UNIVERSITATEA LUCIAN BLAGA DIN SIBIU

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DOCTORAL THESIS
ABSTRACT
KNOWLEDGE CAPITALIZATION IN AUTOMOTIVE RESEARCH & DEVELOPMENT OFFSHORE BRANCHES

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1. INTRODUCTION. OBJECTIVES OF THE Ph.D. THESIS

In a global environment, competition is becoming stronger, companies are looking at every aspect of the process and strive to improve and add more value to the final product. To have an advantage over competitors, a company could promote a dynamic marketing, expanding the client's database, and offering high quality products with low costs of production; at the same time, the companies are looking to increase the profit or at least to maintain it in order that the shareholders are receiving the expected revenues (Pai et al., 2013).

This applies also to the automotive industry, where the companies are striving to offer the best price for the best quality. Especially in the last two decades, according to Paul Woolliscroft, the pressure is rising on the costs of the producers, and companies are looking for innovative solutions (Woolliscroft, 2013).

A solution, which can boost the firms' balance on middle and long term, is internationalization or offshoring. Traditionally, the offshoring strategy included mostly manufacturing activities, but in the recent years this strategy started to include also "administrative and technical services as well as advanced services and R&D-related functions" (Lewin et al. 2009; Castelli and Castellani 2013; Albertoni and Elia 2014; Davide Castellani et al. 2015). This means searching the countries with the lowest costs that matches the company's profile (Krishna et al., 2012).

According to (Fabienne and Eric, 2012), offshoring of production is "*relocation of parts of production to own locations abroad as well as to other suppliers abroad*."

To sustain and achieve an advantage over the competitors, and to adjust the manufacturing prices, many companies, especially from mature markets from Europe, are emerging to markets situated in Eastern Europe (Pai et al., 2013).

Starting from these outcomes, we have identified a series of common problems specific to the offshoring process within the R&D department of the automotive industry:

1) Automotive companies are offshoring, but they must know in what way and which processes should or should not be offshored (Battin et al., 2001; Lamersdorf et al., 2008).
2) After deciding the processes or which orders to be transferred to the new branch, the scope is to obtain the same level of the quality as in the home country.

3) The employees from the offshored country must have the same view over the entire steps of the process (Carmel et al., 2005; Herbsleb et al., 2001; Herbsleb, 2007).

There is needed a framework for the automotive industry to help with the offshoring process, so the best results are obtained, at a lower price. Possibly there are internal and external factors that can be managed better, in a shorter time, and this improvement will come when the process is applied and improved, resulting in the fact that the entire organization can benefit from the ideas from the offshored branches (Sengupta et al., 2006; Beck et al., 2001; Bhat et al.,2006).

4) To obtain an efficient deployment of the integrated quality process, a very detailed analysis needs to be made for the most common standards and processes (Kedia et al., 2007).
5) This framework must be present in the requirements for strategy at the top level and must continue to the details of every project.

Starting from these problems, the objective of this thesis is to develop a framework which can be used in automotive software companies in the process of offshoring, to keep quality of the projects under control, from the first steps, until the project is delivered to the customer. It is imperative that the software product, that is developed or tested in another part of the world than the home country of the company, fulfill the internal standards, the quality standards required by the customer and the standard that was created by the team.

Most of the companies assess their performance in terms of effectiveness, where the focus is to achieve the objectives, mission, and vision. But the biggest advantage for the company is efficiency, a term that refers to the optimal use of the resources needed to achieve its objective (Bartuševičienė and Šakalytė, 2013). The focus in the thesis is to achieve the objectives using the optimum use of resources.

The framework will help the software companies from automotive field to obtain better financial results without affecting the quality and it can be applied to almost any company looking for offshoring, if the basic principles are respected, and with a proper tailoring of the processes and the solutions presented.

A comparison between the quality level of the Headquarters team and the new branch team reveals significant differences, a quick improvement of the results being necessary, confirming the necessity of the framework.

