Expect the Unexpected: An Exploratory Study on the Conditions and Factors Driving the Resilience of Infrastructure Projects

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Abstract

This study originates from the recognition that project management research is replete with normative theories on what need projects to be successful. However, it has performed worse with respect to assisting the understanding of how and why similar projects do not have similar performances during their life-cycles.

It claims that the poor performance of major infrastructure projects, acknowledged by cost overruns and scheduling delays, is due to their lack of resilience when confronted with critical events that are inherent in their life-cycle.

Therefore, it addresses the overarching question: *How do projects cope with the critical events that occur at some point in their life-cycle?* And *why and how are some troubled projects able to maintain positive adjustments (cope successfully) while others cannot?*

By addressing these questions, the first goal of this study is to reveal the “resilience enablers”. These are factors and conditions enabling the successful coping process (maintaining performance after the critical event) in projects confronted with unexpected events. The second goal is to translate the new knowledge of “resilience enablers” into recommendations for practitioners to enable them to actually make use of the insight into a troubled project’s behavior. To study these questions, a qualitative research design was developed. It is articulated on the exploratory case study of one of the most important infrastructure project of this century. The result consists of two sets of findings, both relate to the critical events’ managements and the factors and conditions that enabled the project’s resilience.

This thesis contributes to project management research with a middle range theory. The project performance can be seen and explained from a new and original perspective of project resilience. It also contributes to the project’s management practice with recommendations aiming to help project actors to 1) identify and assess the resilience of their project organization, along with the identification and management of the risks. And to 2) maintain project system performance after the critical event through continuous adoption of risk–focused, and protection-focused strategies, which imply uncostly measures that enable project resilience.

Key words: infrastructure project, critical events management, project life-cycle, project resilience, performance, project system

Résumé

Cette recherche part du constat d'une littérature scientifique relativement riche, en gestion de grands projets d'infrastructure, concernant les conditions préalables à réunir pour assurer leur mise en œuvre, mais qui ne traite que rarement des causes de leur échec. Il paraît, en effet, légitime de chercher à comprendre pourquoi des projets de même nature évoluent différemment au cours de leur cycle de vie et ne parviennent pas au même niveau de performance. La réflexion engagée ici, concernant cette nature de projet, repose sur l'hypothèse que les déconvenues observées et mesurables par des dépassements de crédits et des retards dans la planification, sont dues, pour l'essentiel, à leur incapacité à s'adapter à des événements critiques survenant au cours de leur cycle de vie.

Les objectifs de ce travail visent, en premier lieu, à apprécier comment réagissent les responsables de tels projets face à des événements perturbateurs et, ensuite, à comprendre pourquoi certains projets en difficulté parviennent quand même à leur terme, alors que d'autres échouent.

La démarche sous-jacente passe en conséquence par la recherche et l'analyse des éléments «facilitateurs» de la résilience ou, en d'autres termes, des facteurs et des conditions permettant la mise en place d'un processus d'adaptation et de réajustement des projets confrontés à des événements fortuits. La seconde étape consiste à traduire les connaissances théoriques et pratiques récentes en la matière en recommandations destinées aux praticiens engagés dans la conduite de projets particulièrement risqués.

Les résultats de la recherche débouchent sur deux catégories d'enseignements relatifs à la gestion des événements critiques et à la mise en œuvre des facilitateurs de la résilience de projet. L'originalité de ce travail se manifeste ainsi par une approche nouvelle, celle de la résilience, appliquée aux grands projets d'infrastructure où des dépassements de budget-temps et budget-coût sont fréquents. Elle se distingue des approches traditionnelles, où l'anticipation d'événements perturbateurs est le plus souvent négligée ou ignorée, par une démarche permettant d'identifier et promouvoir la résilience du projet d'infrastructure.

Mots clés: grand projet d'infrastructure, comportement de projet en difficulté, événements critiques, cycle de vie, la résilience, structure, systématicité

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1 INTRODUCTION

One of the fundamental questions in the field of project management is how projects should be initiated, planned, executed, controlled and closed[1] in order to be completed in the given constraints of time, costs and quality. Different streams of the Project Management Body of Knowledge addressed the question from their own perspectives, which led to a wide range of tools aiming to ensure the project performance; for example the ones derived from "control and planning" or "risk and uncertainty management" theories. There is also abundant research on "critical success and failure factors in projects" which provides both academics and practitioners with recommendations on how to structure and manage projects in order to avoid failure.

However, reality shows, and influential surveys[2] and studies[3] confirm that the rate of projects that fail to meet their objectives in terms of time and costs has not improved over the past century; in spite of big developments of project management theory and practice.

In this context, the question "why do the projects fail" is still relevant, inciting both researchers and practitioners to search for new answers.

This thesis originated from this question and is concerned with the development of project performance. However, along with the process of reviewing previous research, two new questions arose and became central to this study.

1.1 Research questions and objectives of this study

The objectives and questions emerged from the recognition that project management research is replete with normative theories on what a project needs to be successful. However has

performed worse with respect to assisting in the understanding of project behaviour and its performance in the face of unexpected events.

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[1] Projects, says the PMI, have five distinct phases: initiation; planning; execution; control; and closure

[2] E.g. Standish Group – in a study conducted in 2004, for IT projects found that average cost overrun was 43 percent, 71 percent of projects were over budget, over time, and under scope

[3] A very comprehensive study of cost overrun by Flybjerg et all, (2002) found that 9 out of 10 projects had overruns, and overruns of 50 to 100 percent were common; the fact is recurrent in each of 20 nations and five continents covered by the study; also overrun had been constant for the 70 years for which data were available.

Therefore the main research question addressed in this study is:

How do the projects cope with the inherent critical events that occur at some point in their life cycle?

Then a second question, which could be derived from the first one, is:

Why and how do some troubled projects maintain a positive adjustment after a critical event while others do not?

In this study the critical event, which is understood as an unexpected event, has a major impact on the potential survival of the project and its objectives.

By addressing these issues, *our first objective* is *to gain insight into the troubled project behaviour in order to uncover the conditions and factors enabling the successful coping process, which in other words is the resilient response after the critical event.* Further, gaining insight into the behaviour of troubled projects is seen as a first step in creating the premises for improving the project's performance.

The next objective is to translate these insights into recommendations for practitioners in order to enable them to actually make use of the new knowledge.

Therefore, the main contribution of this dissertation is an increased understanding of the phenomenon of "troubled project behaviour" and of those conditions and factors (resilience enablers), which account for their positive adjustment (maintained performance) in the confrontation with critical events inherent in their life cycle. This will ideally provide the base for a midrange theory which extends/completes current project management theories on critical factors for project success and failure.

From a practical approach, the second objective of this study is *to offer the project management professionals a new perspective, enabling them to assess the project performance when it is confronted with critical events. As well as give recommendations on how to structure the project in order to confer resilience to its system.*

1.2 Outline of the study

In order to achieve the research objectives stated above, the following methodology was adopted. The first phase is dedicated to the "status quo" analysis of the problems, causes and cures associated with the cost overruns and scheduling delays. The aim of this analysis is to situate and ground the research topic and highlight its relevance for both theory and practice. Taking into account the topic complexity, the research perimeter is established in the beginning of the analysis.

The “status quo” overview revealed the fact that the problem of cost overruns and scheduling delays in the development and implementation of infrastructure projects is a reality of today. This is reoccurring in spite of the continuous development of project management and practice.

Looking at the causes that account for this situation suggests that these projects exhibit “life cycle path dependency” in the sense that they are vulnerable in the face of critical events. These critical events are defined as unexpected events, inherent in their life cycle, which have a potential impact on the project’s viability and its objectives. In practice, in the most common situations, project actors (owners, managers, etc.) rely on risk management processes and will deal with the risk in event consequences by creating contingencies (Airbus, M2 Lausanne). Trying to achieve savings through these contingencies, they hope that they will compensate the over runs (NRLA), or implement learned lessons from similar projects (e.g. in construction projects).

In order to assess how the theory of project management addresses the problem of project performance, the next phase of this study was to review the literature on critical success and failure factors. This section is concerned with the study of conditions and factors to be accomplished in order to develop and implement successful[4] projects. The literature review highlighted the relative lack of empirical studies, focusing on the study of project behavior when it is confronted with critical events. Also there is a lack of relevant theories on how the critical factors change during the project life cycle and their role in maintaining the performance in the aftermath of a critical event. It revealed as well, that traditional project management literature does not specifically define the project resilience and is not specifically assigned to a list of critical success and failure factors found in this literature.

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[4] Although the definition of project success might be controversial it is common to assess that a successful project is the one that achieves its objectives under the given resources’ constraints of time, costs, quality (Lundin & Söderholm 1995, Turner 2006)

Taking into account the importance of this phenomenon with the lack of viable theory and empirical research to explain it, the next logical step was, as suggested by Van de Ven (2007), “to create, elaborate and justify a theory through induction” using an exploratory research design articulated on a single case study.

Following the aforementioned lines, “any emergent theory should put emphasis on developing constructs, measures and testable theoretical propositions” as said by in Eisenhard (1989) and Eisenhardt & Graebner (2007). This research will propose an accommodation of the construct of resilience in a list of critical success and failure factors, as well as the conceptualization of troubled project behavior from the resilience perspective. Taken from empirical findings, the hypothesis will be developed about the factors and conditions (resilience enablers) that are believed to be accountable for the positive adjustments (sustainable performance) of a project system when confronted with critical events.

The last chapter of the dissertation, is dedicated to “problem solving” (in line with Van de Ven 2007), and then discuss conclusions about the research problem with the implications of the study for theory and practice, limitations and future research.

The methodology described above is depicted in the following diagram. This diagram suggests that research phases are not only connected through an input/output mechanism but also through an “iteration and fit” process aimed to ensure the coherence and consistence of this study.

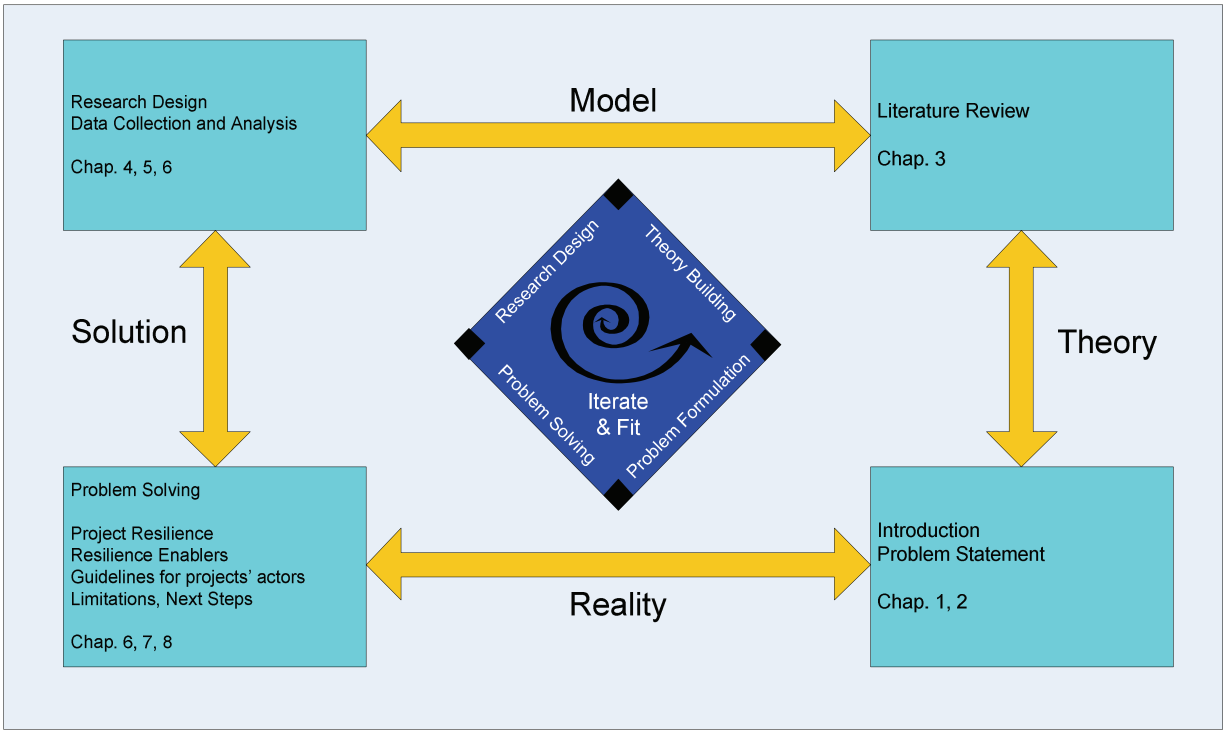

Figure 1-1: Outline of the thesis[5]

The next chapter will further develop the introduction above and is intended to situate, ground, and infer the research problem.

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[5] Adapted from the Engaged Scholarship Diamond Model, Van de Ven, 2007

2 PROBLEM FORMULATION

> *"The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill." (Albert Einstein quoted in Getzels & Csikszentminhalyi, 1975)*

Infrastructure projects[6] are often defined as 1) large-scale investments which cost more than US$1 billion and attract considerable public attention because of substantial impacts on communities, environment, and budgets (Flyvberg et al, 2003). Or 2) as initiatives that are physical, expensive, and public, as proposed by Altshuler & Luberoff (2003). Infrastructure projects include air, road, and railway infrastructures but also power and wastewater plants, dams, oil and natural gas extraction as well as IT infrastructure projects.

As both definitions suggest these major projects are central to the public world because they are meant to enhance the economic growth and social development. However, what the definition does not state is the calamitous historical record of costs and time overruns[7] in their development and implementation as illustrated in the article below; extracted from the Economist at the time when this research started.

> *"WHEN George Stephenson built a railway from Liverpool to Manchester in the 1820s, it cost 45% more than budget and was subject to several delays as it made its way across the treacherous Chat Moss bog. In the intervening 180 years the management of large-scale projects seems to have improved but little. At the end of May the reconstruction of Wembley Stadium, the hallowed home of English soccer, was threatened when Multiplex, the Australian developer of the site, admitted that it faced mounting losses on the GBP750m ($1.4 billion) project. An unanticipated rise in the cost of steel (which doubled in 2004) and the extra labor required to ensure the building is ready for next May's FA Cup Final were said to have thrown the management's calculations out of kilter.*

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[6] Infrastructure projects definition is treated in chapter 2

[7] Cost overrun is defined as excess of actual cost over budget.

> ……………………………………..
>
> *Big projects today are as likely to be built on software as they are on steel. But IT projects are no better at meeting budgets and deadlines.*
>
> *The Standish Group, a research firm which produces an influential annual evaluation of IT projects, judged that in 2004 only 29% of such projects "succeeded", down from 34% in 2002. Cost over-runs averaged 56% of original budgets, and projects on average took 84% more time than originally scheduled.*
>
> *(OVERDUE AND OVER BUDGET, OVER AND OVER AGAIN, the Economist, Jun 9th, 2005)"*

This article witnesses a reality that cannot be denied. The problem of cost overruns and delays is common and recurrent in all types of projects. In project management literature, these facts are documented for *various infrastructure samples,* in studies of Hall (1980), Kain (1990), NijKamp & Ubbels (1999), Bruzelius et.al. (1998), Skamaris & Flyvbjerg (1997), belonging to both *public* and *private* sectors (Major Project Association Study (1994); Morris and Hough, 1987).

Along the same lines, a recent study by Flyvbjerg *et al.,* (2003) examines how common and large cost escalations are in *transport* infrastructure development. This suggests *that this phenomenon is global*, exists across 20 nations in 5 continents of the 258 projects studied. Which is *perennial* since the overwhelming statistical significance proves that cost estimates have not improved and cost escalation has not decreased over the past 70 years for all types of studied infrastructure. The overruns are significant and reach 45% in rail (38 examples), 34% in tunnels and bridges (62 examples) and 20% in roads (30 examples).

Although, this study focused on transport infrastructures, comparative research by Altshuler & Luberoff (2003), Flyvbjerg *et al,* 2002 cited in Flyvbjerg, 2007, shows that the problems identified for transportation apply to a wide range of projects including power plants, aerospace, dams, information technology systems, sport arenas, and museums.

In this context, practitioners and researchers legitimately ask why the performance of projects has not improved in spite of continuous development in project management science and practice; and why the available tools and practices cannot guarantee that projects will be achieved within committed costs and timetables.

In practice, there is often the explanation that poor performance in major projects is that from the beginning promoters *ignore* or *underestimate risks*, sometimes due to *optimism bias* with forecasters (psychological explanations) and *strategic misrepresentation* of scope and/or budgets (political-economic explanations), as asserted by Flyvberg et al. 2003. Project management theoreticians suggest that the poor performance of projects is due to the fact that project management is saturated by 'hard' theories. These theories emphasize the planning and control dimensions of a project that are anchored in a system of engineering methods and related tools. Such tools are the Gant charts, critical path methods and resource leveling heuristic models (Morris 1998, Smith & Morris 2007, Pollack 2007). One of the solutions proposed is to dedicate more efforts in "soft" aspects research, such as people, social processes, and other "soft" factors which emphasize the contextual relevance rather than the objectivity and have a direct impact on project performance (Söderlund 2004, Cicmil et al. 2006, Söderlund 2007).

A common denominator is the idea that projects are more complex[8] today than in the past and the traditional techniques of project planning and risk management, although form the basic and necessary foundation for good project management, are insufficient in order to deal effectively with today's dynamic, risky, and changing projects (Eskerod, 1996; Payne 1995; Shenhar, 2009).

Indeed, the project management basics foresaw that at the project inception, the actors shall attempt to plan for all variables in advance. To be effective, they spend time on project preparation – conducting surveys, analysing data, checking on key-learning from comparable experiences, benchmarking, and so on. Their findings are confirmed by strategists and project designers which then lead to a detailed, multi-year project plan that is meant to be carried out in the given time and budget constraints (PMBOK Guide 2004: 6-8). Yet even though lots of energy and resources are spent on project preparation and design, in a long run project, the probability of having unexpected events is high (Eden et al, 2000). This is particularly true for infrastructure projects that are developed and implemented in modern society, which is characterized by three salient features: interdependency, complexity, and rapid, radical change

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[8] Complexity is one of the intrinsic characteristics of major infrastructure projects explained in detail in the paragraph 2.2.1.

(Nicholas, 2001, p.9). When unexpected events occur, they generate disruptions and delays (Eden et al. 2000, Eden et al. 2005), which threaten the project's objectives, even its survival, and will prevent the delivery of the expected social and economic benefits for which the infrastructure was intended (Anguera 2006; Bruzelius et al. 1998; Grimsey & Lewis, 2004; Flyvbjerg 2005; Flyvbjerg 2007 (a), (b)).

2.1 A changing scope in improving the project performance

A classical approach in project management is to deal with the unexpected events to ensure the project's performance[9] and to rely on risk & uncertainty management processes (Nicholas 2001, p. 306-324; PMBOK 2004, p: 237-264, Cooke-Davis, 2004; Chapman & Ward 2003 p: 5-15; Ward 2005, p: 72-105; Turner 1999, p.233-255). These processes are continuously improved and reinforced through findings on "lessons learned" and "critical success and failure factors". These findings are typically acquired through postmortem analysis of major projects that encountered distresses or even failures at some point in their life-cycle (e.g., Sutterfield et al. 2006; Dvir et al., 2006; Eden et. al. 2000; Graham 2000; Pinto & Mantel, 1990).

However, the experience of companies with highly developed risk management practices (EDAS – Airbus A380 project; Boeing - 787 Dreamliner; NRLA) suggests that traditional, well-established risk management techniques are insufficient to deal effectively with today's dynamic, risky, and changing projects in which the "knock-on" unexpected events become part of the project life-cycle (Eden et. al., 2000; Dvir *et al.* 1998, Shenhar 2001, Shenhar 2009).

This research acknowledges the idea that in the long run a project will probably have unexpected events' threatening the project objectives or survival (e.g.Williams 2005). These events are accountable for costs and delays, with embarrassing consequences for project

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[9] Performance is traditionally assessed against the extent to which the objectives set at the project outline are accomplished under the given resources constraints in terms of costs, delays and quality (e.g. Baccarini, 1999; White & Fortune, 2002; Nicholas 2001, p: 10).

actors and delayed benefits for the economy and society (Morris & Hough 1987; Eden et. al.2005; Flyvbjerg 2007). Unlike other studies which look at the cause of failures or try to identify all possible risks, in order to propose specific counteractions (lessons learned, critical success factors, improved risk management process), this research suggests looking into the "troubled project behavior"[10] in order to identify factors and conditions which enable a positive change after the critical event. Adjustments which could be translated into the fact that the performance is maintained during the project life cycle.

As traditionally thought the capacity of entities to maintain positive adjustments, or recover and bounce back when they are confronted with adverse conditions which are threatening their goals or positive outcomes is associated with the concept of *resilience* (e.g. Gordon 1978[11], Flach 1997[12], Freeman *et al*. 2004[13]). We suggest using this perspective in order to evaluate the project system's response and its behavior in the face of adverse, unexpected events. Indeed, project management research currently lacks a theoretical framework for understanding "how the projects cope with the inherent critical events that occur at some point in their life cycle", "how can a project maintain a positive adjustment or adapt after a critical event", and "can project resilience be invoked, created, or designed?"

This research direction was encouraged by similar management studies with promising results in the context of *permanent* organizations[14]. They dedicate *attention to the applicability of the resilience concept in order to explain sustainable performance and adaptability* of some companies evolving in *adverse conditions,* such as high competitive environments (e.g., March 1991; Suttclife &Vogus ,2003; Egeland, Carlson & Strofe, 1993; Wildavsky 1988p.:120), Sitkin 1992; Levinthal and March (1981, 1993), Teece, Pisano, and Shuen 1997; Weick, Sutcliffe, and Obstfeld 1999; Eisenhardt and Martin 2000; Wildavsky; Porras & Silvers 1991) and organizations confronted with *shocks* such as terrorist attacks (Freeman,

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[10] Troubled project behavior relates to the project system response to an unexpected, critical event likely to threat its objectives or even survival

[11] In material science

[12] In socio-psychological studies

[13] In management studies

[14] Project are by definition temporary organizations; the full explanation is provided in paragraph 2.3.1.

2004). Resilience was also studied to explain how some multinational companies restored their operations successfully after *major disruptions* in their supply chains which produced a loss of key suppliers (Christopher & Peck, 2004; Peck 2005) as well as after natural disasters

(Sheffi, 2005). The findings of these studies suggest that *resilience* could provide insight into "*how* organizations continually achieve desirable outcomes amid adversity, strain and significant barriers to adaptation and/or development" (Sutcliffe & Vogus, 2003, p.94-95; Starbuck & Farjoun 2005 p.4- 5; Weick 173-176).

In a review of studies on the antecedents of resilience at an organizational level, Sutcliffe & Vogus (2003) found recurrent themes on resilience studies at different levels of analysis (individual, group, organizations). These suggests that resilience is enabled by structures that "allow flexibly, rearranging, and transferring expertise and resources" (adhoc problem solving networks, social capital) and "capabilities to quickly process feedback". On the other hand, McManus (2008) states that there is "little consensus regarding what resilience is and what it means for organizations". These different views suggest that there is a need for empirical studies to make the transfer of lessons learned "on resilience" from permanent to temporary organizations possible.

However, according to Van de Ven (2007), grounding a problem also requires the researcher to step outside of his or her boundaries, and be open to and informed by the interpretations of others about the problem domain. Meaning that the process of "problem formulation is not a solitary exercise but instead it is a collective achievement because most problems tend to exist in a 'buzzing, blooming, and confusing' reality". This suggests that grounding the problem in literature is only the first step of the problem formulation process. Immersion into reality is also advisable since "it is only by obtaining and coordinating perspectives of other key stakeholders, that robust features of reality can be distinguished from those features that are merely a function of one perspective" (Azevedo, 1997: 189-190, cited in Van de Ven 2007). In the attempt to ground the problem in the project management reality, and to understand if there were any opportunities to use this approach in practice, preliminary interviews were organized with different project actors. The people interviewed were projects promoters (State Secretariat for Economic Affairs - SECO), bankers (UBS), project managers (Nestlé), and experts working in the European Community in funded infrastructure projects (EVATREN Project consortium). The list of people interviewed is provided in Annex 1. The specific scope of these interviews was to find out if the concept of resilience is in the glossary of an infrastructure project development and management process. In an affirmative case, the interview would seek to see how resilience is understood. The collateral objective was to receive feedback on how different actors explain details involved with the incurrence of costs and time overruns, which are recurrent and what are the related possible solutions.

Considering the aim and motivation of this investigation, the interviews were meant to be unstructured and most of them turned into open discussions. The results, labeled in three categories, which are considered relevant: “resilience”, “overruns”, and “learned lessons and traditional methods”, revealed the recurrent themes described below.

The significance of resilience question was answered with two responses: “don’t we say that people who survived the Holocaust are resilient?” or “Is *life* not the example of resilience”? The context in which resilience was associated with a project was explained with answers such as: “resilience is invoked within the power infrastructure projects in connection with the necessity to design technical back-up solutions in case of a system failure”; “in banking, resilience is employed to give a guarantee that transactions will continue in case of technical disruptions; it is most designed with redundant, although costly systems”. We felt a general agreement (suggested also in the examples described), that the concept of resilience *as such,* is understood from media and life experiences, however might have technical connotations. Yet it is not directly associated with the project management practice or project management performance.

Relating to the reoccurring the problem of “cost overruns and delays”, the results were consistent with those often mentioned in the project management literature. Specifically, it was revealed that they are due to “long execution periods” in which it is quite inevitable for “unexpected instances to become part of the project and the source of delays”. Among relevant answers, possible explanations and suggested cures of this problem were: “although the risk management process is highly regarded and contingencies are created as unforeseen events, it is difficult to accurately plan for the coming 5-7 years in which the object will be finished. Meaning that, to some extent overruns are impossible to prevent”. Therefore any “means to improve the project performance beyond risk management would be useful”. Also revealed were the eventual benefits, but also pitfalls, of this research: “we would welcome new modalities to deal with the unexpected” or “solutions to speed-up the decision making process and avoid costly delays” *but* it would be interesting to know “what is the difference between resilience and risk and uncertainty management”, and “can it be designed”? Another response was “since resilience relates to unexpected events or shocks, shouldn’t it be embedded in the risk management process”?

Limits in traditional research methods which seek to identify the causes of failure through *postmortem* analysis were mentioned as; “in our practice, lessons learned about risks are in general referenced but they are not systematically applied”, “one cannot put a figure on Napoleon’s[15] approach and go to the banker with it”, or “troubled project behavior *should be but is not* on the ‘debriefing list’ at project closure”.

We conclude that this investigation highlighted that the concept of resilience is not part of a project management glossary and the sense of “urgency in the practice of projects” does not normally leave time or means to make projects “proactive and flexible” in the face of the unexpected but rather to reinforce the “shield” through classical risk management methods. However, there was a general agreement among the people interviewed about the potential of studying the resilience of infrastructure projects in the face of critical events.

These results and theoretical interest explained previously, drove this research to lead attention from those learning from failure instances (e.g. lessons learned, continuous improvement of risk management processes, critical success factors check-list) towards those factors and conditions which could be held accountable for resilient response of project systems in the face of critical events. Therefore, uncovering those conditions and understanding resilience in infrastructure projects will constitute the aim of this thesis.

2.2 Research perimeter

The context of this study is hard infrastructure projects, which is by definition characterized by complexity and uncertainty (e.g. Baker 1986; Morris & Hough 1987; Chapman & Ward 2003; Chapman 2006). The following overview of definitions and types of infrastructure will be particularly helpful in discussing the overview of this study.

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[15] this says that in a plan surely something will go wrong

2.2.1 Infrastructure definition

Although most people will agree that infrastructure means *the assembly of tangible assets* such bridges, roads, highways, railways, tunnels, airports, ports, water supply, others would define the notion wider, as being “those physical and social structures that support the life and interactions of a society” (Grimsey 2004 p. 22). Also, it is common to distinguish between “economic” and “social” infrastructure and within each of these between “hard” (physical) and “soft” infrastructure. On this basis, there are *hard economic infrastructures, soft economic infrastructures, hard social infrastructures and soft social infrastructures* (Argy et. al., 1999).

Examples of hard economic infrastructures are highways, railways, bridges, tunnels, telecommunications, electricity, and gas generation. In other words, saying all tangible structures that provide key intermediate services to businesses and industries. Soft economic infrastructures comprise of vocational training, financial facilities for business, R&D facilitation, and technology transfer. Examples of hard social infrastructure are hospitals, education and training buildings, water storage and treatment facilities, etc., with the role to improve quality of life and welfare in the community. Soft social infrastructure takes the form of security systems and community services, those regarded as socially desirable (Musgrave 1959).

Although the perimeter of this research is hard infrastructure projects, from a project management perspective, hard and soft, economic and social infrastructures, are comparable because they all share common characteristics. Specifically, *they are large-scale investments* costing more than US $1 billion and attracting large amounts of public attention because of the substantial impact they have on communities, the environment, and budgets (Flyvberg et al, 2003). They require high initial capital costs, have relatively long lives, and need to be managed and paid on a long term basis (Esty 2008). Also their potential benefits overlap in many respects. For instance “social” infrastructure, such as ones that enhance the health or quality of one’s life, may influence the productivity of an industry just as much as the economic structures. Also vice versa, economic infrastructure, such as transport networks, would definitely impact the quality of life even if it is not the first intent (Argy, et al, 1999; Hirschman, 1967).

Other shared features of infrastructure projects are the *complexity and uncertainty* (Nicolas 2001, p.3-7; Esty 2008 p.5; Morris & Hough 1987 p. 14-15; Baker 1986; Chapman & Ward 2003; Chapman 2006).

According to Baccarini (1996) and Richardson (2002) the level of complexity could be computed as a multiple of *organizational complexity* that refers to the number of people, departments, organizations, countries, languages, cultures, and time zones involved. *Resource complexity*, which relates to the volume of resources (cost, time) and the *technological complexity*, which is the level of innovation involved in the product, process, or novelty of interfaces between different parts of that process or product.

The definition of a project itself suggests "uncertainty related to novel organization or a unique scope of work" (Chapman 2003). It could also be sourced by technology, task difficulty, currency fluctuations, unknown inflation for long-term projects, financing (Baker 1986) available skills, legal aspects, or natural disasters (Hirschman 1967). This will lead to the occurrence of critical events that threat the project's objectives and/or survival (e.g. Sheffi 2005, Eden 2007).

In the figure below adapted from Nicolas 2001, examples are given of infrastructure projects and each one is positioned with respect to the degree of complexity and uncertainty involved. The time and costs will increase with the complexity.

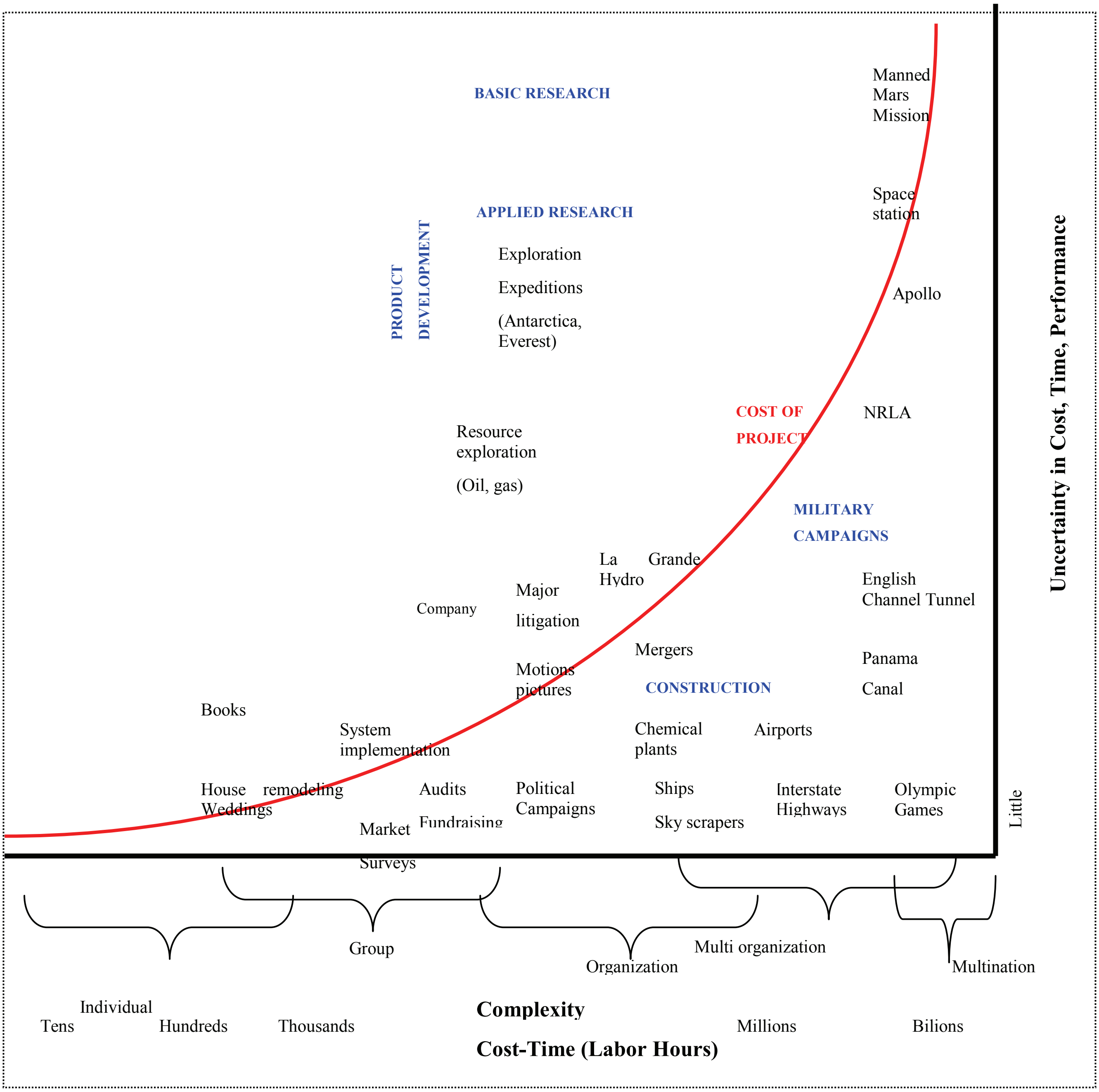

Figure 2-1: Positioning Projects by Complexity (Adapted from Nicholas, 2001)

Apart from complexity and uncertainty another characteristics of infrastructure projects, which are related to the first two, are given by *human factor reflected in the decision making process*. Specifically, the complexity and uncertainty as well as the amount of costs involved will give managers the incentive (and duty) to make careful, deliberate decisions in an environment with changing constraints (Esty 2004 p. 2-6).

