that can be achieved over time

We see that even if the level of turnover has relatively little impact on the time needed to attain a level C design complexity (the curve is almost horizontal), shifting from 10 to 20% turnover requires a further 35 time units (i.e. 47% or almost double the amount of time) for the engineering unit to be able to attain a level-B design activity (passage from point B10 to point B20). We note that even if the threshold of 10% turnover is exceeded, the impact on the time necessary for complex design increases substantially. It is therefore necessary to try to remain well below this threshold, by means of an appropriate HR policy. If we add the fact highlighted above, that 10% of turnover reduces the size of the design collective from 30% at 40 time units and by 40% at 80 time units, we can recommend that a target be set to maintain the turnover below a threshold of 5%. (In this case a reduction in the size of the collective, of some 20% at 80 time units, must be accepted and would be manageable if anticipated.)

Our model has thus enabled us to further the explanation of the link between performance and organization. We show that the main implication of globalization lies in the possibility of creating professional group dynamics – embodied in our simulation in the increasing level of competency – and that the conditions of this emergence lie in the absence of a blockage of global actor dynamics. These dynamics are embodied in the conditions of co-presence allowing for learning, and whose impact is evaluated in our simulations through the turnover that it seems necessary to maintain at a sufficiently low level (only some percentages, below 5%). Finally, during the creation phase, it is necessary to manage the factors influencing the global actor dynamics, with a view to stimulating professional group dynamics.

WHAT ARE THE CONTINGENCY FACTORS OF THE GLOBALIZATION OF ENGINEERING ACTIVITIES?

These results are not valid for all R&D activities; they are contingent on the nature of the product design activities. We have based our theoretical construction on design activities

in the car industry, and research in the aeronautics industry seems to indicate the same type of condition for integration and learning in product development collectives. It seems that this is not however the case in software engineering, for example. This is explained mainly by the possible segmentation of design activities in that field (i.e. the possibility of breaking down a new product to be designed, into independent modules). In addition, software products are developed with only one type of expertise, unlike manufactured industrial products. The nature of the product therefore has an important effect on the importance of interface knowledge (between designers of different modules and between the different occupations concerned) and therefore on the modalities (complexity and timing) of learning within and between professional groups.

Another contingency variable concerns the relative stability of the knowledge mobilized to develop a type of product. In our case there was no major change of paradigm in the main design principles (likely to undermine the very principles of design – which does not exclude marginal innovations) such as radical or architectural innovations. It is possible that today's worlds of electronic product design are caught in sufficiently important changes of paradigm to invalidate our model in this type of activity.

Finally, it is essentially the complexity of design which is concerned here, and therefore the complexity of the product and of the articulation between the different professional groups involved. We therefore note that our results are valid for complex manufactured products involving several different occupations, where the frameworks of knowledge remain relatively stable notwithstanding innovation.

CONCLUSION

In this paper we first analysed professional group dynamics and the global actor dynamics in an experiment in the globalization of engineering activities. The lessons learned from this experiment enabled us to model and to simulate the process of creation of an engineering unit abroad. This we used to show the quantity and rhythm of recruitment as well as the impact of the staff turnover rate. We then discussed the contingency factors of this type of modelling.

Note that the model presented here is valid only for complex design activities in which several occupations are concerned. Moreover, we only consider the creation of an engineering unit in a country that has no local development resources.

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