2. TRENDS AND RISKS IN OFFSHORING

When a new R&D (Research and Development) center is opened in a country different from the home country, the new employees must understand, learn, and apply all the processes from the Headquarter. If regular meetings are held and employees are informed about the status of the work, this could bring a higher chance of success (Herbsleb et al., 2005).

Common problems are when the orders from Headquarters do not contain all the details or are not clear about the tasks; in this case, the offshore team will face difficulties in solving the orders.

This problem is quite usual in the projects, from author's experience. The orders are not properly described, and the problems may appear in a later stage when the integration of the software is being made. In the first period of offshoring, the employees, are not discussing the critical issues with the technical supervisors, nor with their colleagues, situation that often drives to wrong implementation and failing to meet customer's expectations. The challenges in this case are about training the employees from the offshore center to deal with various situations and how can this process be improved to make the new branch more independent.

Based on the literature and on personal experience in the field, the problems that are common for many R&D offshore branched from automotive industry, can be summarized as follows:

- the orders, coming from the customer, are not complete and clear, most of the time. The team from offshored branch need help from the Headquarter that communicate with customer, to clarify all unclear issues, and this leads to delays.
- how can the processes be tailored, so the new offshored branch has the same level of knowledge as in the Headquarters;
- how can the employees help increase the team's knowledge and experience based on their current knowledge and experience;

- projects with high level of difficulty are assigned to employees without experience. This can drive to various problems like deadline not respected or low quality of the product;
- when offshoring is started, a process for evaluating the expertise of the employees is not available;
- the new projects start without a proper training, enough knowledge and mentoring.

If the product does not fulfill the client's requirements, there can result new orders that are correcting the missing quality, this having consequences on the extension of the development time for achieving the desired level of quality (Correia et. al., 2019).

"A problem that has a big impact on the project quality and deadline, is concerning the resources assignation, when experts are assigned to orders that require a low level of competencies or when beginners receive high complexity order to solve.

The best-case scenario is when experts are used at their full potential and support their team to improve their knowledge and experience." (Gal and Kifor, 2020).

For making sure that all the employees are using their full potential, bring innovation in the company and are engaged on the orders, the order's complexity on which they are assigned should match their expertise. In teams with experts, beginners, and medium expertise employees, the allocation of the projects should be made according to their level of expertise.

Trainings have a key role in knowledge transfer process. Through trainings, the new formed team will understand the processes, the methods the company use in the projects, and how to solve different problems with maximum efficiency.

It is important that feedback and troubleshooting in the knowledge transfer are done as early as possible, as in a globalized competition, companies must respond fast to the industry and client's requests, comply with new regulations, adjust, and improve the car's performance and remain flexible and easy to adapt to new challenges. In cases of offshoring, there can be risks like loss of control over functions, loss of focus and the business plans not being respected. In literature are mentioned cases when the cultural differences interfered with the process of knowledge transfer and negatively influenced the relationship between the Headquarters and the offshore branch (Kedia et al., 2007).

Ebert underlines that roughly 50% of the offshored projects crash by reason of insufficient communication, trust and open discussions about the problems encountered (Ebert, 2012). Because team members from the offshore branches are not familiar with the companies' projects and tools, the project's results will not be as expected (Liskin, et al., 2012). These

problems can be avoided if the knowledge transfer is observed closely, and the results of these trainings are verified and prove to have an impact on projects.

When receiving an order from the client it is relevant to know if the team can complete that order in the specified time and at required quality. In offshored branches, the orders are in a foreign language for the team, and they need translation and clarification at certain aspects. In offshoring, if the order is not complete, and the most important steps are not specified, probability of completing that order is low (Tervonen et al., 2013).

The requirements of the order can be misinterpreted, or it can exist interface misunderstanding, and these facts can lead to bigger problems when they are discovered (Sengupta et al., 2006).

If the adequate management techniques are applied, the results can be considerably enriched.