These characteristics are relevant for the discussion of this study, generally speaking, which takes example of the New Railway Link through the Alps (NRLA). This is a Swiss federal project that is the centerpiece of the Central European rail network. This infrastructure, which will result in the construction of 3 base tunnels several hundred metres below the current level of the tunnels will guarantee the speed rail link (250kms/hour) from north to south Europe, across the Swiss Alps, and become "the first flat transalpine rail link with a maximum elevation of just 550m above sea level".

The project is extremely complex in all respects (organization, technology, resources) and has already faced a great deal of distresses, which has made its future become questioned several times. According to the last prospects, it will be completed in 2017. At the time when this research started, the project had a cost overrun of 53% and the completion of the longest tunnel is already in for a 6-year delay.

2.3 Definition of some concepts

In this paragraph we attempt to provide the best possible definition of the main concepts used in this thesis. Some of these concepts are used in other management studies but are interpreted differently in various situations. These differences can lead to confusion which we would like to prevent. It is also worth explaining that at this stage is not possible to give an accurate definition of project resilience and project enablers, as their identification is part of the goal of this study and will be given in the findings. For these concepts, a preliminary, leading definition will be given, which will be repeated in the chapter in which we discuss the findings of this study.

2.3.1 Project

The common denominator in defining projects is to refer to them as a combination of uniqueness, defined objectives, limited time-cycle, and the three-fold constraints: cost, time, and quality (e.g. Turner 1999, Williams 2005, Eden 2005).

This thesis addresses "projects" as "a temporary endeavour undertaken to create a unique product or service" (PMI, 2000), or a "unique venture with a beginning and an end, conducted by people to meet established goals with parameters of cost, schedule, and quality" (Buchanan and Boddy, 1992). It also acknowledges that these characteristics will set the management of projects apart from the management of operations, which take place in a permanent organizational setting (Nicholas 2001). Therefore to some extent, the management of the project is a challenging position since it interacts with time pressures and uncertainty of the results due to the fact that the project completion is something new or/and revolutionary, transient teams, and has risks (Lundin & Söderholm 1994, Turner & Müller 2002, Williams 2005).

In this thesis the project life cycle is considered as a sequence of five distinct phases: conceptualization, planning, execution, control, and closing which could be commonly represented as a function of cost and time (PMI 2004, Nicholas 2001, Perret & Jaffeux, 2002 :68-70), as shown in the picture below.

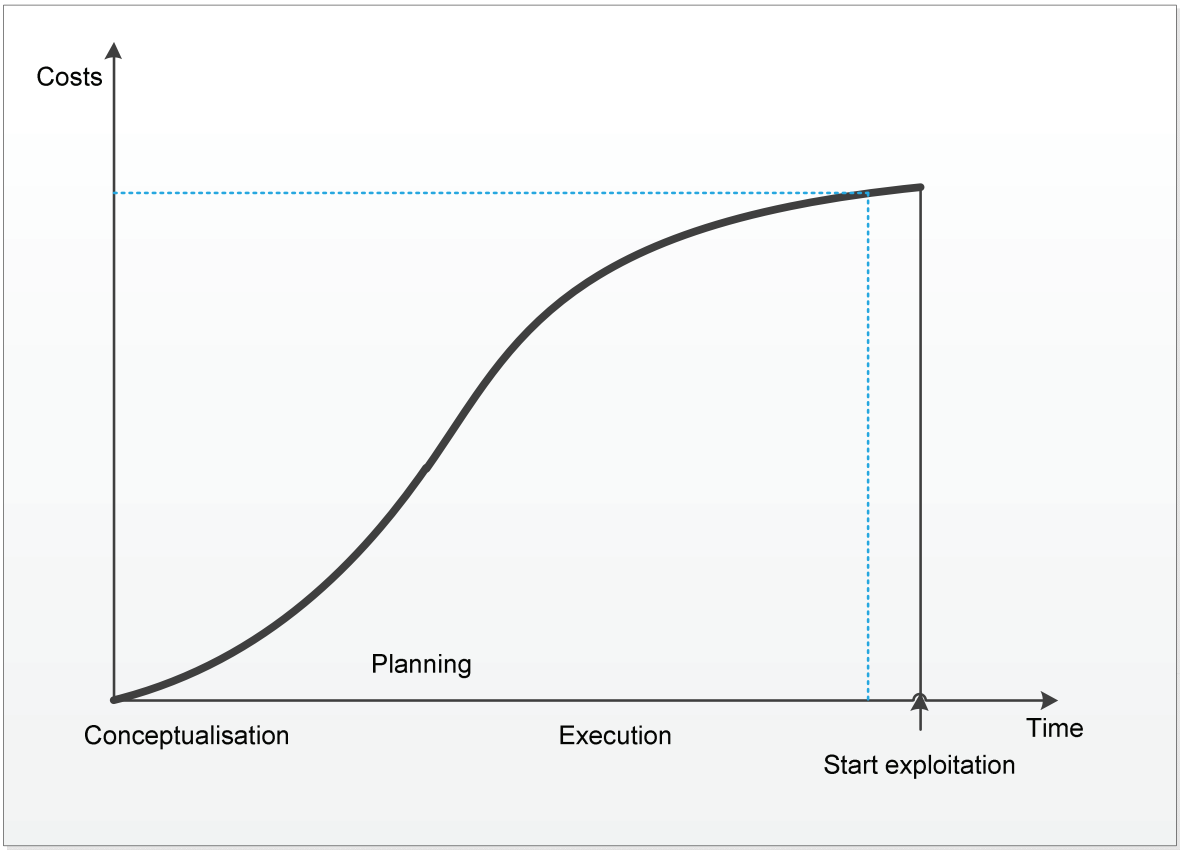

Figure 2-2 : Project life-cycle; Source: Perret, Jaffeux (2002)

This representation suggests that during the project life cycle, the cost, in general, and the cost of changes in a particular are not constant. As an example, the project cost and staffing level are not high in the beginning; they will reach a peak on the execution phase and will decrease towards the closure. Also, the cost of changes will evolve with the project. It is clear that it would be costlier to modify a project which reached the execution phase compared to one found in the early stages of its life cycle (conceptualization). Related to the project ability, to achieve its objectives within the committed budget and timeframe, we define the project performance. The adopted approach is known in project management basics as the "golden triangle", named so because each side represent a constraint and the modification of one constraint will automatically impact the other constraints (Nicholas 2001, Lundin & Söderholm 1995, Turner 2006). From this perspective, the cost overrun is considered to occur when the actual cost of the project is higher than the budget. It is typically calculated as a percentage (actual costs minus budgeted costs) in percent of budgeted costs; or as a ratio obtained by dividing actual costs over budgeted costs.

Historical examples of costs overruns include: the Sydney Opera House (1,400 %) or Concorde supersonic airplane (1,100 %).

2.3.2 Project Organization

The organization structure denotes the types of relationships which bonds its elements. The *formal* and *informal* structures coexist in any organization (Nicholas 2001 p.173-176, p.433-445). The first element relates to the hierarchy, reporting relationships, and group tasks. It shows the official communication channels and is publicized in a chart. The second element refers to informal connections, which are stated nowhere and developed and evolve through interactions among people (e.g. Nicholas 2001p.433-470, Perret & Jaffeux 2002 p.75, PMBOK 2004 p. 24-32).

There are several forms of project organization available. They are strategically chosen to fit the project's characteristics (complexity, size, duration) and scope (product development, infrastructure, etc.). They are summarized in the picture below, which is adapted from PMBOK (2004) and Nicholas (2001).

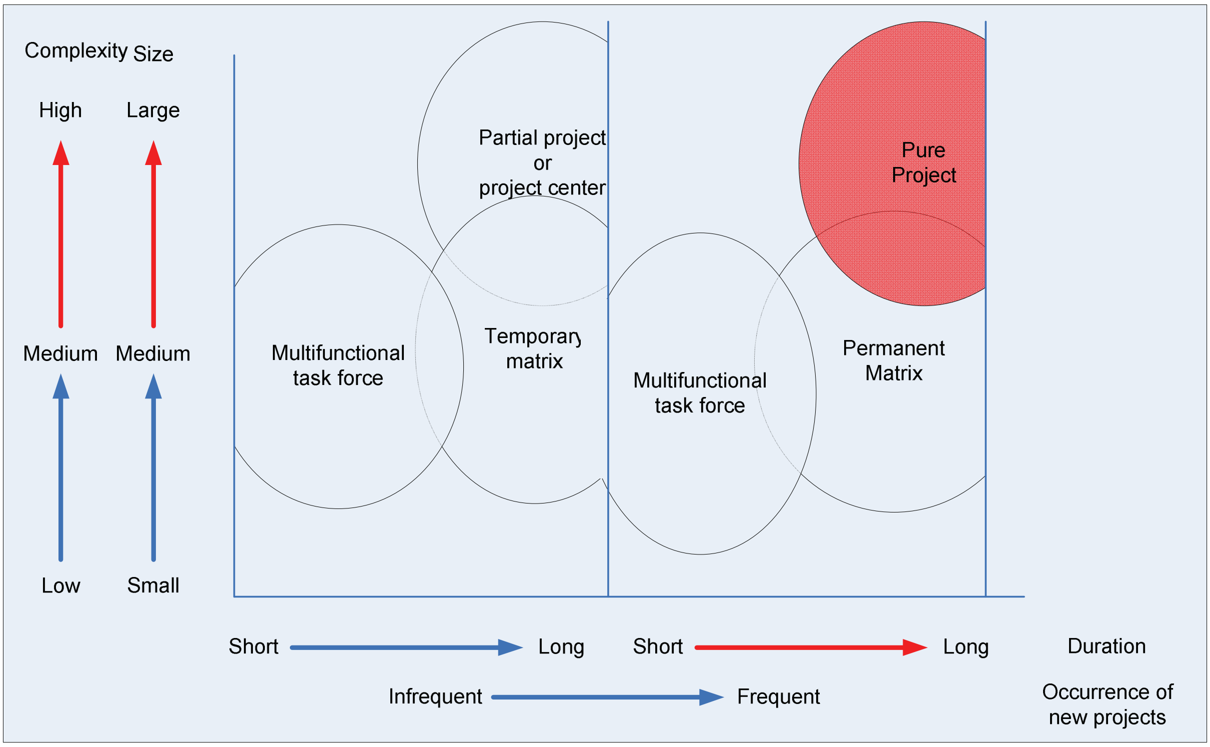

Figure 2-3: The choice of project organization layout (source Nicholas 2001& PMBoK 2004)

When there are complex infrastructure projects, which require a major resource commitment, *a pure project organization form is required.* This is a separate entity, similar to any organization, in which necessary resources are reunited with the scope to achieve the required objectives. Taking into account the size and complexity, undertaking such a pure project organization will rely on the effectiveness of liaisons[16], teams, and taskforces[17] (Nicholas 2001).

A variation of the pure project organization form, which is often used in large-scale infrastructure projects, is the *"stand-alone project"*. This concept refers to an organization created specifically for the purpose of completing the project from different players such as the owner, contractors and subcontractors, suppliers and consultants, etc. As a characteristic,

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[16] Liaison – denotes the role of a person (or group) which links to departments at lower levels

[17] Task force – is a temporary team of persons with different backgrounds reunited to solve a problem

project actors are not involved in the entire project life cycle but in specific phases that are in accordance with their competences (PMI 2004).

These features will be useful for the general knowledge of this study results.

2.3.3 Critical events

In this thesis, critical events are understood as unexpected events with a high impact on the project's objectives and/or its survival. Practical examples of critical events in infrastructure projects are: geological surprises, unforeseen events related to technology (new, not tested, changes in standard requirements, not tested processes), problems with underfunding, disruption of material supply, safety regulation changes, contracting breaches, etc.

According to Hirschmann (1967), it is common to assign these events as uncertainties that either occur on the "supply" or on the "demand" side. The *supply* side refers to the uncertainties connected with the *process of production* of the project's output (the infrastructure itself) and the *demand* side refers to the *service provision,* or otherwise known as the service offered by the project output. From this perspective, the events which occur in the execution phase (e.g. technological and geological surprises, material supply disruption, etc.) will fall traditionally on the supply side. On the *demand* side, the main source of uncertainty, and therefore unexpected problems, is the disequilibrium in the service provision. This occurs in the case of an inaccurate demand forecast (Flyvbjerg 2006) as in the illustrative case of Channel Tunnel[18] (Morris & Hough, 1987). Here, overly optimistic prospects of future traffic and a lack of consideration for ferry competition (Anguerra 2006) resulted in a rate of return on investment of -14%, driven by a number of users "approximately half of those forecasted" (Flyvbjerg 2009).

Another way to classify unexpected events is based on the extent at which they could be influenced by the project management (Perret & Jaffeux 2002, p.68; Barber 2005). In this respect, *endogenous* events are those under the direct influence of the project management; such as management style, contractual relations, skills, etc. *Exogenous* events are created by the environment and therefore project management cannot (normally) influence them. Examples of exogenous events are politics (aggressive forces, unjustified political

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[18] "The final cost of the tunnel was £12 billion, and left Eurotunnel plc, the Anglo-French company that built the tunnel, £9 billion in debt. In its first year, it made a loss of £925 million. Its first net profit was announced in March 1999" (Helicon Publishing, 2009)

interferences), economic or institutional changes (inflation, change of regulation), environmentally related (the undesirable impacts of a project's outputs on life or well-being), and demand related events. In the table below, we combine both perspectives in order to classify the critical events based on the nature of uncertainties that can occur on the demand/supply side of project's output and the project management's influence. This classification will be particularly useful in the selection of the research design. The events on the supply side relate to the process of production of a project's outputs and human and financial factors. Each category contains endogenous and exogenous critical events. On the demand side, the main source of uncertainty that could lead to critical events remains the demand disequilibrium, which is by definition exogenous.

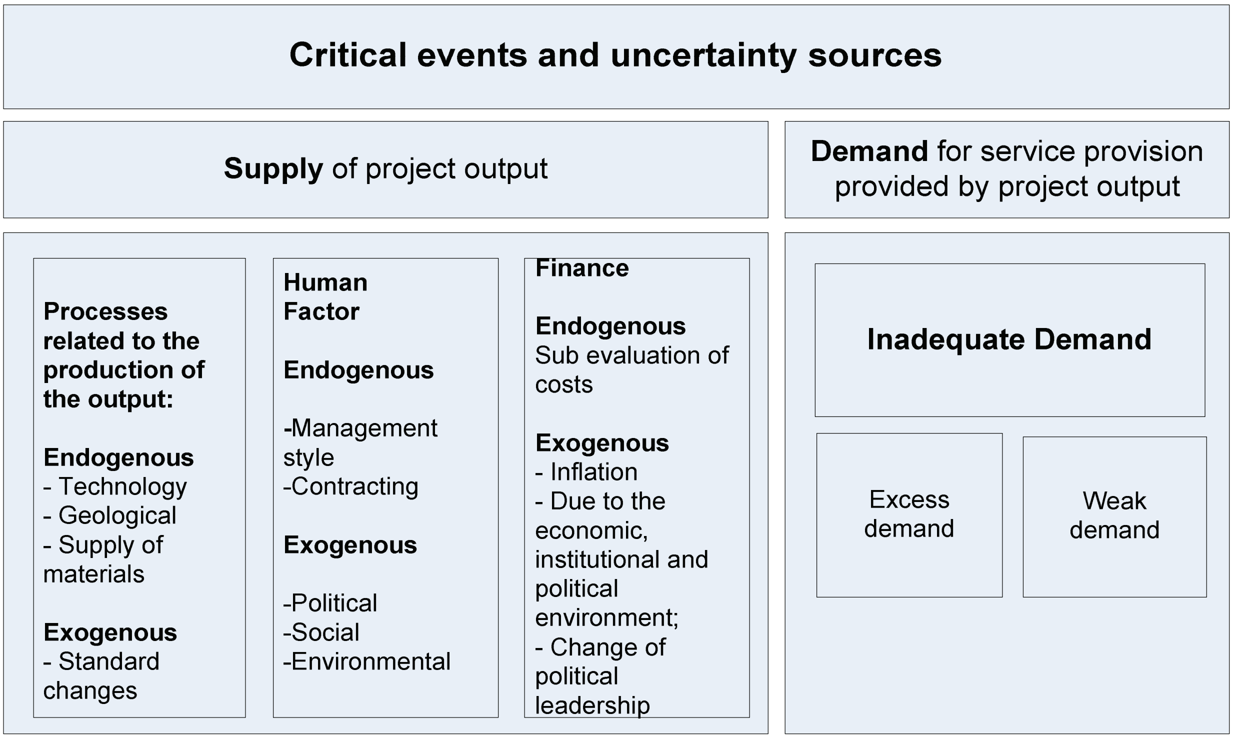

Figure 2-4: Critical events classification (Based on Hirschmann 1967)

It is common to say that the critical events could appear at anytime in the project's life-cycle (Williams 2005, Eden 2005). As our definition suggests, their criticality does not refer to their drama but it is based on the significance of their consequences (Angelides 2001) and the meaning given to them by the players (Trip 1993). Critical incidents tend to mark significant turning points or changes in the life of a person or an institution; or in some social phenomenon, and they are often unplanned, unanticipated, and uncontrolled (Tripp, 1993). In respect to the critical events, we study the *troubled project behavior,* which is understood in relation to punctual and overtime impacts on critical events in the project system. The measures taken made by different actors to limit or mitigate these impacts and manifested factors and conditions, influenced the positive adjustment of the project system. They are called the resilience enablers.

2.3.4 Resilience and resilience enablers

In management studies, resilience is often defined as a characteristic or capacity of individuals or organizations to maintain positive adjustment—or even thrive—under adverse conditions (Sutcliffe & Vogus , 2003).

We propose this definition of resilience, because is the most exhaustive since it encapsulates both images of resilience embraced by its research adepts, specifically the *"'super material' facet, which could be translated into a characteristic" or "attribute"* (Anderson 1994; Anthony 1987; Werner 1990, Luthar, et al. 2000; Wanberg & Banas 2002; Cicchetti & Garmezy 1993; Masten 2001; Masten & Reed 2002; Kelly 2001) and the *developmental perspective*, which lead to understanding the resilience as a dynamic process of positive adaptation (Egeland *et al.* 1993; Wildavsky 1988 p:120, Sitkin 1992; Levinthal and March (1981, 1993); Teece *et al*. 1997; Weick *et al.* 1999; Eisenhardt & Martin 2000; Porras & Silvers 1991).

Similarly, we propose to define project resilience as its capacity or characteristic to maintain positive adjustments when confronted with critical events that are inherent in its life-cycle. As this study is concerned with the project's performance with respect to its costs and delays, positive adjustment is understood here as "costs and delays to keep on track".

In the same area, we propose to define resilience enablers as those conditions and factors (if any) which facilitate the manifestation of project resilience in face of critical events. As recommended by Masten (2001), as well as Suttcliffe & Vogus (2003), we shall identify and assess these enablers in respect to the critical event (evidence of threat) and the performance / objectives (evidence of positive adjustment).

At this stage of research, these working definitions have a guiding role and are grounded based on the literature. The case study's empirical findings will allow us to validate and update these proposed definitions.

2.4 Research locus within the chair activities

The Chair of Logistics, Economics, and Management is responsible for the development of methods and tools for systemic analysis, project evaluation, and uses logistics, as a science, which is applied to the management of physical and logical flows. This study is fully

integrated into the chair's activities, as its main objective is to shed light onto the dynamicness of complex projects by analysing their system's city with a new perspective offered by the concept of project resilience. The scope is to reveal those factors and conditions, which will help the project to stay on the track, of committed budgets and delays in spite of the negative impacts of unexpected critical events. The field of this study is also compatible with the researcher's background and her former working experience.

3 LITERATURE REVIEW

> *"Budding investigators think that the purpose of a literature review is to determine the answers about what is known on a topic; in contrast, experienced investigators review previous research to develop sharper and more insightful questions about the topic" (Yin, 1994).*

For this research, one main stream of literature was targeted. The review process covers the period between 1960 and 2006 on the theory of critical success and failure factors (CSF). The material reviewed comprises both, academic research as well as works by international project management organizations. The target was to acquire a holistic image on the conditions and factors proposed from the literature for the management of successful project and related research methods. For many years, the factors denoting effective monitoring and control and risk management processes were considered critical in the development of major infrastructures (Fortune & White, 2006; Morris & Hough, 1987). Therefore, a particular attention was given to the review of critical success factors associated with risk and uncertainty management, and controlling and planning. Therefore, this part should be seen as a completion of the literature review done in the previous chapter, which aimed to ground the research problem.

3.1 The Challenge of Identifying the Critical Factors Leading to Project Success[19]

The scope of this literature is to search for the conditions essential to the success of a project (Turner, 2004). From a methodological perspective, research of critical success and failure factors includes surveys, case studies, or theoretical papers about successful and unsuccessful projects (Fortune & White 2006). As a general observation, there is little agreement among the authors as to which factors are critical to a project's success (White 2006) and their

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[19] We understand project management success measured against the project declared objectives (De Wit, 1987).

domain applicability (Belassi, 1996). However, from the seminal work of Avots (1969), Martin (1976), Cooke-Davies (2002), and White & Fortune (2002), there are some factors that reoccur systematically in all studies. They are summarized with relevant citations in Table 3:1. This overview relies heavily on a study of White and Fortune (2002) who reported on the findings in a survey involving over 995 project managers. Their response rate was 27.2%. It revealed that: 1) "The three criteria most used in literature (on time, to budget, and to specification) were also the highest ranked success criteria identified." 2) "46% of projects have been described as generating side effects." 3) "The identified critical factors for a project's success were realistic schedules, adequate resources, and support from senior management." The same study revealed two important criticisms of critical success factors. 1) The CSF approach does not consider the changes occurred throughout project's life cycle and 2) The CSF implementation is seen as a static process, ignoring the potential for a factor to have varying levels of importance at different stages in the implementation process (Larsen and Meyers 1999, in Fortune and White 2006).

Critical factor	***Literature***
Common vision, Goal alignment, senior management support	Avots [1969]; Morris [1986]; Pinto and Slevin [1987]; Morris and Hough [1987]; Magal et al. [1988]; Pinto and Mantel [1990]; McComb and Smith [1991]; Yap et al. [1992]; Pollalis and Frieze [1993]; Tennant [1993]; Selin and Selin [1994]; The Standish Group [2000]; Couillard [1995]; Wastell and Newman [1996]; Munns and Bjeirmi [1996]; Belassi and Tukel [1996]; KPMG [1997]; McCormack [1997]; McGolpin and Ward [1997]; Dvir et al. [1998]; Kasser and Williams [1998]; Whittaker [1999]; Turner [1999]; Weir [1999]; Taylor [2000]; Thite [2000]; Poon and Wagner [2001]; Cooke-Davies [2002]; Andersen et al. [2002]; Caldeira and Ward [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Clear realistic objectives	Baker et al. [1983]; Morris [1986]; Hughes [1995]; Pinto and Slevin [1987]; Pinto and Mantel [1990] Tennant [1993]; Selin and Selin [1994]; Harding [1995]; Couillard [1995]; Yeo [1995]; Wateridge [1995]; The Standish Group [2000]; Beare [1995]; Tan [1996]; Cicmil [1997]; Dvir et al. [1998]; Glass [1998]; Kasser and Williams [1998]; Clarke [1999]; Weir [1999]; Taylor [2000]; Thite [2000]; Poon and Wagner [2001]; Anderson et al. [2002]; Caldeira and Ward [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Strong/detailed plan kept up to date	Avots [1969]; Baker et al. [1983]; Cleland and King [1983]; Morris [1986]; Morris and Hough [1987]; Pinto and Mantel [1990]; Pollalis and Frieze [1993]; Martinez [1994]; The Standish Group [2000]; Wateridge [1995]; Smart [1995]; Williams [1995]; Belassi and Tukel [1996]; KPMG [1997]; McGolpin and Ward [1997]; Dvir et al. [1998]; Kasser and Williams [1998]; Glass [1998]; Clarke [1999]; Turner [1999]; Taylor [2000]; Andersen et al. [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Good communication/	Avots [1969]; Cleland and King [1983]; Morris [1986]; Hughes [1995]; Pinto and Slevin [1987]; Curtis et al. [1988]; Magal et al. [1988]; Pinto and Mantel [1990]; McComb and

feedback	Smith [1991]; Cash and Fox [1992]; Pollalis and Frieze [1993]; Wateridge [1995]; Tan [1996]; Gowan and Mathieu[1996]; Hilderbrand [1996]; Dvir et al. [1998]; Kasser and Williams [1998]; Clarke [1999]; Turner [1999]; Thite [2000]; Cooke-Davies [2002]; Andersen et al. [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
User/client involvement	Morris [1986]; Pinto and Slevin [1987]; Curtis et al. [1988]; Magal et al. [1988]; Pinto and Mantel [1990]; McComb and Smith [1991]; Yap et al. [1992]; Wateridge [1995]; Smart [1995]; Wastell and Newman [1996]; Belassi and Tukel [1996]; Cicmil [1997]; McCormack [1997]; Dvir et al. [1998]; Jang and Lee [1998]; Turner [1999]; Caldeira and Ward [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Skilled/suitably qualified/sufficient staff/team	Baker et al. [1983]; Morris [1986]; Pinto and Slevin [1987]; Curtis et al. [1988]; Magal et al. [1988]; Pinto and Mantel [1990]; McComb and Smith [1991]; Cash and Fox [1992]; Pollalis and Frieze [1993]; Tennant [1993]; Willcocks and Griffiths [1994]; The Standish Group [2000]; Dvir et al. [1998]; Glass [1998]; Jang and Lee [1998]; Poon and Wagner [2001]; Caldeira and Ward [2002]; Westerveld [2003]
Effective change management	Avots [1969]; Pinto and Mantel [1990]; McComb and Smith [1991]; Cash and Fox [1992]; Pollalis and Frieze [1993]; Martinez [1994]; Willcocks and Griffiths [1994]; Smart [1995]; The Standish Group [2000]; Hougham [1996]; Cicmil [1997]; McGolpin and Ward [1997]; Dvir et al. [1998]; Weir [1999]; Taylor [2000]; Thite [2000]; Poon and Wagner [2001]; Cooke-Davies [2002]; Yeo [2002]
Competent project manager	Avots [1969]; Baker et al. [1983]; Morris [1986]; Pinto and Slevin [1987]; Pollalis and Frieze [1993]; Martinez [1994]; Pinto and Kharbanda [1984]; Belassi and Tukel [1996]; Dvir et al. [1998]; Glass [1998]; Weir [1999]; Taylor [2000]; Andersen et al. [2002]; Westerveld [2003]; Turner [2004]
Strong business case/sound basis for project	Avots [1969]; Smart [1995]; Pinto and Kharbanda [1996]; KPMG [1997]; McGolpin and Ward [1997]; Dvir et al. [1998]; Whittaker [1999]; Poon and Wagner [2001]; Cooke-Davies [2002]; Andersen et al. [2002]; Caldeira and Ward [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Sufficient/well allocated resources	Morris [1986]; Pinto and Slevin [1987]; Morris and Hough [1987]; Yap et al. [1992]; Tennant [1993]; McCormack [1997]; The Standish Group [2000]; Belassi and Tukel [1996]; Gowan and Mathieu [1996]; Dvir et al. [1998]; Kasser and Williams [1998]; Turner [1999]; Caldeira and Ward [2002]; Westerveld [2003]; Turner [2004]
Proven/familiar technology	Morris [1986]; Pinto and Mantel [1990]; McComb and Smith [1991]; Cannon [1994]; Williams [1995]; Yeo [1995]; KPMG [1997]; Dvir et al. [1998]; Glass [1998]; Poon and Wagner [2001]; Caldeira and Ward [2002]; Yeo [2002]
Realistic schedule	Cleland and King [1983]; Morris [1986]; Morris and Hough [1987]; Pinto and Mantel [1990]; McComb and Smith [1991]; Tennant [1993]; Selin and Selin [1994]; Dvir et al. [1998]; Glass [1998]; Kasser and Williams [1998]; Weir [1999]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Risks addressed/assessed/ managed	Morris and Hough [1987]; Selin and Selin [1994]; Williams [1995]; KPMG [1997]; Baldry [1998]; Dvir et al. [1998]; Whittaker [1999]; Weir [1999]; Cooke-Davies [2002]; Yeo [2002]; Westerveld [2003]

Effective monitoring/control	McComb and Smith [1991]; Cash and Fox [1992]; Pollalis and Frieze [1993]; Selin and Selin [1994]; Cicmil [1997]; Dvir et al. [1998]; Weir [1999]; Thite [2000]; Poon and Wagner [2001]; Cooke-Davies [2002]; Westerveld [2003]; Turner [2004]
Adequate budget	Baker et al. [1983]; Cleland and King [1983]; Morris and Hough [1987]; Dvir et al. [1998]; McComb and Smith [1991]; Tennant [1993]; Glass [1998]; Caldeira and Ward, [2002]; Westerveld [2003]; Turner [2004]
Organisational adaptation/culture/structure	Pollalis and Frieze [1993]; Cannon [1994]; Willcocks and Griffiths [1994]; Martinez [1994]; Couillard [1995]; Hougham [1996]; Taylor [2000]; Thite [2000]; Cooke-Davies [2002]
Good performance by suppliers/contractors/ consultants	Morris and Hough [1987]; Pollalis and Frieze [1993]; McCormack [1997]; KPMG [1997]; Glass [1998]; Jang and Lee [1998]; Caldeira and Ward [2002]; Yeo [2002]; Westerveld [2003]; Turner [2004]
Planned close down/review/acceptance of possible failure	Avots [1969]; Cleland and King [1983]; Pinto and Kharbanda [1996]; Munns and Bjeirmi [1996]; McCormack [1997] McGolpin and Ward [1997]; Dvir et al. [1998]
Training provision	Magal et al. [1988]; Yap et al. [1992]; Pinto and Kharbanda [1995]; Pinto and Kharbanda [1996]; McCormack [1997]; Dvir et al. [1998]; Caldeira and Ward [2002]
Political stability	Morris and Hough [1987]; Pollalis and Frieze [1993]; Tennant [1993]; Sauer [1993]; Yeo [1995]; Pinto and Kharbanda [1996]
Correct choice/past experience methodology, tools	Hughes [1995]; Munns and Bjeirmi [1996]; Dvir et al. [1998]; Glass [1998]; Jang and Lee [1998]; Turner [2004]
Environmental influences	Morris [1986]; Cleland and King [1983]; Archibald [1992]; Pinto and Kharbanda [1996]; Caldeira and Ward [2002]; Westerveld [2003]
Learning from past experience	Yap et al. [1992]; Dvir et al. [1998]; Jordan et al. [1988]; Sauer [1993]; Cooke-Davies [2002]
Large, complex, duration (over 3 years)	Hughes [1995]; Selin and Selin [1994]; Cannon [1994]; Cooke-Davies [2002]

Table 3-1: Critical success factors in infrastructure development projects (Based on Fortune & White 2006)

The general aim in these studies is to identify those factors that impact project performance. Therefore, it overlooks their relative importance during a project's life cycle and the relationships it has with project components. Belassi and Tukel (1996) were a step ahead when they proposed a more systematic approach to CSF research. They proposed a new framework in which critical success / failure factors are assigned to different areas: 1) project related 2) management and staff related and 3) organizational and project environment related. This conveyed the identification of statistically significant relationships between critical success factors and project structural attributes. (E.g. "When project size and value are critical factors, projects will need a matrix organization; when time is used to measure project success, the project management's skills and communication among team members become critical to the project's success"). Another study that addressed CSF dynamics, was Pinto & Slevin (1987). They focused on the relative importance of CSF for each stage of a project's life cycle development (strategic vs. tactical) over the entire project's life cycle. They found that the relative importance of success factors varies and depends on the measures used.

The number of articles covering CSF in infrastructure projects is not overwhelming. As a common denominator, there are cases of large complex projects with great economical potential, as in Morris and Hough (1987), and Pinto and Slevin (1987, 1989). The identified CSF's patterns relate to common vision, senior management support, and strong monitoring and control.

The first conclusion that stands out after reviewing the literature on CSF is that it does not offer insight into which factors contribute the most in maintaining performance in case of crises.

3.2 Criticisms of CSF to Project Performance

The critical successes and failures are supposed to supply a formula for the desired end of the project. However, very often this list is long and difficult to implement in practice. As stated above, there is limited knowledge on how these factors will evolve during the project's life cycle, their relative importance, and their relationships with the project components.

Another drawback is that it does not take into account how project environmental changes will impact them. We can see that "one size does not fill all," or that one set of factors does not apply to all situations (Shenhar and Dvir, 2007).

The next sections discuss why Risk Management Processes, Planning, and Controlling, indicated in a majority of the cases as essential CSF, cannot alone ensure an infrastructure's project performance.

3.2.1 Risk Management Processes

The concept of risk describes the assessment of the frequency of occurrence and magnitude of consequences associated with hazard (stressor) activity (Hood and Jones, 1996). Risk management implies a mixture of anticipation (looking forward) and resilience (bouncing back), conferring upon risk management models to encapsulate perspectives that cover growth and distress. One limit of this approach comes from the risk management process *itself.* According to the PMBOK[20], the risk management process consists of four phases: a) risk identification, b) risk quantification, c) risk response development, and d) risk response control. PMBOK described it with a two-time period model. In time 1, the present, (a) risks are identified and (b) future states are analysed. Their probability distributions lead to a rational plan of outcomes that maximizes the probability of positive outcomes. In time 2, the future, the plan is implemented (c) and the consequences of the risks are controlled (d). As a consequence, this approach implicitly assumes that the project management during the project is essentially *passive*. This is so because it follows the implemented plan and the risks are known and constant. However, reality of projects proves that in practice, this assumption does not hold.

Another limit from assuming that futures states are known and definable, is that the probability based paradigm overlooks the uncertainty with regard to human actions, thus making the future unknowable. A related limit from assumptions, is that the derived methods are predominately quantitative and therefore normative (PMBoK, 2004, PMI 2002).

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[20] Project Management Body of Knowledge

3.2.2 Planning and Control

Planning and control are essential functions of project management. Planning is needed to coordinate people's activities, deliver materials, and allocate resources. "Deciding and specifying what to do is the function of project planning. Making sure that this is done right is the function of project control" (Nicholas, 2001:159).

