UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ECONOMIA, ADMINISTRAÇÃO E CONTABILIDADE

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EARLY TERMINATION OF R&D PROJECTS

TERMINAÇÃO PRECOCE DE PROJETOS DE P&D

SÃO PAULO
2015

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Dissertação apresentada à Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, como parte dos requisitos para obtenção do título de Mestre em Administração de Empresas.

Área de concentração: Administração de Operações

Orientador: Prof. Dr. Paulo Tromboni S. Nascimento

Versão Corrigida
(versão original disponível na Faculdade de Economia, Administração e Contabilidade)

São Paulo
2015

FICHA CATALOGRÁFICA
Elaborada pela Seção de Processamento Técnico do SBD/FEA/USP

Gonçalves, Leandro Rodrigues
Early termination of R&D projects / Leandro Rodrigues Gonçalves -- São Paulo, 2015.
100 p.

Dissertação (Mestrado) – Universidade de São Paulo, 2015.
Orientador: Paulo Tromboni de Souza Nascimento.

1. Inovações tecnológicas 2. Administração de projetos 3. Portfólios - Administração I. Universidade de São Paulo. Faculdade de Economia, Administração e Contabilidade. II. Título.

CDD – 658.514

Aos meus padrinhos Maria Acenete Gonçalves e Luis Antônio Rodrigues

AGRADECIMENTOS

Ao Dr. Abraham Yu, que me mostrou o caminho da pós graduação em Administração de Empresas, muito me ensinou em nosso convívio diário nos tempos de IPT, e me inspirou a iniciar a jornada que tem seu primeiro fruto neste trabalho.

Ao Dr. Paulo Tromboni Nascimento, pela orientação e apoio durante todo o período do programa de mestrado, por acreditar no resultado do trabalho e por contribuir com meu crescimento como cientista.

Aos amigos Virgínia e Américo Tristão, pelo apoio e incentivo desde 2007, quando nossas Trilhas se cruzaram, até hoje, quando seguem como principais incentivadores da minha carreira acadêmica.

À amiga Edna Gubitoso, pelo apoio metodológico e revisão de todos os trabalhos produzidos desde 2011, sem o qual a realização do presente trabalho teria sido muito mais difícil.

À minha família, pela compreensão e apoio durante todo o período do mestrado.

À minha companheira, Carol Amaral, pelo carinho e amor diários, pela paciência e pelo estímulo dado ao meu crescimento pessoal, acadêmico e profissional.

E à Oxiteno, na figura dos meus gestores Nádia Armelin, André Conde e Alessandro Nogueira, que me permitiu conciliar o trabalho acadêmico com as minhas funções na empresa, sempre me apoiando no que foi necessário.

"... I thank my fortune for it,
My ventures are not in one bottom trusted,
Nor to one place; nor is my whole estate
Upon the fortune of this present year..."

William Shakespeare, The Merchant of Venice, Scene 1

RESUMO

Gonçalves, L.R. (2015). TERMINAÇÃO PRECOCE DE PROJETOS DE P&D. Dissertação de Mestrado, Faculdade de Administração, Economia e Contabilidade da Universidade de São Paulo, São Paulo.

Terminação precoce de projetos é uma das decisões mais difíceis a serem tomadas pelos gerentes de pesquisa e desenvolvimento. Enquanto há o risco de terminar bons projetos, há também o risco oposto de não encerrar maus projetos e ter recursos alocados em pesquisa improdutiva. Os critérios utilizados para a identificação destes projetos são objeto comum de investigação em Administração de Empresas. Além disso, as empresas podem tirar lições importantes com seus projetos interrompidos que poderiam melhorar o desempenho técnico e comercial da sua carteira. Finalmente, o conjunto de critérios e respectivos pesos, bem como os procedimentos usados pelas empresas para reter aprendizado a partir da interrupção de projetos, podem variar dependendo do tipo de projeto. Esta pesquisa pretende contribuir para a compreensão das políticas aplicadas a projetos que já foram considerados atraentes, mas por alguma razão não são mais apreciados. A pesquisa abordou a questão: Como as empresas lidam com projetos que se tornam pouco atraentes? Mais especificamente, esta pesquisa procurou responder às seguintes questões: (1) São os projetos encerrados ou (caso contrário) eles morrem naturalmente por falta de recursos? (2) Que critérios são usados para encerrar projetos durante o desenvolvimento? (3) Como as empresas aprendem com os projetos terminados de modo a melhorar o desempenho geral da carteira? (4) Os critérios e procedimentos de aprendizagem são diferentes para diferentes tipos de projetos? A fim de responder a essas perguntas, foi realizado um estudo de caso múltiplo com quatro empresas que são referência em administração de empresas e inovação: (1) Oxiteno, considerado o caso base, (2) Natura, a replicação literal, (3) Mahle e (4) AES, as replicações teóricas. Os estudos de caso foram realizados utilizando um protocolo semiestruturado para as entrevistas, que foram gravadas e analisadas para comparação. Descobrimos que os critérios usados pelas empresas para identificação dos projetos candidatos ao cancelamento são muito semelhantes àqueles antecipados pela literatura, com exceção de um critério relacionado com a existência de indícios de corrupção. A pesquisa gerou evidências que corroboram a ideia de que o conjunto de critérios não é alterado quando se lida com diferentes tipos de projeto, no entanto, varia o peso atribuído a cada um na sua aplicação. Também descobrimos que a aprendizagem com projetos cancelados é ainda muito incipiente. As empresas descreveram muito poucos procedimentos formais estruturados para a captura de aprendizagem com projetos terminados precocemente. No entanto, pode-se observar que estes procedimentos são mais comuns quando se trata de projetos rotulados como inovadores, arriscados, grandes e caros. Os projetos derivados, menores e mais baratos, não são objeto de uma investigação completa sobre o aprendizado que eles trouxeram para a empresa. Para estes, a rota de aprendizagem mais comum é a informal, onde a equipe do projeto aprende e passa o conhecimento à frente por meio de intercâmbio de informações entre as pessoas. Nós explicamos este achado como uma questão de custo versus benefício de pessoal de P&D para investigar profundamente projetos com pouco potencial de trazer conhecimentos valiosos para a organização.

Palavras-chave: Gestão de Portfólio de Projetos. Terminação de projetos. Aprendizagem organizacional. Pesquisa e desenvolvimento.

ABSTRACT

Gonçalves, L.R. (2015). *EARLY TERMINATION OF R&D PROJECTS*. Dissertação de Mestrado, Faculdade de Administração, Economia e Contabilidade, Universidade de São Paulo, São Paulo.

Early project termination is one of the most difficult decisions to be made by Research and Development managers. While there is the risk of terminating good projects, there is also the opposite risk of not terminating bad projects and overspend resources in unproductive research. Criteria used for identifying these projects are common subject of research in Business Administration. In addition, companies might take important lessons from its interrupted projects that could improve their overall portfolio technical and commercial success. Finally, the set and weight of criteria, as well as the procedures companies use for achieve learning from cancelled projects may vary depending on the project type. This research intends to contribute to the understanding of policies applied to projects that were once considered attractive, but by some reason is not appreciated anymore. The research addressed the question: How companies deal with projects that become unattractive? More specifically, this research tried to answer the following questions: (1) Are projects killed or (otherwise) they die naturally by lack of resources? (2) What criteria are used to terminate projects during development? (3) How companies learn from the terminated projects to improve the overall portfolio performance? (4) Are the criteria and learning procedures different for different types of projects? In order to answer these questions, we performed a multiple case study with four companies that are reference in business administration and innovation: (1) Oxiteno, considered the base case, (2) Natura, the literal replication, (3) Mahle and (4) AES, the theoretical replications. The case studies were performed using a semi-structured protocol for interviews, which were recorded and analyzed for comparison. We found that the criteria companies use for selecting projects for termination are very similar to those anticipated by the literature, except for a criteria related to compliance. We have evidences to confirm that the set of criteria is not altered when dealing with different project types, however the weight they are applied indeed varies. We also found that learning with cancelled projects is yet very incipient, with very few structured formal procedures being described for capturing learning with early-terminated projects. However, we could observe that these procedures are more common when dealing with projects labeled as innovative, risky, big and costly, while those smaller and cheaper derivative projects aren't subject of a complete investigation on the learning they brought to the company. For these, the most common learning route is the informal, where the project team learns and passes the knowledge though interpersonal information exchange. We explain that as a matter of cost versus benefit of spending time to deeply investigate projects with little potential to bring new knowledge to the project team and the organization.

Keywords: Project Portfolio Management. Project termination. Organizational learning. Research and development.

CONTENTS

1 INTRODUCTION

This research's main theme is R&D Project Portfolio Management. The subject was chosen for being one theme of scientific relevance in Business Administration research. Besides it is part of the author's interest and professional experience.

The research begins presenting some facts about Project Portfolio Management and its main challenges, paying special attention to project termination, trying to understand the mechanisms, criteria, reasons and managerial consequences of projects early termination.

The author then discuss parallel themes that are relevant to better understand early termination of projects, such as dependences among projects in the portfolio, decision analysis, error typology, organizational learning and competence acquisition.

The document starts presenting the problem, research questions, objectives and methodology used. Then, it discusses the classical and most recent literature on the themes. The results are then presented and discussed. Finally, the conclusions, findings, new research questions and limitations are presented.

1.1 Motivation

Some facts and knowledge lead the motivation to study the present research theme. First of all, the Learning curve in New Product Development is accepted as a fundamental competence for competition (Clark & Wheelwright, 1992). This view teaches that a quick "probe-and-learn" cycle provides the ability to achieve innovation and outstand competition.

Project Portfolio Management (PPM) is also accepted as a way of keeping a highly valuable set of projects by means of project evaluation, selection, prioritization and termination (Cooper, Edgett, & Kleinschmidt, 2001a).

Project selection is the main theme studied by academics in PPM (Nascimento, 2013), however many authors have discussed factors for project termination as well following Balachandra & Raelin (1984).

Project Termination may be a source of competitive advantage. When companies correctly take the decision to terminate projects, resources are made available to be invested in other projects, avoiding waste of time and money, and improving productivity of the resources invested in R&D (Balachandra, 1996). The earlier a company decides to terminate an undesirable project, the lesser resources will be wasted.

Projects may be killed for a series of reasons we will discuss further on this thesis. However, it seems wise to recycle not only the resources (researchers, material, equipment and money) freed by the project, but also the knowledge and capabilities it brought the company during its development (Bowen, Clark, Holloway, & Wheelwright, 1994).

The authors of the present project have already studied the theme. Gonçalves, Mello & Nascimento (2014) examined factors relevant for project termination in different types of project (from derivatives to highly innovative). This study indicated that there might be a relevant difference when dealing with different types of project on PPM.

Gonçalves, Camargo Junior & Nascimento (2014) also studied the impact of learning with terminated projects in the overall success of portfolio. The research suggested that informal individual learning usually surpass organizational learning when terminating projects.

These papers, although using a single case study methodology, gave birth to a series of new questions that may be better understood with a broader research. Terminating a highly innovative project is indeed different from terminating a derivative project. Is this pattern observable in other companies in different industries and positions in the value chain? Individual learning have shown itself as the main driver for the impact of terminated projects over the overall success of the portfolio. Is this pattern observable in companies of different sizes and origins? Will we find different results if we take each project type separately? Why not studying both aspects of project termination in a single research, trying to link different types of project termination and the learning they can provide to the company?

This is the main motivation for this study: to provide a general view of the processes related to project termination, from the criteria used by companies to terminate projects to the learning this termination may provide to the company in order to improve the overall success of the portfolio.

1.2 Research Question

This research intends to address the fundamental question: *"How companies deal with projects that become unattractive?"* More specifically, the research intends to answer the following questions:

- *Are projects killed or (otherwise) they die naturally by lack of resources?*
- *What criteria are used to terminate projects during development?*

- *How companies learn from terminated projects to improve the overall portfolio performance?*
- *Are the criteria and learning procedures different for different types of projects?*

Study propositions

In this section, we present at least one proposition for each research question, in order to guide the data analysis after the field study, as advised by Yin (2009).

We expect to observe projects that die by lack of resources, as they become less and less prioritized. Thus, we expect to find "deprioritization criteria" instead of "termination criteria". We however also expect to observe a more rigorous project termination process in some companies – in those, we expect to find active project termination as a general rule.

We expect that the criteria, either for deprioritization or termination, will be those anticipated by the literature, either for process intensive companies or for product intensive companies.

We also expect a difference on the use of these criteria when comparing companies in different positions on their value chain. B2B companies are expected to strongly link the continuation of their projects to the existence of one or more potential customers that can guarantee a minimum volume bought of the resulting product. B2C companies, on the other hand, are expected to give less importance to this criterion.

Third, we expect to find generic learning mechanisms, not specific for R&D projects. We expect to observe a higher incidence of individual learning over organizational learning.

We also expect to find a grading in the strength of the criteria applied to different types of project: most innovative projects should get more tolerance when the criteria are observed by the managers, while derivative projects should be terminated with very low emotional stress.

Finally, we expect to find different patterns in learning when companies terminate different types of projects. When terminating low risk and low budget projects, we expect that the company should not worry about learning lessons from the experience.

1.3 Objectives

The present research has the following objectives:

- To select companies that are reference in innovation management;

- To map the companies' processes of R&D management;
- To identify factors, criteria and motives that lead projects to early termination;
- To identify processes of learning with terminated projects;
- To identify types of lessons learnt with terminated projects.

2 LITERATURE REVIEW

This section will analyze and review the most relevant literature for the proposed themes. It begins with a definition of the main object, early termination, and then puts it in perspective as a project portfolio management decision. The literature on criteria for project termination is reviewed and the differences on terminating distinctive types of projects are discussed. Finally, the learning that may outcome from terminating projects is analyzed, with the most relevant literature from organizational learning.

2.1 Defining early termination

A project may be terminated in any phase of its development, but we are interested in a specific period in which the project has already begun to spend a great amount of resources. The literature provides a reasonable number of cases of premature projects termination.

Havila et al. (2013, p. 92) defined premature termination as follows:

> Premature project closure refers here to endings that fall clearly short of the set time (and consequently, short of the set project targets) and that therefore cause considerable changes to project management, as well as a need for reorganization that affects both internal and/or external stakeholders of the project.

The author studied two cases of early-terminated projects, but his focus was other than R&D. Havila and his colleagues (2013) studied projects that entered the Sales phase, but never achieved the goal set at the Idea phase.

Balachandra (1996), whom studied specifically R&D projects, built a framework where we can identify the generic project phases and companies commitment at each one:

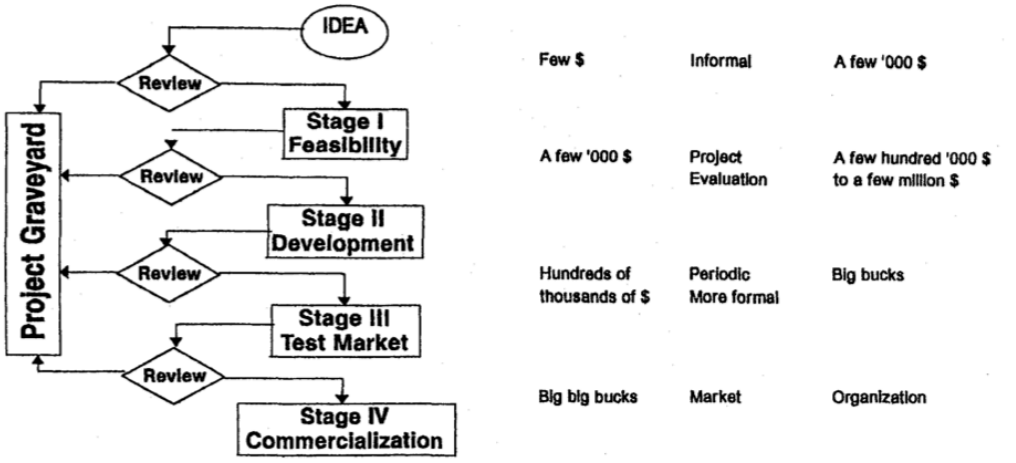

Fig. 1 – Stages in the life of a R&D Project
Source: Balachandra (1996, p. 89)

To enter the portfolio, every project is considered to be perfectly viable – or else it would not be selected as an idea at first. Factors for selecting projects were comprehensively studied (Cooper, Edgett, & Kleinschmidt, 2001a; Ghapanchi, Tavana, Khakbaz, & Low, 2012; Henriksen & Traynor, 1999; Lee & Om, 1996; Loch & Kavadias, 2002; Nascimento, 2013; Verbano & Nosella, 2010). As Balachandra (1996) points out, with passing time, some projects reveal themselves as more viable than others. Environmental factors may influence this shift on the project's attractivity (Carbonell-Foulquié, Munuera-Alemán, & Rodríguez-Escudero, 2004; Hsu & Hsueh, 2009; Mahagaonkar, 2008). Havila et al. (2013) agrees with this idea. At this stage, resources have been consumed and much more will be if an undesirable project is not killed.

A project may be undesirable for a series of reasons. Some projects become more attractive than others, and yet others experience technical difficulties that lead them to a bad relation between cost and benefits (Balachandra & Friar, 1997; Balachandra, 1984). Unsuccessful projects are among the undesirable, but we cannot mistake the two concepts, for the unsuccessful projects the decision is much easier: the manager already knows the project has failed.

According to Balachandra (1996), the R&D projects termination decision is relevant in the Development stage - Stage II in fig. 1. The earlier the decision is made, the fewer resources it will expend before complete failure. We can, then, call "early termination" the decision to kill projects during the Development stage, after Selection (the Feasibility stage) and before Launch (the Test Market stage).

After Launch, the project can still be killed, but the decision will be understood as a product termination instead of project. However, scholars that study this kind of decision also indicate that the earlier the managers get the information, the easier is to kill the product (Simester & Zhang, 2010).

We define "early termination" as the decision to terminate projects that have been approved in the Idea stage for the pipeline, but have not yet reached market. In other words, early termination refers to the decision to terminate projects during development phase, after an amount of resources have been spent, but before giving birth to an actual product.

Terminating prematurely a project may cause negative effects on stakeholders and team members (Shepherd, Patzelt, Williams, & Warnecke, 2014; Ucbasaran, Shepherd, Lockett, & Lyon, 2012; Warnecke, 2013), making this one of the most critical decision in the routine of a R&D manager.

2.2 Project Termination as a Project Portfolio Management decision

Project Portfolio Management (PPM) can be understood as a series of decisions that are taken in order to increase the overall value of the portfolio (Cooper et al., 2001a). According to Hormozi et al., (2000, p. 45), "the success of future projects may depend on not only the success of past ones, but also on how unsuccessful projects were treated by the organization and its stakeholders".

As a well-studied theme, we can find a classical definition of PPM in the work of Cooper et al., (2001, p. 361):

> Portfolio management is a dynamic process, whereby a business's list of active new product (and R&D) projects is constantly up-dated and revised. In the process new projects are evaluated, selected and prioritized, existing projects may be accelerated, killed or de-prioritized; and resources are allocated and re-allocated to the active projects.

As we can see, killing projects is part of the core nucleus of the PPM concept. Cooper & Edgett (2012) in a recent paper have shown that most of the top performers in portfolio management have clear criteria for terminating projects. The authors also say that the attribute is not widespread.

Project termination is one of the most difficult decisions in a company (Balachandra & Raelin, 1984; Balachandra, 1984, 1996; Cooper & Edgett, 2012; Cooper, 2009a; Sarangee, Schmidt, & Wallman, 2013; Simester & Zhang, 2010). The difficulty of the decision is its

non-routine characteristics. Routine decisions can rely on a great amount of data in a well-known environment, making the forecasting more precise. For non-routine decisions, there may be a lack of data and previous experiences. They are thus more difficult to forecast. Therefore, greater is the incidence of Type I (false positive) and type II (false negative) errors (Dong & Chen, 2011). However, depending on the degree of newness, the termination process may be easier and be more similar to a routine decision. (Gonçalves, Mello & Nascimento, 2014).

Emotions also play a vital role on this subject. Early termination is surrounded by a very peculiar phenomenon called the "anticipation of regret" (Sarangee et al., 2013). Actual regret is backward looking, while the anticipated regret is forward-looking. This means that the regret is present even without knowing the decision outcomes. This anticipated regret might cause errors and biases in decision-making.

2.3 Criteria for terminating projects

During the life cycle of a project there is a series of important decisions to be made in different points of the timeline. The literature is clear when defining these decision points (Cooper, Edgett, & Kleinschmidt, 2001a; Cooper & Edgett, 2012; Cooper, 1983, 2009a; Nascimento, 2013). The key decisions are made on Idea and Project review phases. During these phases, projects are selected, terminated, prioritized, deprioritized, merged or divided, in order to improve the overall portfolio value.

Many authors have studied project termination and have already built a very comprehensive framework on criteria for killing projects. This have been a very studied subject, due to the fact that having the wrong projects on the portfolio (either by poor selection or poor termination) results in poor portfolio performance (Cooper et al., 2001a). Balachandra & Raelin (1984) first discussed the idea and came up with 12 factors to which the manager should pay attention in order to identify R&D projects that could be killed. The 12 factors from Balachandra & Raelin (1984) are:

1. Lack of top management support;
2. High rate of new product introduction;
3. Low probability of technical support;
4. No clarity on the technological route to be followed;
5. The project leader is not a project champion;
6. Lack of association between marketing and technical aspects;

7. Lack of focus on the product design (designing for a myriad of end uses);
8. Low effectiveness of the project manager;
9. Lack of commitment of project workers;
10. Life cycle of the product being developed is not on growth phase;
11. Low internal competition for resources (competition acts as a catalyst for successful project completion);
12. Frequent revision of the cost schedule.

Balachandra (1996) then deepened his own discussion by studying practices in four different industrial countries, where he could identify 16 "cross-countries" criteria, towards a "universal criteria" theory. Belassi & Tukel (1996) developed a framework to identify critical success and failure factors and organize them in groups. This work did not, though, take into account different project types or phases. The 16 criteria are listed below. Note that most of the factors from Balachandra (1996) had already appeared in Balachandra & Raelin (1984).

1. Probability of success via the selected technological route;
2. Deviations in time schedules;
3. Deviations in cost schedules;
4. Time of anticipated competition;
5. Chance event;
6. Smoothness of technological route;
7. Pressure on project leader;
8. Presence of a project champion;
9. Change in probability of commercial success;
10. Change in number of end uses;
11. Change in support of top management;
12. Change in support of R&D management;
13. Change in commitment of project leader;
14. Change in availability of experts;
15. Stage of lifecycle;
16. Adaptability of project leader.