For the Ishikawa diagram, a meeting was organized with the team and representatives of the management, where the irrelevant causes were eliminated, and the most important ones were kept for further analysis and solution identification:

1. *Random order's allocation.*
2. *Inefficient communication.*
3. *Orders are incomplete – lack of details.*
4. *Lack of established methods of work.*

There are four solutions recommended to solve the problem low quality and deadlines not respected:

- *Efficient resources assignment.*
- *Create a knowledge transfer plan.*
- *Order check list.*
- *Standardization of the work methods.*

Considering these problems and the causes identified in the new research and development offshoring centers, a framework was created that includes all the solutions proposed in this thesis. These solutions are introduced within the team in stages, so that the transfer of knowledge from the headquarters is easy to follow and implement.

3. FRAMEWORK FOR ORDERS DEPLOYMENT IN OFFSHORE BRANCHES

In Figure 3.1, the frameworks for order deployment in offshore branches is presented, together with the models and algorithms involved:

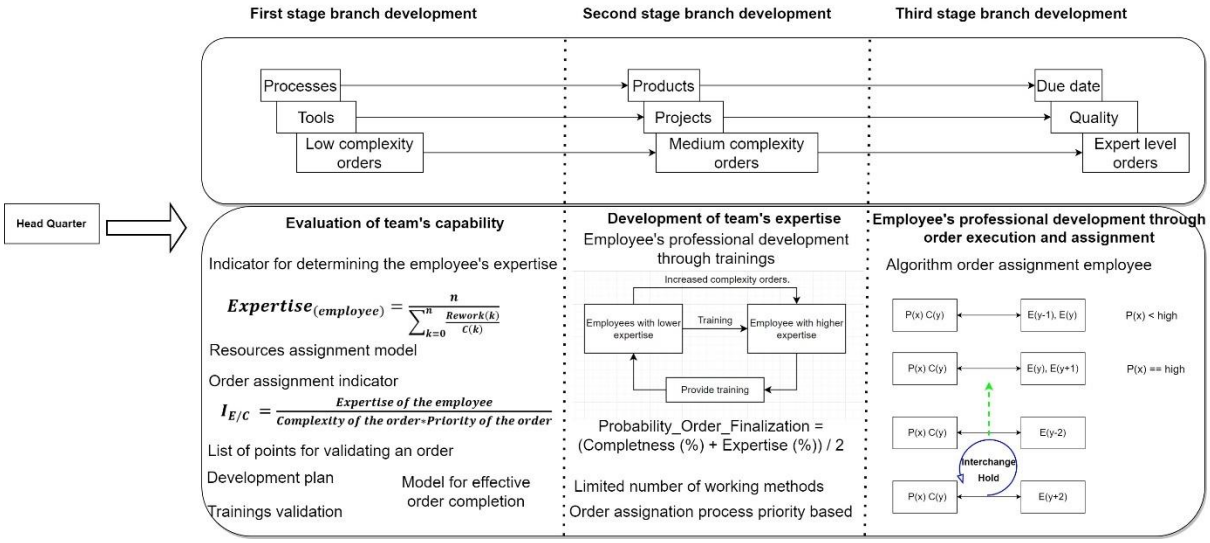

Figure 3.1: Framework for orders deployment in offshore branches.

This framework is composed of all the suggestions for improvement from this thesis, ordered in such a way that they are used at the appropriate development stage. Therefore, the models and the algorithm appear in the chronological order of the stages that were applied in the company. These solutions were created and modeled to help the team in stages defined by the team's expertise.

While the team gains more experience and expertise, the level of responsibility and independence will increase until the team is independent.

The architecture is divided in three stages that are strongly interconnected as revealed in Figure 3.1.

In the first stage, the team’s expertise is assessed so that in the second stage, the knowledge is developed uniformly so that the employees can solve high complexity assessments (stage 3).

The designed architecture supports any automotive development and software testing company in the transition of opening a new branch for Research and Development in offshore.

The increase of expertise will happen in stages, and the final goal will be divided into three stages necessary for a solid employee base.