It is a fact of life that planning and control, although indispensable, cannot alone guarantee a project's performance for at least two reasons.

On one hand, the embedded idea in traditional project management that planning is the cure for project uncertainty turns out to be not true in the reality of projects. It is costly to elaborate a detailed plan and requires a lot of time, while it cannot totally eliminate the uncertainty in a project. The side effect of detailed planning is a complicated plan, which is often hard to understand and change (rigid). This is illustrated in Annex 8 - Limitations of Planning Tools.

3.3 Conclusion

The literature discussed in this chapter leads to the following concluding remarks:

- There is no research that connects the non-performance of projects to their lack of resilience when faced with unexpected events that are inherent in their life cycle.
- The traditional theories and tools to ensure and control the project performance have limitations, mainly due to their key assumptions.
- There is no explicit research on the evolution of the critical success factors during a project's life cycle.
- "Project management has long been considered as an academic field for planning-oriented techniques and, in many respects, an application of engineering science and optimization theories." Although it has received a wider interest from other academic disciplines lately, *very limited literature exists on analysing projects or their management from other disciplines' perspectives*.
- A large amount of research has been devoted to the search for success factors, but less effort has been allocated to studying *the conditions and factors that enable the*

project's system to cope successfully with the unexpected events. This implies that relationships between projects' structural elements and CSF are underexplored.

⇨ Knowledge about *project behavior when confronted with unexpected events* (troubled project behavior) is limited.

4 A QUALITATIVE EXPLORATORY RESEARCH DESIGN

4.1 Introduction

It is common to say that making the distinction between qualitative and quantitative research could often be misleading. Research is rather distinguished, between deductive and inductive or hypothesis testing and theory building, but all are carried out with the scope of adding value to an existent body of knowledge. The choice for the research design of this study takes into account the status quo of the current research into the behavior of the project when confronted with critical events and the goals of this study. Miles and Huberman (1994) suggested that researchers should use qualitative research design *when there is a need for deep understanding, local contextualisation, and exposing the points of view of the people under the study*.

Looking from their perspective at our research problem, qualitative research in this study will consist of:

➔Collecting empirical data to identify the enablers of resilience, or otherwise said, the factors and conditions enhancing the successful completion of projects confronted with critical events

➔Collecting empirical data, which are qualitative in nature; they are primarily drawn from interviews with project stakeholders involved in the design and construction of two major infrastructure projects[21]

➔Data analysis will focus on the interpretation and conceptualization of the phenomenon of troubled project behaviour

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[21] Lötschberg rail tunnel basis achieved in 2007 and Gotthard rail tunnel basis actually under construction

Furthermore, according to Yin (1994) every research design (surveys, experiments, case studies) can be either exploratory, explanatory, or theory testing. The logic behind this division is given by the level to which the phenomenon under study has been elaborated in theory. Exploration is needed when a theory is lacking credibility and research is needed to uncover which attributes of the phenomenon (variables) are important for further research. Description is concerned with the frequency of the reoccurrence of variables, while explanatory research aims to test a hypothesis on causal relations of variables. Given the lack of theory about the behaviour of troubled projects and their capabilities of coping when confronted with critical events, it becomes clear that this study should be exploratory in nature. Our main concern is to collect and analyze rich data on project behaviour when they are confronted with critical events in order to develop a middle range theory[22].

4.2 Why case studies

Within an exploratory qualitative research design, several research strategies could be adopted. A case study is an inquiry into an empirical phenomenon which has a close relationship and unclear boundary with a real-life context (Yin 2003). The case study strategy is appropriate if the following three conditions exist: a *(1) "how" or "why" question is asked about (2) a contemporary set of events (3) over which the investigator has little or no control.(Yin 1994,2004).*

The in-depth information about a troubled project's behaviour cannot be gathered by addressing the "who, what, where, how many, or how much" questions, they should rather look into survey strategies or analysis of archival, as in economic research (Yin, 1981a; Edmonson & Manus 2007). Similarly, the questions formulated in this research are the *"how"* and *"why*" questions and they deal with the "operational links needing to be traced overtime, rather than mere frequencies or incidence" (Yin 1994, Eisenhardt & Graebner 2007).

Furthermore, the study's focus is on a *"contemporary set of events"* because it concerns the study of events that have occurred *recently* in the project life cycle as opposed to older events.

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[22] **Middle range theory**, developed by Robert K. Merton "is an approach to sociological theorizing aimed at integrating theory and empirical research". Middle-range theory starts with an empirical phenomenon and abstracts from it to create testable hypothesis (Merton, R.K. "Social Theory and Social Structure" (1968) Enlarged Ed ed. Free Press. ISBN 0029211301

Historical data would have not been appropriated in this study for at least two reasons; collection of rich data about how the event and its impacts unfolded over time would have been dependent on the interviewed person's capacity to remember and it is known that people's memory alters over time. In the same respect, uncovering resilience enablers in projects to be used today, the reference must be made in contrast with modern management theories and therefore historical projects will not have complied with these criteria.

Moreover, an event that has occurred in the past and was already studied ensures that the researcher did not have any control over the event under study and could not influence its project behaviour.

Last but not least, as explained by Siggelkow (2007), "if only limited theoretical knowledge exists about a particular phenomenon, an inductive research strategy that lets theory emerge from data can be a valuable starting point".

The arguments highlighted above support the fact that this study is justified by a phenomenon-driven inquiry, for which there is a lack of viable theory and limited empirical evidence, and therefore the case study strategy is appropriate. The next step is to design the case study. According to Yin (1994, p.20-25) the "five components of research design that are especially important for case studies are 1) a study's questions, 2) its propositions, if any, 3) its unit of analysis, 4) the logic linking the data to the propositions, and 5) the criteria for interpreting the findings. Each of these elements will be addressed in the following section.

Components of research design in case studies

Study questions were previously discussed in respect to their suitability for a case study strategy in this research. The main study question is: *How do projects cope with the critical events that occur at some point in their life cycle?*

And the supporting study question, which could be derived from the first one, is:

Why and how could some troubled projects maintain a positive adjustment after the critical event while others cannot?

Their scope is to shed light on the behavior of a project's system when it is confronted with critical events, and to reveal those factors that might enhance its positive adjustments after the critical events. In comparison to the question "why do projects still fail?" which drove this research in the first place, these study questions are more precise and directly relate to the phenomenon under study (troubled project behavior).

Study propositions are not necessary in research strategies in which the topic is focused on "exploration" (Yin 1994, p: 21). However every exploration should still have some purpose. From this perspective, the scope of our exploration is to study how critical events unfolded and impacted the project's objectives and related performance. This will be done by capturing their effects, positive and negative, in the aftermath of the critical event and the overtime.

The *unit of analysis* is the project system itself; its selection resulted from specifying, as accurately as possible, the research questions. The focus is on its behaviour when confronted with critical events. This is understood with respect to (1) the critical events unfolding but refers as well (2) to the actions made by a project's actors to limit or eliminate the punctual or overtime impacts of the critical events. From the methodological perspective, critical events are seen as a useful way of managing great volumes of qualitative research data (Angelides, 2001). For this research study, they are particularly appropriate because they "qualify" the threat (one cannot come to a conclusion about the eventual positive adjustment of a project system without evidence of a potential threat to its expected performance and objectives).

The case study's physical boundaries are given by the project's system components, as described in chapter 6, while the time boundaries result from the project life cycle.

Another important element of the research design refers to linking the data to propositions and setting the criteria for interpreting the findings. This is in reference to the data analysis. Since the "current state of art does not provide specific guidance in this respect" (Yin 1994), the data analysis process in this study will follow the model and insights of the most quoted authors. They are those who based their research on case studies such as Mintzberg and Waters (1982), Hargadon and Douglas (2001). We have also followed the recommendations of the authors who are particularly sympathetic to qualitative research. These are the authors who wrote about: building theory from case studies (Eisenhardt & Graebner, 2007), the properties of rich description in case study (Weick, 2007), ethical issues in qualitative data analysis (Miles & Hubermann, 1994), the persuasion power of case study research

(Siggelkow, 2007), and the importance of methodological fit in any type of research (Edmonson & Mcmanus, 2007).

As a result, this case study is in a “narrative that is interspersed with quotations from key informants and other supporting evidence with the aim to demonstrate the close connection between data and emergent theory”. The last was developed by “recognizing patterns of relationships among constructs and their underlying arguments”.

For the critical event analysis, some elements of systems’ theory were used as suggested by Williams 2005 (Cicmil et. al 2006). This approach facilitates to define the critical events and understand their dynamics in relation to the project structure. Technically, the project was represented as a system of components linked to reach a final objective. By visualizing the complex interdependencies between the various parts of the project, we set out to capture the causal feedback induced by the critical events and their punctual and long-term effects.

A data analysis process concluded with an assessment of the theoretical contribution (Whetten 1989) with terms of: proposed concepts and constructs relevance (what), how are they related (links), causality explanation (why), and a general overview (who, where, when).

4.3 Data collection

As with Miles & Hubermann, 1994 (34:37), our case fits into the situation in which there are exploratory and confirmatory times, with exploration at the outset and confirmation near the end. Consequently, little prior implementation with structured instrument designs will be alternatively used. In this respect, the concern during data collection was to allow for “open ended” interviews. This allows for the interpretation to occur along the way (the interviewed person is allowed to discover new relationships or patterns on the spot) combined with highly structured control (critical incident technique) in order to avoid deluding the interviewer to total control. Also, it ensures the quality of the data collected and the way the analysis was carried out. In establishing the data collection method, we deliberately wanted to cover the contextual conditions, which we believe to be highly pertinent for the study of troubled project behaviour. The main validity factors considered were:

➔Ensure that the interviewers presence will not disturb the interview’s setting

➔Have well-grounded concepts

➔Get comparable measured responses from different people

Primary and secondary data collection from different sources was combined in order to tackle a broad range of chronological, attitudinal, and behavioural issues. Primary data collection prioritized the unstructured interviews with the various project actors. The discussions focused on the critical event that was unfolding and were carried out according with a technique adapted from disaster management research. This technique has an advantage of minimizing the biases given by both interviewer and interviewee. The fact that the object of the study received long lasting media coverage and public attention, offered the unique opportunity to use data from the media broadcasts that were realized at different moments within the project life cycle. However, this is also obliged to careful triangulation of the information from primary data sources. This must be done in order to be able to discern the facts beyond actors' testimonies, to look for patterns, and similitude of the data collected.

Collected data is qualitative in nature. The data on which this report is based will include: interviews transcripts, feedback reports, ails, phone conversations, T.V. broadcast reportages, information from the web sites, and company documents.

The primary data was mostly comprised in semi-structured interviews. The informants included political personalities, high level managers, operation managers, outsourcing companies' managers (Lötschberg), and the managing director of the company in charge of all technical feasibility studies of the Gotthard tunnel base.

As in any qualitative research, the processes of data collection, data analysis, and the development and verification of relationships (and theory-building) were interrelated.

Specifically, the first round of data collection was followed by an analysis. This led to new questions, or refining old questions, for the second round of data collection; which in turn led to discover new patterns and relationships in the previously collected data.

The process is pictured in the figure below and served as the "grounding of themes and findings to the data", in accordance with Glasser and Strauss (1967) and Eisenhardt (1989).

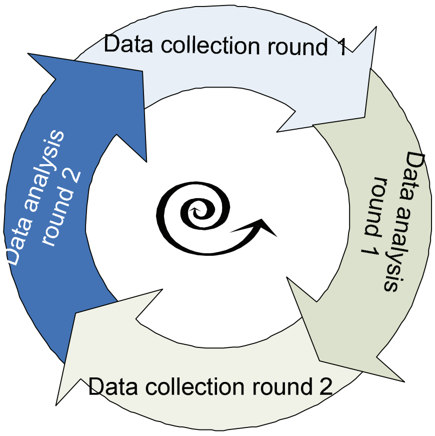

Figure 4-1: Data collection process

Another source of primary data was written records. Written internal documents were offered by the respondents. They encompass the common procedures related to quality and safety management, on-site communication roles, and the responsibilities matrix.

The secondary sources of data include reports, press releases, newspapers articles, and company web sites. They were mostly used to gather information at the organisation level. At the project level, other sources of data were meeting minutes, project progress reports, activity scheduling and planning, and budgets.

Taking into account the amount of funding and the strategic importance of this project, the organization and its control integration of the authorities, different organizations and services (OFT[23], DETEC[24]) represent the confederation's interests and they issue several reports on a regular basis. These are publicly available on their websites and have been used as secondary sources of data.

4.3.1 Interviews

The semi-structured interviews were the first source of empirical data in this study. Four sites were visited and interviews were performed with high–level managers from the two different

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[23] « Office Fédéral de Transport » (French)

[24] « Département Fédéral de l'environnement, transport de l'énergie et de la communication » (French)

project organizations, security specialists, consultants (designers) and political representatives (see Annex 2, and Annex 4).

At each site, semi-structured interviews were conducted with a prepared list of questions, lasting from two to four hours. Technically, the critical event interview method was adopted. This is derived from the critical incident technique developed by Flanagan (1954) and has the advantage to "minimize the biases introduced by both interviewer and interviewee". It was successfully used in the research of the failure of high reliable organisations (nuclear power plants, airlines) and disaster management research. Annex 3 provides details about this technique that were considered relevant for this study.

Whenever appropriate, questions "not in the list" were asked (questions and discussion topics in Annex 5). Eight in-depth interviews were realized (minimum two hours each) in two rounds. The additional information, whenever needed, was requested by e-mail.

Interview transcripts elaborated within 3-5 days after the interviews; these were the main source for primary data. Other primary data sources included phone conversations and e-mail exchanges between May 2008-March 2009.

Agreement among sources within the same project organization was found to be moderately high. It was estimated that the percentage of agreement between sources was in excess of 85%. Between interviews and written records, consistence was also moderately high. Discrepancies were clarified by telephone or mail whenever possible. The critical events were chronicled based on the sources above. The main criteria for providing details about the critical events, which were not publicly mediatized, were as follows: for factual statements and intervention strategies that involved several participants, we required at least one source to agree and no source to deny that the event happened. Personal statements and anecdotes were reproduced in the narrative, as they were told.

4.3.2 Rationale for the choice of NRLA case

It is common to say (e.g. Eisenhardt & Graebner 2007; Yin 1994; Miles and Hubbermann, 1994) that in case study research, theoretical, and not random or stratified, sampling is appropriate. Furthermore, the same authors assert that the theoretical sampling of single cases should be straightforward.

"They are chosen because they are *unusually revelatory, extreme exemplars, or opportunities for unusual research access"*. The case[25] of the "New Rail Link through the Alps" (NRLA) project was strategically selected for this study because of the following reasons:

This case is *revelatory* for the topic under study in the acceptance of Yin (1994; 2004), and Flyvbjerg (2006), in the sense that it offers the unique opportunity to study, in-depth, one of the largest infrastructure projects of this century. Also, it consists of "two projects in one," meaning that it offers the unique chance to gain insight into two different project organisations. This turned out to display different coping capabilities and approaches to their confrontation with similar critical events.

The proximity combined with the *access to several sources* (political, practitioners, scientists, and the media) offered the opportunity to develop a *significant* case study as defined by Yin (2004). The proximity was a particularly valuable attribute in gathering empirical data (testimonies) from the actors who quit the project immediately after the life cycle phase; in which their involvment was completed (e.g. designers and engineers who participated in the feasibilities studies).

Last but not least, during the process of data collection it became obvious that the NRLA case had the attributes of a *"paradigmatic case"* as described in Flyvbjerg (2006). Meaning in the sense that it "transcends any sort of standards because it sets the standard" in connection to the topic under study. Indeed the case displays a *variety* of critical events, which *troubled* the project's course in *all of the project's life-cycle phases*. In spite of huge cost overruns and delays, as well as a set of *never ending critical events*, the project was not closed. Moreover, its achievement was justified by the fact that the project is *"the chantier of the siècle"* in all respects[26]; it became a strategic objective of the Swiss transport policy. There is also a general belief that all the efforts put into the implementation of this infrastructure are justified, and will be paid back when the NRLA project will be completed. In spite of the incurred delays

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[25] Yin, (2004) argues that the "case" is the real set of events from which data will be drawn. In contrast, the "case study" is the substance of the research inquiry, consisting of research questions, theoretical perspectives, empirical findings, interpretations, and conclusions. (14-15)

[26] Financial, technical, geographical challenges

and cost overruns, the neighbouring countries show their “boundless admiration” for the tunnel and Swiss transport policy.[27]

For the above reasons , it was considered that the interpretation of such a case could provide a unique wealth of information. The theories will emerge and allow the formulation of testable propositions about the factors and conditions (resilience enablers) that account for their positive/negative adjustments (performance).

4.3.3 Rationale for the single-case study selection

The previous paragraph highlighted the fact that the NRLA case is, at the same time, revelatory and paradigmatic, allowing for development of a significant case about a topic which received relatively little attention in project management literature. As explained by Yin (1994; 2004), these attributes “are likely to involve only single cases, by definition, because the rationale for single-case design usually cannot be satisfied by multiple cases”. Indeed, similarly to the methodologies which use multiple experiments, (Yin 1994) the choice of cases in a multiple-case design research strategy must follow the replication logic. This means that the “same results are predicted for each of the three cases, thereby producing evidence that the cases did involve the same syndrome”.

If we put the rationale for choosing the NRLA case in perspective, it becomes clear that it would have been difficult (if not impossible) to find *representative* cases of hard infrastructure projects exposed to similar critical events with as convenient *proximity that will grant the same amount of access to information from various sources*. Another inadvertence of this design would have been given by the status quo of knowledge and available theory about the behaviour of projects when they are confronted with critical events that are inherent in their life-cycle and their performance, understood here in terms of committed costs and delays. Specifically, as explained by Yin (1994) and Miles and Hubermann (1994), *considering the actual status quo of research on this topic, it would have been hard (if not impossible) to develop a rich theoretical framework stating the conditions under which a*

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[27] Cited from the article: “*A tunnel that provokes “boundless admiration” by* **Doris Lucini and Andreas Keiser**, swissinfo.ch

particular phenomenon is likely to be found (literal replication) as well as the conditions it is not likely to be found (a theoretical replication).

Therefore a case study strategy used in this single case is at the same time paradigmatic and revelatory. It was chosen as being the most appropriate investigation tool to shed light into the phenomenon of troubled project behaviour when it is confronted with critical events.

4.3.4 Operationalization

In this research, the real meaningful concepts and constructs will emerge from the "analysis of the process itself, rather than being clearly specified a priority", as explained in Eisenhardt, 1989; Miles and Huberman, 1994. Nevertheless, the exploration is guided with literature based working definitions, sharp research questions, and clear boundaries of the research perimeter.

4.3.5 Analytical generalization

Case studies rely on analytical generalization (Yin 1994). Consequently, the basis of the generalization in our case would not be on typical points of the project but on the existence of particular factors (attributes, processes) that influence the behaviour of troubled projects; in the sense that they could enable projects to respect the committed budget and time lines. These attributes and processes are revealed through the analysis of project behaviour from an original perspective, which is the resilience approach. In this light, the scope of analytical generalization in this study is to produce a *middle range theory on the applicability of the resilience construct in the management of infrastructure projects and conceptualization of troubled project behaviour. This theory will contribute to an increase of the understanding of those conditions and factors which account for the positive adjustment when a project faces critical events.*

4.4 Conclusion

This chapter discussed the choice of the research design retained for this study. The arguments given aimed to demonstrate that a qualitative, exploratory strategy, articulated on a single case, is consistent with the phenomenon-driven research questions (chapter 2) and tightly scoped with the formulated problem (chapter 2) for which there is a lack of plausible existing theory (chapter 3).

5 THE NEW RAIL LINK THROUGH THE ALPS (NRLA) CASE STUDY

> *A case study is expected to catch the complexity of one single case. A single leaf, even a single toothpick, has unique complexities, but rarely will we care enough to submit it to a case study. We study a case when it itself is of very special interest. We look for the detail of interactions with its context. A case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances.*
>
> ……………………………………………….
>
> *"The case is one among the others. In any given study we will concentrate on the one. The time concentrating on the one may be a day or a year, but while we so concentrate we are engaged in case study.*
>
> From the "The Art of Case Study Research" *by Robert E. Stake*

The case study presented in this chapter is described at two different, but related levels. The first level captures the "objective" side of the case. This is the project's organization which provides a *static* view of the project's system with a focus on the characteristics of the organization and management processes; specifically the decision process, controlling, and contract and risk management. The second level is the critical events, which capture the "subjective side" of the case. Contrary to the first level, the critical events provide a *dynamic* view on the project system. Here, the project behavior in the face of critical events is described based on the collected qualitative data, with the help of a systemic model developed for this purpose.

5.1 Background

In this section, the context of the New Rail Link through the Alps (NRLA) project, its challenges, and the financing structure will be described. The facts mentioned will finally highlight the following, very specific, features of this project: 1) the project is backed by the Swiss government 2) it was conferred an indubitable legitimacy by the fact that its implementation will not only respond to a clear formulated demand, but it is also aligned with both the European and Swiss transport policies and long term objectives 3) St. Gotthard base tunnel is, as of today, over the initial timetable and over budget, while Lötschberg was achieved "on time" but with a non-negligible modification of the original design (one rail instead of two). Although the statement as to its "on time" completion it might be contested, the Lötschberg tunnel base is not valid because of the important modification to the original design was made. This was the way the project achievement was communicated in all official documents and media, and asserted as well by the project's organization. [28]

As any emblematic infrastructure project, the NRLA has an historical ground. The idea of building a base tunnel through the Alps, in the mythical passage of St. Gotthard, can be dated back to 1947, although the first studies were carried out in 1962 and 1963. This was when the Swiss government founded the commission "Railway Tunnel through the Alps" (KEA). Since then, the concept of future alpine crossings suffered radical modifications in content and form.

The concept today, also known as the "New Rail Link through the Alps" (NRLA)[29], was approved in 1992 by popular vote, but the first political talks about its necessity were dated to 1980. Indeed, the inauguration of the road Gotthard tunnel in 1980 attracted traffic from all over Europe and led to an animated ecological debate at a national level. To limit this traffic affluence, Switzerland implemented a vehicle fee for vehicles over 28 tons, but Europeans put more and more pressure on obtaining permission for 40 ton vehicles to pass through the Alps.

Challenged to prove more flexibility towards the European transport policy and to find a cure for the ecological problem, the Minister of Transport, at the time, developed the NRLA project. He promoted it as the best strategic compromise in order to show that Switzerland was not against the mobility but that its objective was mobility by rail because of its environmental friendliness.

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[28] « Nous pouvons nous féliciter d'avoir réalisé un ouvrage aussi important en respectant les délais ponctuellement à la semaine près » cited from the speech of Moritz Leunberger at the inauguration ceremony of Lötschberg tunnel basis.

[29] French: NLFA (Nouvelle Liaison Ferroviaire Alpine) ; German : NEAT (Neue Eisenbahn-Alpentranversale)

As a consequence, the European Community's members were convinced by the project opportunity and agreed to the heavy vehicle limit of 28 tons, but only on the condition that Switzerland builds two base tunnels, which would become the NRLA.

This was the ground on which this project was born. As shown in Figure 5-1, it mainly[30] consists in the construction of two masterpieces which are the St. Gotthard Base Railway Tunnel and the Lötschberg Base Railway Tunnel. At 57 km, the St. Gotthard Base Railway Tunnel will be the longest railway tunnel in the world, along with the Lötschberg Base Railway Tunnel, which is 34 km long.

Figure 5-1: NRLA Project Concept

The NRLA project encapsulates many meanings for many parties. Swiss people are known for their enthusiasm about railway usage: the average Swiss person travels roughly two

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[30] The Monte Ceneri base tunnel is part of the NRLA; it will be completed before 2019, and it will be a very important feeder in the south for the Gotthard Base. The execution of this Monte Ceneri base tunnel is not treated on this case study.

thousand kilometers by train each year and railways have always been considered a factor in national cohesion; bringing the different language regions closer together[31].

Also, for the Swiss electorate, the project is a dream in having the roads relieved from freight traffic, while preserving the future generations' environment and the Alps. For Europe, the NRLA will bring a flat rail link that will set up a new era for 21st century travel through the Alps. New high-speed lines for passenger and freight trains, designed for interoperability will connect Europe and make it the first high-speed link from North to South.

It will provide a travel time decrease to 2.5 hours from Zürich to Milan, and the possibility freight trains of over 4,000 tons to pass through the Alps as if they did not even exist. These are only two aspects among many other major improvements expected to come from this project; which perpetuates Switzerland's pioneering tradition in tunnel construction.

In concerns of the country, the new alpine crossing will increase the capacity of the existent axis from 20 to 50 million tons per year. This makes Switzerland more appealing for the business by respecting, simultaneously, the transport policy strategy and its objective in achieving an environmentally compatible system of mobility. The infrastructure will improve people's life quality by offering a real alternative to journeys by car or plane. Also, "very many Swiss citizens are proud to see such a vast and sophisticated project undertaken by so small a country."[32]

At a higher level, the commitment to build this major venture, with its own finance endorsed, and the Swiss political promise to integrate its public infrastructure into the European network. This triggers admiration for the Swiss self-financing transport policy compared to other countries in which the "transport policy is always in the middle of disputes between transport and finance ministers"[33].

The acceptance, by the Swiss electorate, of the above described concept provided the basis for planning and the start of construction in September 1993. Simultaneously, the sites of Gotthard and Lötschberg, each project was confined to a different project organization (Maîtres d'ouvrages), specifically AlpTransit Gotthard AG and BLS AlpTransit AG.

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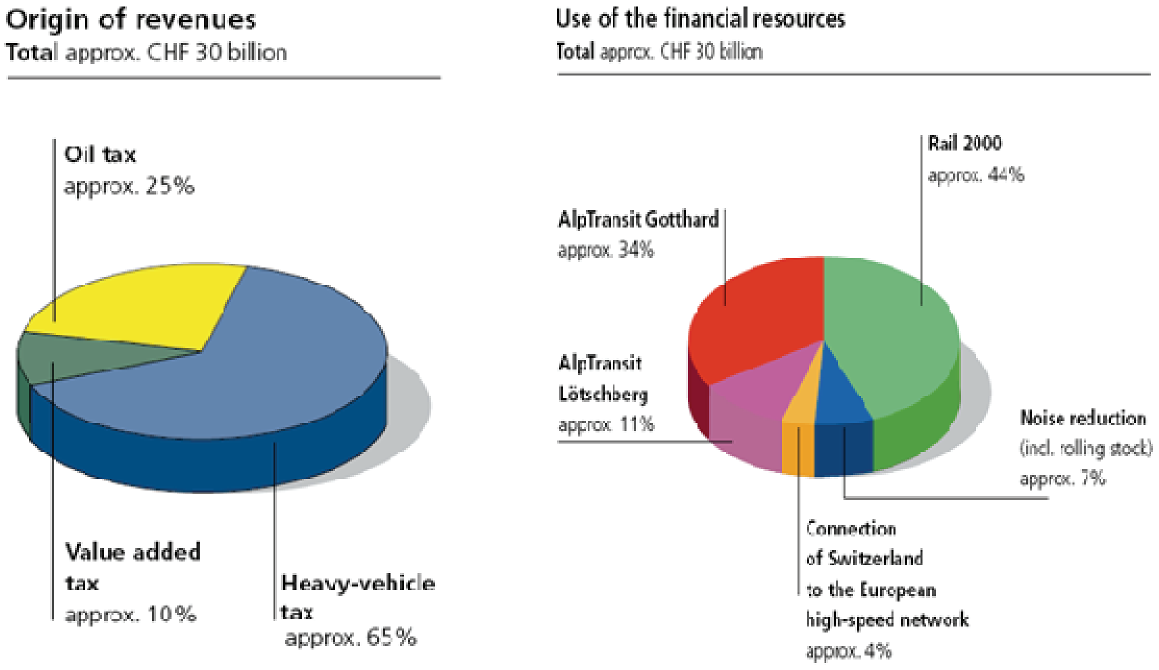
[31] Source : article "Alptransit, a record-breaking tunnel," swissinfo.ch, October 2009

[32] Said by spokeswoman Monica Knapp in article "Alptransit, a record-breaking tunnel," swissinfo.ch, October 2009

[33] Minister Moritz Leuenberger tells swissinfo.ch.

The first proposed financing structure, according to which the government credit should have entirely covered the future benefits in the service provision, raised questions on the economic viability and therefore, it was replaced in 1998 with the actual financing structure, depicted in the figure below. This financing scheme foresees the NRLA embedment into the Rail 2000 project; which has a scope of the existent infrastructure improvement and the implementation of the structures for "noise reduction."



a) b)

Figure 5-2: Financing scheme (FinöV fund) Source: Alp transit information brochure

The whole package (FinöV) is financed through a special fund alimented with a tax on oil products, the heavy-vehicle tax, and the value added tax (VAT). The figure b) on the right shows the forecasted investment's repartition between the three projects. According to it, almost half of the total amount (approximately 30 billion Swiss francs for over 20 years) will be used to cover the costs of the NRLA project.

Today, similarly to other major infrastructure projects worldwide, the construction of the St. Gotthard base tunnel is running over time and over budget. Although its completion has been projected for 2011, the tunnel may not be completed before 2017. Various unexpected events troubled the course of the project and required an additional investment representing 53.4 % more than the original cost estimate. In September 2008[34], the Swiss parliament approved a total credit of CHF 19.1 billion (price level 1998, excluding inflation, value added tax, and construction interest). Of this amount, CHF 13.157 billion were reserved for the Gotthard route: the Gotthard and Ceneri base tunnels. The current estimate of the final costs for the AlpTransit Gotthard project is CHF 12.25 billion: Gotthard CHF 9.83 billion and Ceneri CHF 2.42 billion.[35]

On their official website, this overspending is mainly justified in terms of “greater safety and latest technology, but also because of politically motivated delays and the difficult geology.”

Meanwhile, the completion of Lötschberg was accomplished. In June 2007, the Lötschberg base line was handed over to the operator BLS AG, marking the construction achievement of the Lötschberg Base Tunnel. The project was finished on time but with one major modification to the original design; two tubes were constructed but only one was equipped this resulted in one rail instead of two as originally conceived.

5.2 Part A: NRLA – Two Projects in One

This section focuses on the NRLA project structure with a highlight on the output description, its execution, organization structure, project risk management, controlling, and the decision making process. This description is based on facts as stated in the data collected (secondary data), and therefore gives an *objective, static view of the project system.*

The NRLA project is also known as the “chantier of siècle.” The reasons for this surname include not only the amount of the money invested, but also the technological and geographical challenges, as well as the complexity of work and the management processes that were carried out in order to build this infrastructure.

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[34] Swiss Government decision on the amendment of the NRLA total credit (Alp Transit Financing decision)

[35] Source Alp Transit web site updated in October 2010.

Another feature that makes this project unique, is that the construction of both two base tunnels were confined to two distinct entities ("maître d'ouvrages"). AlpTransit Gotthard AG, a fully owned subsidiary of the Swiss Railway, is building St. Gotthard base tunnel. While the construction at Lötschberg was completed by BLS AlpTransit AG, which belongs to a private railway operator with the same name. Therefore, the NRLA is a 2-in-1 project between two different project organizations that share similar controlling systems.

In this case study, the St. Gotthard base tunnel and Lötschberg base tunnel will be presented either separately or at the aggregate level (NRLA) based on the relevance of the discussed topics for this case and the importance of their structural differences.

5.2.1 St. Gotthard base tunnel

> "*A route through the mountain – the longest ever made. The first tunnel under the Gotthard was finished in 1882, linking Germany, Switzerland, and Italy and was a record 15 kilometres long. Just over a century later, history has repeated itself. On October 15, 2010, the last breakthrough will be made in the new rail tunnel and the Gotthard will once again be the scene of a record.*"[36]

Physical Infrastructure and Service Provision

The St. Gotthard base railway tunnel is being built on the Gotthard axis, which runs from Arth-Goldau to Lugano.

It consists of two, 57 km, 37 long bores between the portals of Erstfeld and Bodio, connected every 325 meters by emergency escape passageways. Its itinerary is shown in Figure 5-3 and is the result of the prevision made by experienced geologists endorsed with the results from exploration tests. The open-air section itinerary, linking the St. Gotthard base tunnel to the existent railway, was chosen in order to conciliate both requests formulated by habitants and political decisions. The itinerary layout was approved by the Federal Council in 1995. To limit the construction times, it was decided to head the excavation from the two portals and, at

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[36] Source : swissinfo.com on September, 2010

[37] There are also approximately 13 km of approaches.

the same time, from three intermediary access points: Amsteg (1782 meters), Faido (2646 meters) and Sedrun (800 meters). The geology represents a complex dimension since "the tunnel crosses crystalline rocks belonging to three important geological units: the Aar massif, the St. Gotthard massif and an area of Penninic gneisses." These units are separated by sedimentary areas, namely the Tavetsch massif and the Piora formation. The maximum overhead rock reaches 2,300 meters in the St. Gotthard massif area. The Gotthard base tunnel is built in a traditional open track method. A system of approximately 180 communication branches and exchange diagonals enhances the passage from one rail to the other and allows each tunnel to serve as a security tunnel for its pair, in case of accidents.

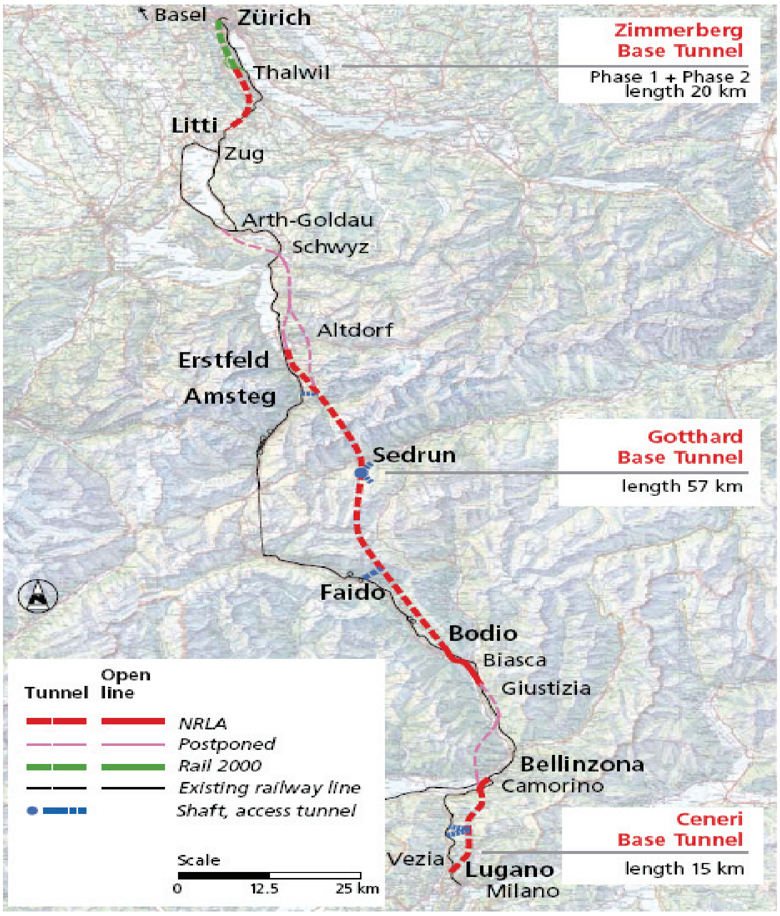

Figure 5-3 St. Gotthard base tunnel itinerary

The execution technology is classical and the tunnel is created through the use of explosives, partial excavation, and a tunneling machine (TBM).