Carbonell-Foulquié et al. (2004) then took the criteria available in the literature and organized them into the project phases, following the Stage-Gate® model (Cooper, 1983, 1996, 2009b) to illustrate. They shown that as the project is developed, different criteria,

factors and decision makers become relevant when deciding whether to continue the project or not. They have achieved the following results for each phase of development.

See Table 1 for Carbonell-Fouquié et al. (2004) results.

Table 1 – Criteria and importance for go/no go criteria

Usage and relative importance of go/no-go criteria at the gates

	Approval of							
	New product concept		New product design		Production start-up		Keeping product on the market	
	Usage[a]	Weight[b]	Usage	Weight	Usage	Weight	Usage	Weight
Project total cost for a given cycle time	**72**	**12**	**70**	**11**	47	**9**	36	5
Availability of resources	65	6	**65**	**9**	**59**	**9**	23	3
Alignment with firm's strategy	**70**	**9**	51	5	40	6	26	3
Window of opportunity	**67**	**9**	49	6	36	4	30	4
Leverage of firm's technical resources	63	5	55	7	50	5	21	1
Leverage of firm's marketing resources	40	2	26	1	28	2	29	2
Product patentability	43	3	37	3	20	1	15	1
Product quality	**74**	**9**	**66**	**10**	**71**	**12**	**70**	**11**
Market acceptance	61	7	55	7	51	7	**71**	**14**
Customer satisfaction	61	**9**	**59**	**13**	**55**	**10**	**71**	**16**
Internal rate of return	42	4	36	5	40	6	34	6
Payback time	41	4	29	3	30	3	19	2
Margin rate	45	4	43	4	37	4	51	6
Sales volume	**72**	7	55	5	**62**	**9**	**71**	**10**
Market share	50	4	41	4	43	5	59	8
Long-term sales growth	63	8	47	5	42	5	52	8
		100[c]		100		100		100

[a] Percentage of firms that employ each criterion. The most frequently employed criteria at each gate are presented in bold.
[b] Relative importance or weight of each criterion. The most important criteria at each gate are presented in bold.
[c] For each review point, respondent were asked to distribute 100 points among the chosen criteria.

Source: Carbonell-Foulquié et al. (2004, pp. 311)

Cooper & Edgett (2012) study evidences some practices that the best performer companies have when it comes to PPM. According to the research, in top performers the gatekeepers play a vital role on go/kill decisions. The best companies also have clear criteria for the gates. These companies also may have different gatekeepers for each stage or each project type. A project with a lower degree of novelty may run into an abbreviated Stage-Gate®, while a highly innovative project goes through a bigger funnel, with senior managers keeping the gates and performing the go/no go analysis.

Most of the literature, though, studied the matter without making distinction between different types of projects.

2.4 Terminating different types of R&D projects

Managing different types of projects is at the heart of portfolio management. Sharpe & Keelin (1998) reported the experience of a company that reorganized its portfolio by creating

a process where the projects are reviewed and modified before approval, removing the previous “all-or-nothing” culture. Following the same idea, Spradlin & Kutoloski (1999) prescribes a decision table applied to PPM in order to help focus efforts in the choices that actually have alternatives, eliminating from the table doomed and favorite projects, focusing those that they call “equivocal”, and then comparing combinations of projects in order to select the best portfolio.

Wheelwright & Clark (1992) defined types of R&D projects, according to its novelty level. They suggest that these projects should be managed differently, as their roles in the portfolio are distinct. While a derivative project takes advantage of an existing platform to further exploit known markets, breakthrough projects will target the acquisition of new capabilities, development of new platforms and exploration of new markets. As Wheelwright & Clark (1992) suggested, their taxonomy may not be the best categorization for a given company. Indeed, Mello & Marx (2013) shows that the discussion is still active and far from an end.

Prioritization of projects on a portfolio was described by Brenner & Merrill (1994), and its relation to project termination was cited by Cooper, Edgett & Kleinschmidt (2001a). The authors also present the processes applied by the companies with best performance in PPM. Among these processes is portfolio balancing by defining buckets of resources, scorecards and financial methods. More recently, Nascimento (2014) summarized the main findings on PPM from the past years, organizing them in a logical and didactic way.

Recent research shows empirically that there are different approaches for different types of project. Salerno et. al. (2014) identified eight different processes for managing projects, many of them found on the same company. Their taxonomy can be divided in three categories: (1) the traditional process, which they call “from idea to launch”; (2) the processes that anticipate sales, either developing tailor-made, from specification or by a governmental call; and (3) processes with a stoppage in the middle, either for actively building market or for actively develop the needed technology in order to get market success.

Gonçalves, Mello & Nascimento (2014) made an exploratory study to find evidences of different criteria for different project types early termination. The study, although relying on a single case study, has shown that there are indeed different procedures for different project types in terms of novelty degree. The authors found that the same criteria are applied, but with different weights. The study also suggested that termination is an extreme case of deprioritization of projects, being this the most common way of relocating resources in the portfolio. The criteria and groups from this study are listed below.

Table 2 – Criteria for termination grouped.

Group	Criteria
Financial	Financial feasibility
	Financial returns (Gross margin)
	Resource consumption
Regulatory	Toxicological analysis and restrictions
	Environmental analysis and restrictions
	Legal aspects
Customer	Customer willingness to buy a certain volume of resulting product (Customer commitment)
	Customer's sensitiveness to price
	Impact on customer's relation
	Impact on Company's image
Strategic	First in market
	Competitive barriers
	Impact on portfolio
	Possibility of acquiring new capabilities
Technological	Existence of capability and competence
	Technological challenge
	Product life cycle
	Product performance
	Production costs

Source: Gonçalves, Mello & Nascimento (2014)

When organizing these criteria in the different project types from the studied company, the authors observed differences not in the set of criteria, but in the relative importance of them. Line extension projects, which can be understood as an equivalent to derivatives in Clark & Wheelwright (1992), have shown a very low termination rate. Usually, bad financial or costumer anticipated performance is enough for de prioritization and eventual termination in every gate.

Application projects, a highly challenging derivative project, have shown that termination is more likely to happen. Although bad anticipated financial or commercial performance may also be sufficient for termination, technological and regulatory issues gain weight as arguments for keeping the project alive. Strategic concern gains weight to keep projects alive as technical challenge grows.

Finally, Innovation projects, equivalent to platform in Clark & Wheelwright (1992), have shown low termination rate, mostly due to unsurmountable technical problems. For this type of project, strategic concerns may have the upper hand in keeping a project alive even if anticipated financial or costumer performance is not well. New capabilities acquisition here may be paramount.

2.5 Dependences among projects

Projects in the portfolio interact both positively and negatively, although the current practice on PPM does not give this fact much importance. Nascimento (2013), in his essay, says that there is a Project Selection Paradigm (PSP), which bases most of the PPM practice in selecting projects to compose the portfolio. The author says that projects are seen as "closed packages", and suggests they should be opened to enforce the positive interactions and avoid the negative ones.

Other authors made a taxonomy of these interactions that may occur. Projects are interdependent when the success of one project depends on other(s) (Killen & Kjaer, 2012). According to Verma & Sinha (2002), Blau & Pekny (2004) and Eilat et al. (2006), there may be resource, market, outcome, learning or financial dependencies.

The learning dependence, as defined by Blau & Pekny (2004), means the resource and time economy that a project gets through the learning curve of another project. The authors showed examples of a difficulty level reduction of 20% when developing drugs for the same disease.

2.6 Learning

Many authors have studied individual and organizational learning (Fiol; Lyles, 1985; Bell, 1985; Madsen; Desai, 2010; Shepherd et al., 2014; Warnecke, 2013; Zedtwitz, 2002). Argyris & Schön (1978) built a classic model for organizational learning, which divides the learning in single-loop and double-loop.

Bell (1984) noted a tendency to over-evaluate the importance of learning by doing on companies that improve its performance over time. He defends that learning may come by two different ways: (1) effortlessly, as a result of repetition over time, and (2) actively, as a result of a resource allocation on acquiring the knowledge, either by hiring, training or searching.

Maidique & Zirger (1985), Nobeoka & Cusumano (1995, 1997) and Danneels (2002) have shown that capability development results from iterated and interacted processes of exploration and exploitation among successive and parallel product and process projects. According to the authors, to balance the portfolio, the company should determine resource baskets available to each type of project. The management, then, proceeds to select the projects to compose the portfolio in order to reflect the company's R&D objectives.

Nonaka (1991) took the discussion further when analyzed how the top Japanese companies dealt with their learning cycle. He described the “spiral of knowledge”, where Tacit knowledge is converted into Explicit knowledge through a cycle of (1) socialization, (2) externalization, (3) combination, and (4) internalization.

Learning may also come through projects, as postulated by Danneels (2002), which analyzed firm renewal by its new product development projects. The author finds a relation between product innovation and the creation of new competences in a dynamic system that keeps the firm competitiveness up to date.

This learning dynamic was also studied by Maidique & Zirger (1985). The authors affirm that the knowledge gained in failed projects was often instrumental in achieving subsequent success in their sample, while successes may result in unlearning of the process that led to the original success. The authors then formulated the “new product learning cycle”, in which commercial successes and failures alternate in an irregular pattern of learning and unlearning.

Learning from past projects can indeed improve R&D engineers’ creativity, as shown by Ling Tan & Ping Chang (2015). Gonçalves, Camargo Junior & Nascimento (2014), however, indicated that learning from terminated projects comes from the individuals and organizational learning is rarely achieved.

As Salerno et al. (2014) shown, different types of project are managed in different processes. Therefore, different types of project may result in different levels – and kinds – of learning. The higher the novelty level of the project, greater is the knowledge the company and the project team get from development. When achieving a long range technology development, the probe and learn process (Lynn, Morone, & Paulson, 1996) develops the capabilities the company needs through successive prototypes that may fail miserably on market at first, but teaches valuable lessons to be practiced on the next versions. On the other hand, when developing a new version of a known product with little changes to the original, learning is very limited.

3 METHODS

This research will study two aspects of Innovation Management: Criteria for early termination of R&D projects and the consequential learning that terminating different types of project may bring to the companies. These subjects, when observed together, represent a new view on the Project Portfolio Management literature. As far as we are concerned, there is no literature relating these subjects, which characterizes the present investigation as exploratory. This means the research will be qualitative, in terms defined by Theóphilo & Martins (2009).

Exploratory research is meant to give an overview of a determined subject when there is not enough knowledge to formulate precise and operational hypotheses (Gil, 1995).

Some of this research's characteristics may also classify it as an "explicative" research. According to Gil (1995), this kind of investigation aims at identifying factors that cause a certain phenomenon. Differing from the exploratory research, the explicative is deep and complex.

Yet another view of this research qualifies it as "explanatory" (Yin, 2010). The author classifies as explanatory those research questions beginning with "how" and "why". These questions deal with "operational links needing to be traced over time, more than the mere frequency or incidence" (Yin, 2010, p. 30).

When debating the subjects separately, the research stands atop of well-defined concepts and the research may be defined as explicative. However, when relating terminating different types of projects with the learning these experiences may give to the companies, we are dealing with an unexplored territory and, therefore, the research assumes a full role of an exploratory study.

When dealing with this kind of research question, the literature provides a range of methods to answer it. Yin (2009, p. 29) summarizes the most common methods, the types of research questions each attends, the need for environmental control and the focus on contemporaneous events.

Table 3– Relevant situations for different research methods

Method	Type of research question	Need for control of behavior events	Focus on contemporaneous events
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
File analysis	Who, what, where, how many, how much?	No	Yes/no
Historical research	How, why?	No	No
Case study	How, why?	No	Yes

Source: Yin (2010, pp. 29)

Our research asks, *"How companies deal with projects that become unattractive?"* Therefore, according to the table, the most adequate methods would be an Experiment, a Historical research or a Case study. The second criterion Yin (2009) used was the need for control of behavior events, which we won't have, as we're studying projects that are already closed. We will look behind in time, so we won't be able to control any variable on the studied phenomenon. This characteristic makes impossible for us to investigate our object in an Experiment.

The third and last criterion used by the author is the focus on contemporaneous events, which in our case is a desirable characteristic. We will not deal with the "dead" past, in which "no alive person in available to tell what happened" (Yin, 2010, p. 32). Case study and Historical research have many techniques in common. The Case study, however, can rely on two techniques that Historical research can't: the direct observation of the events and interview with the people involved on the events. By this criterion, Historical research is excluded and we find Case study as the most appropriated method for this project.

3.1 Case study variations

A case study may cover a single analysis unit or many of them. There are some situations when a single analysis unit is enough to take good observations and conclusions: when the case is critical, typical, extreme or revealing (Yin, 2010). A critical case is one that meets all the requirement of the theory and can help to confirm, challenge or expand it. A typical case represents a daily situation or a commonplace event. An extreme (or peculiar) case represents a case that is so rare that even a single event needs to be documented. Finally,

a revealing case is an opportunity to observe or study some situation that was not possible before, hence bringing new revelations for the theory.

A Case study with more than one unit of analysis is called “multiple case study” and adds replication for the theory test. It is important to note that the replication the Case study adds is not statistical, as in a Survey, but theoretical, similar to an experiment replication. Yin (2009) teaches that adding cases to the study can bring two kinds of replication: the literal replication and the theoretical replication.

Literal replication means adding one or more cases that are, at first, similar to the original case study. In this kind of replication, the method expects to find similar results. Theoretical replication, on the other hand, means adding one or more cases that are completely different from the first case study. Similarities on the findings may indicate a robust theory (Yin, 2010).

Despite defending the single case study as a robust research method, Yin (2009) advises the researcher to take a step further and study at least two cases. The number of cases will be, according to the author, “a reflex of the number of replications of the case – literal and theoretical – that you need or want in your study” (Yin, 2010, p. 81).

This study relies on a multiple case study, as advised by Yin (2010). We studied four companies with operations in Brazil.

We considered as a primary case the company Oxiteno, a Brazilian chemical industry (thus, process intensive) that has B2B operations in the Americas, Europe, Asia and Africa and R&D Centers in Brazil, Mexico and Venezuela. We took Natura, another Brazilian process intensive company, as a Literal replication of the base case. As Theoretical replications, we took Mahle, a German auto parts company, and AES, a United States energy company. These companies are expected to be adapted to their environments, which are very distinct from that in which Oxiteno and Natura are. Therefore, these companies are expected to show different policies in their innovation management.

3.2 Cases selection

We selected our cases using the intentional sampling method (Theóphilo & Martins, 2009). The companies were selected by their relevance on their industry and the importance they give to Innovation on their operation. The criteria that were used to identify these companies followed the logic of the work of Morilhas (2007), with an adaptation to our interests:

a) Companies and/or business units that have effective performance in terms of business administration and are recognized by this aspect; and
b) Companies that systematically invest in R&D and Innovation.

To meet the criterion 1, we took the list of the "Biggest and Better" in Brazil, edited by EXAME magazine for the last 5 years. We will not filter companies by a specific industry such as Chemical and Petrochemical, as we will select companies for our theoretical replications from those that are not part of the same industry as Oxiteno.

Criterion 2 was met by collecting the amount of resources invested in R&D by the companies, information available at the companies' websites, as well as in reports from associations such as ANPEI (Brazilian association of innovative companies). We considered for the research those companies that constantly invest in R&D and Innovation, that have a R&D structure for managing projects and that agree to be studied and have the results reported.

3.3 Study model

Following the recommendation from Gil (1995, 2010) and Theóphilo & Martins (2009), as well as the example from Rubio & Nascimento (2005a, 2005b), this research was be supported by a reference model, which provides the basis for analyzing how the PPM processes are managed.

We took the model from Rubio & Nascimento (2005b) as basis and built our own research model to serve our research purposes. The model is illustrated in Figure 2.

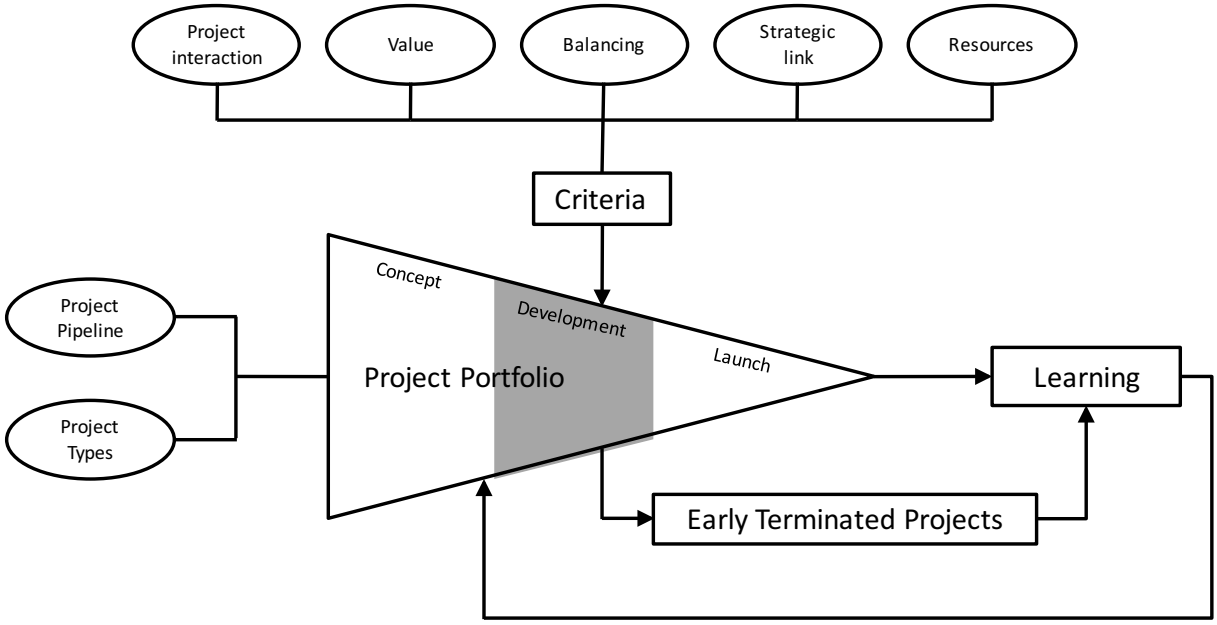

Figure 2. Study reference model

Rubio & Nascimento (2005b) intended to represent the portfolio selection process. We have elaborated our model in order to represent the early project termination process, influenced by the criteria, the project typology and the project pipeline procedures. It also represents the learning that might come from the set of early-terminated projects, and the influence it may have on the portfolio. As the original model, the components follow recommendations from Yin (2009), presenting categories that will guide the data collection, classification, analysis and comparison. The components are explained below:

a) **Project portfolio.** Represented as a projects funnel, it is the set of projects being developed by the company. It is normally divided in phases by the project pipeline procedures and its projects are organized in types.
b) **Criteria.** Information and parameters collected in order to identify projects candidates for termination. In this research, we are interested in the application of these criteria in a portfolio context.
c) **Early terminated projects.** Projects that were at first selected for development, but were later identified as unattractive, therefore were cancelled before completion.
d) **Learning.** Knowledge, capabilities and competences that might be provided by the early terminated projects. This learning influences the overall performance of the portfolio.

3.4 Data collection and analysis

We collected primary data from the selected companies. Primary data are defined as those information that are extracted from the studied object (Theóphilo & Martins, 2009) – in our case, from the members of the studied companies.

We used semi-structured interview protocol with the companies' R&D managers to collect information on early project termination. We followed the model explained above in order to collect, classify, analyze and compare the data.

The field study stage took six months, from December 2014 to May 2015. During this stage, we interviewed the R&D manager for four companies: Oxiteno, Natura, Mahle and AES. Each interview had an average duration of 90 minutes and took place in the studied companies' facilities.

The interviews were based on the study model presented earlier. Each concept presented in the model was discussed individually in order to describe the company's R&D management practices. The typical interview protocol was:

1. Project pipeline organization
2. Project types
3. Project termination frequency
4. Project termination criteria
5. Termination procedures
6. Learning procedures
7. Differences between terminated and completed projects
8. General information on company's R&D management

The interviews were recorded for later analysis and case writing. After writing, the cases were submitted for revision by the interviewees, in an iterative process. After a variable number of rounds, the cases were approved as a precise report of the information provided during the interviews. The complete cases are available at the appendices.

4 RESULTS

This section will bring the results of the multiple case study we have proposed in the initial chapters of this document. After presenting the four cases, we will compare the findings in the Discussion section. Conclusion, afterwards, will bring the contributions for research and practice. In this section, we will bring only what is relevant for our research questions and objectives. For a full report on each case, see the appendices.

4.1 Case Oxiteno

Oxiteno is a B2B chemical company from Brazil founded in 1973. Its revenue in 2014 was around US$ 1,5 billion. Oxiteno has around 2.000 employees and launches an average of 15 new products per year. The company invests around 1% of its income in R&D and Engineering. Oxiteno's R&D is based in developing solutions for many markets such as Home and Personal Care, Agrochemicals, Paints & Coatings, Oil & Gas etc.

Oxiteno's projects are managed in a Innovation funnel (Clark & Wheelwright, 1992) divided in six phases, following the Stage-Gate methodology (Cooper, Edgett, & Kleinschmidt, 2002; Cooper, 1983, 1996, 2009a). See Appendix A for a more detailed view. The phases are illustrated in Figure 3.

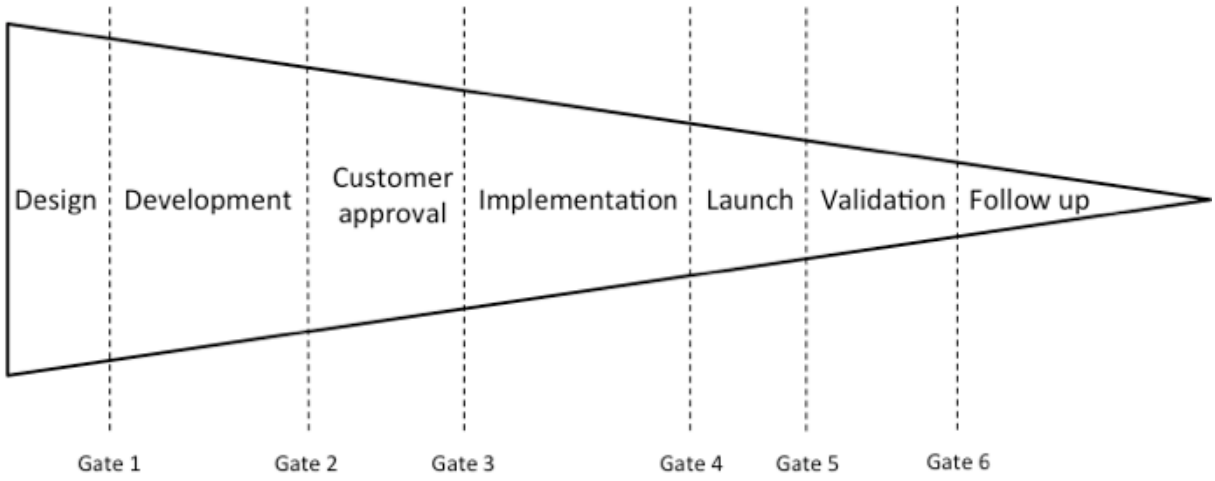

Figure 3. Oxiteno's pipeline

Oxiteno also divides its portfolio in six possible types, three of which might result in new product development: Line Extension, Application Development and Innovation. Line

extension projects are those intended to introduce a product based on well-known specifications and technology. Application Developments projects are aimed at developing new ways of using the existing portfolio, while Innovation projects are those that develop new technologies and deals with knowledge that Oxiteno doesn't have.