In Figure 3.2 the stages of development plan are detailed, and it is emphasized the dependency of the second and third stage on the previous one and how the knowhow is gradually increased:

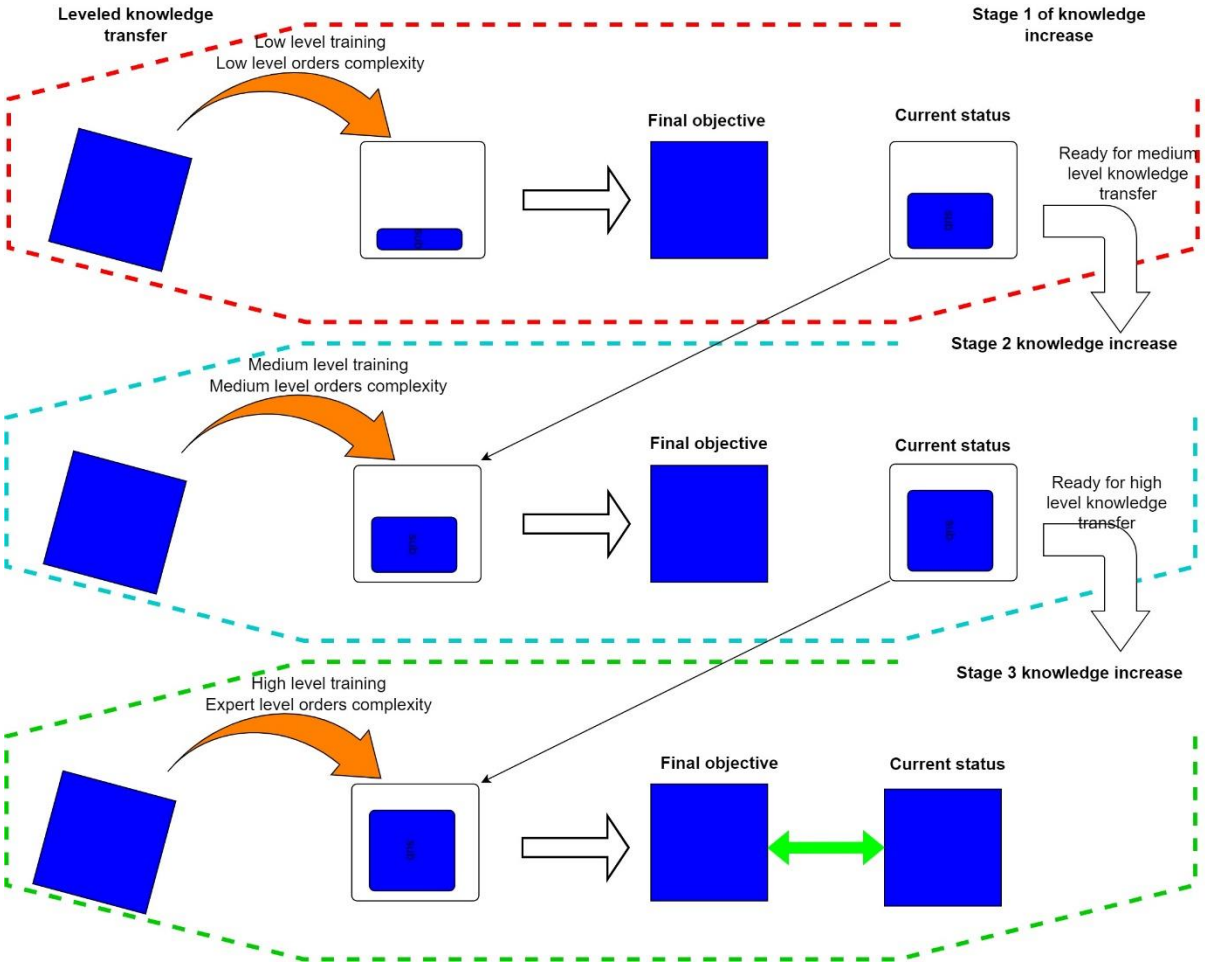

Figure 3.2: Stages of the development plan.