After completion, the Gotthard Base Tunnel will be the most important element of the NRLA. The flat line, no higher than 550m above sea level, will reduce the travel time from Zürich to Milan by one and a half hours, will allow for a capacity of 40-60 passenger trains per day and 200-210 freight trains per day. The speed range will be as follows:

- Passenger trains (200 km/h)
- High speed passenger trains (230-250 km/h)
- Freight trains (100-160 km/h)

The estimated cost at the 1991 price level was CHF 7.6 billion. The project is financed by public funds in a proportion of 100%, but private financing for certain elements may be taken into consideration in the 2nd phase (Ceneri tunnel). Its construction started in 1998 and its completion was first foreseen for 2011. Today, it has been readjusted to where the tunnel will not be fully completed and finished before 2017.

Project Specifications and Risk Management

The new created infrastructure will be part of the European high-speed network. The infrastructure requirements are based on the UIC[38] standards and Swiss railway guidelines as well as on general Swiss and CEN[39] standards. The operational requirements and the basic technical parameters were defined by the Swiss Federal Railways and approved by the Federal Office of Transport. The detail specifications were elaborated by AlpTransit Gotthard AG and stated in comprehensive specification documents concerning civil works, railway installations, and the future survey and maintenance (Schalcher, 2000).

AlpTransit Gotthard AG believes that risk management is the key to control risk and it has developed its own method in risk assessment. This method is based on the theory of system dynamics and all actors involved in the project; such as consulting engineers, contractors, and suppliers who are all obliged to apply this technique systematically and periodically. In order to control the important risks, Alp Transit Gotthard AG has implemented an extended quality management that is project oriented and applicable in all phases of the project's life cycle, from design to the execution.

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[38] UIC = International Union of Railways

[39] CEN = European Committee for Standardization

Project Corporate Governance

Project governance structure is presented in the Figure 5-4 below.

The assigned roles and responsibilities are:

Owner

The Swiss government is represented by the Ministry of Environment, Transport, Energy, and Communication. Its task is to ensure the strategic monitoring of the project, free-up the necessary funding, decide on the utilization of the reserves, and credit augmentation in order to cover VAT, interests, and inflation. It has delegated the Federal Transport Office (FTO) to the overall project's controlling on a governmental level and the reporting to Parliament. Therefore, 15 employees from the Federal Transport Office are in charge of the AlpTransit project. They have multidisciplinary (engineering, finance, transport specialists) backgrounds.

The FTO is committed to fulfilling various tasks starting with the establishment of planning norms and finishing with the approval of exploitation authorizations. They work in collaboration with the future operators, elaborate the submission procedure, and ensure the free competition among the subcontractors.

Builder

The role was assigned to AlpTransit Gotthard Ltd. The project company was founded on May 12, 1998 and is fully owned company by the Swiss Federal railways, with approximately 130 employees.

Operator

Once the project is completed, the Swiss Federal Railways will operate the infrastructure, which is the largest public Swiss based transport company (over 28,000 employees).

Design

AlpTransit Gotthard AG executed the layout design in collaboration with private consultants for the framework of four design contracts.

Project Management

AlpTransit Gotthard AG is in charge of the project management, which is carried–out from their head office in Lucerne. In parallel, there are management offices in Altdorf, Faido, Sedrun, and Bellinzona. Local site supervision is provided by the engineering companies, which were, in general, also responsible for the design.

which were, in general, also responsible for the design.

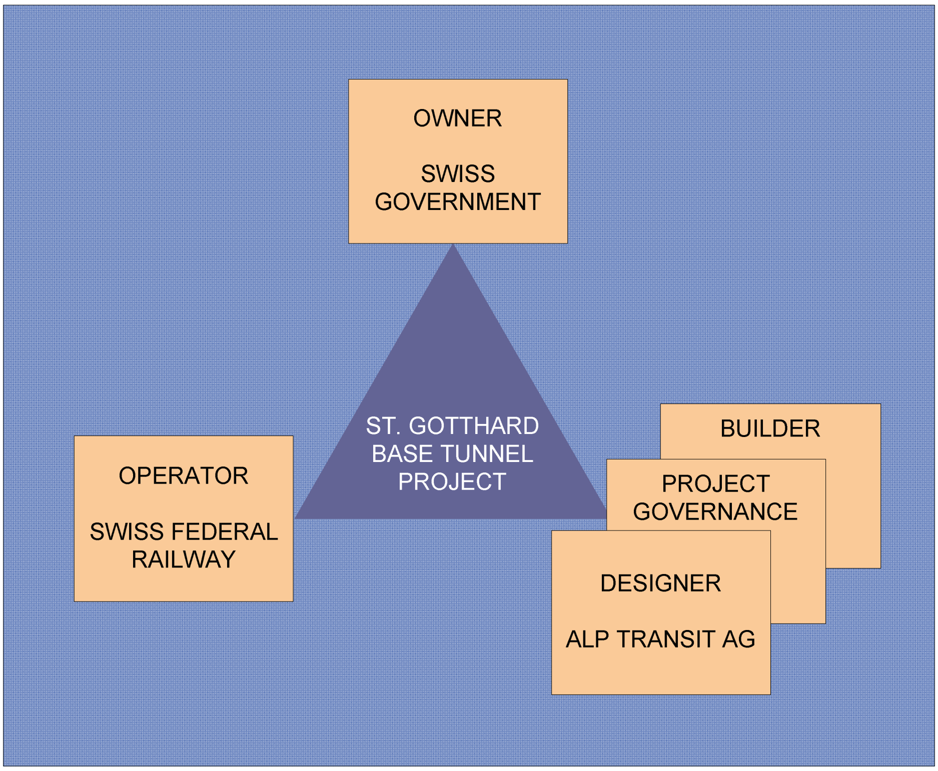

Figure 5-4: Corporate Governance St. Gotthard Base Tunnel

Contractors

A consortium of different contractors will carry out the construction work. Five main contracts for the civil work and one for the railway installation have been drawn up. In addition, there will be approximately eight minor contracts and numerous small contracts.

Decision Making Process

As explained in the beginning, the decision about the project concept and the construction belonged to the Swiss people; who approved them through two important national votes in 1992 and 1998.

A notable point is that in a country where the direct democracy principle is one of the main shared values, the public opinion matters. Meaning, Swiss people are actively involved in political decisions, and in connection with this project, their open attitude towards the NRLA endorsed the project's political legitimacy conferred by the government. This pro-tunnel attitude is exemplified through the fact that, in general, the Swiss people are known worldwide as supporters of public transportation. Either as a citizen or a contributor, they are always enthusiastic about transportation infrastructure projects. As a self-speaking example, projects submitted to the popular vote in the past years gave the authorities the power to allocate the Swiss Railway implementations of "2,674.1 million francs and a package of 1,143.7 million francs is for the construction of NRLA at St. Gotthard"[40].

In 1995, the Swiss Government made the decisions about the general itinerary and time schedule. The environmental impact assessment was carried-out in accordance to Swiss law for environmental protection. The final report was approved in 1998, after intensive negotiations between the federal representatives, the cantonal authorities, and with a couple of compromises to the open-air sector trajectory. In finance concerns, the Swiss Parliament approved, in autumn of 1999, an overall credit of CHF 12.6 billion for the first phase of the NRLA project. However, the credit was insufficient and therefore further augmented. The yearly credit contributions for both the Gotthard and Lötschberg base tunnels were subject to Parliament release.

Contract Management

A consortium of different contractors will carry out the construction work. AlpTransit Gotthard AG is fully responsible for the contract's management; meaning that they are accountable for tendering, contract negotiations, and closing, execution, and fulfilment. In most cases, bid and performance guarantees are requested from the contractors. On the client's side, AlpTransit AG acts as a contractual party.

The contracts are prepared in accordance to the Swiss Law and standards of the Swiss Society of Engineers and Architects (SIA). Additionally, the contractors are invited to submit alternatives at their own risk and cost. The contracts include a price index clause, which is based on the cost variation of salaries, transport, energy, materials, and other main cost items.

Project modifications that do not affect the functional criteria, the milestones, or the budget, are negotiated and agreed upon between the contractor and the builder on the basis of a

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[40] Source: http://sbb-gb2009.mxm.ch/?lang=2 (Swiss railway web page)

contract variation and corresponding addendum. However, it is mandatory to have all the major changes approved by the Federal Transport Office.

Claim management – "There are standardized procedures for the claim management, according to the Swiss VSS code".

Project Controlling

Project controlling is based on the "NRLA Controlling Regulation," which is issued by the Ministry of Environment, Transport, Energy, and Communication. This regulation defines the controlling elements at the governmental level and the related measUring methods. Project controlling is AlpTransit AG's main task. "The consulting engineers who supervise the sites provide support for controlling but they are not authorized to make any important decisions." FTO is responsible for the NRLA project's overall controlling, reporting to Parliament, and issuing related reports for DETEC and the Confederation. Four to six times per year, FTO writes reports on the current situation of the projects for the Parliamentary Delegation; which was assigned to NRLA for monitoring.

The FTO is also responsible for updating the directives related to the NRLA controlling, the establishment of exams and audits, technical hand-over of those projects elements which are ready for exploitation, the management of information systems, and updating the conventions between the Confederation and the two project organizations. Like in the traditional project management, the work's breakdown structure framework, defined by the Federal Office of Transport, enables controlling. The work breakdown structure is output-oriented and is divided into six levels: the top level covers the NRLA's assembly while the lowest level is defined by the project elements. AlpTransit AG is responsible for detailing the work breakdown structure into each single contract.

There is also an entity which is in charge of surveying the NRLA on behalf of the Parliament ("Délégation de surveillance de la NLFA"). Its main responsibilities consist of high financial control on the current and post execution of NRLA; parliamentary control of the project administration; permanent control in respect to the interpretation of legal basis; provision of services, costs, delays, and credits for all project components; as well as the responsibility of auditing and controlling the project's organization structures and management processes.

Controlling Elements

The controlling elements consist of the quality, time schedule, performance cost, and finances.

Quality

The quality of the work's execution is assured by a quality management system of the contractor or consortium. Although this quality management system should be in line with ISO 9001 requirements, the official certification is not compulsory. Quality is tested (ordinary testing) against the control/inspection plan, which is part of the binding contract. In addition, a project-oriented quality management, in accordance with SIA 2007, is practiced. Its main focus is on the major risks involved. For each identified risk, the responsible contractor must elaborate and implement a quality plan.

Cost & Time

Cost controlling is done against the contract items that have already been invoiced. Periodical cost information is given and includes target costs, actual costs, forecasts, and comments on the cost development and controlling. The periodical cost's information objective is to ensure that the final costs do not exceed the targets, to provide transparency, and to allow cost variations to be identified at an early stage. Time control is organized similarly like cost control.

Performance

The performance is measured against the actual degree of completion in a percentage for each "unit of work"[41] in the breakdown structure. The site supervisors prepare estimates and forecasts of these values on periodically basis.

Reporting

According to the reporting concept, the site managers will report to upper-level management in alignment with the work breakdown lines. They will send monthly reports to the section managers, who in turn will send quarterly reports to the AlpTransit AG management. The board or directors of AlpTransit AG and the Federal Office of Transport will receive comprehensive reports twice a year. This report will contain the following points: summary,

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[41] Traditional contracts are based on a bill of quantities and unit prices.

performance/progress (actual status vs. forecasted), scheduling (status vs. forecast), cost (status vs. forecast), financing (status vs. forecast), organization, and project environment (overall evaluation of the project's chances and risks). The Federal Office of Transport will control only the information coming from the four upper levels of the work breakdown structure. Lastly, Parliament will also receive a comprehensive report from the Federal Office of Transport twice a year concerning the status and the forecast of the NRLA project's assembly.

In case of unusual or unexpected events the reporting concept foresees intermediate reports. All the documents are on paper. The tools used in the project organization are Primavera for scheduling, KOFAT for cost and finance control, CAD software, Document Management system, E-mail.

Project Organization Chart

The project organization chart of AlpTransit AG is depicted in Figure 5-5.

According to the PMBoK (3rd edition 2004), its structure corresponds to a Functional Organization.

In this type of organization, there is a clearly defined hierarchy in which each employee has one clear superior. Employees are grouped by specialty; in this case there are tunnel and track construction, railway engineering, and commercial division employees with legal, planning, and quality employees at the top level.

Track construction may be further subdivided into functional organizations at the site level. In this kind of organization, it is traditionally assumed that the scope of the project is often limited to the boundaries of its function. Also, each function will do its work independent from the others according to a consecutive concept of planning. A job will start when the work of a previous function is finished (e.g. track construction and railway engineering).

Communication Channels and Protocol

Different departments have (mainly) monthly meetings. The coordination among departments is organized in the executive management meetings (every 14 days). The departments are also organized in special working groups for technical coordination, time schedule coordination, and quality control. Their meetings are held monthly or quarterly.

The project's construction drawings or changes have to be approved by the Tunnel and Track Construction department and the Railway Engineering department.

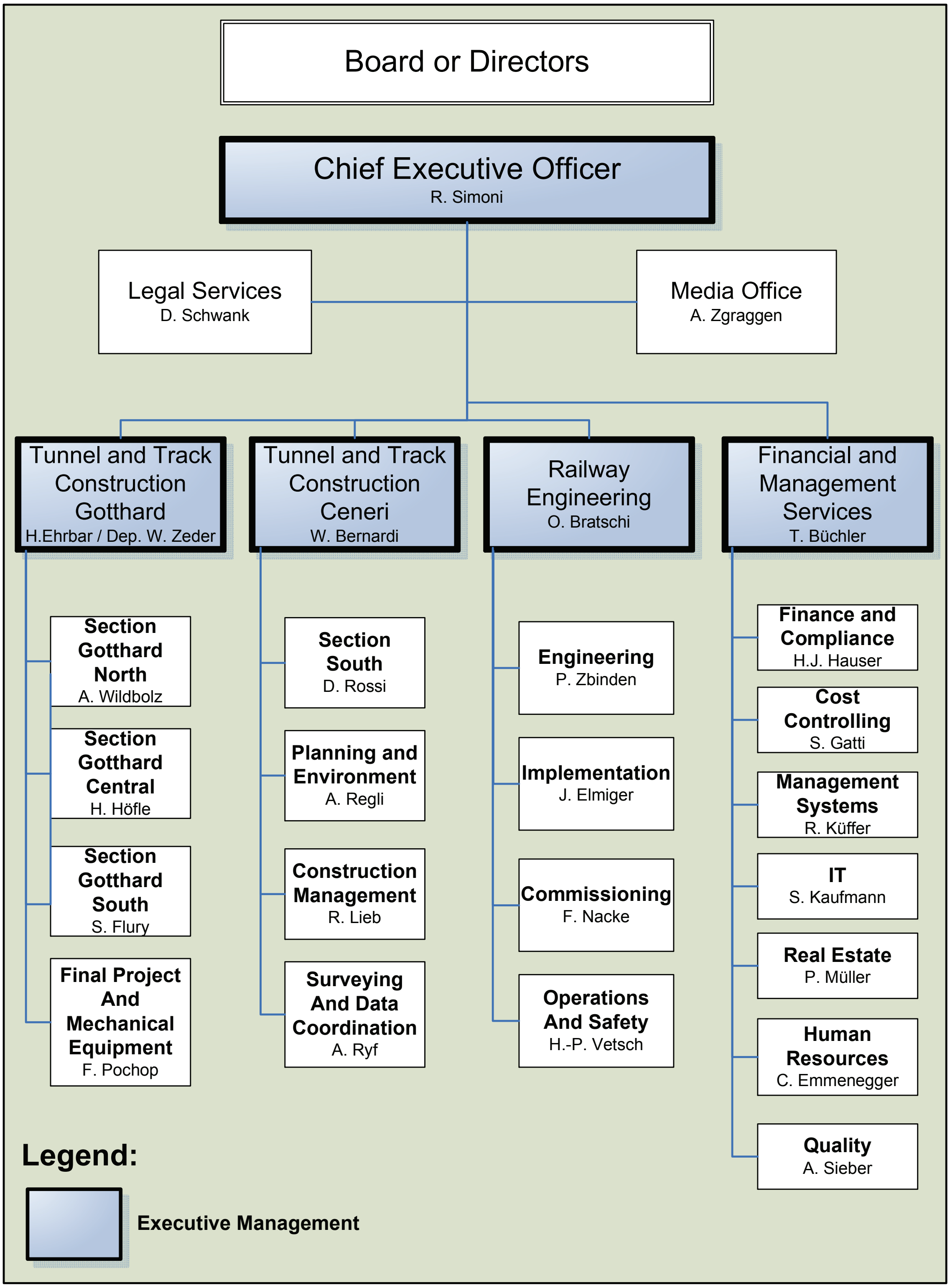

Figure 5-5: Alp Transit Organization Chart (Source: primary and secondary data collection)

The detailed roles and responsibilities are described in the Table 5-1.

ROLE	**RESPONSIBILITY**
CEO	The CEO is the leader of the executive management and the main representative of the company towards the federal government, board of directors, and the public.
Legal Procedures	This lawyer is responsible for all legal aspects concerning public law (authorizations, environmental aspects, commissioning).
Contracts	These are responsible for the legal aspects of the contracts with the engineers and constructors (elaboration of tender documents, tendering, finalization of the contracts, claims).
Media Office	Responsible for relations with the media and the site visitors, they also coordinate the communications with the Federal Office of Transport.
Tunnel & Track Construction Gotthard	They are responsible for the design and construction (only civil works) of the NRLA from Altdorf to the south portal of the Gotthard Base Tunnel (including the 57 km long Gotthard base tunnel) within the predefined restrictions (cost, time, technical standards, environmental aspects, safety etc.). DUring construction, this department is the main partner in negotiations and the daily business with the contractors and the engineers.
The Sections	The sections have the same responsibility as the whole department but only on a smaller part of the project.
Final Project and Mechanical Equipment	This is a group of engineers that has responsibility for the coordination and approval of the design (which will be done by private engineering companies).
Tunnel and Track Construction Ceneri	This department has the same responsibilities of the sister organization from the Gotthard. They are responsible from the southern portal of the Gotthard Base Tunnel to Lugano (including the 15 km long Ceneri Base Tunnel).
Railway Engineering	This department is responsible for the engineering, implementation and commissioning of all the railway equipment. They are the partners of the contractor for the railway equipment.
Financial & Management Services	This department has a centralized support function for cost controlling, compliance, real estate, human resources, and quality management.

Table 5-1: Roles and Responsibilities in Alp Transit AG project organization (Source: primary data collection)

5.2.2 Lötschberg base tunnel

In passing through the Lötschberg tunnel from north to south "we have made our way from the watershed of the Rhine to that of the Rhone": "water that we saw flowing past us before entering the Lötschberg tunnel was on its way to the North Sea; that

> *which now comes into view, in the Lonza gorge, will flow into the Rhone and be carried by that river into the Mediterranean."*
>
> Cited from *Cecil J. Allen*[42] in "Lötschberg tunnel makes rail history" *Swiss info, April 2005*

The Lötschberg base tunnel is the second part of the NRLA master project and thus, in most aspects, projects controlling, methods, and tools employed are similar to the St. Gotthard project. However, the project organization itself, BLS Alp Transit, differs from the Alp Transit AG organization. The purpose of this section is to present the differences between the two projects, with respect to the principles of the first part of the case study. This will provide a static view, based on facts, of the project organization, governance, and basic management processes.

Lötschberg Base Tunnel: Physical Infrastructure and Service Provision

The Lötschberg base tunnel itinerary is depicted in Figure 5-6. As shown, the tunnel links the canton of Bern, from Frutigen to the canton of Valais, in Raron.

The tunnel has a length of 34.6 km and is designed as a two-tube, single-track rail tunnel; where each tube carrying trains run in opposite directions.

The Federal Council phased the tunnel expansion as the result of a decision on April 24, 1996, to re-dimension NRLA (New Rail Link through the Alps) for costs reasons. In the phase 1, the two, single-track tunnels were supposed to have drilled over the whole length. However, only one track will be completely installed for operation. As for the second track, only the rail between Ferden and Raron (approximately 13 km) will be put in operation. The completion of the second track and the connection to Steg both belong to the second phase of the project. The Steg/Niedergesteln portal western branch and the western tunnel between Ferden and Mitholz will remain as a shell construction and has plans to further adapt them in several stages dependent of the needs triggered by the demand.

Similarly to the St. Gotthard base tunnel, the construction of the Lötschberg base tunnel is sub-divided into sections (Mitholz, Ferden, and Steg as intermediate points). In terms of the construction method, the tunnel was realized with repetitive machines (TBMs with a 9.6

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[42] Cecil J. Allen: railway writer and historian

meter diameter in the Steg lateral adit/base tunnel and the first 10 km of the eastern tube from the southern portal at Raron).

Figure 5-6: Lötschberg base tunnel itinerary

In areas with variable geology or rock, the traditional method of blasting was used because of the level of difficulty.

Considering that the geological conditions were assessed as favourable and the tunnel design was well thought, the construction time, including installation of the rail equipment, was estimated at approximately eight years. The reality proved that this estimation was correct. According to BLS Alp Transit AG, the construction was completed safely and efficiently by 2007, in part thanks to the “meticulous planning and ultra-modern technology.”

The Lötschberg base tunnel started operating in June 2007 and it brought multiple advantages with its opening.

First, together with the existing dual-tube Simplon tunnel, it constitutes the first high-speed North-South rail link through the Alps and a unique connection of its kind for many years still to come. It created important reductions in journey times for long-distance domestic rail travel. Thus, Switzerland will become the railway ‘turntable’ for European rail traffic. Service provisions allow for a capacity of 30 passenger trains per day and 80 freight trains per day. The speed range is as follows:

- Passenger trains (200 km/h)
- High speed passenger trains (230-250 km/h)
- Freight trains (100-160 km/h)

Secondly, the tunnel opening marked the moment when Switzerland will finally be able to collect the full rate for the mileage-related heavy vehicle tax. This constitutes a major revenue stream for Switzerland and finances the St. Gotthard project. It represents as well, a regulatory tax for Europe, which will increase the attractiveness of railway transportation. Thanks to the modern Lötschberg transit axis and the Mileage-Related Heavy Vehicles Tax (MRHVT), it will be possible to shift the goods traffic from road to rail in stages.

The estimated cost at the 1991 price level was CHF 3.1 billion. The project was financed 100% by public funds. Its construction started in 1994 and was completed as scheduled in 2007. Its costs have been higher than estimated, but most people seem to agree that this was money well spent.

Overall, it was considered a big success. At its inception, NRLA critics argued that Switzerland did not need the Lötschberg. Today, 75 percent of its capacity is already exploited and with an increase in freight traffic, it will soon be at a 100 percent. As foreseen, Bern and Brig are "now within commuting distance" and therefore, the tunnel has changed many people's lives.

Project Corporate Governance

As a part of the NRLA, the Lötschberg base tunnel corporate governance evidently follows the same structure model as the St. Gotthard base tunnel. The main differences are that the operator of Lötschberg is a private company and not a public one. It owns a 100% of the company in charge of the infrastructure design, construction, and management.

There is also a difference of scale (size) and organization structure. The differences are relevant for the result's analysis, discussion of validity, and the general terms. They are detailed in the sections that follow.

Builder

BLS Alp transit AG, the constructor of Lötschberg axis, was founded in 1993 as a fully owned company of the private railway operator Bern-Lötschberg-Simplon Bahn (BLS). It has a small organization of 30 employees.

Operator

The infrastructure is operated by the private company Bern-Lötschberg-Simplon Bahn (BLS).

Design

The design was executed by BLS together with two other private consultant firms.

Project Management

BLS was in charge of the overall project management carried-out from their head office in Thun, with management sites in Brig, Bern, Mitholz, Raron, and Steg. Specific project management was provided by private engineering companies, *which contrary to the case of St. Gotthard, are different from the design companies.*

Contractors

There are eight main contracts for the civil works; in addition, there are approximately 30 minor construction contracts and one contract for the railway installations.

Project Controlling

The basic approach to the project controlling is similar to that of the St. Gotthard base tunnel project; the NRLA Controlling Regulations issued by the Ministry of Environment, Transport, Energy, and Communication apply and are mandatory for this project. The Federal Transport Authority has the same duties and responsibilities as in the Gotthard base tunnel.

Special Features of Lötschberg Base Tunnel

One special feature of the Lötschberg base tunnel, when compared to the Gotthard, *is in fact that BLS, the project and site management services, have been outsourced*. Consequently, BLS Alp Transit performs only the overall project management, whereas the *site management and supervision serivces, including the local contract management, are carried out by private consulting firms.* This impacts the *project organization number* and its functional structure, which is considerably smaller than that of AlpTransit AG, and is explained in the next paragraph.

Project Organization Chart

The project organization of "BLS AlpTransit AG consisted of a team of 33 employees *who have set a goal for themselves in implementing the construction of the Lötschberg base tunnel, on time, within budget, and with due regard for future expansion"*[43]

The *project organization depicted in the figure below corresponds to a flat one,* in which the different competencies and roles are clearly defined. The direction of work is ensured through people whose backgrounds match those competencies and skills. There is a *direct link between the BLS representatives, those who have the deciding power, and the sites managers*.

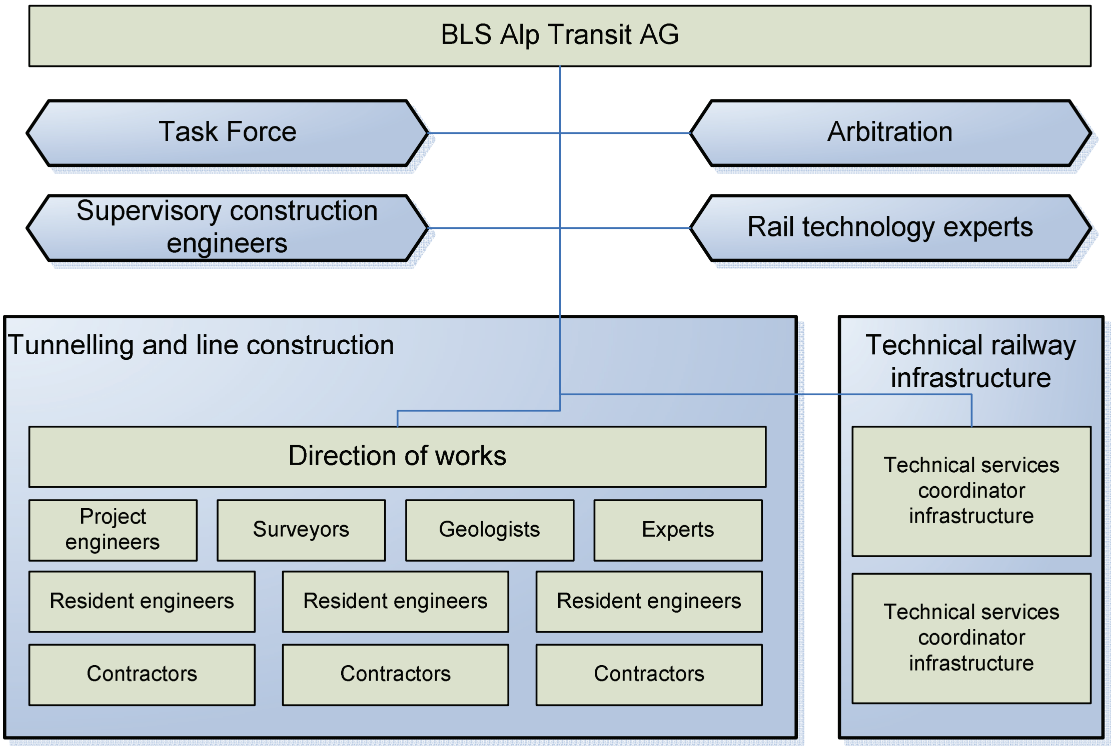

Figure 5-7: BLS Alp Transit Organization Chart (Source: primary and secondary data collection)

The task force is formed with people of different backgrounds. It is supposed to intervene in the case of unexpected events and could loop the formalized communication channels.

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[43] Goal is emphasized on the web site in the presentation of project organization

Conclusion

Part A of the case study was concerned with the description of structural aspects of the NRLA project, with a focus on the description of the physical infrastructure (project output), service provision, project organization, governance, and basic management processes. It aimed to explain the duality of the NRLA project (two projects in one) and the structural differences between the two project organizations. It also introduced the status quo of these projects, which are actually in different life cycle phases: execution (Gotthard) vs. exploitation (Lötschberg)

Part B of the case study is dedicated to the analysis of critical events identified in the process of data collection and the phenomenon of troubled project behavior.

5.3 Part B: Critical Events and the Troubled Project Behavior Phenomenon

> *Events are the natural units of the social process; events are what key actors do or what happens to them. (Abbott, 1990)*

In this study, critical events are defined as unexpected events that have a major impact on the project's objectives and/or its survival; meaning that they have the potential to threaten the future of the project (chapter 2). In connection to them, troubled project behaviour is understood here in respect to:

1) The impact of critical events, and their "punctual" and "over-time" effects on the project system.
2) The coping process, which is how the critical event unfolded; including the actions taken by project actors to limit or eliminate the critical event's effects and maintain performance.

Therefore, the reconstruction and interpretation of a troubled project will go through the following phases in altering its processes: *identification of critical events*, *analysis of their impacts* on the project system, and analysis of the *coping process,* including the *decisions and measures taken* by a project's actors. The focus is to spot those factors and conditions, which aim to keep the project on track in terms of committed costs and delays, and enhanced, positive adjustments on the project system. We attempt to provide a narrative description of the facts and highlight relevant aspects while citing various sources.

5.3.1 Critical Events Identification Process

In order to identify the critical events, two rounds of data collection and analysis were necessary. The first round of data collection led to the identification of twelve critical events. They were brought to our attention because they all received high public attention, were fully reported upon in the media, and, even more importantly, had significant, acknowledgeable consequences. These events and their over-time effects are listed and coded in chronological order from CE1 to CE12. Each code denotes one event which occurred one time.

Identified events after the first round of data collection:

1993 – Political conflict (Financing scheme is contested and thus the economic viability questioned)
1995 – 1999 Work is frozen due to the political conflict
1999 – New financing strategy is voted upon
1999 – Concession for 40 tons
1999 – Miscommunication of the price index
1999 – Decision to build Lötschberg with one rail
2000 – URI canton habitants addressed to OFT 900 oppositions for project trajectory on environmental issues
2003 – Geological problem at Sedrun (Gotthard)
2003 – Tunneler is stuck
2005 – Claim against the award for the Erstfeld tunnel construction
2007 – Water infiltrations
2007 – Connection solution with the Italian network is questioned
2003 – 2007 Safety and technology changes

Consequences:

a) 6 year delay for Gotthard construction (2017 vs. 2011)
b) Investment increase from CHF 12.8 to 34 billion
c) Under-capacity at Lötschberg (one way instead of two)
d) Doubts on the opportunity of the project layout (connection with Milan questioned by the fact that the infrastructure and the political and economic environment changed over the last 20 years)

In the next step, we have grouped the events in four categories based on their nature, as explained in chapter 2, pg. 19-20.

The exogenous critical events (the project's management cannot exercise any control over them) that were identified in the first round of data collection and analysis were political and strategic (Table 5-2), geological (5-3), organizational (5-4), environmental (5-5), and technology/process related. They apply to the whole project system (listed in bold are the critical events that have been chosen for the exposition in this thesis).

POLITICAL + STRATEGIC	
CE 1	**1994-1995 – Financing scheme is contested and thus the economic viability questioned**
CE 2	**1995 – 1999 The work on both sites, Gotthard and Lötschberg, are frozen**
CE 3	**1999 – A new financing strategy is voted upon**
CE 4	**1999 – Concession for 40 T**
CE 5	1999 – Miscommunication of the price index
CE 6	**1999 – Decision to execute Lötschberg as a on one – way rail tunnel**
CE 12	**2007 – Connection solution with the Italian network is controversial**

Table 5-2: Critical events related to politics and strategy

CATEGORY ORGANIZATIONAL	
CE10	***Contracting in 2005*** **– Claim against the award of the Erstfeld tunnel construction**

Table 5-3: Critical events related to the project organization

CATEGORY TECHNOLOGY/PROCESS RELATED	
CE 13	Safety regulation changes[44]

Table 5-4: Critical events related technology/process

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[44] Refers to the changing expectations regarding state-of-the-art technology and safety due to thelong planning and construction time of more than 25 years.

CATEGORY ENVIRONMENTAL	
CE7	**2000 – 900 oppositions addressed by URI canton habitants to OFT**

Table 5-5: Critical events related to the environmental issues

Interestingly, the first round of data collection and analysis revealed that the exogenous events were perceived more as a "fatality" rather than "critical" (since they were out of the control of the project management). The events of a political nature were seen, in particular, as dangerous to the project's outcomes because of their straight impact on the project's financial resources. *"Political work is like taking out a sailing boat. The wind keeps blowing from different directions and you constantly have to find a majority for each of these bills - the New Rail Link through the Alps (NRLA), the Performance-related Heavy Vehicle Fee, the bilateral agreement with the European Union on overland transport and the fund for the financing of public transport."*[45]

The endogenous events identified in the first round of data collection were of geological nature (Table 5-6) and relate to the Gotthard tunnel base.