Strong prioritization procedures prior to Termination

Oxiteno strongly relies on a prioritization methodology that relies on a scorecard to measure the familiarity with the technology and the expected financial returns. This prioritization affects which projects will be developed first and organizes a line for utilizing shared resources, such as the analytical laboratory or the pilot plant. The prioritization is updated every quarter by a forum with the R&D managers for each market division.

Deprioritized projects are terminated if it spends too much time on the line without being developed. The time it stays on the portfolio prior to termination is variable and depends on the reason that deprioritized it.

There are, however, some reasons that lead projects to early termination, listed at Table 3.

Table 3 – Oxiteno's criteria for early termination

Value	Commercial success, Intellectual Property and Regulation
Project interaction	Comparing for prioritization ranking
Balancing	More innovative projects have more tolerance. No official balancing recommendation.
Strategic link	Not applicable
Resources	Too much effort, rework, lack of industrial resources for ramp up

Learning is mostly informal

At Oxiteno, we observed a high incidence of informal procedures for learning. It is common to learn from interpersonal information exchange when a researcher needs information on past projects. Team members usually keep the complete set of documents of previous projects in their personal computer or in the form of annotations in their notebooks. This material is shared when needed.

Formal procedures are based on searches on the company's projects database. However, not every early-terminated project has a comprehensive final report on the reasons and difficulties that took it to termination. It is common to have such report when dealing

with more innovative projects. However, they are rare on Oxiteno's portfolio and, therefore, the amount of formal learning is very limited.

There are also children projects that are born in the occasion of the cancellation of a project. In those cases, learning is direct as the new project continues the development of the most interesting points of the old one.

4.2 Case Natura

Natura is a Brazilian company founded in 1969 that operates B2C in the Home and Personal Care market. Its revenue in 2014 was US$ 2,8 billion. Natura has around 6.000 employees and launches about 250 new products per year. Annually, Natura invests about 3% of its revenue in R&D.

Innovation funnel (Clark & Wheelwright, 1992) and Stage-Gate (Cooper et al., 2002; Cooper, 1983, 1996, 2009a) models are also present in Natura's projects pipeline. Natura has two funnels: Technology, for projects intending to develop new technology and new platforms; and Products, intended to develop new products and launch them on market. It is common to observe projects being developed in Technology funnel as part of the development path for a parallel project at Products funnel. See Appendix B for more details. Natura's pipeline, with its two-funnel system, is illustrated in Figure 4.

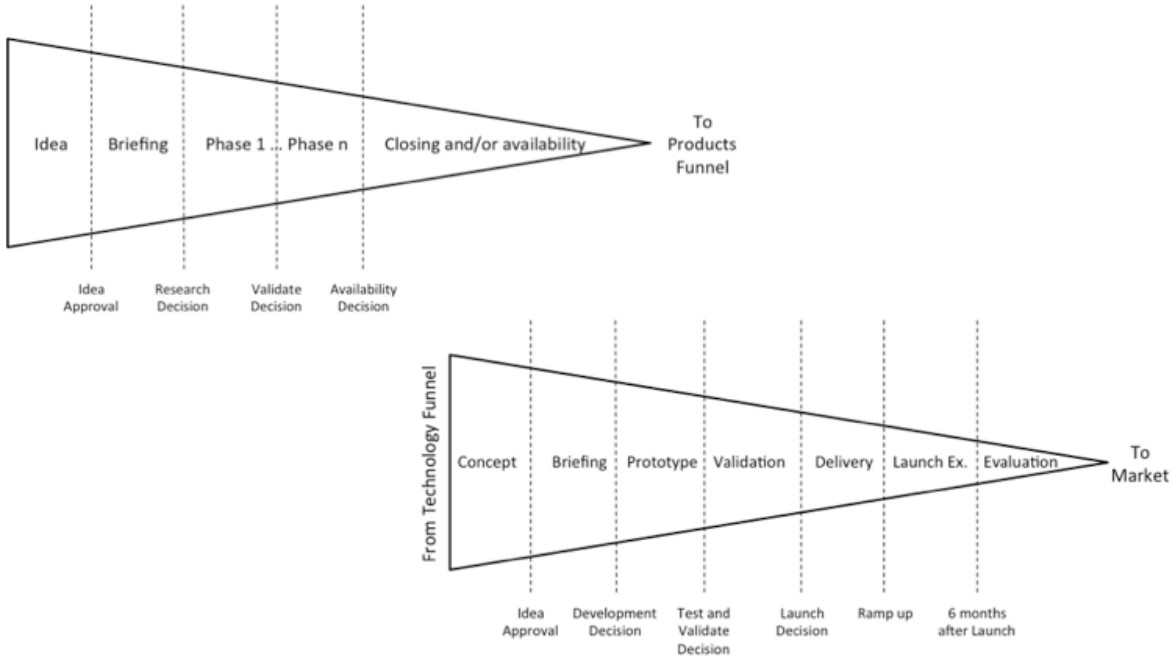

Figure 4. Natura's funnels

Natura's projects are divided in different types depending on the funnel. Technology funnel's projects are divided in: (1) New raw materials, (2) New field technology, (3) Ecodesign and (4) New models and methodologies. At Products funnel, projects may be: (1) Network animation, (2) Core business or (3) Radical bets.

Prioritization plays important role in portfolio

Just as observed in Oxiteno, portfolio at Natura is mainly managed in terms of prioritization, with termination being an extreme case of deprioritized project. A different forum, each with different seniority level, keeps each gate. When deciding for termination, Natura observes the criteria from Table 4.

Table 4 – Natura's criteria for termination

Value	Commercial success, Company's Mission, Vision and Values
Project interaction	Projects affected by changes in other projects may become uninteresting
Balancing	More innovative projects have more tolerance. No official balancing recommendation.
Strategic link	Not applicable
Resources	Resources shortening trigger stricter portfolio evaluation

Formal learning is more likely for big, strategic projects

Projects at Technology funnel always goes through a Closing phase, when a final report is written, regardless of the project's technical success. However, for Products funnel, writing a detailed final report for early-terminated projects is rare, despite recommended. It is more common for big, costly, risky and strategic projects.

For the majority of projects, then, there is no final report in case of early termination. To learn from these experiences, researchers rely in informal learning, which normally happens through interpersonal exchange of information in a non-structured procedure.

We could also observe the presence of children projects, where a project gives birth to other projects that will continue the most interesting parts of the development.

4.3 Case Mahle

Mahle is a German auto parts industry that operates B2B founded in 1920. Its revenue in 2014 was US$ 12 billion. Mahle has about 66.000 employees and launches an average of 60 products per year. From 3% to 6% of its annual revenue is invested in R&D.

Mahle's pipeline, as already observed at Oxiteno and Natura, is based on the Innovation Funnel (Clark & Wheelwright, 1992) and Stage-Gate (Cooper et al., 2002; Cooper, 1983, 1996, 2009a) models. Mahle's process, however, is much more complex than that of Oxiteno and Natura. See Figure 5 for an illustration of the complexity of the funnels.

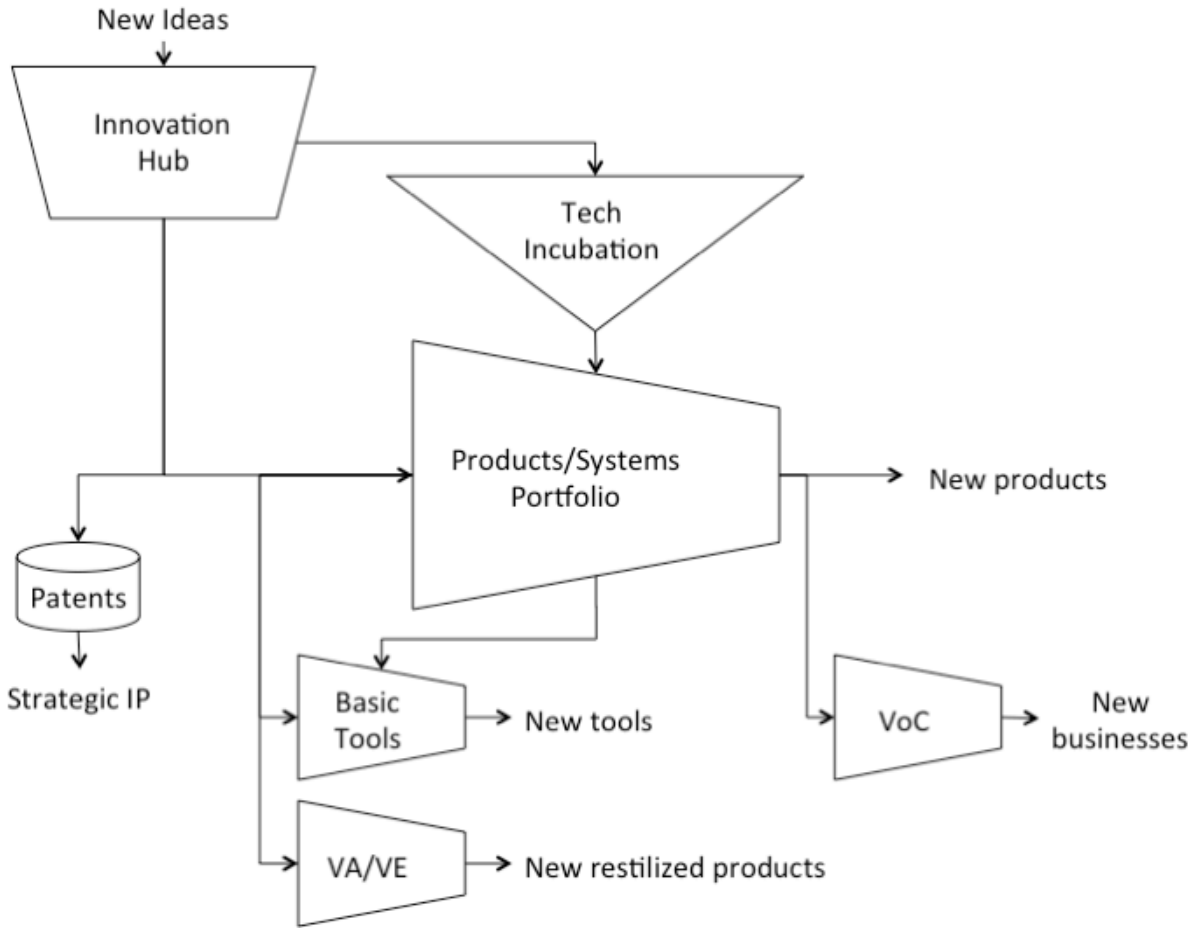

Figure 5. Mahle's funnels

A complete description of each funnel can be seen at Appendix C. Each of the funnels is dedicated to a part of the innovation chain developed by Mahle. There are funnels for new technologies, new products, demonstration of new technologies, new tools and minor changes in existing products. The Stage-Gate for each funnel varies in size. The full model is illustrated in Figure 6.

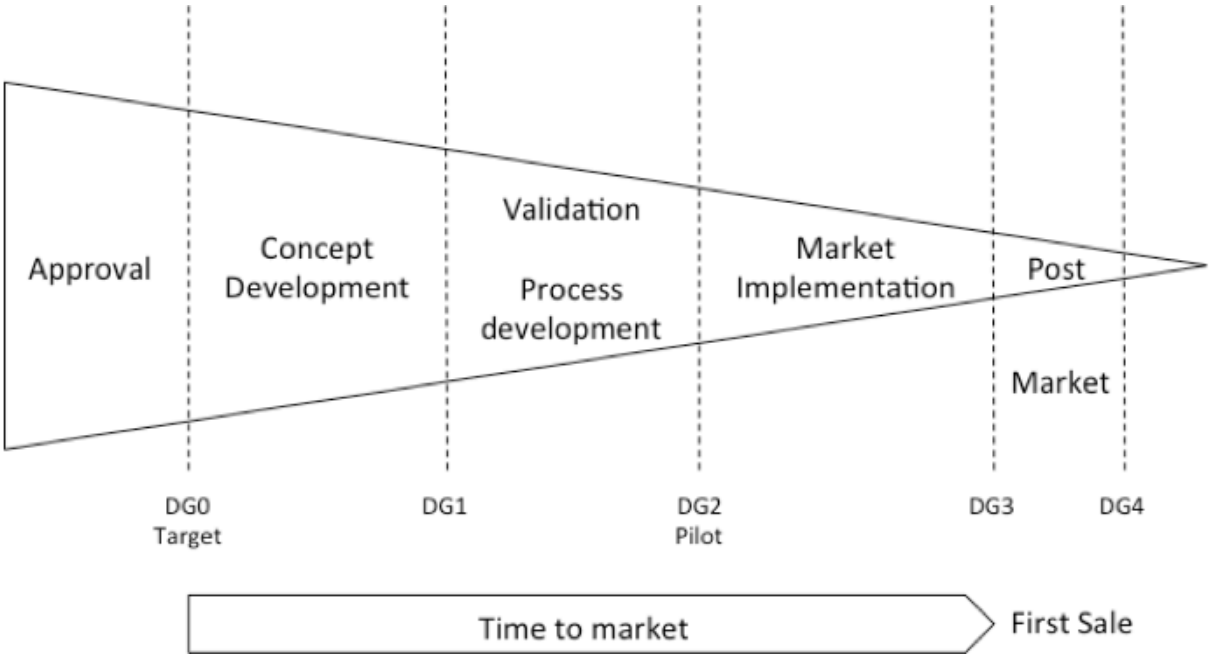

Figure 6. Mahle's Full Stage-Gate

Mahle's projects are divided in three types, depending on the novelty level for the market: (1) Me-too projects; (2) Incremental projects; and (3) Innovative. This later type is intended to introduce a product that can be considered new to the world.

Termination is expected and used as a tool for accelerating Innovation

Mahle's projects are indeed terminated when the company understands it has served its purpose in the portfolio. Prioritization is also present in the portfolio, being influenced by the same factors that trigger early termination. See Table 5 for Mahle's criteria. Decisions are taken monthly at Portfolio Review Meetings.

Table 5 – Mahle's criteria for early termination

Value	Technical success, Commercial success
Project interaction	Competing projects with the same goal
Balancing	Balancing recommendation is followed.
Strategic link	Strategic planning changes may cancel projects
Resources	Budget released by stage, resource overflow causes deprioritization

Formal learning is strong and systematic

Every project at Mahle gives birth to a final report when terminated. This final report tells the complete history of the project, including the reasons that took it to early termination. Every report includes the lessons learnt with the development. The lessons may be of managerial or technical nature. Every lesson is related to an action that might change, create or eliminate procedures or give birth to new technical guidelines for future projects. The more innovative the project, more lessons will be learnt and higher is the likelihood of substantial changes in the company's procedures and capabilities. Children projects are common.

Informal learning is also strong, with interpersonal exchange of information when needed. But Mahle has a strong procedure for finding relevant information about past projects in its database.

4.4 Case AES

AES is a United States energy company founded in 1981. It operates both B2B and B2C by generating and distributing energy. AES controls formerly state-owned Brazilian energy companies such as Eletropaulo and Uruguaiana. Its revenue in 2014 was US$ 17 billion. AES has about 18.000 employees. By regulatory imposition, it invests 0,4% of its income in R&D, developing about 10 technology projects per year.

AES has a very simplified pipeline, as their projects are 100% developed by third parties such as universities or research institutes. Figure 7 illustrates its Innovation Funnel with the Stage-Gate phases represented.

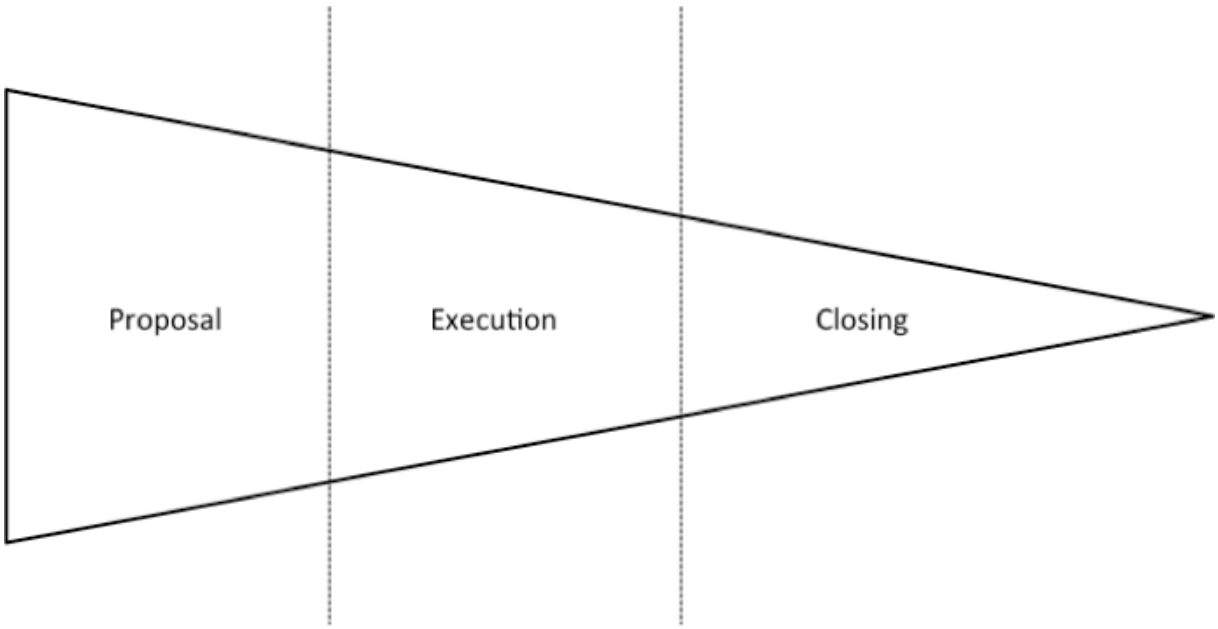

Figure 7. AES' pipeline

Technologies at AES are developed in many sequential projects until reaching market. They start as Basic Research projects and end as Market Insertion projects. See Figure 8 for a scheme of the technology development at AES.

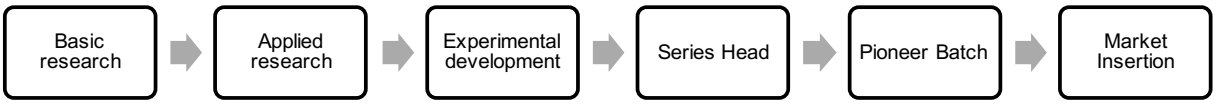

Figure 8. AES' technology development scheme

Projects are yet divided in three categories: Software, Methodologies and Equipment. And are also classified by the time they will take to reach conclusion. Incremental projects are short term, while Disruptive projects take 4 to 5 years to reach market.

Project classification is for information purposes only

AES doesn't apply different policies to the different project classifications of the portfolio. Every project competes for the same human and financial resources. However, it was reported that is easier to interrupt a project at "basic research" level than at "market insertion". Every two months there is a meeting to evaluate projects, where many factors are evaluates (for a complete description, see Appendix D). Some factors, however, can immediately cancel projects. The stronger is compliance. If there is some kind of suspicion of corruption, the project is immediately terminated, regardless of the type and development stage. See Table 6 for the criteria that may lead projects to early termination at AES.

However, AES sees the development not by their projects, but by technology. It is not common to early terminate projects, but it is common to stop the development of a technology after one specific project. The development is early terminated, once the technology will not reach Market implementation level.

Table 6 – AES' criteria for early termination

Value	Commercial success, Technical success, Compliance
Project interaction	Not applicable
Balancing	More innovative projects have more tolerance. No official balancing recommendation.
Strategic link	Avoids termination by demanding top management sponsors
Resources	Budget deviances don't kill projects, but it would be desirable to kill

Technical learning is strong, managerial learning is weak

AES strongly learns from technical development of its projects. For every terminated project there is a closure meeting to sum up lessons learnt. These lessons, as well as the history of the project are communicated in an open workshop for the AES community. Children projects are also very common at the portfolio by the nature of AES' technology-based view development. The mechanisms are formal, but there is no database for keeping the information about the terminated projects. Learning, then, happens informally by interpersonal exchange of information.

Managerial learning is reportedly weak. The reason given is the constant changes in strategy caused by frequent changes at the board of directors.

5 DISCUSSION

This section is dedicated to the comparison and analysis of the different cases. We will try to find points where the project termination policies meet and where they disagree, and try to formulate our contribution to the study of Project Portfolio Management. We will continue to follow our study model to discuss the results. The next chapters, therefore, will be organized the same way as the individual cases.

We have studied four cases, each with its particularities and each with its role at the multiple case study, as teaches Yin (2010). Oxiteno was our base case, as the company where we had more access and therefore we could do a deeper study. Oxiteno is a Brazilian chemical B2B company that operates in a myriad of markets, mainly providing commodities, but with an increasing importance on innovation as a way of providing more personalized solutions to its clients. Natura, also a Brazilian company, takes part on the Oxiteno's value chain as one of the clients for its Home and Personal Care market. However operating B2C, the size and nature of the companies' R&D operations are very similar. Moreover, many of the projects developed at Oxiteno are done in partnership with Natura. These facts lead us to consider Natura as a literal replication of the base case.

The other two cases, Mahle and AES, showed contrasting backgrounds, as well as very particular processes and structure. These companies are both linked to a foreign controlling group and operate in completely distinct markets from Oxiteno's. Mahle, a B2B German company that operates in the automotive parts industry, and AES, a United States company, operating in both B2C and B2B, focused in generating and distributing energy, are two very particular cases that could be considered as theoretical replications of the base case. See table 7 for a comparison.

Table 7 – Companies' general information.