3.1. FRAMEWORK FOR ORDERS DEPLOYMENT APPLIED IN AN OFFSHORE BRANCH

The project used in this case study is a software testing for a premium car manufacturer. This software is related to the dynamic management of the car, such as the ability to properly oversteer or understeer by applying brake pressure to individual wheels and adjusting the engine's power output. In the testing process, the product functionality was analyzed, and compared with the industry standards.

There are 30 employees in the HQ working on the selected project, the numbers of orders processed monthly in 2020, together with the number of complains being presented in Figure 3.3:

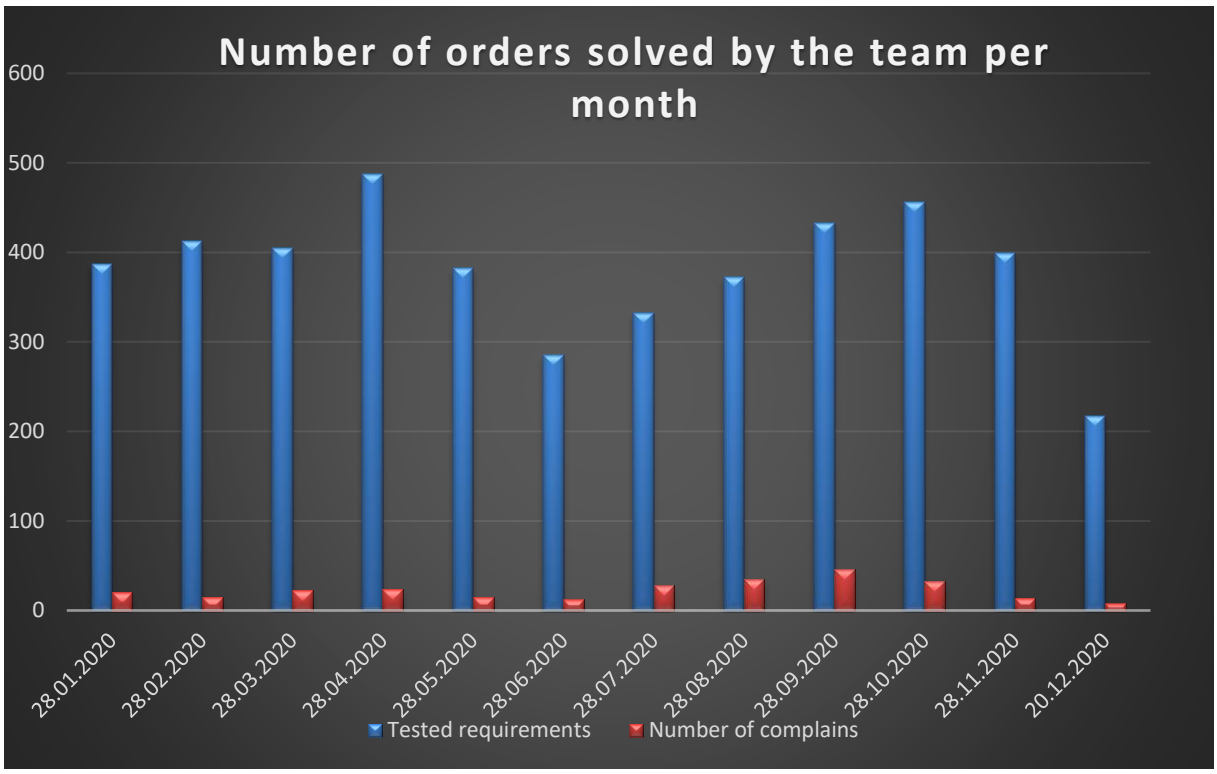

Figure 3.3: Headquarters' performance per month.

A tested requirement means that a customer specification has been verified and the results are available in the report. All electronic controllers have a specific ASIL level allocated depending on the risk and safety integrity factor from ASIL A to ASIL B, C or D. ASIL A represents the lowest of the safety critical identification, whilst the level D represents the

maximum level of safety required (Kosuru and Kavasseri, 2022). In Level D testing, the goal is to test an average of four requirements per day. In Figure 3.3 it can be observed that the number of complaints from the customer is low when compared to the number of tested requirements.