CATEGORY GEOLOGICAL	
CE8	2003 – Geological problem at Sedrun
CE9	2003 – Tunnel worker is stuck
CE11	2007 – Water infiltrations

Table 5-6: Critical events of Geological Nature

They were perceived as being ones with a bigger probability of occurrence and this, "*in spite of forecasts made by experienced geologists and sample bores, gave a reasonable degree of certainty."* The general belief that "*what tunnellers actually experience at the rock face, can never be predicted in advance"* or "*a tunnel is only built after the breakthrough"* assumes the

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[45] Transport Minister Moritz Leuenberger for swissinfo.ch. on September 15, 2010

same sense of fatality embedded in the project, as in the case of exogenous critical events. Every person interviewed seemed to agree that this gigantic construction was a risky venture particularly because of the geographical challenges. It was even suggested that dUring certain periods[46], the critical events of geological nature could be considered as a continuous event. When it comes to the Gotthard, where "*every day may bring a new problem, which may put the future of the tunnel under a question mark.*"

These first results of data collection and analysis showed the necessity of running a second round of interviews with the various project actors. This was done in order to gather detailed information about the actions triggered after exogenous events *at the project organization's level.* More importantly, about how both project organizations behaved when there were endogenous events of geological nature. Lötschberg's tunnel base was finished on time. This raised the legitimate inquiry of how this performance was achieved: did the drilling go smoothly as predicted or was this performance attained in spite of geological surprises that are by definition associated with drilling in the Alps?

As a consequence, the second round of data collection and the analysis' scope was to gather more data about the endogenous critical events dUring the construction of the two tunnels. It was also to reveal the differences (if any) of how the two project organizations handled the geological surprises.

The result was a very long list of identified critical events. At Lötschberg, **38 critical events** and related actions were identified and described in the project chronicle (Annex 5). Another **60 unexpected events** relating to the Gotthard tunnel execution are mentioned in a report from the Federal Transport Office from 2007. They refer not only to the geology but also strikes, accidents, and contractual breaches, since they are not publicly available, their criticality could not be validated.

Recurrent themes, from which the critical events unfolded, emerged from the beginning of the second round of data collection and analysis. Interestingly, patterns apply to both the intervention strategies employed and the event's consequences for all critical events, no matter what their nature. This finding was, to some extent, expected and could be explained by the fact that the construction started more than 15 years ago. The lessons learned were, in

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[46] Periods that coincide with the drilling of the most difficult sectors e.g. Sedrun - Faido

general, referenced and put in practice whenever possible, and the risk management processes were extremely well developed in both project organizations. Considering these specificities, and in the light of post-collection data analysis, we selected ten critical events for exposition in this thesis. The selection criteria obeyed the following rationale. These events were recognized as critical a*fter their consequences were known.* In the case that they were exogenous, *they were criticality reinforced by the fact that they marked turning points in the project's life-cycle*. In the case that they were endogenous, *their criticality was justified by their major impact on project performance, acknowledged through important costs overruns and scheduling delays*. Last but not least, the selection ensured a significant number of *different events (by nature)* in order to confer strength in the argument. The endogenous events of geological nature are described separately for each of the two project organizations. This was decided after the second round of data collection because the intervention strategies and their underlying concepts, revealed differences between organizations. For simplicity and clarity reasons, but also justified by patterns discovered in the level of impact of critical events on the project's system, the geological events at Lötschberg were given the overarching code **CGL** "Critical Event Geology Lötschberg." Those related to Gotthard were similarly coded CGG. The events selected are described in the following tables:

CATEGORY GEOLOGICAL	
CGL	November 14, 2001 – lowering of the ground level (first information to the St. German population) 2002 - At the northern edge of the Gastern granite, sedimentary carboniferous rock was encountered April 11, 2002 - Driving the tunnel boring machine in Steg is stopped because of rock containing asbestos December 31, 2003 – The southern tunneling operations in Mitholz unexpectedly encounter sedimentary rock, which was unexpected April 24, 2004 – The two tunneling teams driving south from Mitholz are at a standstill because of problems with the rock. The trial bore, which had been started, has to be aborted. June 20, 2005 – DUring the excavation work on the Widi tunnel, the construction crew encounter a rock line which was substantially higher than the geological survey predicted.
CGG	2003 – Geological problem at Sedrun (Gotthard) 2003 – Tunneler is stuck 2007 – Water infiltrations

Table 5-7: Critical events related to the geology (Source: 2nd round of data collection)

As suggested in Williams, 2005, Cicmil *et al.*, 2006, elements of systemic modeling have been used in order to capture the interdependencies between project elements. Specifically, we developed the model[47] presented in Figure 5-7, which represents the project's system for interpretation and analysis of the collected data. It is built with the project's structural elements, which are standard for any infrastructure project. The *project output* (project finality), the physical infrastructure itself, is located in the center of the system. This is comprised above in *links* (e.g. tunnels trajectory) and related *capacity.* Both structural elements were decided in the very first stages of the life cycle. Together they will define the type of *service(s)* provided and, implicitly, the mission of the project (service provision). The economic feasibility study will determine the *revenues* expected and decide on the most suitable *financing* structure. The bottom side of the diagram suggests that in order to obtain the project output, its *components* should be built first (e.g. the base tunnels of Gotthard and Lötschberg). This requires a certain amount of resources to be brought together. The resources are represented as the *technology* and all the necessary *processes, including people.* From the perspective of data collected (specifically, knowing the level in the project system at which the critical events occur), this model is sufficient enough to understand the critical event that is unfolding. It is also simple enough to ensure the clarity of interpretation without ignoring the complexity of the interdependencies between project elements.

Furthermore, the model shows that the resources should be *planned* and related *costs* should also be determined. In the system, the costs will be logically linked to the financing structure, which is supposed to cover them. On the right side, the financing box reaches the service provision through the "impact measures" box. This suggests a common theme in the development of transport infrastructure projects; and states that finding funds may imply measures with a direct impact on the service provision (e.g. Eurotunnel). The absence of arrows in this basic project system model means that "a priori" among the interdependencies, and between these elements, could go in any direction.

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[47] There are two main concepts underlying this representation. The notion of system refers to the interdependent components which together perform/have a specific objectives and the model is an abstraction of this system (Source: modeling and simulation in PM course support)

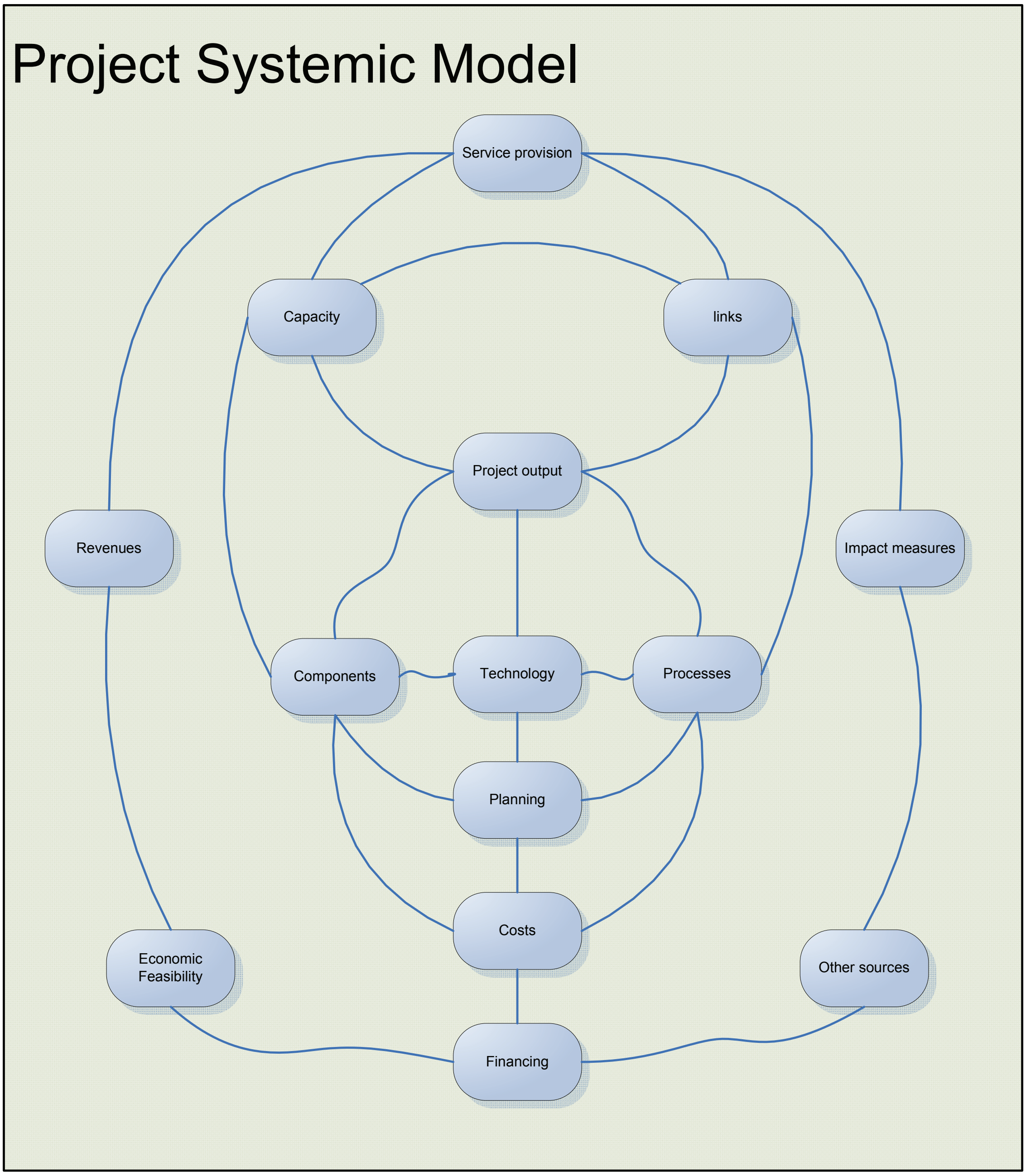

Figure 5-8: Infrastructure Project System (Source: PhD Research Proposal[48])

The next step in reconstruction of the troubled project's behavior was to situate the identified critical events into the project system. This led to the Figure 5-8 below, showing the punctual

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[48] There are differences between the model presented in the research proposal and this presented here, since the last was updated with the results from the data collection.

impact of events on the project's system. The numbers allocated in the Table 5-2, 5-3, 5-4, 5-5 are retrieved in the project system, at the level of impact.

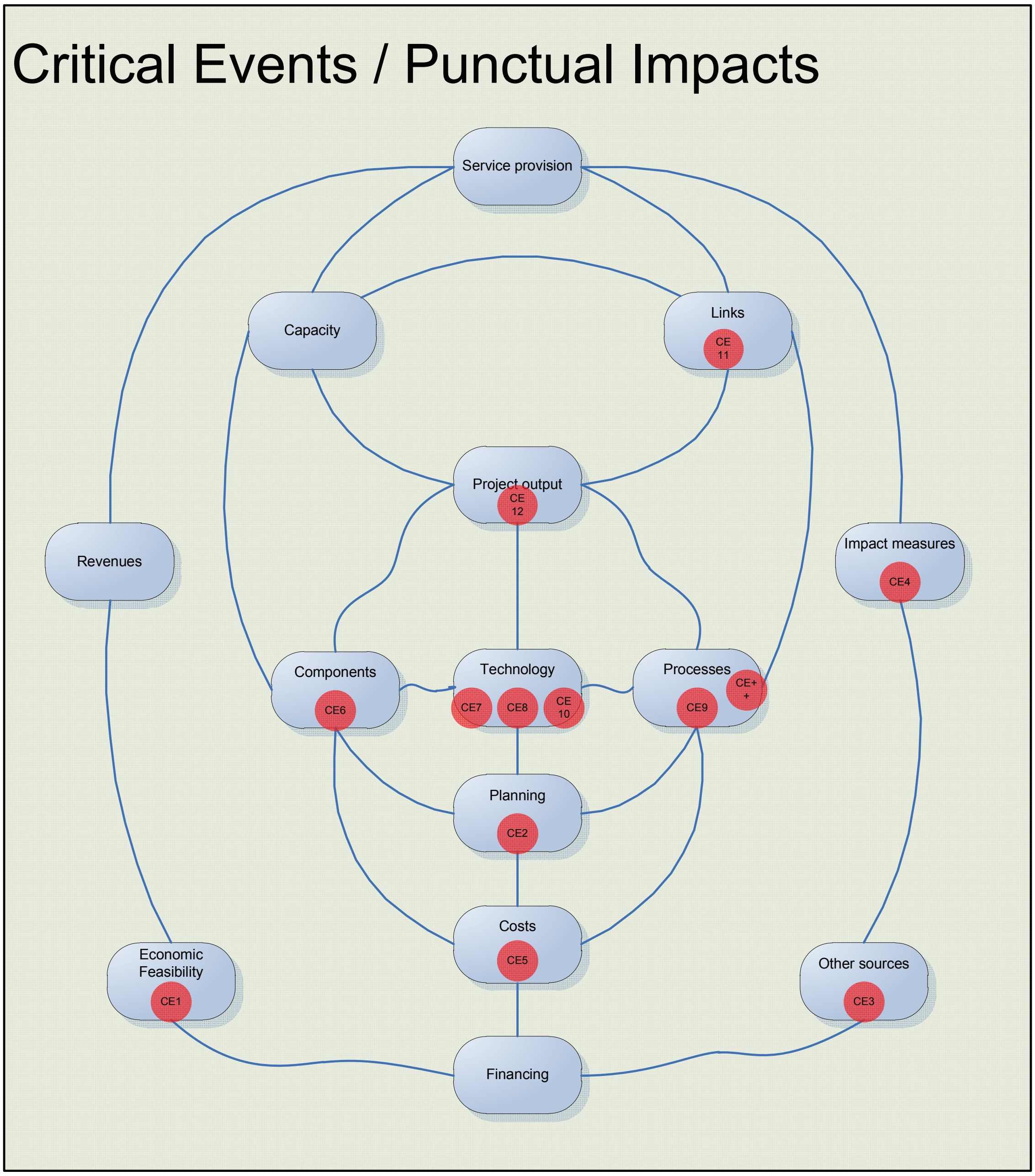

Figure 5-9: Positioning of critical events in the project system

As an example, CE1 was a critical event of political nature that occurred in 1994. Since **the financing scheme and the economic viability associated with the event were contested, we positioned the event in the box "economic feasibility."** Following that same logic, each of the critical events that we chose for the exposition in this thesis were represented in the project system model in the box corresponding to the project's component that was first impacted. This "'association' represents the project system from the point of impact" where the critical events started to effect and propagate to the other parts of the system. The next logical step was to reconstruct how the critical event unfolded in order to uncover the coping process. Specifically, we created a rich description of the critical event's impacts and the measures taken by project's actors to limit and counteract them. For each event exhibited in this thesis we described the *context in which it appeared its nature*, and the *punctual and overtime effects.* We also highlighted the *project actors' actions* that were triggered by the events' occurrences.

Political conflict due to the contestation of economic feasibility – CE1 (1993-1995)

The inauguration of the Gotthard road tunnel in 1980 attracted traffic from all over Europe and led to a national animated ecological debate. To limit this traffic affluence, Switzerland implemented the 28-ton heavy vehicle fee. The European community's reaction was immediate pressure on Switzerland to give them permission for 40-ton vehicles to pass through the Alps.

Challenged to prove more flexibility toward the European transport policy and to find a cure for the ecological problem, Adolf Oggi, Minister of Transport at the time, developed the NRLA project. He promoted it as the most suitable strategy for both the European community and the Swiss nation. The European community's members were convinced about the project's opportunity. They accepted and pursued with the heavy vehicle limit of 28-tons with condition that Switzerland builds the two base tunnels.

With this commitment in mind, Adolf Oggi carried out an energetic campaign in order to persuade people to spend millions of the public's money on the NRLA. "*Try to imagine what would be our country will be without the NRLA! The answer is chaos on our roads; if you still doubt, think of 3-4 million trucks that we are going to shift from road to rail.*" His enthusiasm and mantra discourse were endorsed with a strong argument that will be contested later. He promised the people that the project would finance itself and the rail operators will pay the investment off in 60 years.

This information is reiterated in the voting information brochure, which clearly states that the "prudent traffic forecast, and realist assumptions of costs evolution guarantee the economic viability of the project and thus the railway operator could reimburse the investment, evaluated at 14 billion francs, in 60 years."

This last argument brought Oggi's campaign to fruition. On September 27, 1992, the NRLA project was approved in a large majority, and within one year the construction began at Gotthard and Lötschberg.

In the month following the inauguration of the construction of both sites, Gotthard and Lötschberg, Otto Stich, the Minister of Finance at the time, started to openly contest the NRLA financing plan. He said that, for obvious reasons (weak revenues generated by rail freight traffic) the payback period of 60 years is not realistic, and thus the project is not economically viable.

He also said that the financing solution retained, "*reflects either stupidity or lack of honesty."* As an alternative, he suggested to reconsider the project's detailed design in order to reassess the decision of constructing the base tunnels at the same time. He proposed building the Gotthard tunnel first, and then waiting and to see if the "after-completion environment," would make the second base tunnel construction still relevant.

But the project developer, Alfred Oggi did not want to hear this argument. According to Otto Stich, Oggi "took these critics personally, as an offense to himself and his department." Instead of openly and objectively discussing the problem and trying to find a solution together, as expected by Stich, Oggi "felt excluded from the team" and blamed Stich for a lack of fair play. The dialogue between these two stakeholders was impossible; even in general meetings face-to-face communication was avoided. One of their colleagues remembers that "*behind their smilingly attitudes, the relations were tense*." Today, Oggi affirms that the conflict was necessary but he regrets for not having dealt with it differently.

The political conflict marks a turning point the project's course.

The NRLA project could not be continued until the disagreement was solved. Meanwhile, the Swiss people did not suspect anything. This event is considered critical not only because it questioned the project viability (it could have been stopped), but also because it had a significant impact on its future course.

The consequences of this critical event led to the occurrence of another critical event at the execution level. *The construction of the two tunnels had to stop and the work was frozen for a four year period*. Peter Testoni, Vice-Director of the Federal Swiss Office at the time says that "even today, after ten years, we still feel the disastrous consequences in the realization that our main work is in tunnel drilling."

In February 1995, the Federal Council met on the shore of Lake Neuchatel in order to find a solution to this conflict. The discussions lasted until late into the night. The empty boxes of pills and crumpled papers left in the conference room proved the intensity of the board. DUring the discussion, the scenario from the Finance Minister, Otto Stich, promoting the building of the Gotthard base tunnel alone and renunciation of Lötschberg in a first phase was not kept.

The council decided to have the two tunnels built at the same time, meaning that they adopted the network scenario. Otto Stich is marginalized, although further decisions will prove that he was right in his decision to contest the project's financing structure. In August 1995, Otto Stich convoked a press conference "à l'improviste" and officially stated his demission. This decision was not without consequences to Adolf Oggi's career, which will soon be constrained to give up power.

Andrea Hämmerle, specialist in transport policy, orchestrated the transfer of power and stated: "*a change was necessary, NRLA needed a new head*" but we knew that was going to be difficult. He remembered: *"Oggi did not want the change; he was convinced that we should build the tunnels and the cash will come; when the change became obvious he said that he will only get down to the second league."*

In the end, the Federal Council cut off the issue. It was unanimously decided that the NRLA project would not be stopped. Adolf Oggi, the project developer, was given other responsibilities. In 1995, the council appointed Moritz Leunberger as the new Minister of Transport. He received the NRLA file and its first mission was to find new financing sources to save the project.

The effects of this critical event on the project system are depicted in Figure 5-9 below.

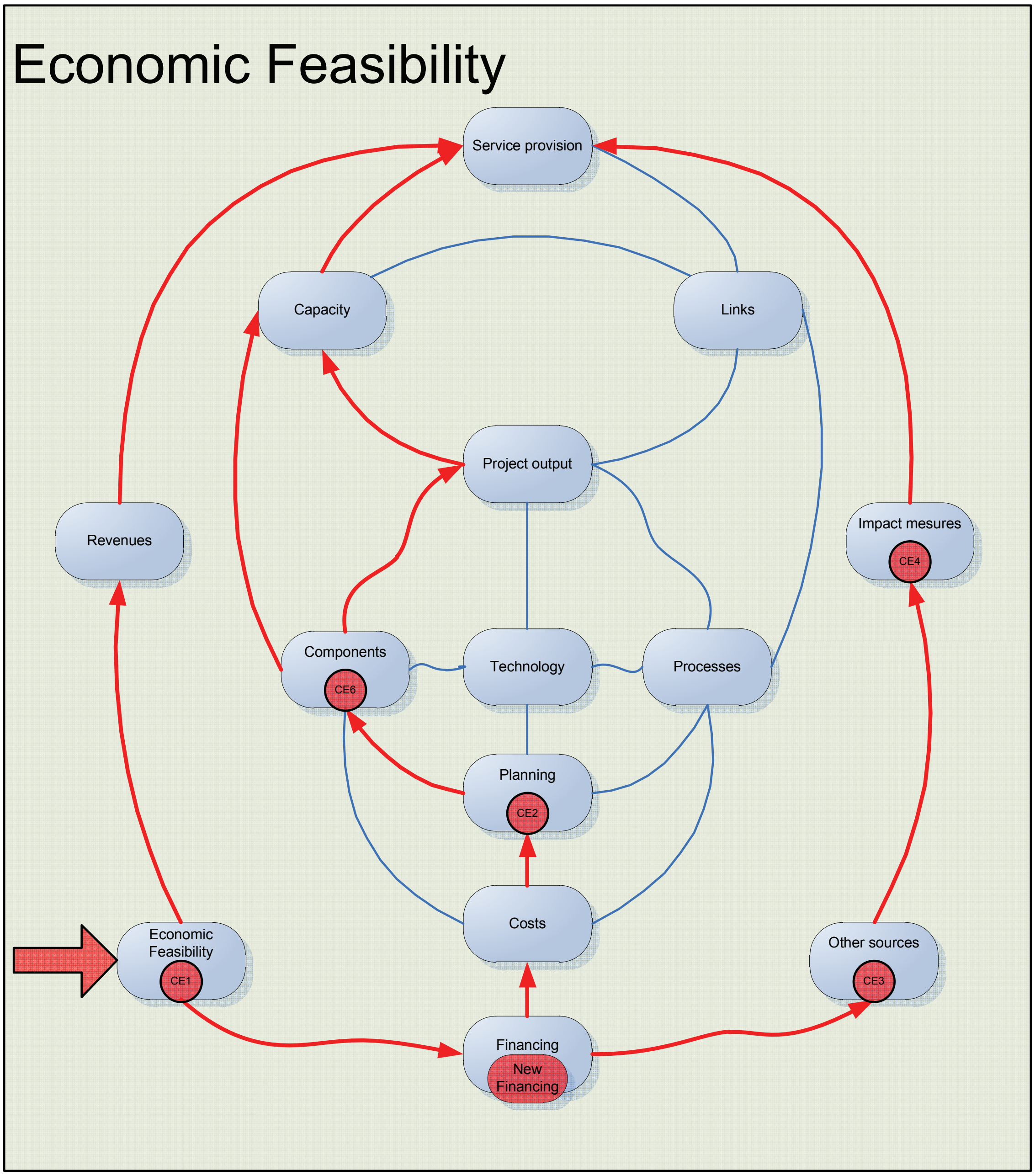

Figure 5-10: Political conflict generated by the contested economic viability

The causality relationship represented by the red arrows is interpreted as follows: the payback period in the case of self-financing could not have led to an economically viable solution. The accuracy of calculated *revenues* was contested and implicitly the *service provision*; finding a new *financing* strategy took four years. The time lap had a direct impact on the costs which further impacted the planning, since the work on both sites was frozen, which we assimilated with **CE2**. To mitigate the time effects on costs, a compromise on which project components to further was made. Specifically it was decided that in the tunnel base of Lötschberg, only one rail would be equipped (Lötschberg at one rail ***CE6***) instead of the two initially designed. This decision affected the future link capacity and hence the service provision, thus why it is resented today. On the left side, the first critical event was not without consequences. It led to the new financing strategy from the other sources **(FinöV[49] CE3)**, which became possible due to a new compromise, the Heavy Vehicle Fee Tax[50] **(CE4)**. The decision to introduce the heavy vehicle tax was approved through a referendum in 1998, and had, by definition, an impact on the *service provision*. The project chronicle in Annex 5 reconstructs, in detail, the decision making process for the period of 1992–1998. It states all the important instants of the project (67 in total), ranging from design studies and call for tenders, to media events organized for lobbying the network's scenario with both tunnels being constructed simultaneously.

In addition, Moritz Leunberger also evokes this chain of decisions and compromises in his speech at the Gotthard breakthrough celebration on October 15, 2010. "*DUring these 15 years in which I defended the project in parliament, there were always malicious, doubting voices who predicted that it wouldn't succeed, but there is always a solution when compromises are sought and found*"; the *"Swiss voters demonstrated their courage for the challenge of such a tunnel at the ballot box." They:*

➔*Said yes to the Gotthard and Lötschberg tunnels*

➔*Said yes to the financing, namely*

- *Yes to a special fund*
- *Yes to the heavy vehicle fee that feeds it*
- *And yes to the agreement with the EU*

The description of the **CE1** unfolding, denotes that although this critical event had serious punctual and long term impacts on the project system, and alone led to the occurrence of three

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[49] This financing scheme was described in the first part of the case study

[50] RPLP « La **redevance** sur le trafic des **poids lourds** »

other critical events, it did not halt the project. Parliament decided to retain the "network scenario" stating that two tunnels to be built at the same time. The Swiss people approved by saying yes to a series of measures necessary to degage the finance required for their construction. The trade-off was that some of these measures approved through these referendums affected the service provision.

Geological problems at the Gotthard tunnel basis (2003)51: CE 7, CE8, CE9

At Faido, on one cold morning in January 2003, the engineer, Matthias Bucher, entered the tunnel. He noticed immediately that a serious problem had arisen with the tunnel's walls in the excavated area. The alarm was set off at the site in Faido because deep open cracks showed the mountain's tendency to change with temperature fluctuations. On that morning, the engineer assessed that the situation was not dangerous but that it could not be solved underground. When he commented, he said: "for a couple of days, we must go to the surface and study the issue quietly, in the office." Two days later, they went to the site but underground there was a bad surprise. The pressure exercised by the rocks, had broken the steel reinforcement on the tunnel's walls. The crevasses and collapsed reinforcements were signs that the zone had squeezing conditions (the rocks behaved as if they were plastic). By extraordinary chance, there were no victims but everyone became aware that huge and costly problems were likely to occur. On the unpredictability of this event, Rinaldo Volpes, Geologist in Chief on the Faido site, remembers: "*we were all surprised to find such a geology in the base tunnel; just before reaching this zone we excavated the access gallery of 2.7 km where the rock is of good quality; yet, as soon as we passed over the multifunction station at the foot of Faido we found the "tachylite" a very bad rock and thus we are in a very uncomfortable situation."* Indeed, MFS Faido was intersected tangentially by a fault zone running from southeast to northwest which had not been predicted in the geological forecasts and therefore required additional supporting measures.

As shown in Figure 5-11, geological critical events hit the project system either at the "technology" (CE8, CE11) or "processes" level (CE 9) or at the both levels at the same time. The association of critical element's level of impact resulted from the data collection and

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[51] Although it does not speak for the assembly of the events of same nature, the post-data collection revealed a lot of commonalities in terms of both impacts and actions taken;

critical events, which are geology related, require measures for changing or adapting the work processes and/or the drilling technology. These measures led to cost and delay escalations as shown by red arrows in the figure below. The accumulated over-costs that impacted the financing, put further delays on the "mise en service" of the infrastructure and on the service provision.

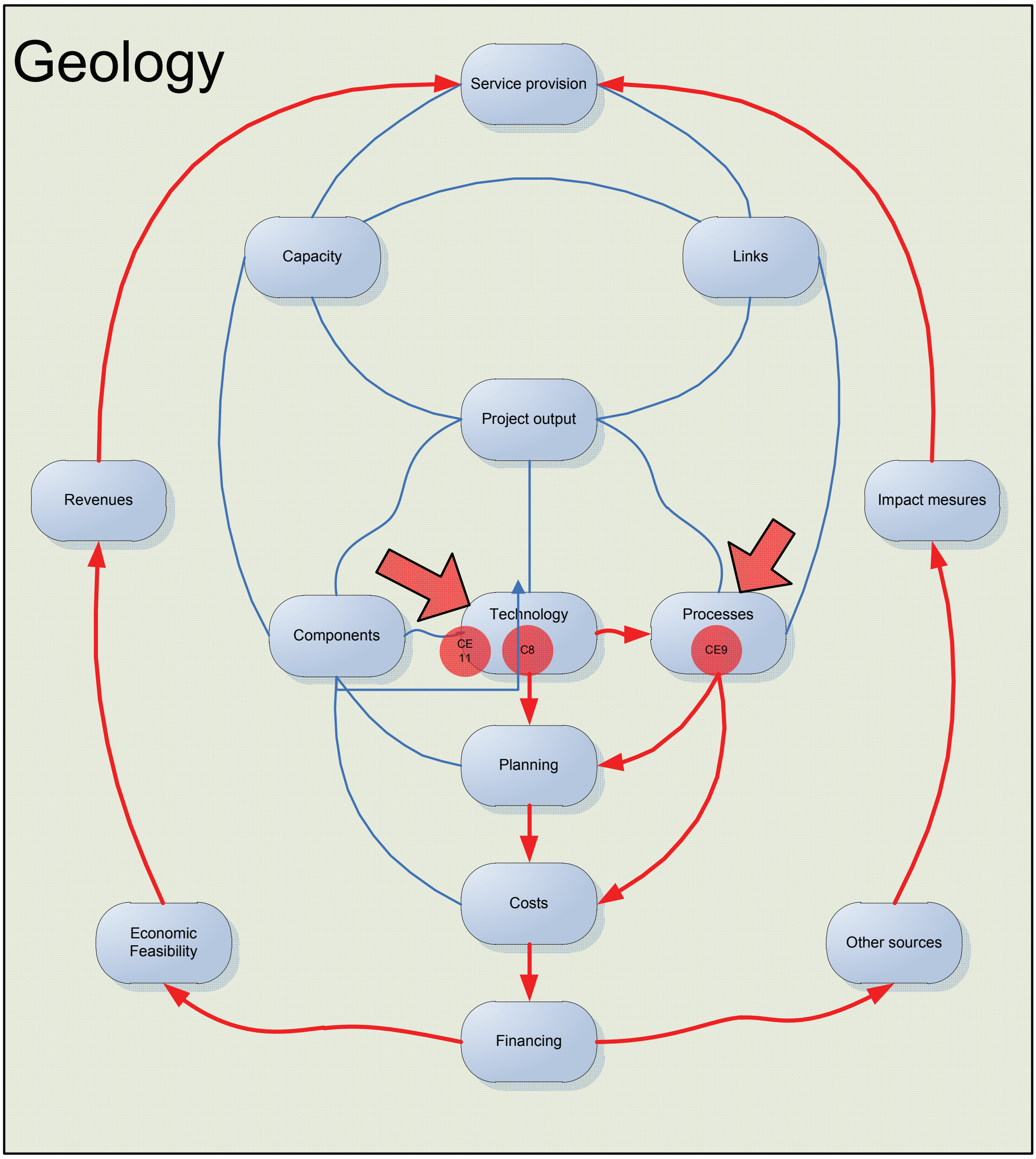

Figure 5-11: Critical events of geological nature (CE 7, CE8, CE9)

We illustrated this causality with the Faido example. It was found that present commonalities with other geological events, in respect to the level of impact, effects the project system and the measures taken to mitigate them.

In the case of the Faido geological problem, the solutions were extremely demanding on the resources. Additional work was required for reinforcing the tunnel walls after they were excavated. This work induced a two year delay for the Gotthard base tunnel excavation and an estimated CHF 285 million overage of the budget. After this critical event, at the end of 2003, the NRLA budget reached CHF 15.8 million; which represented CHF 1.1 million over the forecast costs. Moreover, nobody could guarantee that the future would be exempt from further surprises. But the Federal Council decided again that the project must pursue its course and approved CHF 900,000 in credit extensions with the hope that saving elsewhere could achieve the difference of CHF 200,000.

Giovanni Lombardi, whose company was in charge of the Gotthard tunnel underground design, states*: "the excavation methods and technology were chosen based on in-depth analysis; various aspects have been taken into consideration involving geology, geo-technics, the rate of advancement, the cost of construction and the possible reuse of rock muck. However, due to the length of the tunnel and the necessity to limit the number of test bores in advance, the occurrence of such underground conditions always remains a possibility when constructing tunnels."*

Data collection revealed that Gotthard geology was more problematic than expected.

The following hazardous scenarios had to be managed: squeezing rock, rock fall, rock burst, and the occurrence of methane. On overcoming these problems, the Chief Construction Officer of AlpTransit remembers:

"Some people doubted whether the tunnellers would get through the Piora Fault Zone, where initial tests had suggested 'running ground', a granular dolomite mixed with water." Work was put on hold - and the whole project was threatened while engineers debated what to do.

"Extra bore holes were ordered which found that the poor quality stratum did not, as feared, extend to the deeper tunnel level. Work was able to resume.

There was also a difficult area just north of Sedrun where the rock was crumbly and subject to severe pressure. This called for thinking outside the box."

The manager of the tunnel and track construction of the Gotthard base tunnel, in reference to the impact of the geology on the execution of Gotthard, states that*" there were periods in which every day was a challenge and one could safely say that from punctual critical events, we actually moved to a continuous one. With all these bad surprises, not once had we thought that the project will be closed one day or another; but each time we found a solution."*

The communication channels allowed the decision makers to become aware of each critical event very quickly after it happened. To find solutions to these problems, they relied on their specialists (who have special competencies and skills within the organization), and their contracting practices. Technology used for drilling played an essential role in mastering these difficulties. *"Thanks to the high flexibility of conventional tunnelling, all of these difficulties could be mastered. Additional working groups and equipment could be mobilized very quickly. Nevertheless the very unfavourable ground conditions caused a delay of two years in the excavation work and additional costs of more than 200%. TBM*[52] *drive would not have been feasible in the encountered conditions."*

To cope with the unexpected, formalized procedures for trouble shooting are in place and the site engineers have the power to decide "on the spot" for extra expenses (the amounts are limited to four-zero sums). Problem solving follows the formalized decision making process and might involve legal representatives. An important role is in the contract practices, which are adapted to conventional tunneling: the drilling process of tunnel excavation.