Company	Origin	Markets	New products per year	Revenue 2014 (US$ Billion)	Employees (Global)	R&D investment (over revenue)
Oxiteno	Brazil	B2B Chemicals (commodities and specialties)	15	1,4	2.000	1%
Natura	Brazil	B2C Home and Personal Care	250	2,8	6.000	3%
Mahle	Germany	B2B Automotive	60	12	66.000	3%-5%
AES	United States	B2B/B2C Energy generation and distribution	10 (Brazil)	17	18.500	0,4% (Brazil)

Organizational structures

We could observe different management R&D structures. Oxiteno's R&D is directly linked to the CEO, with teams accountable for the application markets and a matrix structure for technology & innovation, which is responsible for the shared resources such as regulatory affairs, intellectual property, processes development, pilot plant and analytical laboratory. This structure is very distinctive from Natura, whose R&D area is organized into activities for each research type (Advanced research, Applied research, Technology transfer etc.). R&D at Natura is linked to the Innovation VP, which in turn responds to Brands and Business Executive VP and then to the CEO. While at Oxiteno the R&D is at the first level below the CEO, which might lead to a closer evaluation of the R&D activities, at Natura there are two levels between the R&D and the company's main executive. This structure puts the R&D operations under the Brands & Business strategy and planning. Both studied structures are the companies' R&D headquarters, accountable for managing the global R&D program.

Mahle is organized in Business Units (BU) and Product Families. Each BU responds independently to the CEO and has its own R&D structure, dedicated to develop the product families under each BU. The Product Families Management is distributed among the R&D centers, which respond to the Regional Director. The Regional Directors respond to the VP of the Business Unit, which in turn responds to the CEO. There are, then, three levels between the R&D teams and the CEO. As Mahle is a company with more than 60 thousand employees, this structure divides the management in smaller parts to make management possible.

Finally, AES has its R&D under Innovation Director, which is two steps away from the President Director. R&D operations are under the Business & Distribution strategy. This

structure is very straightforward, and is explained by the nature of the R&D made at AES, based on development by contracting instead of maintaining an internal team for projects development. Table 8 compares the companies' structures.

Table 8 – Companies' structures comparison.

Company	Steps from CEO	Market/Activity-based	Internal/external development
Oxiteno	0	Mixed	Mainly internal
Natura	2	Activity	Mainly internal
Mahle	3	Mixed	Mainly internal
AES	2	Activity	Exclusively external

Project Pipeline

This is the conceptually least diverse aspect of the studied companies, and at the same time the most diverse in complexity. All of the studied companies use a variation of the Stage-Gate® methodology (Cooper, 1983, 1996, 1999, 2009a), along with the Innovation Funnel model (Clark & Wheelwright, 1992). The variation occurs at the number of phases and funnels. While at Oxiteno we observed one single funnel divided into six phases (Design, Development, Customer approval, Implementation, Launch, Validation and Follow up), at Natura we have found two funnels: (1) Technology Funnel, divided into three fixed phases (Idea, Briefing and Closing and/or availability) and a variable number of intermediate phases, depending on the complexity; and (2) Products Funnel, divided into seven fixed phases (Concept, Briefing, Prototype, Validation, Delivery, Launch execution and Evaluation).

Mahle has an outstanding complexity on its pipeline organization. There are six funnels, one for each level of maturity of the idea: (1) Innovation Hub, where new ideas are evaluated and chosen for development in the other funnels; (2) Tech incubation, where good yet immature ideas are developed; (3) Products/Systems Portfolio, where new products are developed in partnership with clients; (4) Basic Tools, where tools and methodologies are developed for implementation at Mahle's laboratories; (5) VA/VE, where current products are restilized and revalidated with the market; and (6) VoC, where recently launched products are demonstrated in order to create new businesses for the company. Each of these funnels is divided in phases, with the full model being applied to Products/Systems Portfolio, Basic Tools and VA/VE. The full scale Stage-Gate is comprised by six phases (Approval, Concept development, Validation, Process development, Market implementation and Post). VoC

funnel is composed only by the Demonstration phase, while Tech incubation comprises only the Concept development phase.

AES has the simplest Stage-Gate of the studied companies, with only one funnel divided in three phases (Proposal, Execution and Closing). Once more, this is explained by the fact that AES develops externally 100% of its projects. Table 9 summarizes the companies' project pipelines.

Table 9 – Project Pipelines

Company	Funnels	Phases
Oxiteno	1	6 fixed phases.
Natura	2	3 fixed + n variable phases for Technology funnel. 6 fixed phases for Products funnel.
Mahle	6	6 fixed phases for Products/Systems Portfolio, Basic Tools and VA/VE. 1 fixed phase for Tech Incubation funnel. 1 fixed phase for VoC funnel.
AES	1	3 fixed phases.

Project types

Every studied company has a system for classifying projects by its level of complexity and novelty, following Wheelwright & Clark (1992). This classification, however, is sometimes combined with other systems that provide the management with different points of view of the projects portfolio.

Oxiteno classifies its projects by level of complexity. Of the six project types, three result in new products (Line Extension, Application Development and Innovation) and one in new processes (Optimization). The other two (Tolling and New Sales) are aimed at new businesses. Natura has a classification for each funnel. Technology funnel has four possible project types, depending on its outcome (New raw materials, New field technology, Ecodesign and New models and methodologies). Products funnel is divided into three archetypes, depending on its position on a complexity versus potential matrix (Network animation, Core business and Radical bets).

Mahle organizes its projects in three types following their novelty level (Me-too, Incremental and Innovative). It also flags the most important 10% as strategic, which elects these projects to be followed by the Board of Directors.

AES has the most complex classification system for its projects. The company classifies its projects in three different ways. The first is by its outcome, which classifies projects in three types (Software, Methodologies and Equipment). The second is by the time it

requires for development, which divides projects in two types (Incremental and Disruptive). The third way of classifying projects is by its maturity. Projects may be classified as six types in this system (Basic research, Applied research, Experimental development, Series head, Pioneer batch and Market insertion). Some of these classifications could be also understood as different funnels. Differently from the other studied companies, however, AES does not use any of these classifications to apply different policies to them. AES uses these categories for information purposes only.

See table 10 for a summary of the companies' project typologies.

Table 10 – Companies' project typologies

Company	Project classification system	Project types
Oxiteno	Level of complexity	Line Extension, Application, Innovation, Optimization, New Sales, Tolling
Natura	Project Outcome (Technology funnel) and Complexity vs return (Products funnel)	New raw materials, New field technology, Ecodesign and New models and methodologies (Technology funnel); Network animation, Core business and Radical bets (Products funnel)
Mahle	Level of novelty	Me-too, Incremental, Innovative
AES	Project Outcome, Project time to development, Project maturity	Software, Methodologies and Equipments (outcome); Incremental and Disruptive (Time); Basic research, Applied research, Experimental development, Series head, Pioneer batch and Market insertion (Maturity)

Project Portfolio Evaluation

Portfolio evaluation techniques observed at most were based in meetings that intend to evaluate individual projects, not necessarily the whole portfolio. We did not observe as common evaluation procedures that would take into account the portfolio perspective in order to evaluate a project, with rare exceptions. As Nascimento (2013) anticipated, the meetings and forums give very strong attention to project selection and yet very little to project portfolio evaluation. There are, of course, exceptions, as we can see at Mahle.

At Oxiteno, portfolio evaluation happens in two different groups. The first is composed by those projects that only require work from application researchers. The second comprises those projects that need work hours from the shared resources at Technology and Innovation management (processes development, pilot plant, analytical laboratory, regulatory affairs and intellectual property). The first group follows each application manager's internal rules and is evaluated relating Effort and Attractiveness at Projects Forums. The second group

follows a prioritization dynamic that relates familiarity with the technology and potential financial return, the prioritized projects list being updated every quarter.

At Natura, there are forums with different seniority levels that keep different decision gates. Evaluation, then, is done observing six factors for each project: (1) Expected Revenue, (2) Schedule deviance, (3) Strategy Buckets' Budget, (4) Project specific budget (5) Human Resources Allocation, and (6) Archetypes distribution (balancing).

Mahle also relies in meetings to evaluate the portfolio. They are called Portfolio Review Meetings (PRM) and evaluate the portfolio by two axes: technical and commercial attractiveness. There is always a process for comparing the actual development with that planned at the beginning of the project. During PRM the project team is invited to propose actions for the project under review. In addition, there is a list of projects ready to be started as soon as there are resources available. Reportedly this helps to relieve the project leaders' fear of losing their projects.

AES evaluates its portfolio every two months, during the General Project Meetings (GPM), and look at five main factors: (1) Potential patents, (2) Scope changes, (3) Financial review, (4) Schedule deviation and (5) Communication strategy. There is also the constant search for inter-project learning that could accelerate development.

Table 11 summarizes the findings.

Table 11 – Project Portfolio Evaluation procedures

Company	Evaluation method	Focus	Frequency	Criteria observed
Oxiteno	Project Forums and Prioritization dynamic	Individual projects in view of portfolio value	Project forums: Monthly, Prioritization dynamic: Quarterly	Project forums: Effort x Attractiveness. Prioritization: Familiarity with technology x Potential financial returns
Natura	Different forums with different seniority levels that keep decision gates	Individual projects in view of portfolio value and balancing	Variable, depending on the forum seniority level. Usually every two months	Expected Revenue, Schedule deviance, Strategy Buckets' Budget, Project specific budget, Human Resources Allocation, Archetypes distribution (balancing)
Mahle	Portfolio Review Meetings	Individual projects in view of portfolio value and balancing	Monthly	Technical and Commercial attractiveness
AES	General Project Meetings	Individual projects	Every two months	Potential patents, Scope changes, Financial deviations, Schedule deviations, Communication strategy

Project Termination

This is the theme in which we observed more similarities between the base case and the literal replication, while the theoretical replications showed some similar characteristics, but in general very distinctive procedures. At Oxiteno and Natura, we saw a very strong tendency to save projects and avoid project interruption. We have already observed this at a previous work (Gonçalves, Mello & Nascimento, 2014), but the finding got stronger with the present research, as now we have more evidence. By Oxiteno's and Natura's cases, we can understand project interruption as an extreme case of project deprioritization.

Mahle's management, however, expects to interrupt a certain rate of projects during development. The practice of maintaining several funnels with different objectives allows Mahle to apply different policies to better achieve the company's development objectives. Projects are indeed terminated if they show some characteristics that will be analyzed in the next section. Nevertheless, the prioritization dynamic is yet present and very strong, as some factors will lead to a deprioritization of the project, with the development intentionally slowed down. This could also be evidence that project termination is an extreme case of deprioritization, but it could lead to an understanding that the escalation of intensity that changes the decision from "slow down" to "terminate" may be variable among companies in different markets.

AES has a completely distinct view on project termination. It almost never interrupts or deprioritizes any project, unless there is a very strong reason. As the project pipeline is short and the projects usually gives birth to other more mature projects until the technology reaches market, AES believes that it is sufficient to interrupt the chain of innovation of a certain technology. The projects are completed, but the resulting technologies are not implemented or used in new projects. This is a new perspective over technology development interruption: the development chain based view instead of the project development view.

See Table 12 for a summary of project interruption procedures in the studied companies.

Table 12 – Project interruption in the studied companies

Company	Frequency of project interruption	Importance of prioritization	Projects/Technology development based view
Oxiteno	Low	Very High	Projects
Natura	Low	Very High	Mainly Projects
Mahle	High in Tech Incubation funnel. Average in Products/Systems portfolio.	High	Technology in Tech Incubation funnel. Projects in Products/Systems portfolio.
AES	Very low	Very low	Technology

Criteria for Termination

We observed that the criteria that lead projects to interruption are strongly linked to the observed factors at portfolio evaluation. This was expected, as the forums that evaluate projects are the same that will terminate them. We could observe high coincidence of the criteria used by the different studied companies in all the criterion groups of the study model. We will review each aspect in this section. At the end, Table 13 will summarize the importance and observed operationalization of each group of criteria.

Value

We observed that the understanding of Value is strongly linked to two main aspects of the projects: technical and commercial success. As these are also the stronger factors that terminate projects earlier than expected, the Value dimension of the portfolio stood out as the most important for project interruption. This category was also linked to intellectual property and regulatory affairs.

At Oxiteno, the strongest factors in this category were Customer withdrawal and Market, both related to commercial success. Natura divides its understanding of Value in tangible and intangible aspects. Intangible aspects are related to the company's Mission, Vision and Values statements. The tangible factors are very similar to Oxiteno as they are strongly related to commercial success.

At Mahle, projects at Tech Incubation funnel are strongly judged by their technical success probability. This is not an important criterion for Products/Systems Portfolio, however. For projects at the latter funnel, the main criterion is the cost at which the technology will reach market – in other words, probability of commercial success.

AES is not different and assesses its projects by their probability of generating new income, absorb investment costs and avoid or reduce costs. In addition, AES is strong at reviewing the technical success of its projects.

For every studied company, the importance of technical success grows in directly proportion as the project complexity, challenge or novelty. In addition, the importance of commercial success grows in inverse proportion to the same factor.

Project interaction

We noticed two ways of dealing with the project interactions at the portfolio. The first, present at the base case and at the literal replication, is the constant comparison of attributes of the different projects in the portfolio in order to build a prioritization ranking. The second is present at Mahle, a theoretical replication, and is based in trying to solve a problem by concurrent projects.

At Oxiteno, projects are constantly compared to each other in order to compose the prioritization. A project extremely deprioritized end up by being cancelled. At Natura, schedule deviations of a project may affect the success of others. Changing the success probability of a project, as cited earlier, might flag it as a termination candidate. In addition, changes in the scope of a project may make it compete with others, augmenting its probability of cancellation.

Mahle works with intentional competing projects trying to solve the same problem via concurrent technological routes, especially in Tech Incubation funnel. Only one project, the one that achieved best results, will reach the end of the development phase. The others will be interrupted.

AES doesn't use project interaction as criterion for terminating projects.

Balancing

Balancing the portfolio is usually not seen as a priority in all studied companies. We could not observe a recommended balancing of the portfolio in the base case, in the literal replication and in one of the theoretical replication. The only company we could find this official recommendation reportedly doesn't use it as the main reason for interrupting projects.

At Oxiteno, managers try to keep balance by increasing tolerance for the most innovative projects. However, it is not an official procedure, as there is not a recommended

proportion of the different types of projects in the portfolio. The same is observed at Natura and AES.

Mahle has an official recommended balancing of the portfolio (30% Innovative, 50% Incremental and 20% Me-too). However, it is not an important factor for terminating a project.

Strategic link

Strategy plays an important role on the studied companies for project selection and idea generation, however, not at the decision to interrupt a project. Base case and its literal replication do not show evidences of project interruption by strategic reasons. Theoretical replications take strategy into consideration, but in a weak manner. While Mahle uses this link as a source of new projects and predicts several projects termination in the case of a change in the strategic planning, AES tries to ensure this will not be an important issue along the life of the project.

At Oxiteno and Natura, there are no evidences of termination for strategic reasons. It could be a possibility if the companies decide to retire from a certain market, but it is a possibility we cold not verify for the lack of available data.

Mahle yearly revises its strategic planning involving the R&D, Operations and Sales teams. This planning usually brings new demands from the clients, while others are removed from the priority list. This almost always is a reason strong enough to terminate a series of projects that attended the demand.

AES demands every project to be sponsored by a member of the top management and a link to a concrete issue to be addressed, in order to avoid future interruption. The main trigger for termination is a change in the board of directors.

Resources

Resources factors are usually understood as human resources, laboratory and equipment hours, amount of essays and budget. Every studied company reported to find resources overflow very undesirable. However, this is not an important reason for project termination.

At Oxiteno it is common to deprioritize and eventually cancel projects that need too much effort from the shared laboratories. The tolerance for rework is extremely low. There

could be also lack of resources for industrial implementation of a certain product. This case would, though, cancel a project *after* project development phase. At Natura, resources shortening usually don't terminate project, however, may trigger a process of portfolio review and lower the tolerance for other factor.

Mahle usually doesn't interrupt projects that exceed the budget. As resources are released stage by stage, each case is discussed individually. The most common policy in these cases is to deprioritize the project instead of interrupting it.

Finally, AES usually doesn't kill projects because of budget deviances. Nonetheless, they are not appreciated at all. Hence the reported effort to implement a policy to indeed terminate projects that infringes a certain yet-to-define threshold of deviance in resource utilization.

Table 13 – Criteria operationalization by company

Criteria Group	Oxiteno	Natura	Mahle	AES
Value	Commercial success, Intellectual Property and Regulation	Commercial success, Company's Mission, Vision and Values	Technical success, Commercial success	Commercial success, Technical success, Compliance
Project interaction	Comparing for prioritization ranking	Projects affected by changes in other projects may become uninteresting	Competing projects with the same goal	Not applicable
Balancing	More innovative projects have more tolerance. No official balancing recommendation.	More innovative projects have more tolerance. No official balancing recommendation.	Balancing recommendation is followed.	More innovative projects have more tolerance. No official balancing recommendation.
Strategic link	Not applicable	Not applicable	Strategic planning changes may cancel projects	Avoids termination by demanding top management sponsors
Resources	Too much effort, rework, lack of industrial resources for ramp up	Resources shortening trigger stricter portfolio evaluation	Budget released by stage, resource overflow causes deprioritization	Budget deviances don't kill projects, but it would be desirable to kill

Learning from terminated projects

We observed a very similar scenario to what was seen in our previous research (Gonçalves, Camargo Junior & Nascimento, 2014). Three of the four studied companies reported having strong informal learning procedures, where the individuals play a central role

on storing and later recovery of information. Mahle was the only company that reported a systematic procedure for formal learning, where the company changes procedures in response to what was observed in previous experiences.

It is common to observe the presence of children projects, where a more innovative project gives birth to lesser innovative derivative projects. It is also common to observe final reports for terminated projects, however they are much more common for successful projects. Learning with cancelled projects is yet more common for those projects considered big or strategic. We could observe a stronger inclination for writing final reports and register learning for the most innovative or bigger projects, while the lesser innovative or smaller are usually simply terminated and its resources are redirected to other duties.

Learning level at Oxiteno is directly related to its capacity of retaining historical information on previous projects, both successful and unsuccessful. There is no apparent distinction between learning processes for projects that reach completion from projects interrupted before that. However, it is clear that successful projects generate much more written information than interrupted ones. This relation is due to the existence of a required task at design phase in which researchers must perform a search for previous projects, articles and patents, the first observed route for learning. The second route is the dynamic where innovative projects give birth to new less innovative projects (children projects). The third route for learning is interpersonal exchange of information. Learning may happen in six ways: technology, product, market, customer, bibliography and key contacts. Formal route happens through the two first processes, informal route from the third.

At Natura there is also a system where historical information is stored and recovered during scope definition of new projects. However, the storage frequency is distinct when observing each of the funnels. When a project is terminated at Technology funnel without an approved technology, the Closing phase is intended to report the knowledge and capabilities developed at the project. At Products funnel it is rare, yet recommended, to write a final report for cancelled projects. Natura also works with children projects. At Natura, learning might happen in two categories: project management (schedule, cost, technical difficulties) and market (expected revenue versus actual revenue, if applicable). Informal learning is also present, with the interpersonal exchange of information.

Mahle finishes every project with the same learning process. Every project, either completed or interrupted, generates a final report, stored in an internal database system for future reference. Interrupted projects' reports contain the complete development history, with details of the difficulties it faced that took it to early termination. As Oxiteno and Natura, the

previous projects are source of information for new projects, along with articles and patents databases. It was also observed the presence of children projects. Mahle shows an interesting dynamic of generating actions for each reported learning with the closed project. These actions may change the company's procedures or create new guidelines to help future developments. Finally, there is the practice of applying patents for the knowledge created in projects, even for those technologies Mahle choses not to implement.

AES is reportedly weak in managerial procedures learning with previous projects. There is no internal database for future consulting, except for the files stored at the server. There is, however, a strong attention paid to technical learning with every finished project. Regardless of the decision to implement or not a developed technology, every project goes through a project closure meeting, which leads to final reports, a closing workshop to communicate the results, and often applied patents. AES, as Mahle, works with strategic IP for protecting technology even if they won't be implemented. Children projects are also very common at AES. See Table 14 for an overview of the learning procedures of the studied companies.

Table 14 – Learning procedures for the studied companies

Company	Final report writing	Formal procedures	Informal procedures	Possible learning
Oxiteno	Stronger for successful and Innovation projects	Design phase research, Children projects	Interpersonal information exchange, personal folders with complete projects' history	Technology, product, market, customer, bibliography and key contacts
Natura	Stronger for successful and big projects	Closing phase at Technology funnel, Children projects	Interpersonal information exchange	Project management and Market
Mahle	Strong for every project	Systematic learning procedures that generates actions, Patents application, Children projects	Interpersonal information exchange	Project management procedures, Technical guidelines for future projects
AES	Strong for successful projects	Project closure meeting, Communication workshop, Patents application, Children projects	Projects manager promotes learning among projects	Technical

6 CONCLUSIONS AND FINAL REMARKS

This research intends to contribute to the understanding of the policies applied to the R&D Project Portfolio of a company. Our fundamental research question was: *How companies deal with projects that become unattractive?* This lead us to investigate the structure, policies and procedures implemented by companies that actually had R&D activities, either internally developed or externally, by means of partnerships and contracts.

We could verify that every objective was achieved; as well as every specific question was addressed. Five main findings emerged from our research: (1) value and Resources criteria are critical for early termination; (2) prioritization plays an important role on early termination; (3) learning is normally weak for early-terminated projects, except for bigger projects; (4) learning comes strongly as technical knowledge; and (5) learning mechanisms aren't different from those used with successful projects. We will follow the research model to illustrate our theoretical conclusions to the theme. See Figure 9 for a summary of our findings.

We'll then summarize the findings and impressions that emerged from the research process in the form of answers to the specific research questions.