The project is planned to be transferred in the offshore branch that consists of ten engineers with different levels of expertise that will execute the same orders as the HQ team.

After five weeks from the project transfer in the offshore branch, there is still a high number of complains about the tested requirements (Figure 3.4), especially in the first week where for every executed order are two complaints:

Figure 3.4: The team's evolution in all the projects.

To improve the processes and reduce the number of complains, the management took the decision to implement and apply the framework for orders deployment in offshore branches.

Stage one consists of following steps**:**

- *basic processes knowledge transfer;*
- *software tools used in all the projects were presented: short examples of how to use them and short and easy tasks to understand how they are designed;*
- *trainings for all employees according to the level of low complexity orders;*
- *first set of orders - orders with low complexity and low or medium priority.*

Stage one is considered completed when the employees are acquainted with the tools, processes and projects within the company and can perform low complexity orders.

Stage two consists of:

- *more complex trainings for orders with medium complexity;*
- *first set of orders performed - orders with medium complexity and low or medium priority;*
- *after the objective for stage two is fulfilled, the team can be increased.*

Stage three consists of:

- *high complexity trainings, with tools and orders which require high skills and expertise;*
- *first set of orders - high complexity orders with low or medium priority.*

An important thing about this framework is the flexibility to help all employees, regardless of their current expertise, to progress and help the team as much as possible. Thus, we saw examples of how all employees managed to exceed the level from which they started, the number 9 employee having an excellent track record, reaching the level where he can solve even orders that require a high level of expertise. Based on the evolution monitoring, the employee's expertise has increased, and the orders have been assigned based on a close correlation between the employee's expertise and the complexity and priority of the order. The number of reworks has been reduced in a constant bringing a higher customer satisfaction, immediately after the framework was implemented. We believe that the gradual improvement proposed by this system has been an important component for new employees in the knowledge accumulation process. Another significant component of this framework that helped achieve these good results was the matching component between employee expertise and the complexity and deadline of each order. An integral part of the system is the fact that each employee, regardless of the level they had before the implementation of the framework, increased their level. Working time is more efficient by the fact that there will be trainers in the team for different levels, helping to focus on their well-defined side and the level of involvement on their part will be increased.

To produce best results, the system needs to be continuously improved, in line with the evolution of projects and customer requirements. With this framework, the new branch will be

the same as the HQs offices and its independence will increase as employees reach new stages in the development of their expertise.

4. CONCLUSIONS AND CONTRIBUTIONS

The automotive industry is constantly changing and adapting to customer requirements, due to increasing competition, and any solution that can bring an advantage in attracting customers could bring competitive advantages.

The system proposed in this doctoral dissertation is the experimental result of the study and represents the author's own contribution to a case study. This framework can help to optimize the processes within the software department in the automotive industry and beyond. It is built in such a way that it supports modification for any project requirement.

The framework developed in this thesis is focused on increasing the quality of software products, and this is possible by increasing the expertise of the team as a whole and on integrating knowledge into the work process. The outcome of the research is a framework to be used by management and employees, working on product advancement in the research and development centers of automotive industry. All the members of the team have a free way to evolve, and the help coming from the proposed system is to guide them and make it easier for them to fulfill the potential they possess.

The research aims are to provide support for the companies in achieving the success when offshoring, because this stage is becoming an integral part of every big company from automotive software industry. Success means that the offshore team can provide the same results as the team from the Headquarters. The company should start the offshoring with simple projects because in case that the plan is not working properly the main activity is not at risk.

The increase in knowledge and expertise should be made gradually for a better control of the knowledge transfer process. Further on, the orders must be allocated based on their complexity and priority to employees having the necessary expertise to complete the order.

The outcomes presented in this thesis are the result of five years of continuous research and cover theoretical and experimental contributions:

Chapter 1 includes an introduction in the automotive field and the definition of the objectives of the thesis. The aim of this research is to develop a framework that can be used in the automotive industry by software companies in their plans to expand the R&D operations in other countries. Offshoring is presented as a solution adopted by companies to improve quality

and the financial balance. The chapter also presents the evolution of offshoring from the 1990s to the present day.