Specifically included in the contracts of the Gotthard base tunnel project is *the clause allowing for rapid approval and certification of changed or varied works*. Meaning that *the responsibility of the excavation method is to be selected by contractors under the rock conditions and limits those set by the designer*. *Risk-sharing mechanisms are fair and equitable* and result in reasonable contingencies for the contractors as well as sufficient reserve funds for the client to address unforeseen conditions.

There is also a highly developed management of quality systems and tight controls of costs from entities such OFT and DETEC, empowered by the project owner (as explained in first A of the case study).

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[52] TBM = Tunnel Boring Machine

To compensate for delays when they occur, the project organization tries to planning for instances but this is not always possible. The works are executed in a sequencing logic (tasks are consecutively realized), in order to enable the efficient use of resources available within the company. They also try to take advantage of any opportunity that may occur by trying continuously to spot *"those factors which might enable a faster achievement of the objectives."*

On the 15th of October, 2010, when miners drilled through the last 180cm of rock and pierced through the Gotthard Base Tunnel, Switzerland became the world leader in tunnel construction with the longest tunnel worldwide. It was the day in which the Alps' varied geology was overcome. "*Yesterday we sought to move mountains. Today we have bored right through and created the world's longest tunnel."*

As stated in the media,[53] "*although there were some negative headlines in the run-up to the breakthrough – with the Tages-Anzeiger newspaper reporting calls for an extra SFr. 350 million for the project or that there had been problems with faulty drainage pipes – excitement was high."*

Lötschberg – Geological problems (CGL)

In the case of Lötschberg, the predictions of the geological conditions were close to what was actually encountered. However, the tunnellers were surprised by several factors which had not been predicted. We identified twelve critical events from the period between November 14, 2001 and March 26, 2006. These are described in full detail in the project's chronicle in Annex 5. We would like to highlight the three examples, found from data collection, which reveal some interesting differences on how BLS Alp Transit project's organization managed their geological critical events.

At the northern edge of the Gastern granite, sedimentary carboniferous rock was encountered. In February 2001, in spite of any expectations, the ground collapsed in a big area. In the south, karst water, which had drained away, led to subsidence in the village of St. German.

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[53] "Switzerland has its record-breaking tunnel" by by Isobel Leybold-Johnson for swissinfo.ch

The root cause remains unexplained even today. To cope with the impacts, BLS AT launched an informational campaign for the population and created a parallel working group whose mission was to find solutions and remediate damages incurred. *“Expensive and time-consuming actions to secure the rock were needed to drive these sections of the tunnel.*” Measures were taken to dry the water that had penetrated the ground, so that the ground would become stable. In January 2002, this allowed the tunnel passage under the village of Saint German to be finished.

“The lesson learned from Saint German was that surprises can always arise in spite of careful risk analysis and related mitigation measures, which had been carried out.”

Another unexpected event was finding (on October 6, 2002) natural “amiante” (asbestos), an extremely dangerous rock for the miners’ health, in the southern direction. BLS AT interrupted the work temporarily and “*pursued with the application of a « protection program » already elaborated with SUVA in the previous spring, when another mineral “actinolit” from the same family was encountered dUring the drilling process at Steg*.” The solution to preserve the working conditions in response to the “amiant” effects (polluted working atmosphere) was found with the help of a professor: an academic specialist in “amiante” from the University of Geneva. Actions had to be taken *“regularly or sporadically for a length of 3.5 kms in order to protect the miners health.”* In the Ferden section alone, these measures led to an additional cost of 1.46 million Euros and delayed planning further. However, one month later this delay was practically regained. “*At Steg, the 142 meter long tunnellers (TBM) were drilling the rock starting from the Niedergesteln portal. By midyear it reached 7,637 km and advanced well in spite of this unexpected surprise which had stopped the work for 11 days.”* The unexpected events lasted until the end of the tunnel drilling. In January 2004, *“the geology made the drilling process difficult on the last kilometer of Mitholz.”* Here difficult and unpredicted geological conditions were encountered, namely sediments had carbon instead of granite as expected. This made the drilling difficult in the last six months. *“The mountain had the tendency to considerably converge and diminish the advancement rate.”* Pursuing the work was supposed to *“reinforce the rock with steel arches and make long anchors.”* These measures consequently dropped rate of advancement even more (1.3m compared to 9m, which it would have been if there was granite as expected). “*Therefore the planning should be adjusted in order to compensate for the delays*.” In the end, also in this sector, another unexpected event occurred: *“one of the transversal galleries* *went down just before boring."* However, the miners quickly adjusted this situation: "*she was saved thanks to the intervention of the 'élite mineurs' who secured it with wood trunks*."

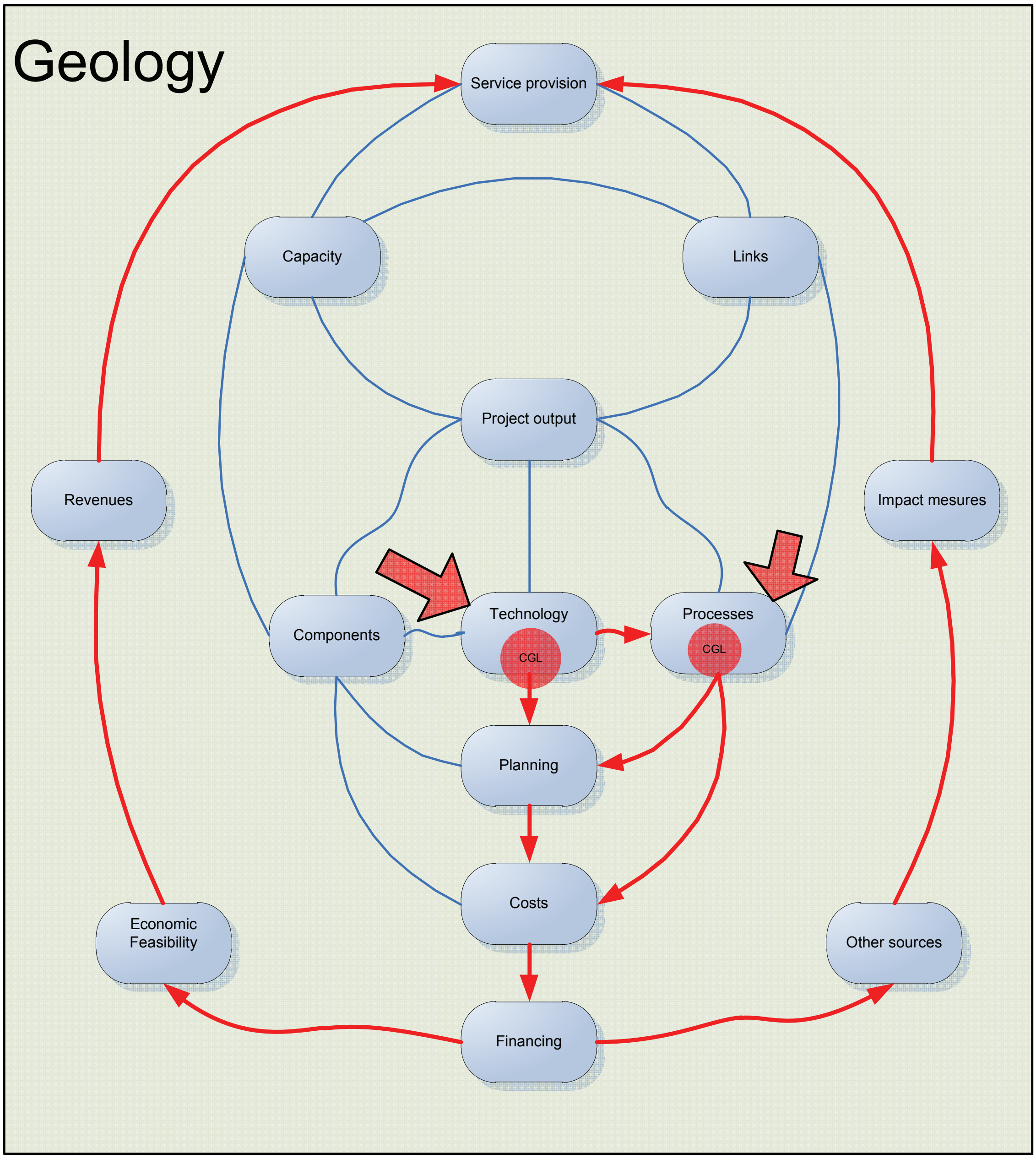

Figure 5-12: Critical events of geological nature at Lötschberg Tunnel Base (CGL)

The red arrows in Figure 5-11 show the effects of critical events on the project system.

Not surprisingly, the way in which the events impacted and spread into the project's system is identical to the graph's representation of the unfolding geological critical events at the Gotthard base tunnel. Indeed, since the occurrence of the geological event required an adaptation or change in equipment (execution technology) as in the case of Ferden or of the work process Saint-Germain. It is appropriate to understand that these events first impact the system at the technology and/or process level, then they spread, following the same rationale as in the case of Gotthard. Specifically, there is an immediate impact on planning and costs. Then, the financing will be directly affected and therefore, the future revenues from the service provision (project finality) will be affected as well.

To compensate for delays induced by critical events, BLS AG constantly and systematically puts efforts into better planning and in most cases this had been possible because of the technology and work processes used. For instance, the work related to the railway equipment was executed in a parallel logic. For example, the assembly of the railway equipment was done in containers at the same time as the excavation. When it was finished at last, the containers were brought into the gallery and the equipment was quickly put in place. The containers protected the expensive equipment from unfavorable external conditions.

Daniel Blaser, the Head of Management Services, and Elmar Lambrigger, On-Site Manager for the south tunnel, believe that the high quality relationships they have with their contractors are key for finding and implementing solutions quickly. *The outsourcing partners who are in charge of the work are highly reliable; "it's true that we have in place good controlling tools but this is less important than our collaboration based on mutual trust and good communication (sometimes we over communicate*). *We solve problems together and our long experience enables us to see immediately if external experts are needed to help us out. They also think that is easy to work with us.*"

Here, the site manager can decide "on spot" for sums with more than four zeros (several hundred thousands in extra costs). In relation to the accountability of people managing the sites and their capacity to take quick decisions, BLS managers say that "*on site, it is necessary to have an aged person with large experience who is not afraid to make decisions because he has no fear to fail and ruin his professional career."* According to BLS Alp Transit AG, the actions described above, partially explain *"how and why the planning elaborated 10 years before the project completion"*.

Claim against the award of the Erstfeld tunnel construction (CE 12, 2005)

A press release announced that on August 11, 2005, Marti Consortium filed a claim against the award of the Erstfeld tunnel construction lot by Alp Transit AG. The work consisted of "*driving the two, single-track tunnels, 7.8 kilometers-long, Gotthard Base Tunnel section from Erstfeld to Amsteg, with an excavation of 23 connecting galleries, and construction of the underground branch-off for subsequent implementation of the 'Long underground' route."* The approximate contract value was CHF 430 million.

"*Until the Federal Appeals Commission for Public Procurement reachs a decision, the work contract with the Gotthard Base Tunnel North Consortium (Murer-Strabag AG, Erstfeld, and Strabag AG, Spittal/Drau, Austria) cannot be signed and construction work on the last construction lot of the Gotthard Base Tunnel cannot begin."*

The federal counselor Moritz Leunberger ordered a quick decision on this issue in order "*to avoid the construction of Saint Gotthard base tunnel to be reported for an undefined period and the important consequences for the project costs and the strategic objective of traffic transfer from road to rail."*

However, the decision was reached only six months later, on February 13, 2006. It stated that *"the complaint of the Marti Consortium against the award by AlpTransit Gotthard Ltd. of the tunnel construction lot Erstfeld-Amsteg was upheld and returned for reconsideration of the offers submitted by the Marti Consortium and the Gotthard Base Tunnel North Consortium (Murer-Strabag)."*

In May 2006, following the request of the Federal Appeals Commission for Public Procurement, AlpTransit Gotthard Ltd. did a sensitivity analysis on the two tenders together with consulted external specialists. The board of directors of AlpTransit Gotthard Ltd. ensured the Federal Transport Minister, Moritz Leuenberger, that the criteria to be used in settling the award would be drawn up by independent experts.

On October 16, 2006, both claimers confirmed that "*they had no objections to this procedure and to such a request being made to external experts."*

On January 22, 2007 (one and half years later) the experts presented their concluding report.

They concluded that "*the award procedure had been correctly conducted, no tenderer had been systematically put at an advantage or disadvantage, and that in the technical clarification of the tenders, and the main problem areas of the respective tenders had been clarified.*" They confirmed that the original decision for this award was correct. With this decision, the work on the Erstfeld tunnel started again in April 2007. The causality above is described and represented in Figure 5-12.

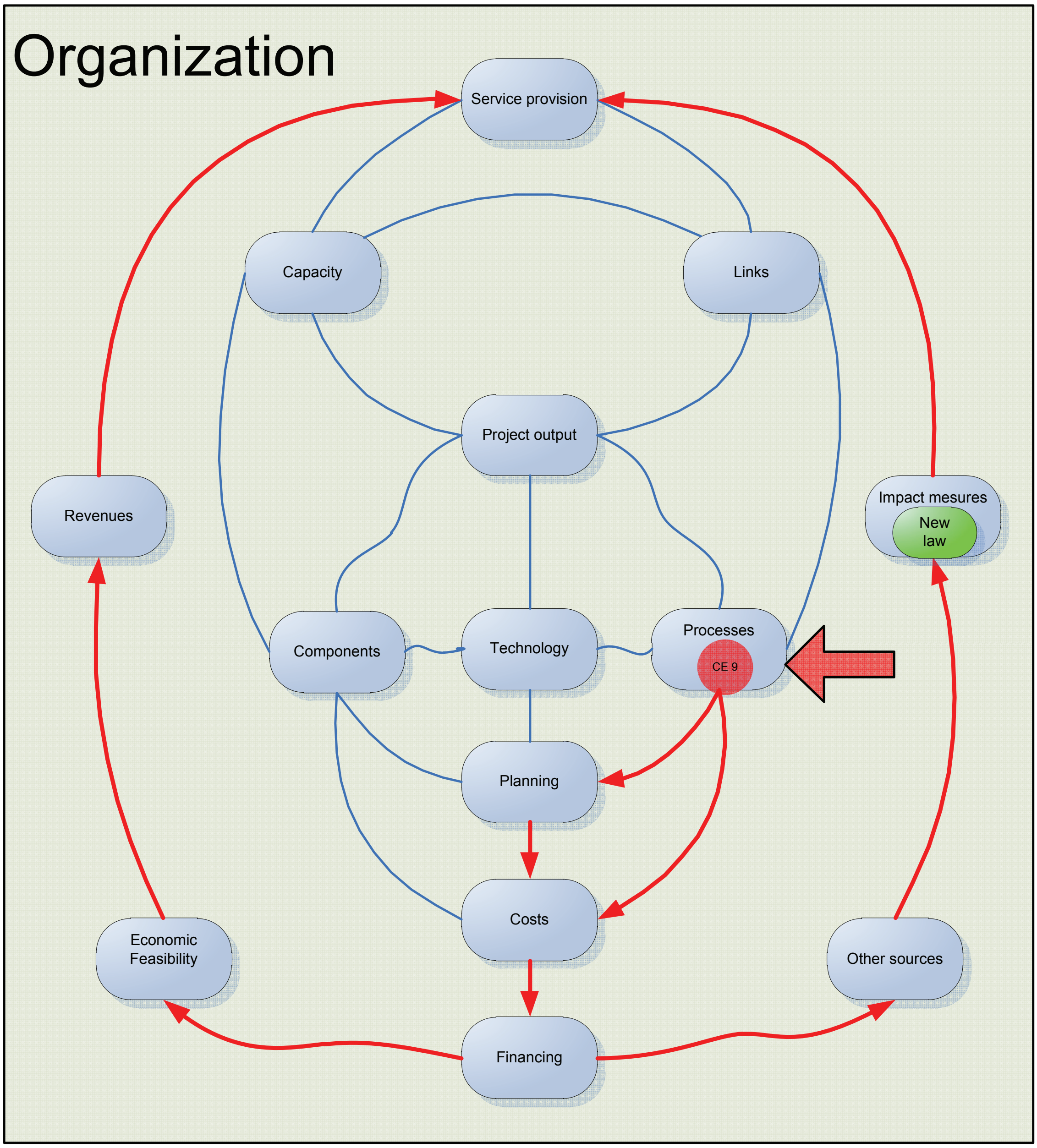

Figure 5-13: Claim by constructor to change the decision of lots allocation (CE 9- 2005)

The critical event first hits the processes and has a direct impact on planning. This will lead to cost escalations, more credit needed, and therefore an increase in the payback period and delayed availability of the service provision. Interestingly, this critical event occurrence led to the opportunity to issue a new law that will protect a project from this problem in future. Specifically, according to the new law, any claim that might induce delays on scheduling is prohibited. This positive effect is represented in green in the "impact measures box."

Environmental issues: Oppositions of Uri habitants against the project trajectory

In 2001, another critical event occurred that could not have been anticipated by the project's promoters. In the canton of Uri, the site preparations generated a strong opposition from the inhabitants. They materialized 900 claims addressed to the Federal Office of Transport to control the organism of the NRLA. Since, at the time, the project was already "approved," financed, and started, it was obvious that this would lead to significant delays and extra costs.

Figure 5-13 below explains the effects of this event on the project's system.

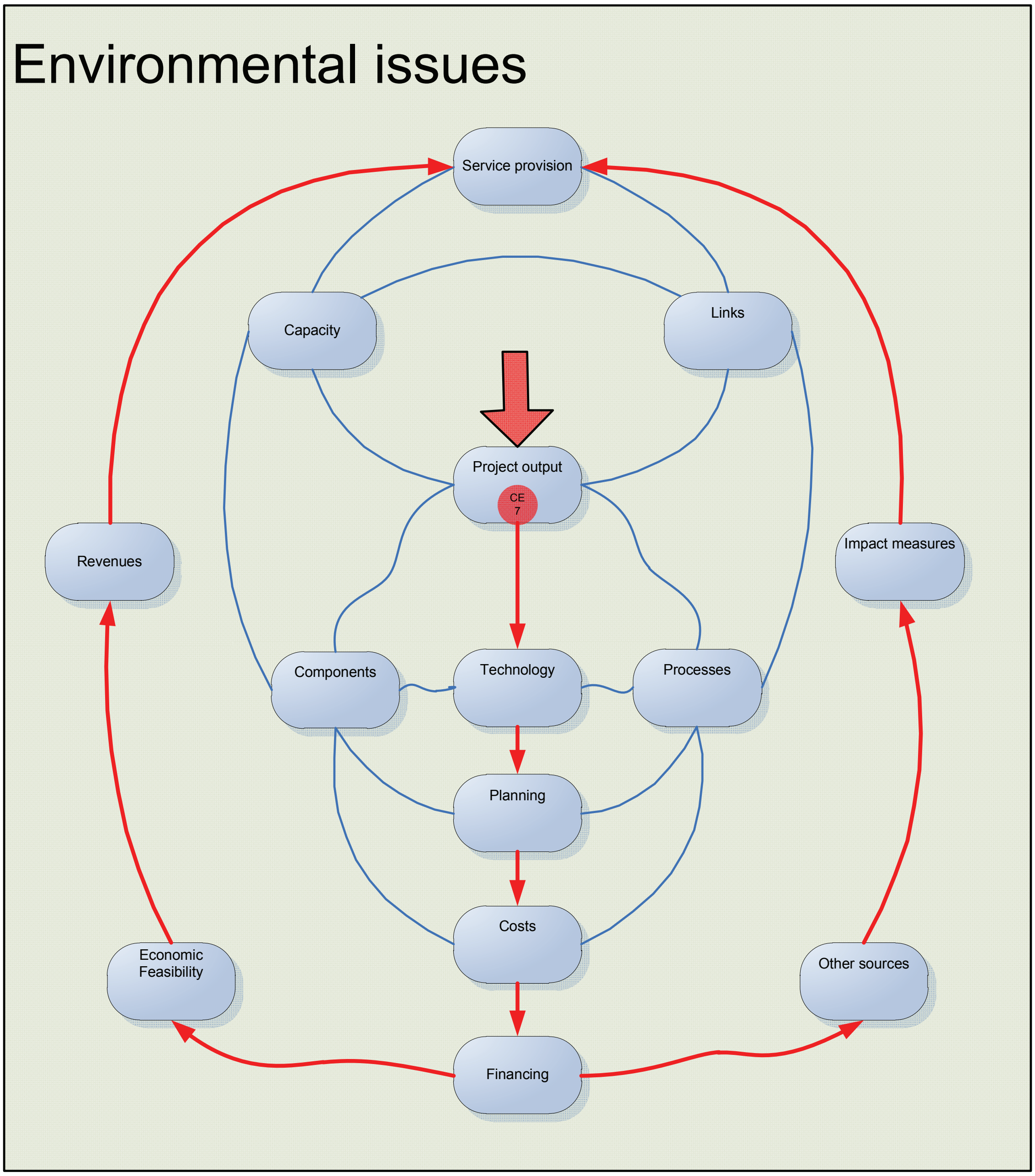

Figure 5-14 : Opposition from Uri canton (CE 7)

Since the claims raised the negative impact of the project's trajectory on the environment and quality of life (e.g. noise), it can be safely said that the critical event hit the project's system at its very heart, namely the project's output. The work was frozen until a solution could be found, however with negative impacts on planning. The conflict created between project promoters and habitants, along with negative publicity on the front page of all newspapers, significantly delayed the date foreseen at the start of exploitation of Gotthard tunnel base. The Federal Transport Office ordered two feasibility studies in order to ameliorate the project's trajectory. In the end, the project organization tried to gain on planning and studied the possibility of tendering of Gotthard northern sector together with Erstfeld sector. The results of this study were submitted to the Federal Transport Office for approval. In 2003, the project with the proposed ameliorations for the population of Uri was publicly discussed. This time, only 360 claims were encountered vs. the 900 in 2001.

Similar to the last time, the claimants pointed out the same concerns of the noise and not it not being sufficiently consolidated underground. On one hand the new layout displayed a lot of improvements compared to the former one, and on the other hand the owners willingness to compromise for work's execution was low. This meant the habitants were required to agree on the sequential schedule of work. The issue was then considered solved, and the project free to pursue its course, however after two years of delay.

Controversy on the opportunity of the connection solution with the Italian network (CE11)

In 2007, the controversy over the opportunity for NRLA to connect with the Italian network was highlighted in the media. In an interview given by a Swiss television network, Mauro Moretti, the General Director of Italian railways, stated that in the last 20 years the transportation and logistics environment suffered from important changes that had not been foreseen in the project's concept. These changes led to new *"transport and logistic philosophies. These are consistent in design with the Italian railway infrastructure in order to avoid the traffic of goods in big centers already supersaturated as in Milan; the whole strategy needs to be changed, and everything should be revised in every detail!"* Andrea Hämmerle, the Swiss specialist in transport who was commenting on this affirmation, admitted that: *"the Italians are deeply convinced that any traffic of goods must skip Milan."*

In this context, the solution to link rails with Lötschberg could be more appealing since it is directed towards Novarre; this is the hub ("plaque tournante") for the combined traffic of goods. Following the same logic, the construction of the Ceneri base tunnel, which will connect the Gotthard base tunnel to Bellinzona, Chiasso, and Milan, does not seem appropriate., In order to direct the traffic on the eastern side of Milan everything in the project's scope would have to be reviewed. This is reflected in our systemic representation where the event impacts the links, outputs, and the service provision, which represents a serious threat for the project's objectives.

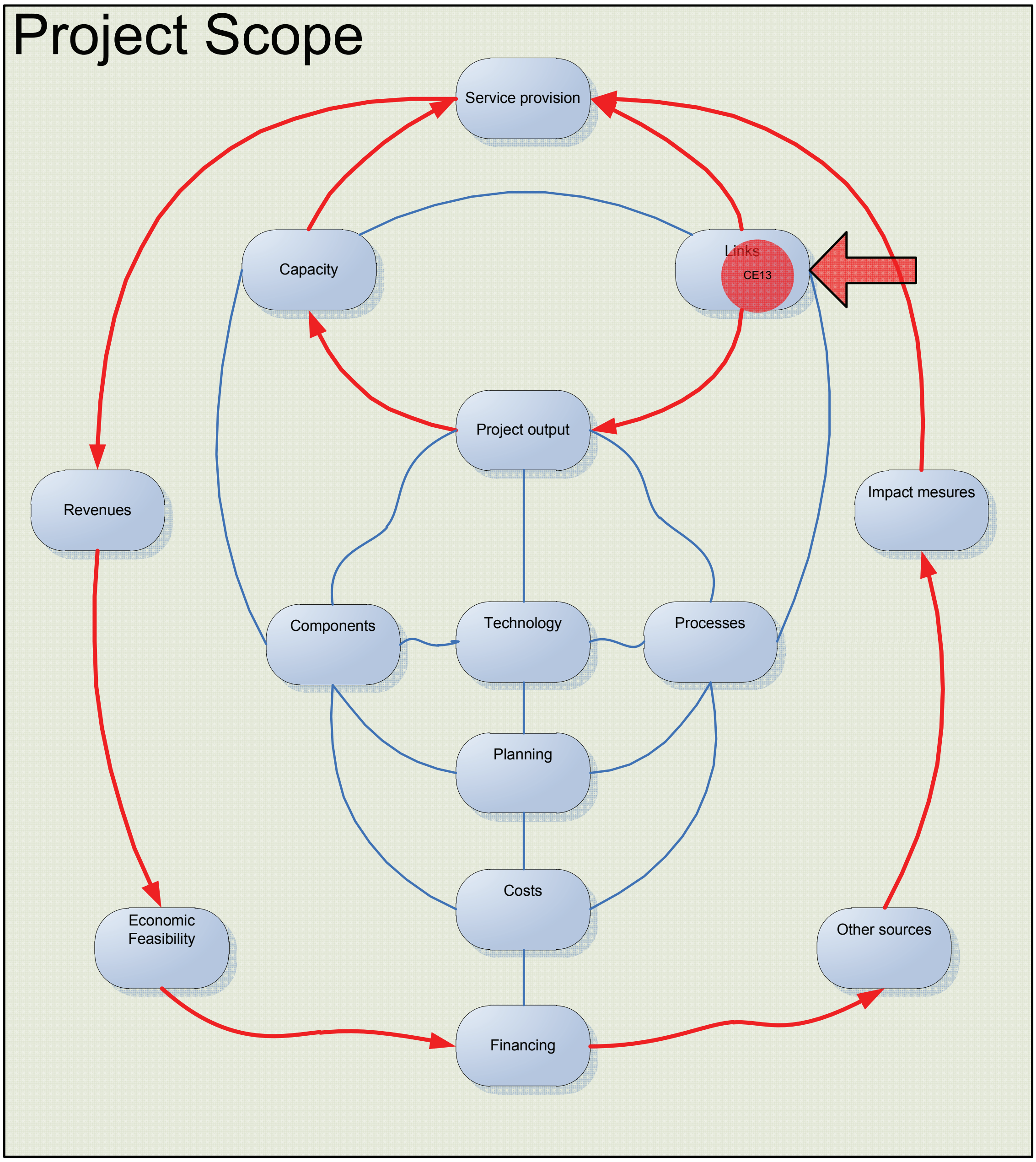

Table 5-8: Opposition from Uri canton (CE 12)

However in Bern, the Federal Counselor, Moritz Leunberger, does not doubt that the concept of Gotthard will not change since we are speaking of the "chantier of siècle." He also said that the Gotthard tunnel base is naturally directed towards Milan, and without this link, the NRLA project does not make any sense unless we want to assist a "Gotthardus interruptus."

Indeed, the NRLA project concept was foreseen as to link "Northern and Southern" Europe. The construction is protected by legal contracts and endorsed by the EC with a commitment to support the construction of the connection, which will link Switzerland to Europe and contribute to the high-speed railway infrastructure development. This commitment was reinforced after the final breakthrough of Gotthard took place on October 15, 2010. The acting director of policy for the Trans-European Transport Network (TEN-T), Jean Eric Paquet, stated *"as far as the Gotthard is concerned, it is part of a priority project which runs from Rotterdam to Genoa and whose alignment goes through the Gotthard and the Lötschberg... This priority project ensures that the two transversal alpine tunnels in Switzerland are fully taken into account when we develop a European transport infrastructure."*

Italy, who will profit a good deal from the tunnel after it opens in 2016 or 2017, praised Switzerland and its National Rail Link through the Alps project at a conference in September in Rome. The senator of Ticino, Filippo Lombardi, said: *"I've never before felt the desire and determination in Italy to support rail transport so strongly."* However, he emphasized the necessity of having the connection at Gotthard properly developed in order to cope with the additional traffic. *"Otherwise we'll have a Formula 1 tunnel but the access routes will be like mule tracks."*

5.3.2 Case study summary

The case study of the New Rail Link through the Alps project was presented at two different, but related levels. The first level illustrated the structural characteristics and management processes of two, stand-alone project organizations that were given the responsibility of building one of the most important infrastructures of this century. This aimed to offer an objective "view" of the project system and to highlight the differences and commonalities between the two project organization's attributes, summarized in Table 5-8. They mainly relate to the parent organization's ownership structure (public vs. private), the project's organization layout (highly vertical/functional vs. flat/weak matrix), and the performance in terms of committed delays (Lötschberg's on time achievement vs. Gotthard's eight year delay).

	ALP TRANSIT AG	**BLS ALP TRANSIT**
Organization	Fully owned by Swiss Federal railways (public) "In house" competencies Resources/Layers allocated based on need	Fully owned by a private railway operator, with strong culture, and goal oriented ;Outsourced resources Small (33 employees)
Contract Management	Construction is executed by a consortia of different contractors; accountable for tendering, contract negotiations, and closing	Site management services have been outsourced
PM Controlling	"NRLA Controlling Regulation"; The consulting engineers who supervise the sites are not authorized to make any important decision	"NRLA Controlling Regulation"; Enhanced decision power at the on-site level
Quality	Quality management system of the contractor or consortia	BLS responsible for the overall project management Specific PM is provided by private engineering companies
Cost and Time	Periodical cost information includes targeted and actual costs, forecasts, comments on cost development, and controlling	Within BLS's responsibilities
Completion time	2017(18) vs. 2011	2007 vs. 2007, Now generates revenues that help finance Gotthard
53.4 % increase in costs explained through safety, technology, politically motivated delays, and difficult geology.	On time 2007 vs. 2007	"On time but with a major change to the concept" They also had geological surprises

Table 5-9: Alp Transit AG vs. BLS Alp Transit

In the next section, the analysis presented will verify, in the light of case study findings, the fact that these differences are responsible for the different coping capabilities of the two projects.

At the second level, the case study provided a rich description of the project's behavior when confrontated with unexpected, critical events. The narrative story is supported by a systemic representation of the project, which was developed for this purpose and facilitates understanding critical events that unfold overtime. The list of observed events is long. From a methodological perspective it is very important to see these events in order to produce "stronger, inductive arguments" (Singleton and Straits 1999: 53). The exploration offered an insight into the measures taken by the project's actors in order to counteract the critical event's effects and maintain an overall performance level. These include the intervention strategies at the corporate (project governance) and project management levels (project organization). The events presented for exposition in this chapter marked turning points in the project's life-cycle and had major impacts on cost overruns and scheduling delays.

Although the data collection and analysis overlapped in this thesis, the case study analysis was presented in a separate chapter for the purpose of clarity. It focused on the interpretation and explanation of the project's behavior, the New Rail Link through the Alps, when it encountered critical events in its life-cycle, which emerged from the exploratory case study.

6 ANALYSIS AND DISCUSSIONS

"A theory simplifies and explains a complex real world phenomenon" (Whetten, 1989)

6.1 Introduction

In this section, we present evidence on the NRLA's project resilience and its enablers. We cite examples from the case and discuss those conditions and factors that enabled the resilience to manifest and develop along the project's life cycle. At the end of the chapter, the insights of this analysis will be translated into guidelines for project practitioners aimed at offering a new way of seeing and assessing project performance. Also giving a more accurate rendering of a project system confronted with critical events, from the resilience perspective, which is lacking in current project management literature.

As previously mentioned, the data analysis began in the field during the data collection process, as notes were recorded and initial interpretations were made during discussions. The complexity of the data analysis process was increased because of an overload of data, a multi-site study with interviews held in French, German, and English, and many people interviewed were Swiss-German native speakers in the majority of cases. This also led to a more cautious interpretation of the findings. Different techniques were used to organize and systematically review large amounts of qualitative data. Part of the data analysis involved content analysis techniques (Strauss 1987, Diesing 1971, Miles and Huberman 1984). In parallel, as suggested by Yin (1994), the individual interviews were recorded and "written-up" in the attempt to demonstrate and document converging (or diverging) evidence from different sources. The contents of the interviews were first coded into different categories corresponding to the components of the project system, as represented in Figure 5-8, and project management process, as described in chapter 5. The first round of data analysis revealed that certain categories were not useful given that nobody mentioned them in the interviews, and some were too broad. This resulted in a reclassification of the reference levels, as shown in the Annex 6, in P (personal), O (organizational) and G (project governance). Within the last two we used the following subcategories: 1) technology, 2) communication, 3) performance, control, and outcomes, and 4) goal statement and culture. The last includes solidarity, risk attitude, and “bricolage”. In addition to these subcategories, which are common for the level of reference “organizational” and “project governance”, the category “organizational” also includes the subcategory 5) “process issues,”which covers collaborative behavior, social networks, and positive relationships.

The analytic focus was on the examination of the interrelationship among categories and their impacts on the outcomes. Firstly, within the study of project system’s behavior when in confrontation with critical events of a different nature, either endogenous or exogenous, then finding recurrent themes and finally making comparisons across the two project organizations to reveal similarities and differences. Quotes collected under each category and subcategory were further subdivided based on causal relationships that emerged from the empirical evidence. (E.g. process issues, bricolage, relate to restoring work process efficacy, communication relates to the decision making efficacy, etc.) This logic is also described in Miles and Hubermann, 1994, p92-93.

From our interpretation of the data, two sets of findings emerged that describe how the NRLA project system responded to its critical events. One set relates to the critical event’s management and its contribution to the project resilience development. The other set of findings relates to the factors and conditions, which contributed to the positive adjustments of project system (maintained performance) after the critical event and thus enabled resilience to manifest.

In this section, we describe and situate each finding within existing literature in order to highlight this study’s contribution. Based on the empirical evidence, we propose to extend the theory of resilience with the emerging concepts of project resilience and resilience enablers, which could form the basis for a midrange theory of resilience in a temporary organization setting (infrastructure project). Consequently, the working definitions of these concepts, presented in chapter 2, were updated in light of the case study findings and graphs.