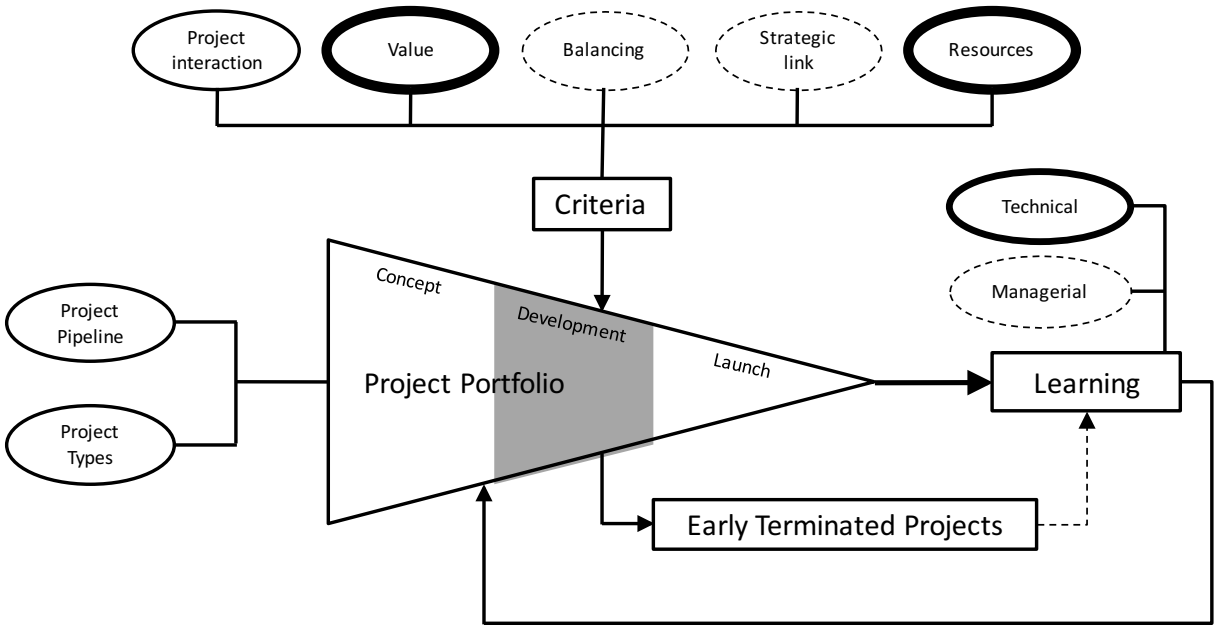

Figure 9. Study model with main findings

Finding #1: Value and Resources criteria are critical for early termination

Differently from the Project Selection phase, in which all of the criteria groups are applied, the decision to prematurely terminate a project is influenced primarily by criteria from Value and Resources groups. This is consistent with what is described by literature.

When observing critical criteria, the factors cited earlier by Balachandra & Raelin (1984, pp. 30) were also observed: technological availability, change in market orientation or size, change in regulation and shortages in raw materials availability or large increase in their prices. An exta critical factor we could observe is compliance, seen at AES. As Balachandra & Raelin (1984) noticed, the presence of these criteria ease the decisions to early terminate an R&D project.

Strategic Link and Balancing are not important for determining early termination of R&D projects. This is explained by the fact that these criteria are already set during project selection. Rarely, a change in initial conditions of preset balancing or strategic planning may trigger termination.

Finally, Project Interaction may be important for early termination when the company decides to have two or more concurrent projects on the portfolio. When one of them wins the competition, the others are killed. However, the main role of this factor is guiding prioritization.

Finding #2: Prioritization plays an important role on early termination

The most common practice is to have clear prioritization criteria. Early termination occurs when the projects are extremely deprioritized. We could observe that termination is an extreme case of deprioritized projects. Even when early termination is part of the company's strategy for R&D projects portfolio management, prioritization plays an important role.

As described by Brenner & Merrill (1994), companies strongly use prioritization in order to improve resource allocations on the portfolio. We observed prioritization after project selection, while projects are being developed. Criteria for prioritization are the same as those observed for early termination. The threshold that changes the decision from "deprioritize" to "terminate" varies depending on the companies' policies.

This can be explained by practical reasons. Decision to early terminate a project is much more difficult to make than to deprioritize a project. Deprioritization is not terminal: the project may be reprioritized again later.

Finding #3: Learning is normally weak for early-terminated projects, except for bigger projects

Companies are not used to learn with its terminated projects. We could observe that companies preferred to report their learning with successful projects. There is, however, some learning from early-terminating more important projects. Importance may be due to cost, resource allocation, time, novelty level or strategy fit. For these projects, companies tend to give more attention after termination, investing more energy at generating reports and investigating the lessons learnt from them.

This can be explained by the assumption that smaller derivative projects have much less potential to achieve important learning than those big breakthrough projects. Companies tend to instinctively know that and force the investment of energy for investigating the project termination and taking some outcome from it. The impact of these projects is also greater, what gives their termination a bigger impact as well.

Finding #4: Learning comes strongly as technical knowledge

Companies tend to learn mainly in technical aspects than managerial aspects. Technical learning may be more natural in these cases, as those interested in the informal learning from the terminated project are normally trying to gather technical information for developing a new project in the same area.

Managerial learning demands extra energy investment from the management in order to happen. A formal and systematic procedure for capturing this type of knowledge is needed and normally not available. Thus, managerial learning is weak when early terminating projects, while technical learning is strong.

Finding #5: Learning mechanisms aren't different from those used with successful projects

When present, the formal procedures used by companies to learn from early-terminated projects are the same as those used for successful projects. Companies tend to use the existing structure for every type of learning that may emerge from any project.

Are the projects killed or (otherwise) they die naturally by lack of resources?

We expected to observe projects that usually die by lack of resources, as they become less and less prioritized. Thus, we expected to find "deprioritization criteria" instead of "termination criteria". This proposition was confirmed. Termination is mostly seen as an extreme case of deprioritization. The criteria in general are used to reduce the priority of a certain project, while allocating resources in more prioritized projects.

We also expected to observe a more rigorous project termination process in some companies, with active project termination as a general rule. Indeed, Mahle, a German company, indeed has policies for active project interruption. The rules are straightforward and clear, as described as best practice by Cooper & Edgett (2012).

We can conclude, then, that projects are deprioritized as a general rule, and eventually killed when deprioritization reaches a threshold variable for each company. There are exceptions, like Mahle, but we can also understand that their threshold for deprioritization is stricter.

What criteria are used to terminate projects during development?

We expected the criteria, either for deprioritization or termination, would be those anticipated by the literature, either for process intensive companies or for product intensive companies. Indeed, what we have found did not reveal any new major criteria for project termination. It is worth, however, noticing that compliance issues are of huge importance at AES. The influence of corruption in innovation was already cited in the literature (Mahagaonkar, 2008), but not as a criterion for termination. It is, however, not widespread over the studied companies.

We also expected a difference on the use of these criteria when comparing companies in different positions on their value chain. B2B companies were expected to strongly link the continuation of their projects to the existence of one or more potential customers that could guarantee a minimum volume bought of the resulting product. B2C companies, on the other hand, were expected to give less importance to this criterion. This difference was observed, however, the research did not show it as relevant.

We found criteria that were described by the literature. However, not every criterion was cited by the literature for influencing early project termination. Some of them were

described as factors for project selection, others as categories of interaction between projects. See Table 10 for a list of criteria found and where they were described earlier.

Table 10 – Criteria described by literature

Criteria	Group	Observed in	Described earlier by
Commercial success	Value	Oxiteno, Natura, Mahle, AES	Balachandra (1996)
Technical success	Value	Oxiteno, Natura, Mahle, AES	Balachandra (1996)
Intellectual property and regulation	Value	Oxiteno	Carbonell-Foulquié et al. (2004)
Company's Mission, Vision and Values	Value	Natura	Carbonell-Foulquié et al. (2004)
Compliance	Value	AES	Mahagaonkar (2008)
Deprioritization	Project interaction	Oxiteno	Brenner & Merrill (1994)
Project Dependence	Project interaction	Natura	Blau & Pekny (2004)
Concurrent projects	Project interaction	Mahle	Maidique & Zirger (1985)
Strategy changes	Strategic link	Mahle	Carbonell-Foulquié et al. (2004)
Top management support	Strategic link	AES	Balachandra & Raelin (1984)
Low Effort vs. Reward	Resources	Oxiteno, Natura	Henriksen & Traynor (1999)
Budget deviance	Resources	Natura, Mahle, AES	Balachandra & Raelin (1984)

How companies learn from terminated projects to improve the overall portfolio performance?

We expected to find generic learning mechanisms, not specific for R&D projects. We expected to observe a higher incidence of individual learning over organizational learning. This is true for three of the four studied companies, except for Mahle, which have a very clear and straightforward process for identifying the lessons learnt in each project and to propose actions based on them. This can guarantee that the company will retain the knowledge in the form of processes and technical guidelines. This is not a new practice for literature, it was already described by Nonaka (1991), as well as Danneels (2002), Maidique & Zirger (1985), Nobeoka & Cusumano (1995, 1997), and earlier by Bell (1984) and Argyris & Schön (1978).

This is, however, a new view on how companies actually apply those techniques. We cannot affirm that the studied companies are immature. They are all well-established companies with revenues of more than US$ 1 billion. Nonetheless, this fact shows that companies are yet setting up their mechanisms of retaining knowledge from their early-terminated projects. As we could see from the literature, there is a strong emphasis in

organizational learning from the company's projects; however, this is the first research (as far as we know) that focuses "failed" projects.

This theme deserves more research in order to deepen the understanding of the procedures of learning when applied to interrupted projects.

Are the criteria and learning procedures different for different types of projects?

We expected to find a grading in the strength of the criteria applied to different types of project: most innovative projects would get more tolerance when the criteria were observed by the managers, while derivative projects would be terminated with very low emotional stress. Balancing category gave us an indication of the strategy that companies use to apply different policies for different project types. Indeed, as a general rule, the more innovative is the project, more tolerant the companies are for applying the criteria. This was observed before by Gonçalves, Mello & Nascimento (2014).

We also expected to find different patterns in learning when companies terminate different types of projects. When terminating low risk and low budget projects, we expected that the company should not worry about learning lessons from the experience. We could verify this tendency. All studied companies confirmed that is more likely to formally learn with big or most innovative projects than with small or derivative projects. When the project is very risky, involved the acquisition of new technology or when it's strategic, the termination procedures are stricter and more likely to be documented for later consulting.

This may be due to the low cost-benefit relation when overthinking projects that could not add competences to the company. On the other extreme, when terminating highly innovative projects, companies do a deep report on the motives, factors and criteria used for the decision to terminate the project. This could be explained by the high potential of learning that these projects may bring to the company.

Research limitations

When dealing with qualitative research, there is always the discussion on whether or not the findings might be generalized. This is due to the biological and mathematical centered view of science. The main questioning is that studies like this lack a large number of subjects, which implies that the sample is not big enough to allow generalization of the findings. The

general understanding is that the conclusions apply solely for the studied subjects. This is not true.

Trough quantitative research it is possible to build statistical generalizations based on correlations. However, it is worth to remember that not every correlation mean causality. Qualitative research like this allows the creation of analytical generalization of the findings. When there is a general understanding and agreement that a certain hypothesis is true, it only takes a single unpredicted case to falsify the assumption. In order to find cases that will falsify the general understanding of a certain theme, the research must try to cover as many different situations and environmental conditions as possible. Alternatively, the description of a single case may be enough if this case could be considered emblematic.

As a multiple case study composed by a base case, one literal replication and two theoretical replications, this study tried to be comprehensive enough to allow analytical generalization of the findings. We could indeed improve the understanding on organizational learning through early-terminated projects. However, the study could not achieve a deep understanding of the matter due to information access limitations.

We could not study individual projects to follow its history from idea selection until termination. We were obliged to trust on the information given by a company's delegate, with all the biases and selectivity they may incur. We were restricted to a single round interview and several rounds of reviews in order to write the case reports. We could not refine the understanding of the procedures and criteria by returning to the company and performing a new interview to deepen the findings.

We could not interview researchers in order to better map the informal routes of learning. We did not have access to scorecards, internal databases, managerial reports or details on the procedures and workflows of each company.

However, we believe that the findings of the present research are valuable for expanding the knowledge on Innovation Management. We could take from the results some important conclusions that will guide future research and even some valuable practical teachings for R&D managers. As always, we need more research on this topic.

Contributions for future research

Our research dealt with the intersection of two well-studied fields and could explore the subject in such a way that new questions emerged. First of all, we believe that there is room for building a closed questionnaire in order to explore the statistical relations between

project types, early termination criteria and learning with early-terminated projects. We therefore suggest that the theme should be studied with a survey methodology. Do the early termination criteria change over novelty axis? Do the mechanisms of learning change for different project types in the innovation scale? It is possible to map these relations and confirm the theoretical assumptions that emerged from this study.

Our research studied companies that implemented their present innovation management procedures 10 years ago or less. What are the difficulties of such implementation? What is the impact of such procedures in terms of overall R&D performance?

One of our studied cases historically has very sophisticated innovation management procedures and policies. Mahle Brazil, formerly Metal Leve, with its innovation process being described in literature since as early as 1981, could be a unique case for studying the maturity of R&D management processes. It could be possible to perform a longitudinal study on the evolution of these processes until the one described at this thesis.

Another question that emerged is the different policies applied to different portfolios at the same company. At Mahle and Natura, for example, there are at least two funnels with different goals. While one funnel is intended to develop new technologies, the other develops projects that give birth to new products. How are the resources divided? How projects are evaluated in each funnel? How the top management deal with unsuccessful projects on both funnels?

Finally, we have studied big companies at this research. It would be valuable to have a view on how start-ups deal with the same problem. It is widely known that many start-ups operate during months and even years before reaching break-even point. How do they choose the projects that should be terminated? How are the learning mechanisms, if any, for these companies? The existence of different (or similar) procedures from what we have described here could be of extreme value for the understanding of R&D projects portfolio management.

Managerial recommendations

As an outcome of this research, we permit ourselves to give some advices and recommendations for practice of R&D projects portfolio management. They are not meant to be seen as rules, but as lessons that emerged from the study of different companies' practice.

The first recommendation is that before setting up a policy for terminating unattractive projects, it is necessary to have very clear criteria for project selection and prioritization. Our

research shown that the companies' main worry is with their productivity. Selection, prioritization and early termination are tools that managers use to achieve this goal. It is mandatory to have clear goals set for R&D operations, aligned with the long term objectives and goals of the company to then build a prioritization methodology, with the right set of criteria and tolerance levels for each research program. Then, decide at which level of deprioritization the company will finally terminate the project.

It also emerged clearly that the main obstacle for early project termination is the fear that project leaders have of ending up with no project at all. This may lead to a behavior of trying to save projects and hide their development problems, causing projects overflow in the pipeline, wasting resources in bad projects and delaying start of newer and better projects. This can be solved with an "idea bank", with projects ready to be started as soon as there are resources. When a bad project is terminated, a new one starts immediately with the released resources.

The third recommendation is to have clear policies applied to each type of project. Breakthrough and Platform projects can't compete in resources with Derivative projects. Moreover, projects with higher level of uncertainties, more expensive or that could take much time to reach market must be supported by a clear long term R&D strategy. It doesn't matter if these projects run in the same funnel as Derivative projects or in their exclusive funnel, the main recommendation is to have clear policies for each group of projects.

The fourth recommendation regards learning. We recommend not spending too much resource investigating the causes of failure of derivative projects. These should be quick and cheap. A summary of the development and a preset reason category for termination is enough for this type of project. It is important, though, to register that the project was cancelled. For breakthrough and platform projects, the potential for learning is high. For these types of projects, we recommend writing a detailed report on the history of development, difficulties and a detailed reasoning of the causes of interruption.

We also recommend the adoption of a practice of generating lessons learnt for every project (successful and unsuccessful), with actions triggered by each lesson. This could be applied for every type of project (even derivative ones), because projects that generate few lessons will take very little time for the procedure. On the other hand, when the project has many lessons to be learnt, the outcomes will be of great value. This practice will formalize the learning that emerge from projects, improving the company's managerial processes and increasing the knowledge base for future projects.

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APPENDIX A – Full Case Oxiteno[1]

Oxiteno is a Brazilian chemical industry that operates B2B in chemical intermediates and specialties since 1973. The company operates mainly in five application markets: Home & Personal Care (HPC), Agrochemicals, Paints & Coatings, Oil & Gas and Performance Products, which is composed by minor markets such as Foods, Civil Construction, Leather, etc. Oxiteno's revenue was US$ 1,4 billion (Ultrapar, 2014) and has about 2.000 employees. Oxiteno invests about 1% of its revenue in R&D and has 10% of its employees dedicated to innovation. As a result, launches about 15 new products every year. In 2013, products launched in the last 5 years accounted for *circa* 10% of its total revenue.

Oxiteno has seven industrial plants in Brazil (three in Camaçari-BA, Mauá-SP, Suzano-SP, Tremembé-SP and Triunfo-RS), one in USA (Pasadena-TX), three in Mexico (Coatzacoalcos-VER, Guadalajara-JAL and San Juan del Río-QUE), one in Uruguay (Montevideo), and one in Venezuela (Santa Rita). The company also has commercial offices in Argentina (Buenos Aires), Belgium (Brussels) and China (Beijing) and a trader in South Africa. Its research centers are located in Brazil (Mauá-SP), Mexico (Guadalajara-JAL) and Venezuela (Santa Rita).

R&D structure at Oxiteno is divided into the five application areas cited above, plus a Technology & Innovation Management that supports the whole structure with a Pilot Plant, a Physical-chemistry laboratory, an Analytical laboratory and staff for Regulatory affairs and Intellectual Property.

Organizational structure

R&D at Oxiteno reports directly to the CEO and is divided into four managements: (1) Technology & Innovation, (2) Agrochemicals, (3) Home & Personal Care and (4) Industrial Markets. Figure 10 illustrates the hierarchy. Each management is explained below:

[1] This case has been further developed after Gonçalves, Camargo Junior & Nascimento (2014) and Gonçalves, Mello & Nascimento (2014).

- Technology & Innovation – Responsible for the Processes Development, Pilot Plant, Analytical laboratory, Physical-chemistry laboratory, Regulatory affairs, Intellectual Property and Project funding (grants, partnerships, etc).
- Agrochemicals – Responsible for the research & development program in Agrochemicals market and for the Agrochemicals application laboratory.
- Home & Personal Care – Responsible for the R&D program in Personal Care and Home Care markets. Responsible for the HPC application laboratory.
- Industrial Markets – Responsible for the R&D program in Oil & Gas, Paints & Coatings and Performance Products markets. Responsible for the application laboratories for Oil & Gas, Performance Products and Paints & Coatings.

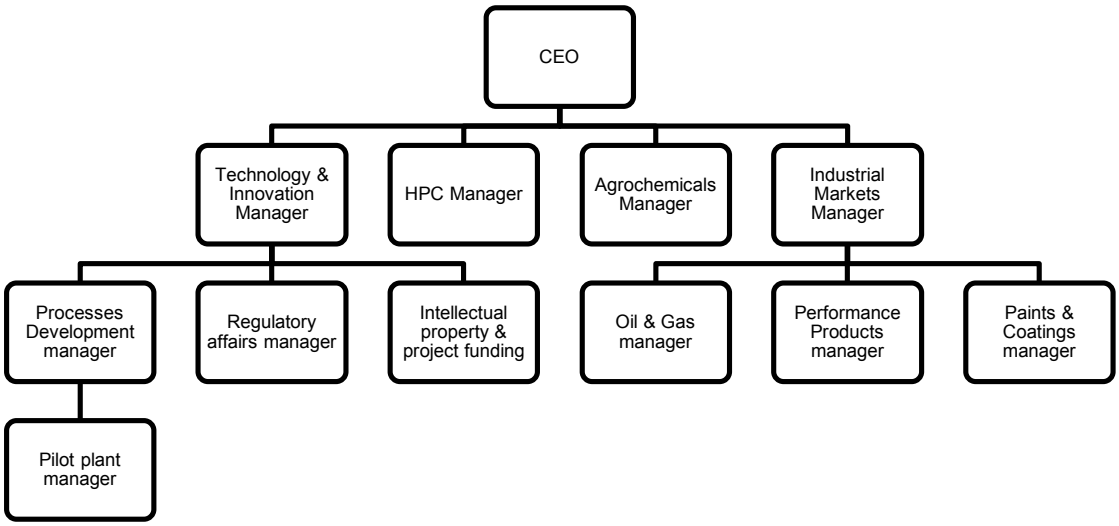

Figure 10. Oxiteno's hierarchy.

Science and Technology Council

In order to help researchers to have a better view of each market segment, Oxiteno has set up a Science and Technology Council (STC), composed by specialists in each area. The meetings happen once every semester and represent an opportunity to discuss ideas and projects, as well as the future technologies that will eventually become relevant for each team.

Project Pipeline

Oxiteno uses a model based on Innovation Funnel (Clark & Wheelwright, 1992) and Stage-Gate® (Cooper, 1996, 1999). Each project passes through six phases during its development. Every project shares the same pipeline, competing in resources against each

other. However, not every project goes trough every phase, as there are cases where specific phases could not make sense.

Figure 11 illustrates Oxiteno's pipeline and its phases. Projects that are still in Design phase are not considered part of the pipeline, as well as those in Follow up phase. Design phase projects are considered ideas for evaluation, while Follow up phase projects are already on market, with no action left for technical development.

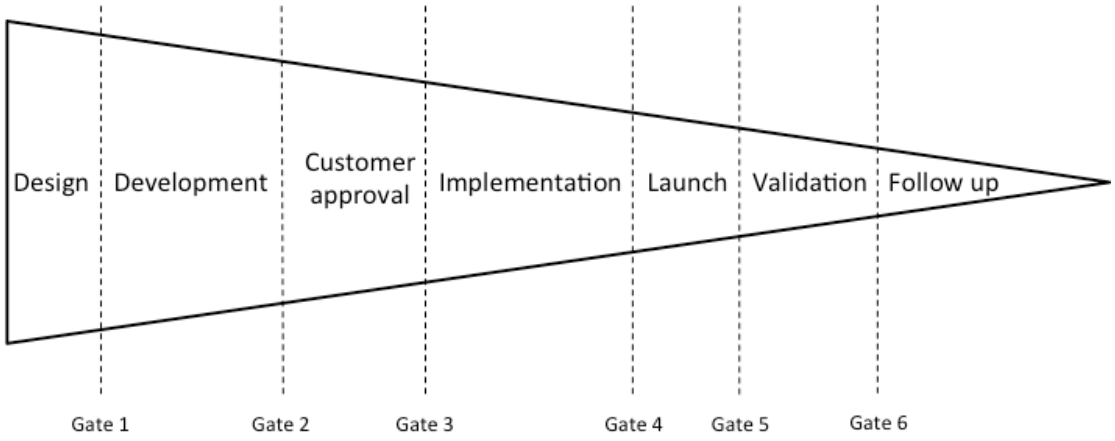

Figure 11. Oxiteno's Project phases and gates.

The process at Oxiteno begins with an idea. Sources for ideas are previous projects, market demands that arise from technical assistance or sales teams, technological trends brought by consultants from STC or by the researchers.