In chapter 2, THE DEVELOPMENT OF THE COMPANY BEYOND GEOGRAPHICAL BORDERS are analyzed in detail the reasons companies decide to do offshoring. In addition to the advantages presented, we should keep in mind the cases when companies failed in the offshoring process, since some major obstacles were not considered. To prevent a failure, several situations are taken from the literature, where companies were wrong and the most relevant reasons in this regard are analyzed.

Chapter 3, TRENDS AND RISKS IN OFFSHORING, presents the problems encountered in a new branch of R&D, which affects the quality and deadlines. The problems are identified and described here, and solutions are proposed staring from the most relevant causes.

In chapter 4, PROJECT MANAGEMENT IN SOFTWARE DEVELOPMENT the most well-known project management techniques from both the production industry and the software development industry are exposed. These management methods are evaluated (Table 4.1) to see how useful they are for the team at the beginning of the road in a Research and Development offshore branch from automotive industry.

Chapter 5, ALGORITHM AND MODEL FOR KNOWLEDGE CAPITALIZATION IN AUTOMOTIVE R&D OFFSHORE BRANCHES comes with more original contributions to the field, the first mention here being the Development Plan, a plan in which each employee will be engaged to be familiar with the tools and the project before starting to work on official orders. The proposed model for effective order completion helps the team to ensure a high level of quality for the software products and help the employees learn from the previous experiences. The Development Plan includes the steps required from receiving an order to the moment the order is completed. An indicator is also proposed here, $I_{E/C}$, that will help the team manager in assigning orders to employees who have the capacity related to the level of knowledge required by each order. The terms *Hold* and *Interchange* are explained and the most appropriate situations to be used are described.

The algorithm for order assignment (Figure 5.2) is a desired way of assigning orders to employees, so that there are no discrepancies between the expertise of employees and the level of expertise required by the assigned order. There is also a pseudocode presented in the Annex, to support the implementation of the algorithm.

An equation *Probability_Order_Finalization* is introduced in this chapter, helping the manager to evaluate the probability of completing the orders based on the expertise of employees and the level of details required to complete it.

There are presented also in this chapters the advantages of using a single method or a limited number of job opportunities in the first offshoring period, to reduce the level of mistakes and improve the general level of the team's expertise together with a study case.

Further we can observe various ways in which the employees' expertise is not used to the maximum level, this being to the detriment of the employees and the company. To avoid this, it is recommended that the level of expertise of the orders be at least equal to the current level of expertise of the employees, ideally it would be slightly higher to stimulate the team to continuously improve. In Figure 5.12: Resources assignment model for a newly created team, we also see how employees are stimulated to gain knowledge, and how they are able to evolve within the team.

A new model for training evaluation (fig. 5.13) is proposed, as validation of all the trainings offered. Thus, the employees can express anonymously how satisfied they are with that training, and if the results are not satisfactory, the management can change or adapt the way of teaching.

The development path for the team expertise (fig. 5.14) proposes a special approach for trainers, so that time is better valued, and the employees are given the opportunity to develop mentoring skills.

In Chapter 6, FRAMEWORK FOR ORDERS DEPLOYMENT IN OFFSHORE BRANCHES, integrates all the models and algorithms presented before, showing how the solutions should be applied and the appropriate stage for them according to the evolution of the team. Emphasis is placed on increasing the knowledge of the team and on the help provided to each team member according to their needs. The framework is tested, and results presented in Chapter 7, CASE STUDY – APPLICATION OF THE FRAMEWORK FOR ORDER DEPLOYMENT IN AN OFFSHORE BRANCH.

The data of each employee in the new branch was collected and verified to see if the framework has contributed to increasing the level of knowledge of each employee. As can be seen from the tables and images that show the evolution of each employee, the results are encouraging, and the team is making significant progress in the direction previously established.