6.2 The Importance of the Critical Event’s Dynamics in Management

Our first observation from the data was enabled by the systematic representation of the project and relates to the importance of the critical event’s dynamics for their effective management.

The NRLA project faced a number of endogenous and exogenous events. Although, at the beginning, their sources were clearly defined and their nature was clearly stated, time elapsed and actors looked for a solution as they changed and became more complex. For example, the occurrence of geological surprises required, in almost all cases, modifications of the work process and/or technology used. For instance, the "squeezing rock" critical event, which appeared at Faido/Gotthard, challenged the engineers and geologists to find new process solutions to reinforce the tunnel walls. Similarly, the unexpected "ground collapse" combined with "water infiltrations" at Saint Germain/Lötschberg required innovative measures to dry the infiltrated water and secure the rock. These solutions were found by working groups with different competences. In general, when geological surprises happen, both technology and processes need to be adapted/changed. As a recurrent theme, solutions leading to these changes were the fruit of multidisciplinary groups of people. Based on the observations we propose, ***the management of critical events require specific and adapted processes and the intervention of multidisciplinary teams***. The proposition is consistent with Sheffi's (2005) claim that solutions requiring fast thinking to unknown problems are better achieved through collective diversity. An example is the case of the UPS drivers, coming from different background and experiences, who teamed up to find solutions for delivering parcels in the aftermath of the Katrina hurricane. It provides empirical support for Freemann's et al. (2004) argument on the role of requisite variety in enhancing creative thinking in people: like in the case of the recovery of Sandler O'Neill investment bank after the 9/11 terrorist attack on the World Trade Center.

The second finding in a critical event's dynamics refer to the actions done by actors to counteract the negative effects. From many observations while critical events are unfolding, ones described in chapter 5, we noticed that: ***"some interventions appeared to facilitate the occurrence of other critical events and thus led to an exacerbation of feedback loops, which make the over-runs worse."*** This finding is particularly well illustrated in the case of exogenous events, like the political conflict presented in the preceding chapter. This critical event occurred in 1994 as a consequence to the questions that arose about the economic viability of the project. The time needed to find a solution to the crisis, combined with delayed decision-making led to the occurrence of other critical events, which generated further delays and associated overruns. These downside effects are "resented even today, 15 years after the project started”. The finding is consistent with the Eden et al. (2000) et Eden et al. (2005) argument in that managerial action is required in response to any disruption but may cause further delays. According to the logic, “a delay has led to a disruption, which has led to a further delay.” A positive feedback loop is then formed, where both disruption and delay feedback come together, causing further disruptions and delays. It also bores the resemblance of a “vicious circle” as described by Masuch (1985). It encapsulates the idea that in trying to avoid the undesired outcomes of critical events, the actors may actually create these outcomes.

Interestingly, although the study of other exogenous events displayed patterns leading to the same finding, in some cases we found evidence ***of desirable side effects.*** They are due to the actions taken purposefully by the project’s owner representatives in order to ensure a future positive adjustment on the system in case a similar event should occur again. As an example, the measures taken by the project owner to solve the consequences of the critical event – generated by a complaint from Marti Consortium against the award from AlpTransit Gotthard to the tunnel construction lot of Erstfeld, Amsteg – led to issuing a new law. This new law guarantees that the consequences of such events cannot harm the project course anymore. Similar cause-effect relationships leading to desirable side effects were noticed in other circumstances, as in the critical event due to an environmental problem in canton Uri. This time, the measures taken by the constructor were to approach the environmental organizations USO (Pro Natura, Rheinaubund, Schweizer Heimatschutz, Stiftung Landschaftsschutz Schweiz, Schweizer Vogelschutz, Verkehrsclub der Schweiz and WWF Schweiz) and carry out regular inspections of the NRLA sites together. For the constructor, these inspections were important means to show the habitants open and transparent information and prevent further claims. Also, during the construction the representatives of USO could see on site the concrete implementation of measures for air pollution prevention, watercourse protection, etc. This transparency prevented stops for time consuming audits or to obtain of new authorizations.

We interpret these measures as an example of efficient critical events’ management aiming to create the premises for future resilient responses of project systems, in case similar events should occur. Based on this evidence we propose that ***in the NRLA project system, the capacity for resilience was developed overtime from continually handling critical events.***

This finding is consistent with the Egeland, Carlson & Stroufe (1993) and Wildawsky (1988) argument that an entity not only strives toward current adversity but also in the process of responding, it strengthens its capabilities to make further adjustments. It can also be associated to the developmental perspective of resilience as described by Teece, Pisano & Shuen (1997), Weick, Sutcliffe and Obstfel (1999) or Eisenhardt and Martin (2000). In their acceptance, resilience is *adaptability,* meaning that the way in which a project organization will respond to future challenges depends on response alternatives derived from a previous experience.

The last finding related to critical events refers to the way they spread and impact the project system overtime. From our observation of the data, supported by figures, we developed each critical event and gave a narrative description, provided in chapter 5. It suggests that ***"the ultimate impact of any critical event, no matter of its nature, is on the project's output and therefore it will overtime affect the service provision."*** As an example in the Lötschberg tunnel case, the lack of funds (after the period in which the project was delayed due to political conflict) led to the decision to equip only 16 km of the second tube at Lötschberg. This resulted in a diminution of transport capacity, resented today, three years after the tunnel was handed over to the operator.

This finding is consistent with other research dedicated to the project system. It claims that the "whole produces more than the sum of its parts" or the effects, and the positive feedback is a key explanation for a project's behavior (e.g. Eden et. al., 2005 or Williams, 2005).

The findings above provide indirect evidence that the management of the critical events could be improved if the intervention strategies took the systemic representation of critical events' dynamics, with project components, into account. By using this system, project actors can take decisions that will impede the occurrence of positive feedback loops and thus the propagation of negative impacts into the system. They could also take measures to purposefully increase of the capacity of adaptation in the future. By doing so, they will confer resilience into the system.

The second set of findings that emerged from our interpretation of the data concerns the conditions and factors that enabled the resilience to manifest by contributing to the restoration of the project system's overall efficacy after the critical event. They aimed to maintain the overall performance, understood here as "keeping the project's costs and planning on track."

We have named them resilience enablers. They are 1) a shared vision of the stakeholders on the project mission and its legitimacy, 2) effective communications and relationships based on trust, 3) culture of risk management and safety, and 4) capabilities to restore efficacy.

6.3 The Importance of Legitimacy and Common Vision for a Project's Mission

"If we possess our 'why' of life, we can put up with almost any 'how'"
Nietzsche (1968, p.23).

The first observation from the troubled project behavior analysis suggests the importance of ***"a shared vision of the political stakeholders on the project mission and its legitimacy.*"** Legitimacy is understood as the result of a process by which the key stakeholders (government officials) accept a venture as appropriate and right, given the existing norms and laws (Aldrich 1994). This project was born from political willingness. Even when it encountered political controversy, its legitimacy and mission to support the Swiss-European transport policy were never doubted. This made all decisions related to the changes of the project structure (financing, components) possible and needed their approval by popular vote. As well as raising the funds, which were added to the initial credit whenever needed. In this respect, this study proved by collateral finding that public funding is appropriate for financing major infrastructure projects in countries where "direct democracy" is the guiding principle in the decision-making process. This is accurately captured by the Minister of Transport, Moritz Leuenberger:

> *"During these 15 years in which I defended the project in Parliament, there were always malicious, doubting voices who predicted that it wouldn't succeed. A tunnel is only built after the breakthrough. Before that there are very many geological risks. We very clearly warned people about this before the referendum and voters still said yes. The Gotthard was proof that the country showed solidarity, no private business would*

> *have been able to assume that risk. Only a political community/alliance is in a position to do so."*[54]

Within the project organization, the political stakeholders' cohesion was enabled by shared values and federal state characteristics, which form the foundation of political stability in the country. To illustrate that, Adolf Oggi, who promoted this project from the beginning, and Moritz Leuenberger, Federal Councilor and Minister of Transport, under whose mandate the project was actually built, were present at the Gotthard base tunnel breakthrough ceremony. They represent two generations of politicians with different political views who both believed in and fought for the project. In the speech given at this event, Moritz Leuenberger stated that: "*This breakthrough is a symbol of what policy can do, when we make it together."* At his end, Adolf Oggi expressed his admiration and thanks for the " *verticality and determination shown in the last 15 years to prevent the project from being stopped in spite of huge problems"*. In relation to the political stakeholders in Italy, the cohesion was insured by contractual agreements signed within the EU regulation framework. Even if the connection with Italy today is controversial, due to the agglomeration of traffic in Milan, the Italian government is committed to cooperating and finding a solution. This becomes mandatory in the context where the successful breakthrough is acknowledged as *"a clear demonstration, and a signal given to Europe, that Switzerland is doing its part in building the European freight corridor from Rotterdam to Italy."*

This finding bores some resemblance to the Pinto and Prescott (1988) claim that a project's mission and its acceptance is a dominant, critical success factor in the first two phases of the project's life-cycle (conceptualization and planning). In addition, this case brings empirical support of the hypothesis that in public projects***, legitimacy is of great significance throughout the project's life-cycle.*** It is also consistent with Morris and Hough (1987), Pollalis and Frieze (1993), Sauer (1993), Yeo (1995), and Pinto and Kharabanda (1995), who argue that legitimacy, political stability, and goal alignment all are critical factors for the development and implementation of infrastructure projects.

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[54] Minister of Transport Moritz Leunberger for swissinfo on 15th of September 2010 (A tunnel which provokes "boundless admiration" *by Doris Lucini and Andreas Keise*r)

Also, with the empirical evidence presented, we interpret ***legitimacy, in concert with solidarity, as key factors for maintaining the positive adjustments of the NRLA project when confronted with critical events, and therefore an enabler of resilience***. This was proved on several occasions through efforts done to find and allocate resources necessary to overcome the crisis and to help the project pursue its normal course.

6.4 The Importance of Effective Communication and Trust

When responding to the geological critical events, a structure that allows direct communication and creates conditions to develop relationships based on trust, solutions to the incurred problems were found quicker. This observation was made by comparing how both organizations managed the unpredictable geological surprises. They both have implemented mechanisms to ensure the effective communication of unpredictable events, and have practiced collaboration to solve them. However, the effectiveness of their actions seems to differ. Interestingly, the Lötschberg project organization, which was quasi flat, seemed to be more reactive when dealing with unpredictable geological problems and more efficient in finding solutions to restore efficacy. This affirmation is confirmed by the elapsed time in which actors found a solution, as well as by the efficacy of the measures taken to "gain on planning". Otherwise said, to keep the timetables in spite of the incurred delays. The empirical evidence suggests that the differences between the two organizations could be explained by the differences in their structural attributes. The organization of the Lötschberg base tunnel project allowed for a certain autonomy in decision-making, given that the on-site manager had the power to decide for hundreds of thousands of Swiss Francs over cost. This was possible thanks to the ***trusting relationship developed with their subcontractors*** (33 people were supervising over 1,500 people working for the subcontractors' account), and ***direct communication*** (24 hours of direct communication available over the phone). Interestingly, the empirical evidence suggests that ***"there is no substitute for experience."*** Indeed, within the BLS project organization the quick decision-making process was enhanced by the project managers. They were people of a certain age, and therefore they were not only ***experienced*** but also ***trustworthy*** since they were not afraid of taking wrong decisions or jeopardizing their professional career. This finding is consistent with the argument of Sheffi, 2005, about “driving the power to make decisions down in the organization” as an important principle of resilience: as in the case of Zara, the clothing manufacturer, in dealing with a disruption in demand.

Face-to-face communication, enabled by weekly meetings, was also considered in both organizations key for ensuring a rapid decision-making process. This observation supports the argument of Weick (1993), from according to which, the development of meanings among two or more communication layers can be developed in rapid changing environments. They can be through face-to-face interaction as well as the claim of Sutcliffe & Vogus (2003), or Dutton & Heaphy (2003), on the role of the effective channel’s communications in organizations confronted with disruptions.

In the case of the Gotthard project, the effective ***communication was enforced by practices aiming to promote dialogue between partners.*** First, the *“dispute review board”* in which three independent, experienced, but impartial members are selected to hear and address disputes. The rule requires that one member is appointed by the contractor, one by the client, and one by the chairman. *The board’s role is to propose solutions to “unsolvable problems”.* This experience proved to have good results which reflected in *“less acrimony at the job site and timely, cost-effective solutions”* to various problems.

The second practice relates to the partnering process which seeks to “*minimize disputes and prevent them from escalating over time.”* It encourages dialogue between the client, the contractor, the engineer, and the construction manager in order to resolve disagreements reasonably. The bottom line is to act in the best interest of the project and to try to solve the problem at the lowest possible level in order to prevent conflict escalation and attorney involvement.

Based on the empirical evidence found, we propose that ***“effective communication”*** is an enabler of project resilience because it leads to prompt decision making after the critical event’s impact. The proactive actions taken by ALP Transit Gotthard to stimulate dialogue with partners and the informal communication developed at BLS Alp Transit are both interpreted as efforts to increase the information’s richness: which is necessary in the decision making process. This finding is consistent with Weick’s (1993) argument that communication channels are extremely important in problem solving, given that they represent the only way to enable rational and documented decision-making. In addition, the empirical evidence presented here suggests that *informal communication channels are "faster" than the formal ones*. However, the management of projects with big stakes call, in general, for highly formalized procedures. They result from a mix of inherited routines from the parent organization and work in compliance with the norms of "public works". Therefore, establishing informal communication could be very challenging. BLS, as a private and relatively small organization, was best positioned to develop and make use of the informal communication channels.

This finding provides empirical support to claim that communication is an enabler and valued principle in cultures of resilience in the works of Sheffi (2005), Burke (2005), who studied resilient companies that communicate obsessively, and Peck (2005), in the analysis of network infrastructures' resilience.

6.5 The Importance of Risk Attitude and Safety Culture

Our exploration resulted in finding that risk management and safety culture is one of the pillars of resilience and is a recurrent theme in the empirical findings associated with both project organizations. Inherent in the nature of the work (tunneling), the risk supervision and control processes needed to be further developed in order to ensure that they achieved the project's objectives. Starting from two basic questions: "what are the factors that may endanger the project's objectives or its viability?" and "what are the factors that could support the objectives attainment?" the two organizations put concrete actions in place in order to mitigate the risks and exploit the opportunities.

> *"Many people think we are exposed to the complete arbitrariness of nature, but this is not correct," explained Kalman Kovari, an emeritus professor of tunneling at the Federal Institute of Technology Zurich and a consultant to the project. "Geologists and rock mechanic experts make detailed surveys of the area. The best route is decided and the tunnel is then designed by a group of experts."*[55]

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[55] Source: swissinfo, September 2010

Both project companies and their contractual partners are responsible for regularly analyzing the risks, anticipating the hazards related to their domain of activity, and adjusting the exposure by planning and applying the proper procedures. Aware of the problems induced by the complex, unpredictable events, a special focus was put on accurate monitoring and detection in order to ensure effective risk management.

Interestingly, in the NLFA project redundant measures to specific procedures, for accurate monitoring and detection, are enabled by the employment of the newest technology. The creation of redundant capacities and abilities for monitoring and detecting hazards in complex processes meet here. It remembers the best practices implemented in order to enhance the operational resilience in firms active in: financial services (telephone banking, ATM networks), telecommunication services (mobile phones, managed data networks), transportation service providers (air traffic control), and warehouses (just-in-time or automated operations) as described in Frost et al. (2001).

The safety culture in NRLA is interlinked with the risk management culture. Both are embedded in the work and management process and people's attitudes. Their principles apply to both people and operations. Both base tunnels are long and therefore safety is exceptionally important. For example, according to AlpTransit Gotthard, the consideration of work safety in the planning phase, when inviting tenders, in the work contracts, and the strict enforcement of contractual and legal regulations "*creates an exemplary safety culture with low accident rates on the construction sites.*"According to the medicinist Irene Kunz, who was in charge of the health and safety of the employees on Gotthard's[56] building site for ten years, *"the accident rate has fallen by around 40 percent since boring began. This means that despite the big Gotthard Base Tunnel construction site, the tunneling work accident rate is only a little over the construction industry sector rate as a whole."*

This is partly explained by the prevention measures implemented. When it comes to people: *"Health check-ups are carried out on all mining candidates before they were allowed onto the construction site; those who were found to be at risk were, where possible, given work on less exposed sites. We would never have been able to build the Gotthard Base Tunnel with so little damage to health and life without these check-ups. Getting the personal responsibility message across is another prevention factor."*

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[56] *with the exception of the Sedrun shaft*

Interestingly, the safety failure lessons, encountered in the construction of other tunnels, were taken into account in the NRLA project. In this respect, Swiss Federal Railways – in collaboration with other European railway operators and supervisory authorities – has defined safety goals for the operation of their new transportation facilities. *“Safety planning will be successively refined right up to the time when the Gotthard Rail Link goes into operation and experience of incidents like the fire in the Channel Tunnel will be taken into consideration the safety measures planning.”*

Also, the evidence showed that there are regular experience exchanges with the project teams of other major European tunnels (Brenner, Mont d’Ambin, Semmering and Channel tunnels). These findings are consistent with the arguments of Bigley & Roberts (2001), Weick, Suttcliffe, & Obstfeld, (1999) and Wildavsky (1988) about the positive relationship between safety culture, implementation of lessons learned, and the resilience of high–reliability organizations (nuclear plants, airline industry).

However, we also found evidence that the *implementation of safety could become a bottleneck* in achieving the project’s objectives.

In the case of the Gotthard tunnel construction, the person in charge of monitoring the safety system on-site was authorized to make any changes needed to ensure safety, even if it would delay the planning goals. As an example, when the water that was pumped into the tunnel to cool and clean the machines, as well as to dampen the dust, produced a rise in humidity which implied a risk for the miners’ health. It was necessary to “*weigh up certain risks from an occupational health point of view and take measures which necessitated some pioneering work.”*

The fact that safety measure implementations require time and extra costs, is a recurrent theme in major project developments. The safety standards, which are likely to change, are needed over a long period and are necessary for a project’s execution. In case of the NRLA project, safety reasons are also described as one of the principal causes of delays and over costs. In spite of these apparently diverging findings, we interpret *the risk management and safety culture as an enabler of resilience,* in the context of the NRLA project for two main reasons. Firstly, the holistic analysis, on which the risk management processes are based on, is one main reason. Secondly, the monitoring and detection practices described above, which imply a prompt acquiring of the information necessary for rapid decision-making, are a case of critical events. This relationship leads to increasing chances for resilient responses of the project system. The finding bores resemblance with arguments to Sheffi (2005) and Christopher and Peck (2002) about the role of risk management and safety culture for the positive adjustment of companies confronted with disruptions in their supply chains. It is also consistent with Starr's et al., (2003) argument about the role of safety culture for the resilience network infrastructures. It brings empirical support to the claim of Hamel (2002), Freemann (2004), Starr et al., (2002), and Burke (2005) that companies who overcome shocks due to unfortunate events (terrorist attack, lost market position, loss of key supplier) are those with an advanced risk culture.

6.6 The Capability to Restore Efficacy

The factors described in the previous sections enable quick decision-making and are therefore accountable for fostering the project's resilience. Besides those, we identified factors, which alone or in concert with others, create the favorable conditions for restoring the overall efficacy of the project systems. Therefore, they lead to the performance maintenance after the critical events. They are 1) Flexibility[57], 2) Proactive planning, 3) Diversity[58], 4) Positive relationship[59], and 5) Work experience and motivation.

In the following paragraphs we will explain the context in which these findings emerged and situate them in the existing literature by evoking studies that suggest similar themes.

6.6.1 The Importance of Flexibility

This finding emerged in connection with 1) the selection of technology that confers flexibility in changing the work processes and related equipment when needed (critical events, standard changes): and 2) the contract practices which give legal flexibility to actually make changes. We illustrate it with empirical evidence on the flexibility of the boring process, due to

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[57]

[58] Reflected in task force components and tunnellers ("mineurs d'élite from 16 nations).

[59] Reflected in solidarity and social relationships

adequate technology selection and flexibility in contracting practices, found in both project organizations. This enabled rapid approval and the ability to obtain the certification required to implement changes, as well as the fair risk allocation/sharing with contractors.

Although, we only present the case of boring process and related contracting practices, observations of other work and management processes converge to same evidence. (e.g. *"concrete system, changing the concrete mix"* and contracting practices with related suppliers).

Flexibility and Technology Choice

In the case of the NRLA project, the empirical evidence shows that the selection of the appropriate excavation technology was a key factor in minimizing hazards and maintaining the drilling performance. This selection was based on the careful assessment of risks and opportunities. If geological conditions are predicted with high variance, as in the case of the central construction section at Sedrun, they *"expected from very good, hard rock to very poor rock, with a high squeezing potential and an overburden of 1.0 km. Eventually karstic rock zones were expected, and in the southward drive, the tunnel had to be excavated close to a concrete arch dam."* The owner selected the conventional tunneling instead of TBM. In turn, this led to the necessity of addressing major logistical challenges for the unpredictable surprises that occurred (e.g. squeezing rock). An example is the driving equipment that had to cope with enormously different dimensions (e.g. tunnel faces from 65 m2 to 135 m2). Also, due to *"the limited amount of space in the temporary base of the tunnel, which restricts the extent to which machines can pass each other, large parts of the installations had to be placed on a hanging platform."* On the Sedrun section, 50 tons had to be suspended from overhead rails and the whole excavation process needed to be adapted. However, this led to a breakthrough nine months ahead of the contract schedule. "*The average advance rate was constantly around 1.3 meters per day. Also, the costs were slightly lower than foreseen. A very successful chapter in the history of conventional tunneling has been written."*

For the excavation in the sectors Bodio (12 km drive) and Amsteg (11 km drive), the method selected was TBM, a revolutionary technology.

"It's like a millipede,"[60] with "a length of 440 meters it looks like a construction site in itself." Over the whole TBM drive, the average advance rates reached 11.5 meters per working day in both sectors, which was far better than foreseen.

We consider that in the case of the NRLA project, the selection of the technology was a key factor in conferring the flexibility to change and adapt the work process as well as the related equipment based. It was also key in being able to maintain the drilling performance in case of geological surprises. As illustrated above, with the case of Sedrun, this is particularly true in the selection of conventional tunnelling. It is a classical technique that "*allows response in both directions – depending on the rock changing; this flexibility makes conventional tunnelling the most advantageous tunnelling method in many projects, which can be located at a shallow depth or under a high overburden, in stable or loading ground, under genuine rock pressure, below the phreatic surface or in dry conditions"* (Ehbar, 2008).

This finding was recurrent in all drilling sections of both tunnels. It is particularly explained by "*years of experience, both in Switzerland and abroad, that enabled engineers to decide what kind of machine is best for the specific circumstances."* At Lötschberg, the excavation method was different: 80 percent of the tunnel was blasted, and 20 percent bored, but the drilling performance was maintained in case of critical events (see chapter 5 for full description).

Our finding could be summarized as ***"the right selection of technology creates the right conditions for achieving flexibility of work process and contributes to the maintenance of performance in the case of critical events."***

Flexibility and Contracting Practices

Interestingly, the empirical evidence suggests that the flexibility to change or adapt the work process and related equipment is not enough without *flexible contracting practices,* which allow the constructor, from the legal point of view, to actually make the changes. The Alp Transit Gotthard experience proved that: "*The contract conditions especially for conventional tunnelling must allow for rapid approval and certification of these changed and/or varied works. With reference to the possibility of encountering changed conditions, the contract*

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[60] Maurus Huwiler of AlpTransit Gotthard, the company overseeing the tunnel construction

should be based on a measurement version. This will help to respond to changed conditions even if relevant provisions for all possible consequences could not be already included at the time of contract award."

The data shows that contracting flexibility could be achieved through a clear delimitation of responsibility, accountability, and risk-sharing principles in accordance to core business and skills. "*The owner should prescribe the method of excavation only if there are compelling reasons to do so based on project restrictions. The responsibility for selection of the excavation method should be left to the contractor, based on the owner's description of the rock conditions and the limits set by the design engineer project restrictions."*

In the case of the Lötschberg tunnel, the same flexibility in the work process was achieved through outsourcing. "*We figured out the right balance between rigor and flexibility based on agreed performance levels, reviews, rewards and penalties for meeting or failing the requirements.*" The fact that the outcome (the what) is managed rigorously and the inputs (the why) are not, increase the operational flexibility.

Based on this insight, we propose that in the case of NRLA, ***the flexibility to change led to a capacity to restore efficacy in the case of critical events.*** Specifically, the selection of technology, in concert with flexible contracting practices, allowed changes to the work process and related equipment and created conditions for process performance maintenance.

This finding is consistent with Rice's (2003) claim that flexibility is one principle method to create resilience in the supply network. Like in the NRLA case, it refers to the flexibility of work processes (manufacturing, distribution network) to change and adapt in case of disruptions in the suppliers' network. It also brings empirical support to the arguments of Bigley & Roberts (2008) and Burke (2005), that the importance of operational flexibility for organizations in overcoming crises is significant.

6.6.2 The Importance of Proactive Planning

To everyone's surprise, BLS achieved the project on time, according to planning that was elaborated 12 years before. The post-data collection analysis proved that one of the enablers of this outstanding performance was, in Lötschberg case, that compensation for delays of planning had always been possible. This was founded on a "parallel work philosophy" enabled by use of adequate technology and equipment. This practice was systematically applied to the execution of all work packages belonging to the critical path, as well as other time consuming activities.

A relevant example relates to the railway equipment preparation and installation, which were carried out according with this parallel logic. Specifically, the assembly of the railway equipment was executed in containers concomitantly with the excavation of the gallery. When it was finished, the containers were brought into the gallery and the equipment was quickly put in place; the containers protected the expensive equipment from unfavorable external conditions. This finding is relevant when it comes to the differences between the two project organizations. Indeed, the underlying logic of planning at Alp Transit AG was the sequential work (derived from diagramming methods). It had the advantage of ensuring optimal use of resources that were internally available, but was difficult to change.

According to the project managers, this planning approach was in anticipation. It was meant to distribute the unknown geological risks enabled by outsourcing. Meaning that, in the case of unexpected surprises, a stop in boring and equipment installation will not multiply. The finding shows resemblance to the contention of Starr et al. (2003), that in the context in which not all risks can be anticipated, there is a growing need for organizations to be adaptive and to respond flexibly to uncertainties.

6.6.3 The Importance of Diversity

The case study revealed the positive relationship between the *diversity of skills and backgrounds* to the quickness in finding solutions to unknown problems. This contributed to restoring the project system's efficacy after the critical event. We illustrate this finding with two examples.

The first is the case of *purposeful diversity* in task forces' compositions. The second is the case of observed *"ad-hoc diversity"* leading to "bricolage" solutions from people on-site. They teamed-up together to overcome difficulties. In both cases, diversity creates conditions for avoiding work to be stopped for long periods.

Task Forces

They are intervention teams foreseen to find solutions to complex problems and were purposefully created in both project companies in order to respond to the lessons learned at the beginning of the project. In the case of critical events, these teams would do a quick assessment of the situation and decide on the necessity to involve external people of other backgrounds (e.g. academics, consultants) to the project. This is very often the case, as described in the narration of critical events in chapter 5. The guiding principle seems to be that the variety of opinions enhances optimal solutions.

"I am extremely impressed by how all the disciplines involved work together; geologists, engineers, builders, entrepreneurs, logistics experts, and cantonal and government representatives have built a multi-layered network and worked well together. It is just brilliant that the breakthrough is nearly ready" (Irene Kunz- occupational health doctor at ATG sites).

This finding is recurrent in studies of organizational resilience such as Beunza and Stark (2003) who analyzed the role of diversity in the revival of operations of the trading rooms of Lower Manhattan after 9/11. Or Weick (1987) who analyzed the role of requisite variety in achieving reliability and resilience.

"Bricolage: Response to crisis can be seen as a particular instance of innovation"[61]

We use this term to describe the creative and resourceful use of materials on hand (regardless of their original purpose) through people working on-site in order to overcome the escalation of critical events' impacts. From the narration provided in chapter 5, describing unfolding critical events, we take the example of one Lötschberg tunnel's geological surprise to illustrate this finding: "*The geology made the drilling process difficult on the last kilometer of Mitholz. In the end, another unexpected event occurred: one of the transversal galleries went down just before boring."* However, the miners quickly adjusted this situation, "*she was saved thanks to the intervention of the 'élite mineurs' who secured it with wood trunks*."

The empirical evidence suggests that on-site, people worked in a team to find solutions to unexpected difficulties. They seemed to be convinced that together they would succeed. *"We are different and debates are animated but I have never doubted that we wouldn't make it…*

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[61] Beunzaand Stark (2003)

Sometimes you only move a few centimeters forward, but you always go forwards." Diversity is enforced by skills, origins, and cultures: "*It is nothing new for the miners not to be Swiss. Traditionally it was Italians who provided the muscle but today people from 16 nations built this tunnel."*

Bigley & Roberts (2008), Burke (2005), and Beunza and Stark (2003) also highlighted the role of diversity in successful *improvisation.* This enabled solutions in crises such as the fire fights and the 9/11 terrorist attack.

6.6.4 There are no Substitutes for Experience, Positive Relationship and Engagement

Many of the quotes collected under the subcategory "bricolage" indicated that "*experience combined with positive relationships"* can create conditions for developing the miners' engagement in the successful achievement of the tunnel. This created the conditions for maintaining performance in case critical events happened.

This causal relationship is not an unexpected finding. We consider that challenges traditionally associated to tunnelling cannot be overcome without the efforts of dedicated people. Alaosin Switzerland said that drilling tunnels "*is an ability born out of necessity and continuous activities over almost 150 years."*

Aware of the miners' role for the successful completion of this project, project owner representatives used every occasion to thank and praise their work. "*Together we risked a lot. Together we achieved a lot, because we know the mountain is large but we are small."*[62]
At the breakthrough ceremony on the 15th of October, the Chief Executive Officer of AlpTransit Gotthard AG singled out numerous miners in his thanks. *"Through their years of tireless commitment, they have made this world record possible. The miners are the heroes of today's celebrations."*

To ensure their engagement, the management adopted a work policy which: 1) Promoted an adequate incentives system to reward their work. "*If I earned the same at home I'd hardly*

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[62] Swiss Transport Minister Moritz Leuenberger at the ceremony organized at the breakthrough event

ever be there, it’s the same, too, for my colleagues. We earn a good salary but it has its price.” “*I’d like to stay in Switzerland, the social security is much better than in the rest of Europe.”* 2) Practiced a hiring policy which strengthened their positive relationships: “*a particular aspect is that in addition to their families at home, miners have a second “family” on the construction site.”* “*The teams are tightly knit; they often come from the same village and are friends or even members of the same family”* 3) Ensured high quality work and safety conditions: *“today's workers live in specially built, neat, prefabricated blocks; in videos displayed at the Gotthard information center, several say how much they appreciate being in Switzerland.”* 4) Challenged their potential to further hone their capabilities: *“steering the TBM is a skilled job, done from a cabin with a bank of screens; most of the other miners are involved in the logistics of getting the right equipment to the right place at the right time. Teamwork is also vital.”* 5) Cultivated the pride of being a part of building a “world wonder”.

We suggest that positive relationships are one of resources that enable resilience.

Examples of studies that link resilience to positive work relationships at the organizational level are Cameron, Bright and Caza (2004), Spreitzer, Sutcliffe et al. (2006), Gittel et.al (2006), Burke (2005), and Beunza and Stark (2003). In same vein, Seeman (1996) and Ryff and Singer (2002) link resilience and recovery to individuals with positive work relationships. Our finding offers empirical support to these arguments.

In addition, we propose a response to the underexplored question: through which mechanism do positive relationships contribute to resilience? Based on the NRLA case study, we suggest that positive work relationships, in combination with experience and an adequate incentives’ system, activate the dedication and sentiment of competency, which further triggers resilience.

This argument is consistent with Harland’s et al. (2005) contention that employees “who feel more competent and valued may be more likely to engage in positive appraisals of the situation because they feel more capable to meet the challenge and less afraid of negative consequences if they fail.”

6.7 Findings Summary

This chapter set out to present empirical evidence on how the NRLA project system behaved in confrontation with critical events of a different nature. From the data analyzed, two set of findings emerged. One set relates to the critical events' management and its contribution to a potential development of project resilience. The other set of findings relate to the identified factors and conditions that enabled the positive adjustments of the project system after the critical event. The positive adjustments represent a resilient response and are understood as successful efforts to help the project pursue its course while keeping the costs and timetables "on the track".

The first set of findings led us to propose that the effective management of critical events requires specific and adapted processes and the intervention of multidisciplinary teams. It is enabled through strong knowledge of interdependencies between a project system's structural elements and the level at which the critical event impacts. Critical events management creates the potential for resilience development (otherwise said, continuous handling of critical events lead to the increase of the capacity of adaptation).

The second set of findings led us to propose that in the face of unexpected critical events, project organization and corporate governance should follow two directions in order to enhance resilient responses. The first is to create the premises for a fast decision making process through 1) ensuring project legitimacy and goals alignment, 2) increasing face-to-face communication, developing informal communication, and building dialogue with partners, and 3) enforcing a risk management and safety culture. Secondly, to create a premises to restore the project system's efficacy through providing a context for 1) flexible change of work processes, related technologies, and equipment in the case of critical events, 2) create operational slacks for anticipated problems (proactive planning), 3) foster a set of diverse skills and capabilities to find solutions to complex/unknown problems, and 4) develop positive work relationships.

Based on these emerging concepts, we propose the extension of the theory of resilience to a temporary setting, the infrastructure project organization.

6.8 The Resilience in Infrastructure Projects

"What does not kill me makes me stronger." Nietzsche (1968, p.8)

In chapter 2, we proposed literature based working definitions of resilience and resilience enablers. We said that they would be updated (completed and/or validated) in the light of our empirical findings.

We suggested the following definition for a project's resilience: *"resilience is the project's capacity to maintain positive adjustments when confronted with critical events that are inherent in its life-cycle.*"

This study is concerned with the project's performance in respect to costs and scheduling delays. We proposed to understand the positive adjustments as successful efforts for "keeping the project's costs and planning on track."

For resilience enablers, we suggested *"those conditions and factors (if any) which facilitate the manifestation of project resilience in the face of critical events."*

As recommended in Masten (2001) and Suttcliffe & Vogus (2003), resilience enablers were identified and assessed in respect to two qualifiers. They are evidence that a threat (critical event) can be overcome and that the project system can continue to do well (performance maintained). Chapters 5 and 6 describe how the enablers emerged from the collected data and discussed and situated them within existing literature. Without observed case-related particularities, which could be integrated into the working definition of resilience enablers, as fore-mentioned, our definition can be validated.