Phase zero, or Project Design, is the project's go/no go decision. At this stage, the quality function deployment (QFD) is prepared, as well as the value proposition and the previous analysis of the project. The phase zero analysis is done by the Strategic Marketing team, with inputs by the researcher that originated the idea. Outcomes from Phase zero analysis are the project's value proposition, initial customer commitment, preliminary intellectual property evaluation and customer or market requirements.

Next is Phase one, or Product Development. This is the longest phase and it is at this stage that the product is obtained (process and application). Here there are regulatory, toxicological and environmental issues, pilot plant test, first draft specification and all information required for defining the product, the manufacturing process and the application. Once the product is developed and a first sample is obtained, project goes to Phase 2.

Phase two, or Customer Approval, has as main objective to get the client's approval, with presentation of the sample, definition of commercial conditions, definition of commercial conditions and all the negotiation involved in the business development.

Upon client's approval of the sample, project goes to Phase three, or Implementation. In this phase several important matters are settled: final approval of suppliers and raw materials, manufacturing plant, creation of official technical documentation and Technology transfer (TT).

Phase four, or Launch, has as key action the launching plan: target customers, communication plan and strategy positioning the new product according to the value proposition.

Phase five, or Validation, consists of a check point to confirm the achievement of customer's needs and expectations, and the feasibility of all aspects of product implementation, manufacturing capability, sources of raw materials, technical documentation and technology.

Finally, Phase six, or Follow up, is when the project's sales are monitored for 3 years. Results of margin and volume will be monitored and compared to the potential of the project, to flag some necessary actions to ensure the project success.

Project types

Six main project types compose Oxiteno's project portfolio: Line Extension, New Sales Development, Application Development, Innovation, Optimization and Tolling. Line Extension, Application Development and Innovation projects result in new products. Optimization projects result in new processes. The Sales team alone develops New Sales and Tolling projects, with little involvement from R&D.

Line Extension projects are those aiming at developing products based in a previously defined specification. Usually, they give birth to products that are new to Oxiteno, but are offered by other companies in market. These projects are usually quick and tend to be less technologically challenging.

New Sales Development make possible to sell products that already exist at Oxiteno's product portfolio, with higher margins, volume etc. These projects may influence the company's demand projection, productive capacity, logistics, regulatory issues, or a new application for an existing product that does not demand technical efforts. Their main objective is to sell shelf products for known applications.

Application Development projects are those in which the client has an application issue and needs a solution. The molecule or blend type to be used is not previously defined and demands technical work for developing the new application. This type of project usually develops a new application for a shelf product.

Innovation projects are those aiming at developing a new product, including results from exploratory developments or market opportunities. This type of project usually creates knowledge for the company, and may be source of a new platform that will give birth to other projects of other types.

Optimization projects are intended to improve processes in order to reduce contaminants or simply reduce costs. These projects must not promote any product changes.

Lastly, Tolling projects are those in which other companies "rent" Oxiteno's infrastructure to process material of their interest.

Project Portfolio Evaluation

Oxiteno has two kinds of portfolios that have different evaluation procedures. The first kind is the Application Projects portfolio. These projects are developed exclusively by the Application research teams and don't need to involve transversal areas from Technology & Innovation Management (TIM) such as Pilot Plant, Processes development, Analytical laboratory or Regulatory Affairs. The second, TIM portfolio, is composed by the projects that involve assets from TIM.

Application Projects Portfolio

Application Projects portfolio evaluation happens during meetings called "Project forums". During these forums, project leaders bring to discussion issues, doubts, achievements and data about their projects. At this moment, projects may change phase, be cancelled or merged, or be deprioritized. Each market segment leader has its own portfolio evaluation rules. However, projects are usually evaluated for a variation of two main aspects: Effort and Potential Financial Return.

Effort is related to the amount of resources the project demands. The company understands as resource expenditure the team and laboratory technicians' hours dedicated to the development. It is not usual to evaluate the material used at the experiments, as this is a resource shared by the R&D Center and has no tracking on which projects it is spent.

Potential Financial Return is the amount Oxiteno expects to sell of the resulting product after the projects' completion. During the development, this value may change according to the project specific client's signaling and the sensitivity of the Sales team. After Phase 4, the value is considered final. Projects that have high expected financial result permit higher effort of the team.

During Projects Forums, specific projects are also debated if needed. If a project is taking much longer than expected due to a technical development issue, or if the project specific client changes his mind about the demand, or even a new information from the Sales or Marketing team that affects negatively a project, the manager, along with the project leader, will try to debottleneck the project. If the changes move the positioning of the project in the Effort x Expected Financial Results matrix, the project is reevaluated and may be terminated.

Technology and Innovation Management (TIM) Portfolio

Projects at TIM portfolio are submitted to a prioritization line according to the familiarity with technology and the potential gross margin. Prioritization methodology is based upon a scorecard that evaluates the two axes and classifies the projects. According to the available work hours from each allocated resource, the projects are prioritized until there is no enough room in the schedule. The non-prioritized projects will be developed if there are any spare work hours after the development of prioritized ones. Leaders may resubmit the projects upon modifications that may improve the project's position on the line.

Prioritization methodology applied to TIM portfolio does not terminate projects at all. This methodology intends to quarterly arrange the projects in a line that permits a better organization of the needed experiments and also to optimize the processes laboratory and pilot plant available hours. This eventually affects the Application portfolio projects, especially those that still don't have a clear expected financial result or are aimed at yet a small market. In order to attend the Application manager's needs and strategy, the Prioritization methodology is flexible enough to allow manual allocation of specific projects. These are called "extra projects".

Project Termination

As said before, TIM projects portfolio is intentionally managed as to not terminate any project. However, the Prioritization methodology implies that the projects that are not on the

top of the line will never be developed if the project leader won't change the main attributes in order to reposition it on the list. As every quarter the TIM planning is updated evaluating every project (old and new), there is a high risk of the deprioritized ones never go trough Processes or Analytical laboratories or Pilot plant. In practice, this leads to the full stoppage of the project.

At Application projects portfolio, termination happens and the decision is taken at Project forums. The rate of termination of projects at Development phase is about 15%, but this number may vary a lot when considering different moments. However, not every non-terminated project is developed with full effort. There is also a dynamic of prioritization on each market segment. The same reasons that lead a project to termination are also taken into account when prioritizing projects. The 85% that remains on the portfolio are organized by its attractiveness (the same effort x expected financial results explained before) in order to elect those projects that will be developed first. The same way as at TIM projects portfolio, projects that are not on the top of the line will never be developed if the conditions stay unchanged.

The dynamic of prioritization as substitute for project termination was observed by Gonçalves, Mello & Nascimento (2014), and also observed in other cases at this dissertation.

There is a general orientation to save projects instead of cancelling them. Cancelling projects during their development is seen as being hard and causes the feeling of wasted resources. It is also a factor the fact that the main methodologies that govern project management at Oxiteno were implemented recently. Project development workplan was implemented in 2011 and prioritization methodology was implemented in 2014. This still causes insecurity among the researchers that are affected by them.

As shown by Cooper & Edgett (2012), having clear go/no go criteria and gatekeepers for each gate is a characteristic of the best performers, whose processes may have high maturity rate.

Criteria for Termination

Termination at Oxiteno is mostly linked to the will of a potential client to buy the resulting product. It is also important the amount of projects terminated because of internal competition with other projects that require the same resources. Minor reasons are technical development issues, intellectual property, and regulatory, industrial or market obstacles. When reviewing the list of cancelled projects, managers couldn't give reasons for terminating about 10% of the projects. We will analyze the main criteria following the study model.

Value

The main criteria observed for this category is Customer withdrawal. This criterion is very similar to "customer commitment", observed by Gonçalves, Mello & Nascimento (2014). It refers to the willingness of the project specific client to buy the resulting product. If the customer withdraws its commitment with the project, it is terminated, as the project is no longer valuable. It is the main reason for terminating, being observed in about 30% of the cancelled projects.

A project may be cancelled due to Market reasons when the company realizes the developing product will not be strong against its competitors. It is usually an issue of currency exchange when trying to reach international markets. However, it could also be linked to a weak performance or to a small projected volume of sales that would not make its production viable. About 10% of the cancelled projects were due to market issues.

A minor number of projects (about 5%) of the projects are terminated because of technical route failure. These projects fail to reach the technical objectives set at the beginning and therefore they are killed.

Regulatory issues are very strong at Oxiteno's markets. However, this is a rare reason for cancelling projects. Only about 5% of the cancelled projects owe its destiny to regulatory obstacles. Usually, projects terminated this way face changes of laws or regulations in target markets and the effort to adapt the scope to the new reality does not worth.

Finally, a project may be interrupted because of intellectual property issues. This is the case when a project potentially will infringe third party's intellectual property in a target market. If there is a risk of running into an existing patent right the project is cancelled. This is also a criterion for a NO GO decision at phase zero, but the search is regularly remade in order to find new material that can harm the company's freedom to operate. Intellectual Property issues reach about 10% of the cancelled projects.

Project Interaction

Interaction at Oxiteno is translated into prioritization. Deprioritization happens when the project's attractiveness is low. As explained before, attractiveness is a function of the effort needed to achieve the project's goals and the expected financial results. When a project

is deprioritized for a long time (that varies according to the market), it is cancelled. This reason terminates about 10% of the projects.

There are also projects that are cancelled due to errors of duplicity in the database. These projects are simply terminated and their development goes on in another project.

Balancing

Tolerance is usually higher in Innovation projects, while is considerably lower in Line Extension projects. This affects the mortality rate at different project types, and contributes to maintain the balancing of the portfolio. When a less innovative project is interrupted, there is a greater chance that there will be other projects to replace it. When an Innovation project is terminated, it is usually harder to replace with new proposals.

Strategic link

There is no evident reason for terminating projects by strategic reasons. The prioritization dynamic set at TIM portfolio is focused in expected revenue and familiarity with the technology, but does not takes into account the company strategy.

Resources

A project at TIM portfolio might be cancelled if it needs too much essays in order to fulfill the client's needs. The resources at this portfolio are shared for every application R&D areas, so the tolerance for rework is very low. The prioritization dynamic also may lead projects to termination if there is no tentative of improving it by the project leader.

The second reason for termination by lack of resources is related to the implementation, when there might be industrial issues. This happens when the project leader realizes a premise taken at the beginning of the project is no longer true. Usually, terminating by industrial reasons means the plant decided not to invest in a determined equipment, or when the project development guides the product to a infrastructure that is not available for the company. Industrial issues terminate about 10% of the projects.

Learning from terminated projects

Oxiteno has an internal database where all the projects are registered and updated in order to stay available for consulting. In this database there should be a comprehensive set of information about the projects' development, such as phase, leader, team, market segment, important dates, reports, etc.

However, it is common to observe projects that are not updated in the system and are terminated without a final report. As said before, about 10% of the cancelled projects don't have a declared reason. The system also has a very limited size, making it difficult to upload detailed reports and other important content related to the projects.[2]

Phase zero bibliographic research

There is a required task at phase zero of every project that demands a complete search on many databases for relevant patents, articles, books and previous projects. This search is usually repeated during the project's lifecycle, and repeated again if the project gives birth to a patent application. It is common to link the new project to one or more previous projects, but this link is usually prior to the search. It is common to observe projects giving birth to other projects (e.g. Innovation projects that originates Application and Line Extension projects), therefore, the link is previously known by the project leader before the search is done.

This search relies also in the everyday contact and information exchange between researchers, being very common to a senior researcher indicate an old project to a newer researcher that is performing the search. Oxiteno has in its research team people with more than 30 years of career inside the company and therefore these people are natural repositories of past experiences and successful and failed projects. This exchange is part of Oxiteno's culture and is encouraged by the top management.

[2] As these are known issues at Oxiteno, during the interviews the company was developing a new internal database to replace the present software. They expect to improve their projects management processes and the projects portfolio management, in order to generate on line reliable KPIs.

What researchers take from previous projects

The interviews indicated that Oxiteno benefits from the experiences and lessons from previous projects, no matter if these projects were successful or cancelled. There is, however, an obvious inclination to remember successful experiences rather than cancelled projects.

Past experiences are usually useful to consolidate the project's scope, sometimes continuing the development of past cancelled projects when they become viable. They can also save resources by providing analysis or application methods, or even by some sort of exploratory tests that has been made before. Finally, the contact with key customers or partners set at previous projects may be useful at the development of new ones. The main outcomes of previous projects at Oxiteno are: technology, product, market, customer, bibliography and key contacts:

a) Technology - Research protocols, important chemical and biochemical routes, information on manufacturing processes and their limitations and possible partners for development.

b) Product - Possible uses, regulatory and toxicological issues, physical and chemical characteristics, product properties, etc.

c) Market - Competitors, market segmentation, possible customers, market size, similar products.

d) Customer – Similar projects for the same customer, needs, analytical methods used by the client, specification deviance tolerance, etc.

e) Bibliography – Patents, articles, books, previous state-of-the-art searches that may be updated, etc.

f) Key contacts – Partners for development, other information on relevant professionals or institutions for the development.

Formal and Informal learning

There are clearly two routes for learning at Oxiteno: the formal route and the informal route. Formal route happens at Phase zero, with its required task of searching for relevant previous projects at Oxiteno's project management system. This route benefits from a network of related previous projects, each potentially contributing to the definition of the project's scope before its development. However, this route has an important obstacle when considering the quality of the information available at the database to be consulted.

The formal route also benefits from the existence of very comprehensive online folders available at the network. Once identified the relevant projects trough the database, the project leader may consult every document available at these folders.

The informal route, on the other hand, is always happening. It happens from Design to Launch. This route benefits from the seniority of the research team: the most experienced the team, the most benefit it will take from previous projects – both successful and unsuccessful.

Another source of informal learning is the consulting of researchers that worked on relevant past projects. Once identified the relevant projects trough formal route, the project leader seeks participants of the previous project to ask for advices on the development. The consulted researchers may also indicate other relevant past projects for consulting.

Learning trough informal route is recognized as being much quicker and more efficient than the formal route, besides from using the same sources of information from formal route.

APPENDIX B – Full Case Natura

Natura is a Brazilian B2C company founded in 1969 that has its primary market in cosmetic industry, more specifically at Home Care and Personal Care (HPC). Its net revenue in 2014 was about US$ 2,8 billion and has about 6.000 employees. The company invests *circa* 3% of its net revenue in Research and Development (ca. US$ 81 million in 2014) and launches approximately 250 new products every year (Horta, 2013; Natura, 2014, 2015).

Natura has as part of its operations eight distribution centers in Brazil, two plants in Brazil (Cajamar-SP and Benevides-PA), and produces in third-party plants in Brazil, Argentina, Mexico and Colombia. In Europe, Asia, North America and Oceania, Natura acts controlling the brand Aesop, besides having a Natura store in France. Natura has two R&D centers in Brazil, located in Cajamar-SP and Benevides-PA, and a knowledge center in Manaus-AM. Additionally, owns an Innovation center in New York-USA (Natura, 2014). Innovation at Natura is divided since 2013 in three R&D strategic drivers: (1) Well-being and relations, (2) Sustainable Technologies and (3) Cosmetic Technologies.

Organizational structure

Natura is organizationally divided in five vice presidencies (VP) and two executive vice presidencies (EVP). The EVPs are vice presidencies that have another vice presidency under its structure. The VPs are Finances, Human Resources, Digital Technologies, New Business and Logistics & Operations. The EVPs are:

- Brands and Business EVP: Responsible for the brands and consumers, for the business units and for the Innovation VP and its structure.
- Networks EVP: Essentially commercial operations and Latin America VP.

The vice presidents are organized in a hierarchy illustrated by Figure 12.

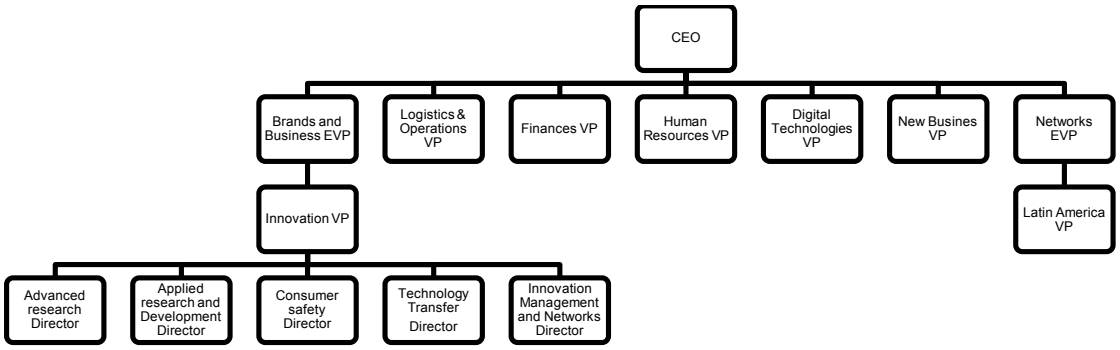

Figure 12. Natura's hierarchy

This structure is accountable for the global R&D management. The technology projects portfolio management is done under the Innovation VP committee. For products projects the management is done under a committee with Brand and Business EVP, Innovation VP, Logistics and Operations VP, Brands and Consumer Director, Applied Research and Development Director, Innovation and Networks Director, BU directors and Financial Manager.

Project pipelines

Innovation at Natura is organized following the Innovation Funnel (Clark & Wheelwright, 1992), as well as the Stage-Gate® methodology (Cooper & Edgett, 2012; Cooper, 1983, 1996, 1999). Projects are developed under two different portfolios: the Technology funnel and the Products funnel.

Technology funnel aims at developing new raw materials, methodologies, formulas, and other processes that may be proposed by suppliers or by Natura itself, when the company judges it has the competences to develop. Products funnel, on the other hand, aims at developing the new products that will be offered to market.

We will study each of the funnels separately on the oncoming sections. We will rely on information from interviews and from Horta (2011), who already made a comprehensive description of Natura’s project pipeline.

Technology funnel

Technology funnel is characterized by its two fixed phases and flexible intermediate phases during development. A Forum composed by the Innovation VP and the Innovation Directors governs the funnel.

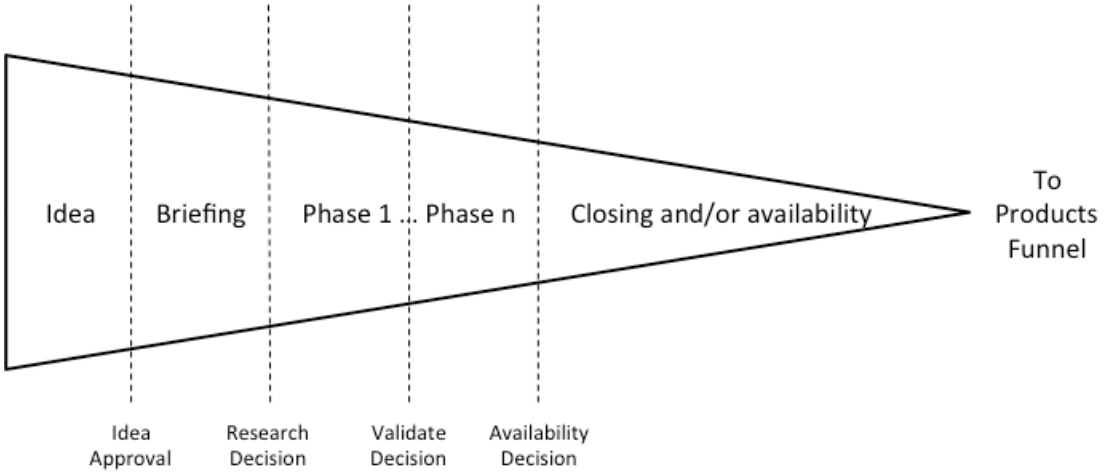

Figure 13. Natura's Technology Funnel

Technology funnel starts at idea phase, where opportunities, bets or market demands are evaluated. During this phase, possibilities of new technologies, new methodologies or knowledge acquisition are discussed.

Briefing phase is dedicated to sharing the objectives and deliveries, building the project scope gathering information and needs from the internal stakeholders, always looking forward to maintain connection with the strategic guidelines.

The intermediate phases vary according to the project type. It will depend on the project's complexity and objectives. This is when the project is actually technically developed.

The closing phase is the delivery stage of the technology to the projects funnel. It foresees the possibility of not having a technology available at the end of the project. This is intended to encourage the submission of projects that aim exclusively at knowledge development. This is also a mechanism of learning from projects that did not have an approved technology (Horta, 2013).

Products funnel

The Products funnel is usually fed by the Technology funnel and projects frequently run in parallel, the Product funnel's project receiving the technology developed on the Technology funnel's project. Products funnel comprises five phases and generates about 250 products per year in average and is governed by a Senior Forum, composed by three VPs (Innovation, Business and Operations) and the Business Directors.

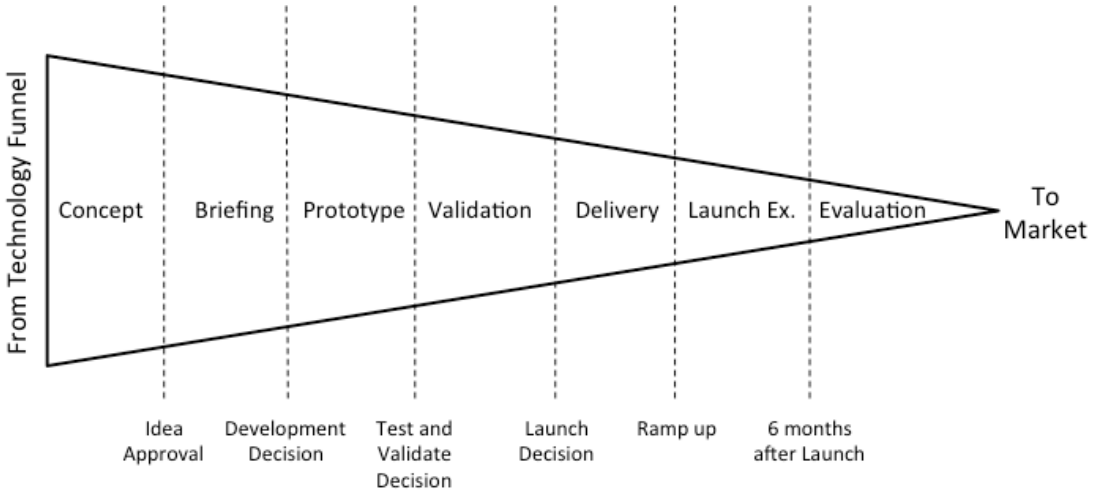

Figure 14. Natura's Product Funnel

The projects start at Concept phase, where the future product's value proposition will be established. During this phase a first version of the business case with the financial assumptions is built, as well as the preliminary schedule and possible risks. These information will be refined at Briefing phase, when the expected revenue is set and the projects are fit into one of the archetypes, according to the innovation degree. Briefing phase will summarize the project's information that will be submitted to approval. After the development decision, the project starts its Prototype phase, where the team will be built project will actually be technically developed.

Prototype phase will define the formula among the preliminary possibilities, the packing and the supply chain. Validation phase intends to carry out safety and performance tests, as well as starting testing in the production. At Delivery phase the Project gives birth to a product that will be launched into Market.

After Delivery, the Project goes into two more phases: Launch Execution, where the ramp up development is done and Evaluation, which happens six months after launch.

Evaluation will check the market performance of the new product and may trigger corrective actions if necessary.

Project types

Natura's R&D projects typology is divided into Technology Projects and Product Projects. For Technology projects, there are four possible types: (1) New raw materials, (2) New field technologies, (3) Ecodesign and (4) New models and methodologies (Horta, 2013).

New raw materials projects usually focus on new processes for obtaining the raw material (i.e. extraction), search for renewable sources for material or biotechnology. New field technologies projects are aimed at bioagriculture, agroforest systems, sustainable handling and certifications. Ecodesign intend to develop projects involving biomimetics, biomaterials, recycling and urban chains (Horta, 2013)

For Product projects, the applied taxonomy is internally called "projects archetypes". The projects are plotted in a matrix complexity x potential, which will position each project in its archetype. The potential is composed by tangible and intangible factors that are valued in a scorecard. We did not have access to the scorecard itself, kept as confidential by the company. However, we could get a qualitative idea of what is analyzed in each factor.

The intangible factors at the time of the interviews are: environmental impact, impact over Natura brand and perception of value by the potential consumers. These factors are especially important when the Forum tries to transform the Natura's Mission, Vision and Values into actual products on the market. The tangible factor is the expected revenue, which is roughly set during Concept phase and improved during Briefing phase. Natura is reviewing these factors and they may change in a near future.

The archetypes are: (1) Network animation, (2) Core business and (3) Radical bets, similar to those described by Clark & Wheelwright (1992). Network animation projects are those with the least innovation degree. They intend to bring quick financial return and take little time to development. They are the majority in number of Natura's portfolio.

Core business projects are those that intend to renew brands or product categories from Natura's products portfolio. They are characterized by a high level of resource investment together with a relatively quick financial results. They take longer to develop than Network animation.

The Radical bets projects are those with the higher risk and high return. However, these projects take much longer to develop. They usually give birth to new products with high market impact.

Project Portfolio Evaluation

Each funnel has its own approval forums that govern the portfolio. Technology funnel is evaluated at Executive Technology Office (ETO) and at ETO Program. These two forums have different seniority levels and keep different gates along the funnel.

There is an ETO for each Director: Science & Technology, Product Development, Innovation Management, and Partnerships. A Pipeline Secretary also takes part at the meeting. The managers also take part at this forum, which keeps the Briefing and Closing/Availability gates.

The ETO Program takes part when there is a specific research program on course. The Technology Development Program manager and scientific managers of related areas compose it. This forum keeps the gates for the Idea and intermediary phases.

There is a third forum, the Scientific Office, which evaluates technically every projects with the greatest technology risks. However, the forum does not keep any gate during the process.

The Projects funnel also has two approval forums: the Products Committee (PC) and the Innovation Committee (IC). As the Technology funnel forums, these two also have different seniority levels and keep different gates along the process.

Brands & Business EVP, Innovation VP, Operations & Logistics VP, Product Development Director, Brand & Consumer Director, Management & Innovation Networks Director and the Finances Manager compose the Product Committee. Senior Managers for the technical areas may be invited depending on the project that the Business area will present. The pipeline management secretary is also in this forum, which meets every two weeks in order to evaluate the projects portfolio (Horta, 2013). This forum holds the Briefing and Prototype and Validation gates for projects with higher impact, and the evaluation phase.

The Innovation Committee is composed by the Business Unit (BU) leader and by the group of managers that supports it. This forum holds pre-briefing and delivery gates for projects with higher impact and every gate for projects with lower impact.

The forums evaluate the portfolio by its budget and by comparing it to the goals set at the year's strategic planning. To do so, a connection grid is built to verify the projects that are

not connected to one of the goals (translated into the company's products portfolio), aiming at realigning the projects to the grid by means of an action plan.

Six factors are analyzed during the evaluation: (1) Expected Revenue, (2) Schedule deviance, (3) Strategy Buckets' Budget, (4) Project specific budget (5) Human Resources Allocation, and (6) Archetypes distribution (balancing).

Expected revenue

The expected revenue (ER) is set during the project development. Achievement of the ER depends on the product activation and gets its full potential on launch, as a characteristic of direct sales, the main channel Natura uses to operate on final markets. Also as a characteristic of direct sales, it is necessary to limit the promised number to the maximum potential of the product during the year cycle. The commercial team performs this control.

Schedule deviance

When analyzing schedule deviance, there are three possibilities of delayed projects. It is interesting to note that the interaction with projects on Technology funnel is an important issue analyzed at this moment: (1) Product project delay, (2) Technology project delay and (3) Product project and Technology project delay.

For each delayed project, the impact on the Expected Launch Date is evaluated. If the impact is substantial and makes it impossible to launch the product on the expected date, the project is selected for a close review.

Strategy Bucket Budget

Each of the Business Directors is responsible for a Strategy Bucket, each with its specific year budget according to the company's strategic planning. When evaluating the portfolio, buckets with too many projects or, on the other extreme, with resources to spare, are taken for closer examination.

Project specific Budget

For Budget analysis, the tolerance varies depending on the company's performance. There is no preset trigger to terminate a project by this criterion.

Human Resources Restriction

When analyzing Human Resources, the Forum tries to avoid the over assignment of researchers, however the company recognizes that there are great opportunities to improve in its governance. According to the interviewee, it is common to find researchers and other involved personnel with more projects than they can optimally develop.

Archetypes distribution (balancing)

Finally, Natura also evaluates the amount of projects of each archetype in order to keep it balanced with short and long-range projects.

Project termination

Project termination at Natura is made at the Forums. However, according to the interviewee, termination is rare on the company. Approval Forums, as the name proposes, spend great amount of attention on approving projects and less time evaluating ongoing projects and recent launches. This finding was anticipated by Nascimento (2013), who observed that literature gives plenty attention to project selection processes.

Termination is substituted at Natura by a dynamic of prioritization. Projects that demand attention by some of the portfolio evaluation criteria previously cited are at first required to propose a renewed action plan aiming at realigning the project. If the plan doesn't get the expected results, the project is deprioritized, and takes time to finally be closed. This was previously observed by Gonçalves, Mello & Nascimento (2014) in a Brazilian chemical company.

The main reason to not terminate projects was explained by the interviewee as being part of the yet recent portfolio management policy, implemented in mid 2013. This is consistent with the findings of Cooper & Edgett (2012), who shown that the best performers

in portfolio management among their sample have clear criteria for go/no go decisions during project reviews. This may be a characteristic of more mature companies.

Another given reason is that no manager wants to get the "onus" of terminating a project, which may cause psychological consequences to the project team. This matter was studied by Shepherd et al. (2014) and Warnecke (2013), and is not in the scope of the present research. Once more, this may be a characteristic of immature companies.

Criteria for termination

Despite rare, termination at Natura actually happens. The criteria used by managers to kill projects will follow the study model previously presented.

Project interaction

As described at "Project portfolio evaluation" section, when there are deviations in schedule in projects that relate to each other, the affected projects are termination candidates.

A change in the project's scope may also make it become irrelevant when compared to its pairs on the portfolio.

Value

Value for Natura is understood as the intangible factors present at the connection grid. It is widely known that the Mission, Vision and Values are hugely important for Natura's business. A project that threatens these statements is a clear candidate for termination.

Another understanding of Value is the revenue each project may bring once the product reaches the market. If the forecast presented does not satisfy the minimum profitability needs, the project, again, is a termination candidate.

Balancing

As part of the Innovation culture of Natura, it is much easier to terminate an incremental project than a radical project. The criteria here exposed acts stronger on projects of the *Network animation* archetype. Hence, the tolerance is higher on projects of *Radical bets*

archetype. However, risk is not a factor deeply examined when deciding which project will be terminated when considering two projects from the same archetype.

Strategic link

Strategy buckets are the mirrored image of the company's strategic planning. A shift on the scope or amount of resources provided to each bucket may cause a mass termination of projects. This situation, however, may ease the psychological consequences of termination over the projects' teams. As this is an even more rare situation, we need more data to affirm this hypothesis.

Resources

Human and financial resources constraints are natural rules for project termination. At Natura a shift on the availability of resources (either by having too many projects on the pipeline or by a constraint in the year budget) can mean death for those projects that meet other termination criteria. More than a criterion for termination, Resources can be understood as a trigger for termination. The threshold, however, is variable and strongly depends on the company's overall performance and *momentum*.

When a deprioritized project becomes a "zombie" (a project that still consumes resources but is no longer at the top priorities for time allocation by the team), a time-to-market analysis denounces it. In this case, the decision to terminate is obvious and less emotionally stressful.

Learning from terminated projects

When a project at the Technology funnel ends without an approved technology, its learning and knowledge are formally recorded at the Closing phase. The same happens to those projects that aim mainly at developing new knowledge and capabilities (Horta, 2013). Natura formally recognizes that every project, even those that were cancelled, bring new knowledge and capabilities. Those that achieve the objectives go into Products funnel. The others have their learning collected for future use.

On Products funnel, when a project is successfully finished and the product reaches market, it is common for researchers to elaborate a report and make it available for general

consulting in a specific area on Natura's intranet. This report teaches the most important lessons the project team learned during development and, however not mandatory, most successful projects are documented this way.

During Delivery phase, researchers elaborate a technical monograph that supports communication of the acquired knowledge to other project's teams that need this information. This report is commonly made when closing bigger projects. The learning achieved with each project is divided into two categories: (1) project management learning, which involves aspects such as schedule, cost and technical difficulties; and (2) market learning, which involves aspects like the difference between expected and real revenue.

Nevertheless, the same is not applied to early-terminated projects. The interviewee reported that few closed projects give birth to a report. Moreover, the internal project management processes don't have this activity as mandatory. For successfully terminated projects, though, writing a final report is recommended.

This fact was also observed by Gonçalves, Camargo Junior & Nascimento (2014). Just like the authors' findings, Natura's processes for formal learning with interrupted projects are scarce, yet present at the Technology funnel, while informal learning is more common.

APPENDIX C – Full Case Mahle

Mahle is a German B2B company that operates in automotive parts industry since 1920. It is organized in four business units: (1) Engine systems and components, (2) Filtration and Engine Peripherals, (3) Thermal Management and (4) Aftermarket. Mahle is one of the top global suppliers for the automotive industry. The company has more than 150 production units in four continents and more than 66 thousand employees. Its revenue in 2014 was about US$ 12 million, 52% of which in Europe. North America bears 22,8% of the sales, while South America contributes with 6,8%. Asia/Pacific is responsible for 17,9% and Africa for 0,5% (Mahle, 2015).

Mahle has ten research & development centers, located in Americas (São Paulo and Detroit), Asia (Shanghai, Tokyo and Pune) and Europe (Stuttgart and Northampton), with over 4,5 thousand engineers and technicians. Yearly, from 3% to 5% of its income is invested into new products development. Mahle launches about 60 products globally every year, and an average of 6 per year in Brazil. About 25% of Mahle's revenue comes new products. Mahle also measures its R&D success by the rate of developed technologies that are being sold in a regular basis, with a formal supply contract. This rate in 2015 is 75%.

We studied the Brazilian R&D Center, located in Jundiaí, São Paulo, responsible for the Engine systems and components business unit. This unit bears a comprehensive R&D structure, with application and analytical laboratories, such as chemical analysis laboratories, a center for modeling and simulation, electronics and instrumentation laboratory, metrology center, a processes and surface engineering laboratory, and engine test laboratories.

Organizational structure

Mahle's R&D structure in Brazil is oriented by development activities and by market. Product Engineering and Material Sciences teams are oriented by development activities, with teams dedicated to each support activity for new product development. The other three teams are organized according to each attended market: Power Cell Unit – Heavy Duty (PCU HD), which is dedicated to develop the power cell (composed by piston, piston pin, piston rings, and cylinder liner) for big engines for trucks and buses, for example; Power Cell Unit – Low Volume (PCU LV), composed by the same structure of de PCU HD area, but is dedicated to low volume engines, and Valve System Technology, dedicated to developing intake and exhaust valves for engines. Figure 15 illustrates the structure.

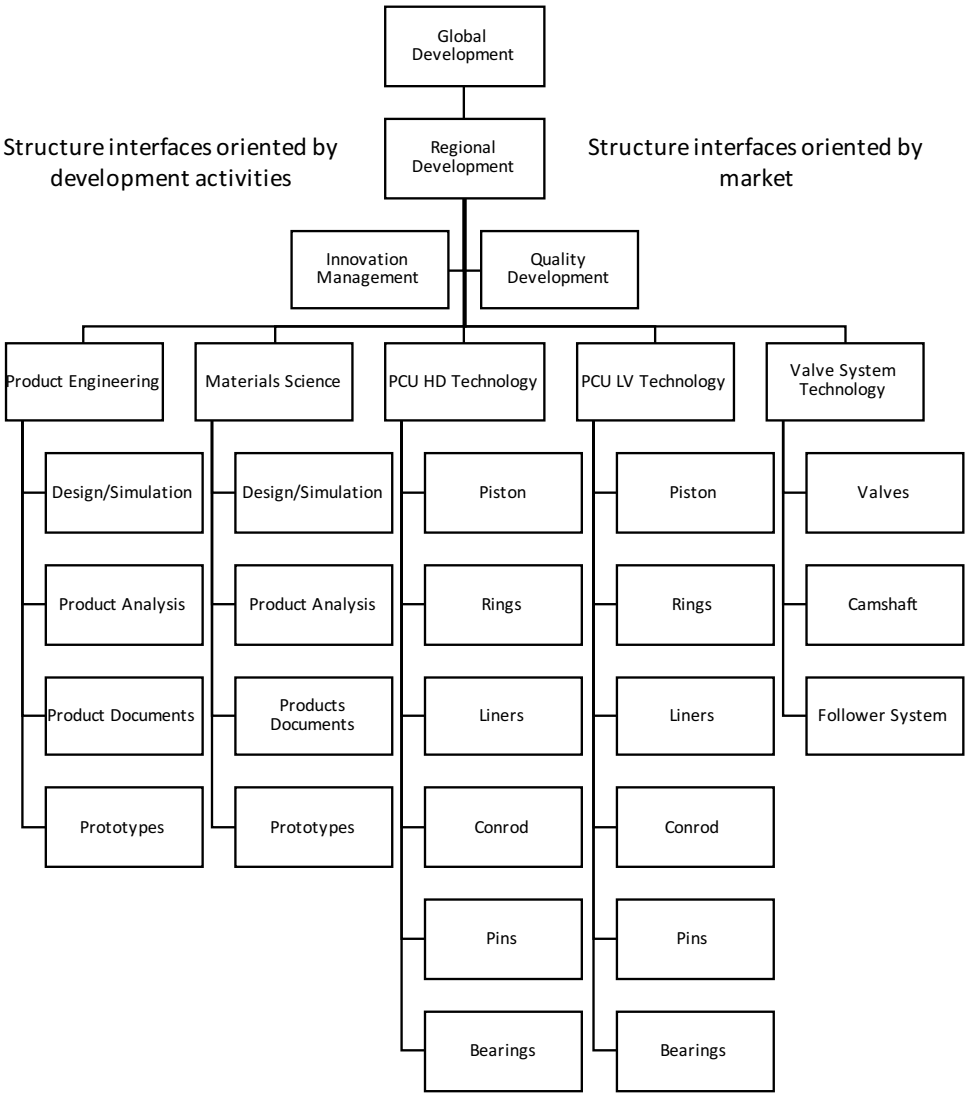

Figure 15. Mahle's organizational structure in Brazil.

However being located in Brazil, this structure coordinates researches globally in the Engine systems and components business unit. It is also responsible to manage globally the Piston Rings and Liners product families.

Project Pipeline

Mahle divides its new product development process in two distinct moments: (1) the pre-development process and (2) the product development, mostly done in partnership with (or under demand of) clients. The company has a pipeline composed by six funnels, as described by Clark & Wheelwright (1992), each divided in phases according to the Stage-Gate® (Cooper, 1983, 1996, 1999) model. Pre-development at Mahle is aimed at developing

technology that is new to the world. This is a strategy that drives every research center at the company, regardless of the business unit. Figure 16 illustrates the funnels and the relationship between them.

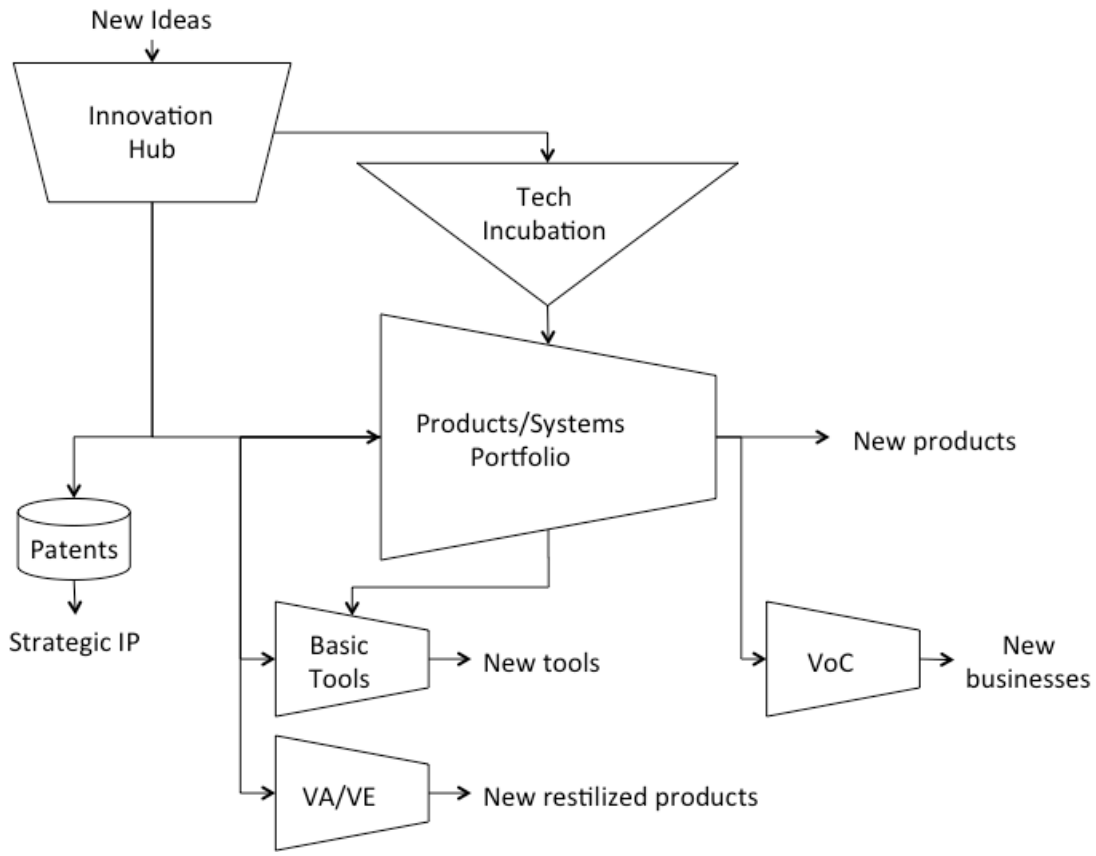

Figure 16. Mahle's funnels and relationship between them.

Ideas are generated either internally, by the company's researchers based on their knowledge of the market needs and technological trends, or externally, by means of inputs by clients. At Innovation Hub, the best ideas will be selected for investment and, depending on the level of maturity of this idea, it will go trough the pre-development process or straight to the product development funnel.

If the idea is interesting but yet immature, it will go trough the Tech Incubation funnel. At this funnel, the idea will be developed in order to generate a business case. The business case describes the idea's potential, strengths and weaknesses and the potential markets. Once the idea is related to a business case, it will become a project at Products/Systems funnel.

The Products/Systems funnel is the main source of new products at Mahle. Projects at this funnel usually are developed in partnership with clients with specific needs that can be attended by the technologies developed at Tech Incubation funnel. There is a

Products/Systems funnel for each product line, so that they don't compete for resources. This is the most common way, from idea to tech incubation to product launch and then to the market.

There are also three auxiliary funnels that help keeping the dynamic of development of new products. The Basic Tools funnel is intended to develop techniques and tools to improve measurement precision in specific tests that support new product development. These tools and techniques help, for example, isolating small performance improvements from the deviance of the test itself.

VA/VE (Value Added/Value Engineered) funnel is where projects of small changes in current products are developed. Usually, projects at this funnel generate new designs and minor new attributes that require a validation from market. Projects that impact only internally at Mahle are not developed in this funnel, as they are seen as continuous improvements at the production plants.

Finally, the VoC (Voice of Customer) funnel is dedicated to demonstrate new technologies to market. After the development of new technologies, there is the need of finding a client to begin development of new products. Usually, technologies already have related clients. However, when this is not true there is the need to prospect clients by demonstrating the new technology for them.

At any funnel, there is the possibility of protecting technology by patents. The patents are applied when Mahle notices any kind of technological risk, even when the project is not selected for development.

Each funnel is divided in phases, following the Stage-Gate® model by Cooper (1999, 1983, 1996). For each funnel, there is a certain number of stages for development. The full scale Stage-Gate is applied to Products/Systems funnel. The phases are illustrated at Figure 17.

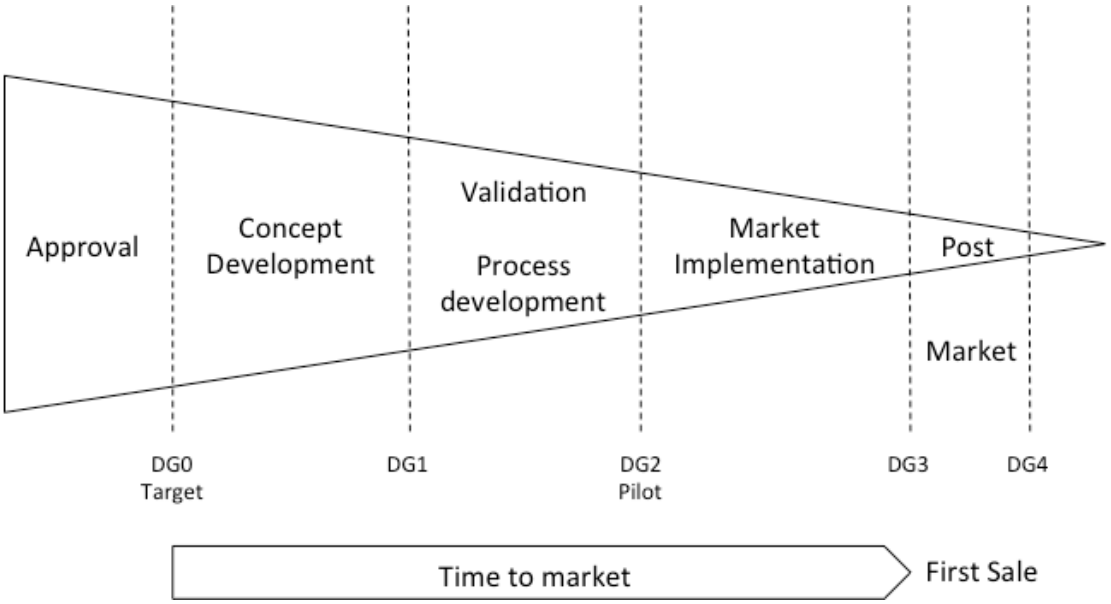

Figure 17. Mahle's projects phases. DG: Decision Gate.

First phase, Approval, is dedicated to the project preparation. The value proposition is made at this phase, as well as its programming for its deliverables. At Decision Gate zero (DG 0), the project has its first go/no go decision, and after this gate the development is started.

Second phase, Concept Development, is when the potential of the project is verified. Also, the team deepens the project's specification for materials, alloys, design, geometry, etc. This phase is dedicated to fine tuning the project's concept and to the first resistance tests.

The next two phases happen in parallel. The processes team starts working at developing a production process in order to validate the possibility of launching the product at Processes phase. The intention is not to have the process implemented, but to be able to generate prototypes to the interested clients. Validation phase is aimed at replicating the prototype performance in a longer test and to verify other characteristics that weren't focused during the development. The engine is validated as it would be by the client.

After DG 2, the technology is internally launched to Mahle community, while the first pilot with a client begins its development. At this phase the project reaches Market and the Industrialization begins. The pilot developed with a client is important to leverage the investments in industrialization. At this point Mahle publishes articles, participates in fairs and roadshows, until there is the final launch of the new product after DG 3, when the Sales team undertakes to finally make the first sale.

There are some adaptations when the project is developed in other funnels. Tech Incubation funnel is comprised only by the Concept development phase because after this phase the project goes straight to Products/Systems funnel. Basic Tools funnel is complete,

but the outcome is not a sold product, but a new tool or method being used at the laboratory. VoC funnel is composed only by the Demonstration phase, and VA/VE funnel is identical to the Products/Systems funnel, as the main outcome is basically of the same kind.

Project types

Apart from the six different funnels, Mahle also organizes its projects by types according to the level of novelty. There is also a second classification that flags strategic projects. We will describe these two classifications at this section.

From the Novelty level perspective, there are three types: (1) Me-too projects, which intend to fill technological gaps, or to develop products that are offered by competitors but not by Mahle; (2) Incremental projects, which are normally an evolution of an existent technology at the company; and (3) Innovative projects, which are aimed at developing projects that are not only new to Mahle, but also perceived as new by the clients.

The second axis used by Mahle to classify its projects it the strategic link. Of the universe of 250 projects being globally developed, the company elects the most important 10% to be followed by the global board of directors. For these projects, the follow up meetings are more frequent and a group of directors is involved.

Project Portfolio Evaluation

Evaluation at Mahle happens at the Portfolio Review Meetings (PRM). These meetings happen every one or two months, depending on the product family and the volume of projects at the portfolio. Every big decision regarding projects must be validated at this forum. The managers for each product family are members of the PRMs.

Portfolio at Mahle is evaluated under two axes of attractiveness: technical and commercial. The evaluation is always a comparison between the project's contract, with the targets for development, schedule and budget, and the actual results. Moreover, the project team brings to evaluation its impressions and a proposal of next steps. The evaluation group at PRM, then, decides if the proposal is adequate or tries to challenge it in order to find better options to the case.

Mahle implemented the current innovation processes by 2005. At start, it was very difficult to evaluate projects, as the researchers would always try to bring new ideas and ways to save projects from termination. There was a lack of impartiality during these evaluations.

The management, then, noticed that this difficulty was due to the project leader's fear of losing the project and end up with no project at all. To solve this issue, Mahle worked to maintain a pipeline of projects in such a way that, when a project leader loses a project by interruption, he is immediately allocated to a new one. There is always a list of projects ready to start as soon as there are available resources.

Project Termination

We will focus our attention at Tech Incubation and Products/Systems funnels, as they're the most important portfolios at the company. The other funnels will be variations of the policies applied to these two portfolios.

Each funnel has different tolerance for terminating projects. Mortality rates at Tech Incubation funnel are much higher than at Products/Systems funnel. About 60% of the projects at Tech Incubation are terminated before reaching Products/Systems, while about 25% of the projects at Products/Systems are interrupted before launch.

Criteria for Termination

We will organize the criterion for termination in the categories presented by the study model.

Value

At Tech Incubation, the main value is technical. When a project can't reach its technical expectations, the project is terminated. At Projects/Systems funnel, this criterion rarely motivates project termination.

The second criterion for these projects is the final cost for the clients. If the relation between cost and performance is not satisfactory, the project is interrupted. However, the cost perspective at Tech Incubation funnel is not precise as the projects are still in a very immature stage of development. At Products/Systems funnel, the cost criterion is stronger. At this funnel, projects are able to evaluate the production process; therefore, the relation between cost and performance is more reliable. Hence, this is the main criterion for terminating projects at this funnel.

When evaluating different project types, Innovative projects are seen with much higher tolerance than Me-too projects. Deviances in the value (either technology or cost) are much more lethal for less innovative projects.

Project Interaction

There is a third criterion to interrupt projects before launch that is due to competing projects. Depending on the urgency of a specific demand, Mahle creates parallel projects to develop different routes. When a project overcomes the others in terms of technical performance and cost, the superseded projects are terminated and its resources are allocated to the lasting one. This dynamics is very common at Tech Incubation.

Balancing

Mahle balances its portfolio by product family. The first perspective is to check whether the company has enough projects to attend all chosen market demands. Then, the balancing is done over the novelty level axis. There is a recommended balancing of 30% of the portfolio composed by Innovative projects, 50% Incremental projects and 20% Me-too projects.

Actions to modify the balancing are only taken if the deviance between reality and the recommendation is huge. Top management does the balancing evaluation, but in the last years the balancing has usually followed the recommended shares. Balancing is not an important criterion to interrupt projects at Mahle.

Strategic link

Mahle revises its strategic planning yearly, involving in this process the R&D, Operations and the Sales teams. The Sales team brings to this review the main tendencies on engine technology. Some demands may rise from the perception of common problems that the automakers are facing. From this perception, solving a high level issue may make a group of lower level projects become unnecessary.

The other way strategy may terminate projects is when a certain demand observed at one year loses importance in the next strategic planning. If the importance lowers at a certain level, the projects linked to this demand may be interrupted as well.

Resources

Individual project budget has a very low importance on termination. Once a year the company builds its economic plan dividing the R&D budget in buckets, one for each portfolio. Each bucket coordinator must contract projects that will maximize the results of the budget. In the last years, Mahle has had more resources than projects to develop. In the case of a project termination, the unused resources are returned to the bucket in order to feed other projects.

The possibility of a project spend more than it was designated is common. However, the budget is released to the project stage by stage to the project. If the project has spent more than previously allocated or if the leader reports the need of an increased budget for the next stage, the coordinator will evaluate the case and decide whether to conceive the increase or interrupt the project.

Normally, projects that exceed the resources are not terminated. This is a case where the most common policy is to deprioritize and slow down the development.

Learning from terminated projects

Mahle deals with terminated projects with the same policies it applies to successfully concluded projects. For every project there is a technical report, which is cataloged and stored in a database for future reference, and a set of lessons learnt. The technical report tells the complete history of the project. Terminated projects will relate the difficulties it faced during development and the motives the team had at the time of the termination decision. This may lead to a new project in the future that could continue the development where the previous stopped.

Basically, the technical report tries to review every characteristic of the product that was under development, such as geometry and materials. Then, identifies the main limitations that the project faced during its development stage, for example, poor fatigue resistance or geometry of low productivity. The report has the main objective of summarizing what has been learnt of that product under development. The researchers that are planning to propose a project with similar characteristics will later consult this report, allowing them to take advantage of the technical knowledge registered.

The report if one of the three main sources of information researchers use in their previous search when defining the scope of a project. The other two are publications and patents.

The lessons learnt may be of managerial or technical nature. Managerial lessons are on how to manage the projects or the portfolio, and technical lessons deal with difficulties that weren't anticipated before the start of the project. Mahle then organizes these lessons in a table relating them to the original projects and to actions. These actions are used to internalize and systematize the lessons learnt in the form of project management processes creation or optimization, or technical guidelines creation to help future developments.

This procedure is believed to guarantee that Mahle is learning with its terminated projects, with the lessons not being restricted to the project team itself. The project team, supported by the Project Management Office, registers the lessons learnt with each project and defines the actions. If the lessons were anticipated by previous projects, they are reinforced, otherwise, they are registered and give birth to the actions previously cited.

There is also an alternative path of learning from interrupted projects that is protecting the concept with patents, even if the company will not use the knowledge immediately. This procedure guarantees that competitors that could develop the same concepts will not menace Mahle. And also keeps open the possibility of exploring this technology in the future, when the parameters of the technology make the project interesting. This path can be viewed at Figure X as "Strategic IP".

APPENDIX D – Full Case AES

AES (which stands for Applied Energy Services) is a United States company focused in producing and distributing energy since 1981. AES operates in both B2B and B2C. In 2014, the company had revenue of USD 17 billion in 18 countries. This amount is distributed 24% in USA, 23% at Andes, 13% in Brazil, 19% in Mexico, Central America and Caribbean, 19% in Europe and 2% in Asia. AES has over 18,5 thousand employees globally (AEScorp, 2015).

In Brazil, AES owns formerly state-owned companies of services and energy generation and distribution. AES generates electric energy through AES Tietê and AES Uruguaiana, representing 2,5% of the country's total energy generation capacity. Distribution is made by AES Eletropaulo and AES Sul, covering 14,3% of the total energy distributed in Brazil. AES also provides technical services through AES Serviços.

AES Brazil serves 8 million of homes, generating 7,8 thousand GWh and distributing 5,6 thousand GWh. The company has 9 hydroelectric plants, 3 small hydroelectric centrals, and 8,7 thousand employees. Together, AES companies in Brazil had revenue of more than USD 5 billion in 2014.

Regulation in Brazil compels energy companies to invest 0,4% of their Net Operational Income in Research and Development activities. AES decided to have a structure where R&D is done in order to bring more value to the company and its operations. The areas AES decided to invest are:

- Alternative sources for electric energy generation;
- Thermoelectric generation;
- Bays and reservoirs management;
- Environment;
- Security;
- Energetic efficiency;
- Electric systems planning;
- Electric systems operations;
- Supervision, control and protection of electric energy systems;
- Quality and trust of electric energy services;
- Metering, billing and control of commercial losses; and
- Other related themes.

Research and Development at AES is not focused in launching new products, but in delivering new technologies for the improvement of its processes of generation and distribution of energy. AES develops and deliver an average of 10 projects every year.

Organizational structure

AES created in 2014 the position of the Innovation Director, in order to better invest the resources applied to research and development and to get better results from them. Innovation Director is under the Business & Distribution Vice President. This was made in order to try to capture more value from the proximity of Business and R&D. Figure 18 shows AES' organizational structure, with a detailed view on the structure under Innovation Director.

Figure 18. AES' organizational structure.

Project Pipeline

AES divides its project in three stages, following the teachings of Cooper (1983, 1996). Figure 19 shows the stages. Proposal stage is focused in evaluating financial, regulatory and anteriority attributes of the idea. While regulatory and anteriority issues are evaluated by a Subcomitee composed by managers, coordinators and analysts from different companies from AES Brazil group, financial aspects are evaluated by a Committee composed by the Directors and Vice Presidents.

The second stage, Execution, is dedicated to development of the idea, which now is already an ongoing project. At this stage, the contract with the executor institution is made. The executors are always an University or a Research Institute, and possibly suppliers or other energy companies that may be interested in the outcomes of the project.

The third and last stage is called Closing and begins as soon as the executor delivers the project results. It is the phase where all the documentation of the project will be reviewed, the technical success will be evaluated, and the implementation decision will be made based on the financial return that the new technology will deliver to the company.

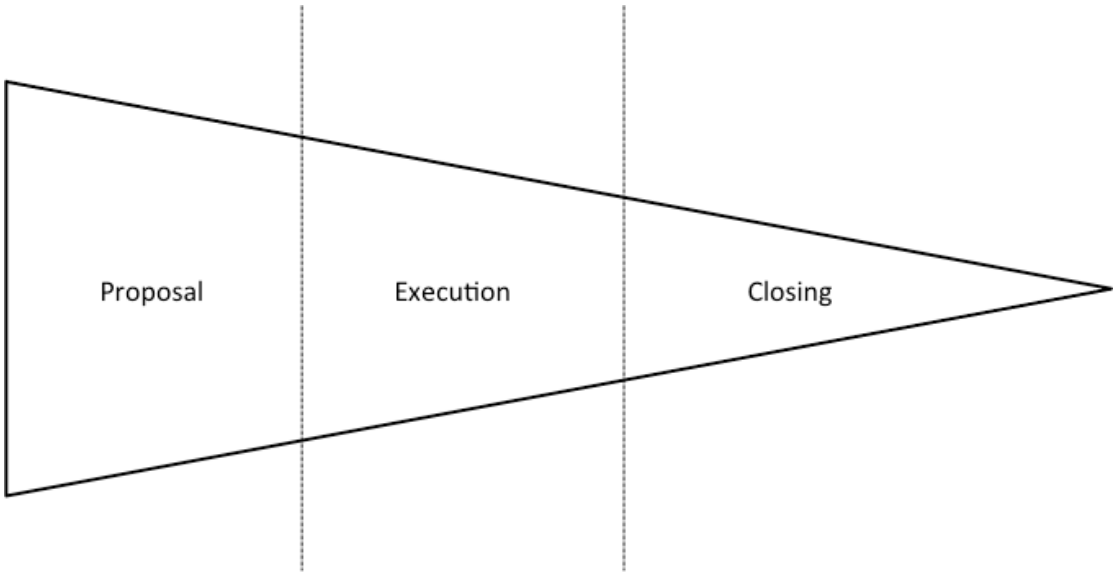

Figure 19. AES' project phases.

It is important to note that AES never develops R&D projects internally. All projects are contracted from one or more third parties that will do the actual development of the projects. At the end, AES will not produce or sell the resulting products, will instead license the technology to a supplier that will provide the new product to AES. This is done because of the agreement AES has with the Brazilian government that rules the privatization of the Country's energy companies. AES can't produce equipment itself, it must be bought from other companies.

Project types

AES categorizes its projects in three different systems, depending on the aspect the management needs to evaluate. The first categorization is according to the outcome of the projects. Under this point of view, AES develops three types of projects: Software,

Methodologies and Equipment. There is no difference in the policies between the three types, as they serve only for information. There is also no official division between more or less innovative projects; however, it exists when evaluating the portfolio. This is the second categorization the company uses.

Projects are managerially divided in two categories depending on the time it will demand to develop and reach market. They are: (1) incremental projects and (2) disruptive projects. Incremental projects are developed in very little time, and the results are obtained in short term. Disruptive projects are those that take longer term to develop.

AES also categorizes projects by their position in the innovation chain. It all starts with a Basic Research project, which can evolve after development into an Applied Research project. Once the application has been developed, it may give birth to an Experimental Development, which, in turn, will become a Series Head project. After completion, the technology goes to Pioneer batch, and finally reaches market in Market Insertion, where it will be finally produced and implemented. See figure 20 for a scheme.

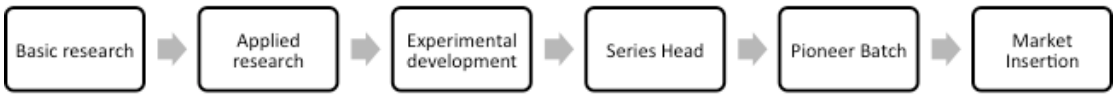

Figure 20. Maturity levels for AES' projects portfolio.

Basic research projects are rare at the portfolio, as they are characterized by high risk and taking a long time to achieve results. They are focused in prospective studies for potential new technologies that may be useful for AES in the future. Applied research projects will take these new technologies and find applications for energy generation and distribution. This level of maturity generates a first prototype. Once the application is found, Experimental development projects will evaluate the use of these applications at the company's operations.

Series Head projects are intended to generate an industrial prototype of the new technology, always in partnership with a potential supplier. Then, a first batch of production is made during Pioneer batch project. This will check the feasibility of production and implementation. Finally, Market Insertion will license the new technology to a supplier that will stock the new technology to one or more of AES's companies.

These categories, however, don't avoid projects to compete against each other for resources. There are no separate portfolios for each one of them. The management doesn't

treat them separately; it is merely a matter of classification and communication. Hence, all projects compete for the same resources.

Project Portfolio Evaluation

Projects in the portfolio are evaluated every two months, when the General Project Meeting gathers the executors, the project leader and the projects manager to discuss each project separately. The meeting evaluates the following points:

- *Potential patents* - The meeting evaluates the decision to apply a patent, eventual strategy for patenting results and the value of the potential patents.
- *Scope changes* – Every scope change is debated at the meeting, always evaluating whether the project is yet attractive or not after the change.
- *Financial review* – There is a discussion of all the financial numbers of the project, such as budget deviations, market value, etc. The same criteria and accuracy applied at the Proposal stage are applied at this meeting. AES is very resistant to change financial schedule.
- *Schedule deviation* – Impacts of scope changes on time schedule are also debated.
- *Communication strategy* – How the project leader will communicate the project development and results. If there is not an efficient communication plan the project is in serious risk of not being implemented.

In a portfolio perspective, the projects manager is accountable for stimulating the learning interaction between the projects. The manager is responsible to take lessons learnt from one project to another, capabilities developed in a project that can be useful to another, etc. This interaction is expected in order to optimize the investments made in the portfolio.

The project manager, because of the accumulated knowledge of the history of the projects, is usually very valuable to AES, and is kept for a long time in the position.

Project Termination

Termination happens at AES based on the same criteria applied to projects portfolio evaluation. There is a great concern on compliance and regulation, but other issues such as technical development or lack of internal resources are also important.

It is however rare to a project be interrupted during execution phase. As the project funnel is short in phases and the projects are always developed in partnerships, AES would rather complete the project and archive its results (instead of generating new projects until reach market implementation).

Project early termination also was reported to cause conflicts with partners and suppliers, while the potential impact of the released financial resources to develop other projects is not great.

Criteria for Termination

We will discuss the criteria based on the research model categories.

Value

Issues observed during evaluation are: new income generation, potential to absorb investment costs (capex), avoid or reduce costs. Project is normally not terminated, it reaches closing phase, but eventually will not give birth to a new project to reach market.

This category also includes the verification whether the project is achieving the technical goals set at the contract or not. Finally, there is a strong attention paid to compliance in AES' projects. At the minor suspicion of corruption or other deviances, the project is immediately cancelled.

Project interaction

As discussed before, Project manager is accountable for promoting project interaction in order to improve portfolio value. However, AES usually don't terminate projects because of other projects' influence.

Balancing

There is no optimal balancing for the portfolio, but projects that are closer to Market Implementation have more strength to complete than the projects that are closer to Basic Research. Again, there is no record of project termination due to balancing at AES.

Strategic link

Projects selected for development are always sponsored by an area manager and linked to an existing issue that can be addressed. A change in the management usually don't terminate projects, but might trigger a full portfolio review, in which process the project manager should defend the portfolio before the new leaders. However, when there is a top down order to terminate a project, regardless of the reason, it is terminated.

Resources

Projects compete for resources in the portfolio, however, deviance in the project budget, for example, is not a serious reason for terminating. It is usually easy to allocate more budget to a project when needed, however the company is resistant for changes in the financial numbers. AES expresses the desire to implement a policy of actually terminating projects when such deviances happen.

Learning from terminated projects

AES Brazil claims that is not common to learn managerial lessons with its errors and previous projects. One of the reported reasons is that the rate of changes in the leadership is very high, with a change in the board of directors every eight months. When such a change happens, there is a great amount of consequences, such as strategy changes, new processes and planning changes. This fact leads the company to an unlearning process, instead of learning. It avoids the accumulation of knowledge on the experiences of the present strategy by causing a rupture on the continuity of operations and a need to re-learn in the new scenario. As reported by the interviewee, this constant rupture in the portfolio's direction and strategy does not let the company learn with its history.

However, is was also revealed that the General Project Meeting is a very important tool to learn technically with the development of the projects and to provide knowledge and competences to other projects in the portfolio. AES also has in its team people that are considered knowledge leaders in their areas. This group is responsible for prospecting knowledge in congresses and other scientific events, as well as reporting and publishing knowledge created in the boundaries of AES' R&D projects.

There is also an orientation to protect the knowledge created at AES by applying patents, which contributes to review the new technologies developed at the company's projects, even if they are not selected for implementation. As non-implemented technologies are akin to interrupted projects, we can take this process as a way of learning with new technologies developed at AES that have their growth interrupted before reaching market.

The project team is also reported to learn a great amount during development. It is common to have project managers studying for Masters or Doctorate in order to better conduct the strategic research programs. Finally, as the projects are always developed in partnerships with universities or research institutes, there is always knowledge being absorbed by the individuals involved.

Every terminated project, either successful or unsuccessful, is evaluated at a formal project closure meeting. This meeting intends to gather all information from the project and organizes it for communication. For every project that reaches its end (either by successful conclusion or early termination) there is a closing workshop for communication of the results, development procedures, difficulties and learning. Even the projects terminated by compliance issues are subject of this workshop.

Nevertheless, there is no structured database for keeping this type of information for future consulting. There is also no formal assessment of the lessons learnt that will generate actions of improvements in the company's processes. Therefore, there is no formal learning when a project is closed. It was reported that people are the main source of previous information on what was communicated at these workshops. The company loses knowledge every time an employee leaves.