In contrast, the empirical evidence from the NRLA case study substantiated two inductive arguments. These need to be considered when updating the proposed definition of project resilience. One argument relates to the "perceived" project performance and the other concerns a possible way to evaluate project resilience.

6.8.1 Project resilience

The first element, which clearly stands out in our empirical analysis, is that the real performance of this project, in the project's stakeholder perception, is the fact that it still alive. Since 1992, when the Swiss first approved the plan, the project faced numerous critical events and was stopped more than once. Its execution is a continuously risky venture with many compromises. The evidence suggests that the stakeholders' solidarity, in spite of their diverging opinions, is to some extent accountable for the performance. The solidarity was founded on strong interests; specifically, the project's strategic importance for Switzerland's transport policy and its contribution to building European infrastructures. *In this light, the goal of the stakeholders is "to keep it going."* The overruns and scheduling delays, although unfortunate, are seen as secondary[63].

Nevertheless, the empirical analysis of the project system's behavior provided evidence of positive adjustments after critical events occurred. Project actors took measures to counteract the critical event's impacts and to control planning delays. One recurrent outcome observed, was the increase of adaptation capacity of the project system.

Therefore, we propose to update the working definition of project resilience to:

Resilience describes 1) the project system's ability to restore capacity and continuously adapt to changes 2) to fulfill its objectives in order to continue to function at its fullest possible extent, in spite of threatening critical events.

This definition embraces a *developmental perspective*, which understands resilience as a dynamic process of positive adaptation. This is argued in the studies of Egeland *et al.* (1993); Wildavsky (1988 p:120); Sitkin (1992); Levinthal and March (1981, 1993); Teece *et al.* (1997); Weick *et al.* (1999); Eisenhardt & Martin (2000); and Porras & Silvers (1991).

It has more similarities to the notion of ecological resilience than to the concept of engineering resilience. As explained in Gunderson and Pritchard (2002), and described in detail in Annex 7, the engineering resilience implies maximising the efficiency of the processes (with the risk of increasing vulnerabilities) in order to quickly return to the

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[63] *"The voters' motives did not lie in the economic profitability of both base tunnels but in the regions coming closer together and in the sustainable management of ever-increasing mobility"*

equilibrium, in which the system was found before the shock. Ecological resilience aspires to effectively increase the magnitude of consequences the organisation could withstand before suffering irreparable changes.

However, one of the recurrent themes across studies in different fields (e.g. Flach 1997; Gunderson 2002), is the general acknowledgement that resilience is a "difficult concept to measure." Based on the insight gained through this exploratory study, and derived from the definition of organizational resilience[64] of Dalziell and McManus (2004) we suggest a method "to measure" resilience at the process level. Project management typically measures process performance against a tangible set of key performance indicators (KPI). The time needed for the project performance indicators to recover will be a function of its adaptation capacity, which leads to a positive adjustment in restoring its capacity (KPIs recovering). Therefore, resilience will be a function of the impact on KPI (Δ KPI) over the response and restore capacity period (Δ elapsed time). This is represented in the figure below:

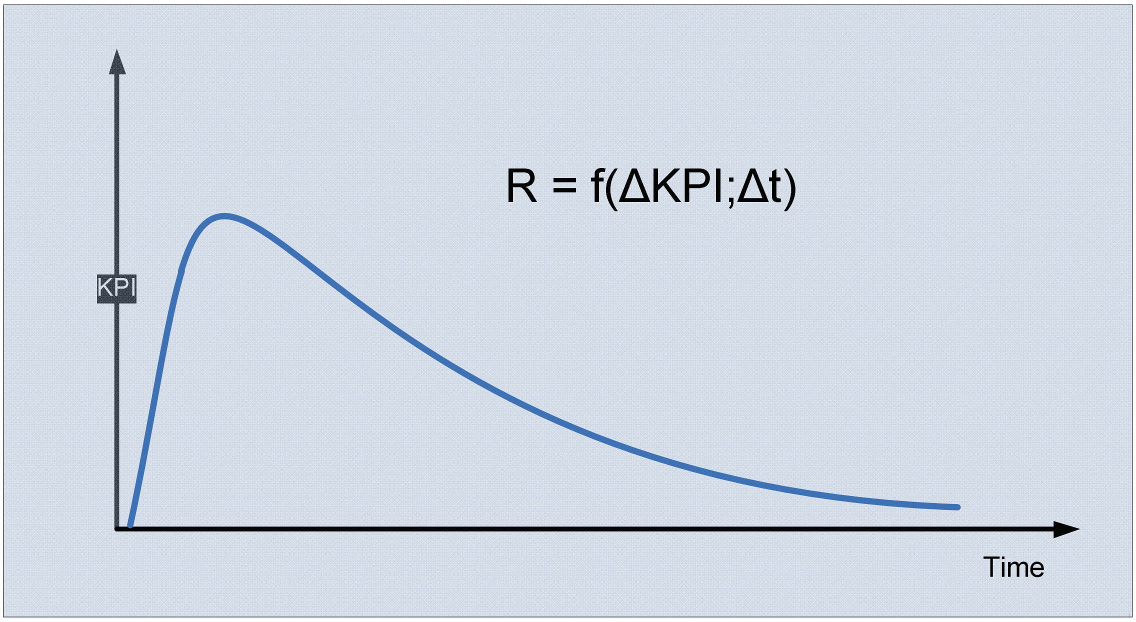

Figure 6-1: Measuring the Process Resilience (adapted from Dalziell, 2004)

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[64] "Resilience may be broken down into two key components: vulnerability and adaptive capacity; The ease with which an organization is pushed after a shock into a new state is a measure of its vulnerability, while the degree to which it is able to cope with that change is a measure of their adaptive capacity" (Dalziell and McManus, 2004).

This shows the importance of impact on the KPIs and time elapsed to their recovery as a measure of process resilience: $R = F (\Delta \text{ KPI}, \Delta t)$. For instance, a key process in tunnel execution, the drilling (boring), measures its performance by the KPI "rate of advancement". In the event of an unexpected critical event, this rate will drop dramatically if the drilling needs to be stopped (equaling 0 meters/day). The elapsed time necessary to find a solution to restore the drilling process's efficacy[65] and the critical event's impact on the rate of importance (how severe it dropped), could be used to measure resilience.

As illustrated in the case study, finding a solution to restore the "rate of advancement" implies awareness of critical event's conjecture. This enables an informed decision-making process, supported by a group of people with various competencies and skills. This will lead to an adaptation or change of processes, equipment, and/or technologies that will enable work to resume. Similarly, this logic could be reproduced for all other critical processes. Cost and time are traditionally among the most important project KPIs. The aim of this logic would be to quantify the costs associated with restoring the efficacy, to complete the set of the resources needed, to enable a resilient response. For an accurate result, the foreseen contingencies[66] (if any) would be deducted from the total sum. This reasoning leads us to propose, in the next section, a graphical representation of the "troubled project behavior" concept. It places the critical events and associated adjustments in the project life-cycle and links them to its performance.

6.8.2 Troubled project behavior

The graph shows that critical events can occur any time during the project's life-cycle (conceptualization, planning, execution and termination) and will disturb the project's course. As proved in the studies of major projects (e.g. Morris and Hough 1987, Eden, Ackerman, et al. 2005), as well as in the NRLA exploratory case study, the critical event's accumulated

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[65] Example of measuring performance in drilling process: "In September, the west tunnel-lining machine exceeded the agreed performance of 600 metres per month for the first time. In the west single-track tunnel, 54 blocks (648 metres) were concreted up to Tunnel Kilometre 234.750. The gap (1,080 m) that arose due to the repairs in the west single-track tunnel is being closed with the small tunnel-lining machine, with which 14 blocks (168 m) were concreted in September"

[66] A contingency represents a source or capability that is intended to help managers cope with uncertainty (Ward, 2005)

overtime can always be translated into overruns (Δ costs) and delays above the original timetables (Δ time).

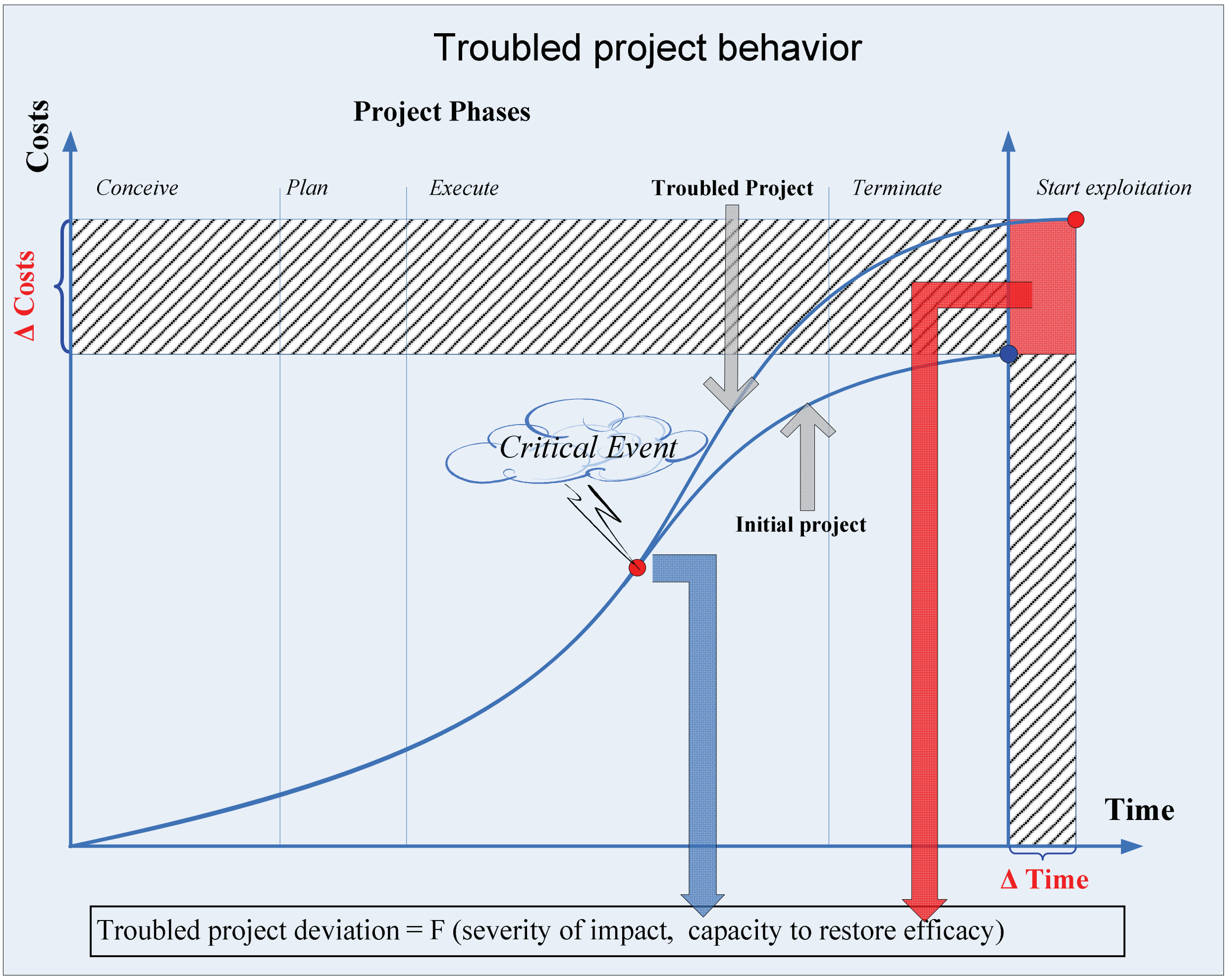

Figure 6-2: Troubled Project Behavior and Performance in Project Life-cycle[67]

Therefore, the troubled project's behavior is represented by the deviation from the project's original trajectory. The magnitude of the deviation will depend on the severity of the critical

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[67] **Based on empirical findings**

event's impact on the project's performance. This then depends on the capacity of the project's system to restore efficacy and maintain a positive adjustment, understood here as project resilience.

The exercise of reconstituting the troubled project behavior at Gotthard and Lötschberg base tunnels led to Figure 6-3. The graphs were constructed based on the data included in the OFT report from December 31st, 2007.

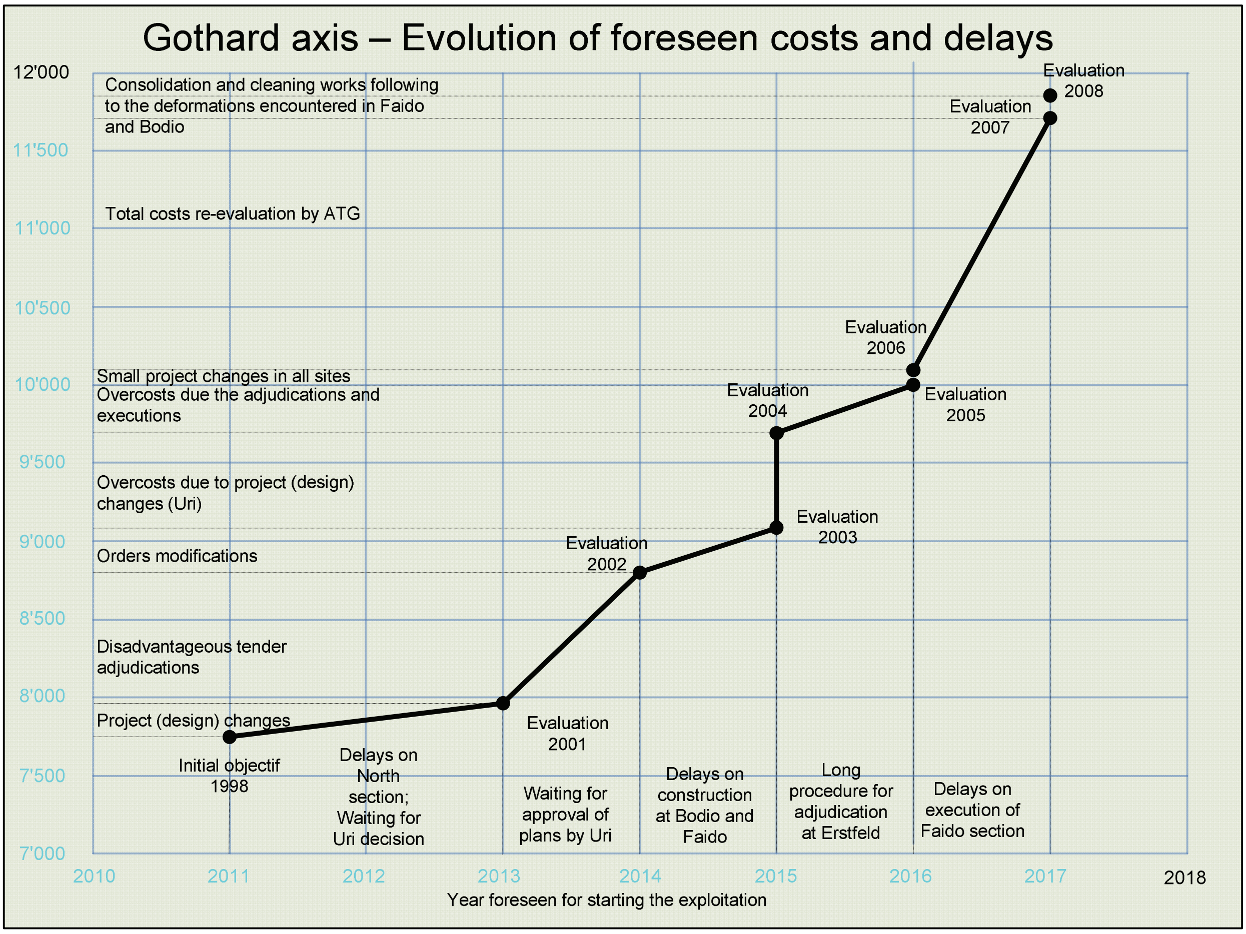


Figure 6-3: Troubled project behavior – Example of Gotthard base tunnel project

(Source: OFT report Dec 31, 2007)

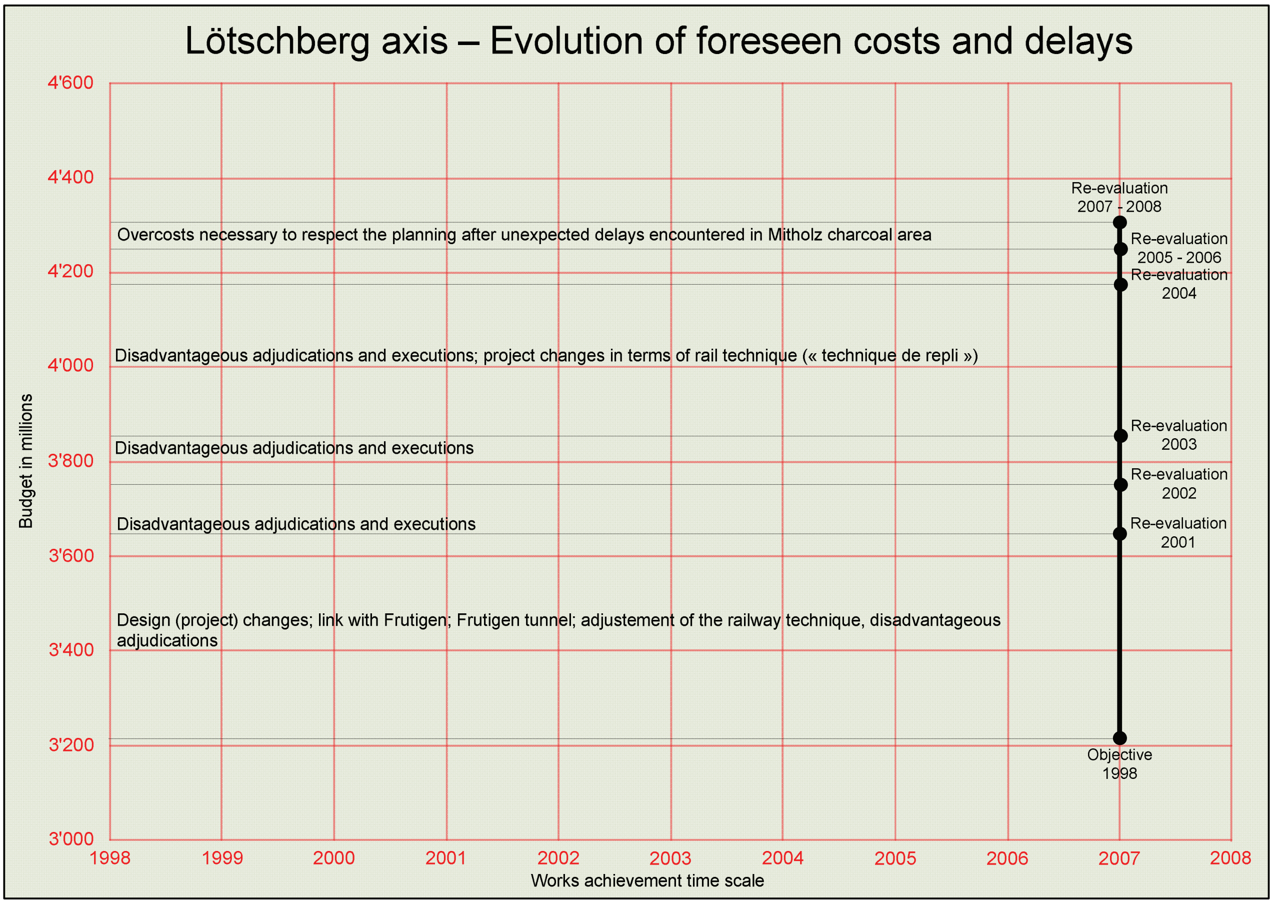
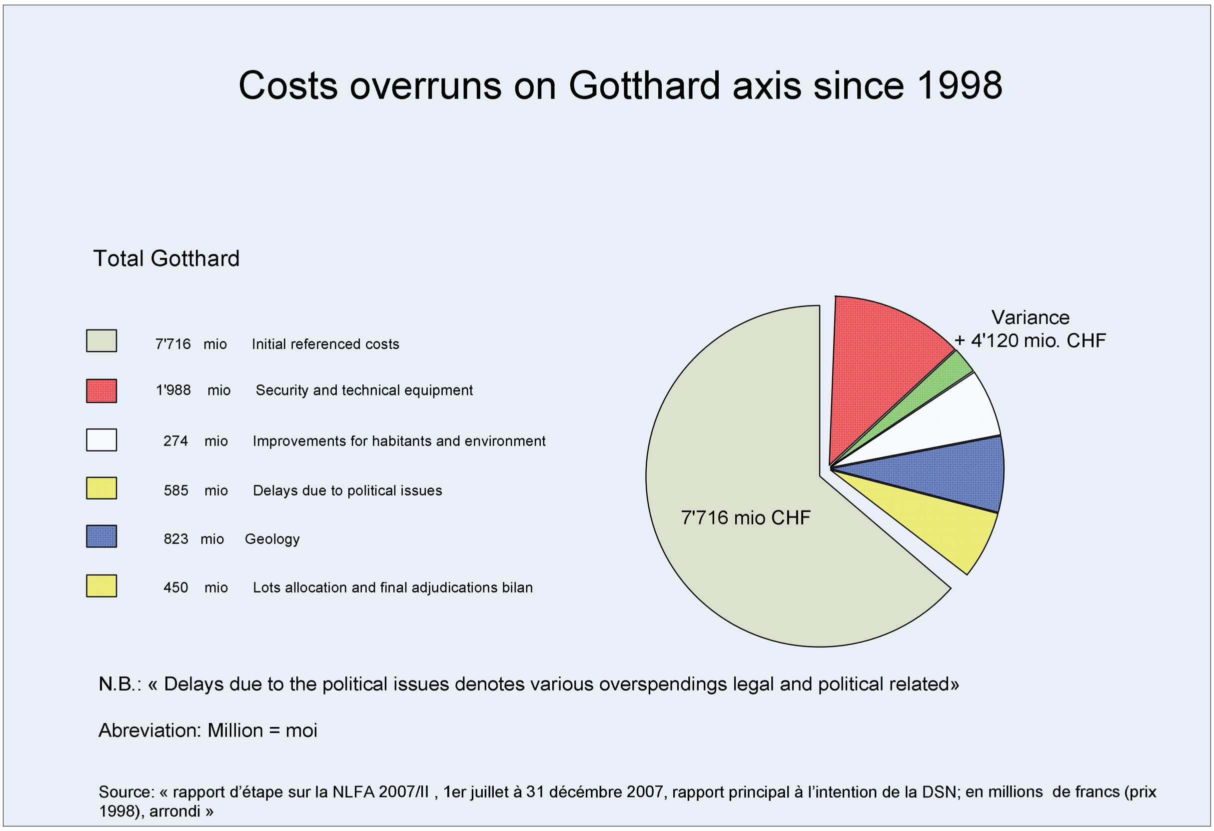


Figure 6-4: Troubled project behavior – Example of Lötschberg base tunnel project

The performance of the actual costs and planning versus the objectives established in 1998, vary for both tunnel execution projects. It shows that in both cases estimated costs were escalated, however only the Lötschberg tunnel was completed on time. Meanwhile, yearly re-evaluations over the project's completion timeline indicate 2018 as the most presumable year that the Gotthard tunnel will be complete.

Interestingly, the severity of critical events, which is evaluated through their impacts on costs and the scale of effects, show comparable overspending for the nature of the costs.



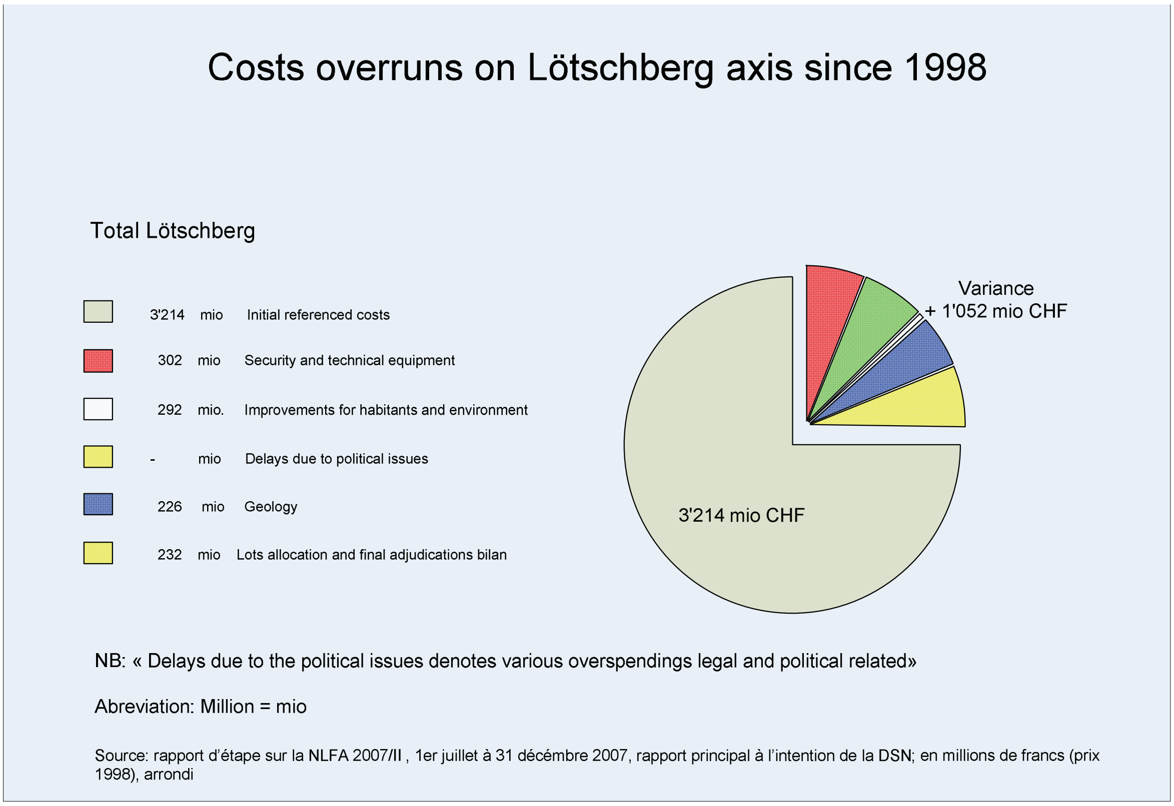
N.B.: « Delays due to the political issues denotes various overspendings legal and political related»

Abreviation: Million = moi

Source: « rapport d'étape sur la NLFA 2007/II , 1er juillet à 31 décémbre 2007, rapport principal à l'intention de la DSN; en millions de francs (prix 1998), arrondi »

Figure 6-5: Critical Events Severity Translated in Cost Overruns - Gotthard Tunnel Execution

(Based on OFT report)



NB: « Delays due to the political issues denotes various overspendings legal and political related»

Abreviation: Million = mio

Source: rapport d'étape sur la NLFA 2007/II , 1er juillet à 31 décémbre 2007, rapport principal à l'intention de la DSN; en millions de francs (prix 1998), arrondi

Figure 6-6: Critical Events Severity Translated in Cost Overruns – Lötschberg Tunnel Execution[68]

From the case study description and analysis, these results suggest that the two projects had different coping capabilities when confronted with critical events, and therefore had different resiliencies.

Nevertheless, when speaking about the NRLA project as a congregate, one can safely say that it showed limited resilience in the key project performers, cost overruns and planning delays. However, it manifested strong resilience in pursuing its course. In other words, resilience is tied into "the real project performance, as it is perceived by project stakeholders and how it emerged from the case study."

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[68] **Based on OFT Reports**

7 RESILIENCE IN PROJECT MANAGEMENT PRACTICE

> *"Connecting theory and practice is no simple trick; but when it occurs it can trigger dazzling insights"* (Lake Wobegan Story cited in Van de ven 2007, Chapter 9, p2)

The NRLA case study verified that unexpected critical events have a negative impact on project performance. The project system does not recover quickly from their consequences. Thus, additional costs and delays over initial planning accumulate, regardless of what caused the critical event. Traditional project management practice does not pay enough attention to critical events for various reasons. Firstly, the consequences are unknown, they are low-frequency events, and a resource shortage can happen. Secondly, many have no previous experience, multidisciplinary and cross-functional requirements are needed, and project managers do not receive credit for problems that never happened.

The research presented in this thesis explores empirical evidence on project resilience. This is a concept that is accountable for a positive adjustment after a critical event, meaning that it matters in order to maintain performance. The NRLA insight reveals that the conditions and factors enabling resilience could boost project performance. On one hand, a fast decision-making process, in case of critical events, and on the other hand, quick restoring of process efficacy is needed. In an attempt to show the value and usability of this concept, we will close the chapter with managerial insights. Included are recommendations for implementation, derived from the knowledge gained over project resilience and its enablers. They are suggestions on 1) general strategies, which could be adopted at the project governance and organization levels, in order to confer general resilience to the project system. And 2) a practical application on the process of building resilience, supported examples from NRLA, but it can customized for any given project.

7.1 General strategies for building resilience in projects

Three general strategies should be adopted based on the observed patterns of positive adjustments in the NRLA case study. These suggestions take into account the position of the emerged resilience enablers in the existing literature of resilience and project management, as well as recurrent themes in resilience research in other fields (socio-psychology and social ecological systems)[69]. They are: 1) Risk – focused aiming to prevent or reduce risk exposure 2) Resource – focused aiming to increase access to all types of resources and 3) Protection – focused aiming to restore efficacy through the mobilization of a project system's capacity for adaptation. The guiding principles of these strategies should be: no elapsed time between the occurrence and the communication of critical events, reduced time in resolving the problem (quick resolution, prevent escalation, and worsening), and developed capabilities to react and respond to critical events.

7.1.1 Risk – Focused Strategy

The NRLA study brings empirical evidence to the importance of effective risk management to successfully cope with unexpected critical events. Specifically through developing and monitoring warning indicators, looking forward, and using predictive analytics in the project organization, a rapid response is created. When things go wrong, better preparation of the project's system for impacting effects and avoiding delays due to work stops make the project run smoother.

In addition, we suggest that risk management processes should include a specific process that identifies the critical events' sources and evaluates the impact from a systemic perspective. By thinking more systemically about risks, managers create the identification context of "key risk drivers". Those are risks that exert influence over a certain number of project components. This should enable the mitigation of forming positive feedback loops in the project system and impede financial consequences. In the NRLA project, the risk management process was reviewed periodically (every 6 months) and continuously improved based on the lessons learned. This leads to developing capabilities for effectively managing risks, and therefore, increases the project system's capacity for adaptation, implying resilience in the case of unexpected events.

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[69] These themes emerged from the conference Resilience 2008, International Science and Policy Conference held in Stockholm (presentations of Fikret Berkes, Ann Masten, Benjamin Burkhard, Elizabeth Malone, etc.)

7.1.2 Resource – Focused Strategy

The aim of a resource-focused strategy is to increase access to all types of resources (human, financial, knowledge, etc.) necessary to solve the crisis that follows a critical event.

At the project governance level, the strategy can be achieved when stakeholders build and preserve project legitimacy during the whole project life-cycle. They share a common vision and their goals are aligned with the project. In the NRLA case, these conditions coaxed the cohesion of stakeholders and enforced their solidarity in the face of critical events. This "warranted" their joint efforts to find the financial resources necessary for the project to pursue its course. It also created a context in which the project's finality could be adapted in case significant changes occurred (political, environmental, etc.).

At the project organization level, the increase in access to resources is enabled through effective communications and relationships based on trust. Their importance in successfully handling critical events cannot be overestimated, particularly in an organization that has a strong mechanistic "command and control" structure. In the NRLA case, effective communications (face to face, informal, and diverse) and trusting relationships with suppliers enable rapid decision-making when critical events occur. The decisions are based on knowledge and skills rather than on formal authority.

7.1.3 Protection – Focused Strategy

The goal of a protection-focused strategy is to restore efficacy through the mobilization of a project's system with the ability to adapt. Based on these research findings, any project system should rely on the following factors to be able to quickly restore its efficacy. Work processes are flexible enough to allow for the implementation of changes (technology and/or related equipment); Operational slacks for anticipated problems (proactive planning); Intervention teams displaying a variety of skills and capabilities necessary to find solutions to complex/unknown problems; and Motivated people who show passion and dedication to their work while having outstanding skills.

Work process flexibility can be achieved through the right selection of technology and flexibility in contracting practices. Operational slacks and proactive planning ideally need to be embedded in the risk management and safety culture. Last but not least, the employees' motivation develops through positive work relationships encouraged by adequate incentives and empowerment mechanisms.

The intervention measures, in the case of critical events, should consider the sustainability of desired effects. Meaning that, it should create a context in which the project system will not suffer the same consequences if the critical event occurs again. This implies the project actors recognize that the "after critical event environment" is changed, and they should adjust their actions appropriately to increase the overall capacity of adaptation. The management will obviously judge these suggestions in connection to their ease of implementation, including other dimensions, such as time and cost. In the case they are accepted and actually implemented, the project organization needs to evaluate their contribution as it actually is as opposed to the predicted effectiveness in influencing the project's performance.

7.2 Toward a Process of Building Project Resilience

Based on the empirical findings from the NRLA case study, and the identified enablers of resilience, we suggest that resilience can either be designed at the project's inception or developed during the project's life-cycle.

Resilience Enablers (NRLA case study)	***Levels of resilience***
Legitimacy and common vision on the project's mission	Strategy
Social networks and relationships based on trust (BLS,ATG)	Culture
Risk attitude and safety culture (NRLA)	
Effective communication (ATG, BLS) and trust (BLS)	
Proactive planning (BLS)	
Positive work relationships	
Diversity (skills, competencies)	
Flat organization layout for direct communication (BLS)	Structure

Financial structure (NRLA) Flexibility through technology selection resultant in low complexity (ATG) Flexible contracting practices (ATG)	

Table 7-1: Levels of Resilience in NRLA Project based on Empirical Findings

It can then be embedded into the project's system at the strategic, cultural, or structural levels: as shown in the Table 7-1.

In this table, the resilience enablers (emerged from the empirical analysis) are assigned to project system structural elements as defined by Turner (1999). This highlights the project system level where the resilience enablers could be embedded and create the context for the implementation of risk-focused, resource-focused and protection-focused strategies.

Further, the experience of the NRLA case study, led to propose a practical tool consisting in a three-sequence process for building project resilience, as described in Figure 7-2.

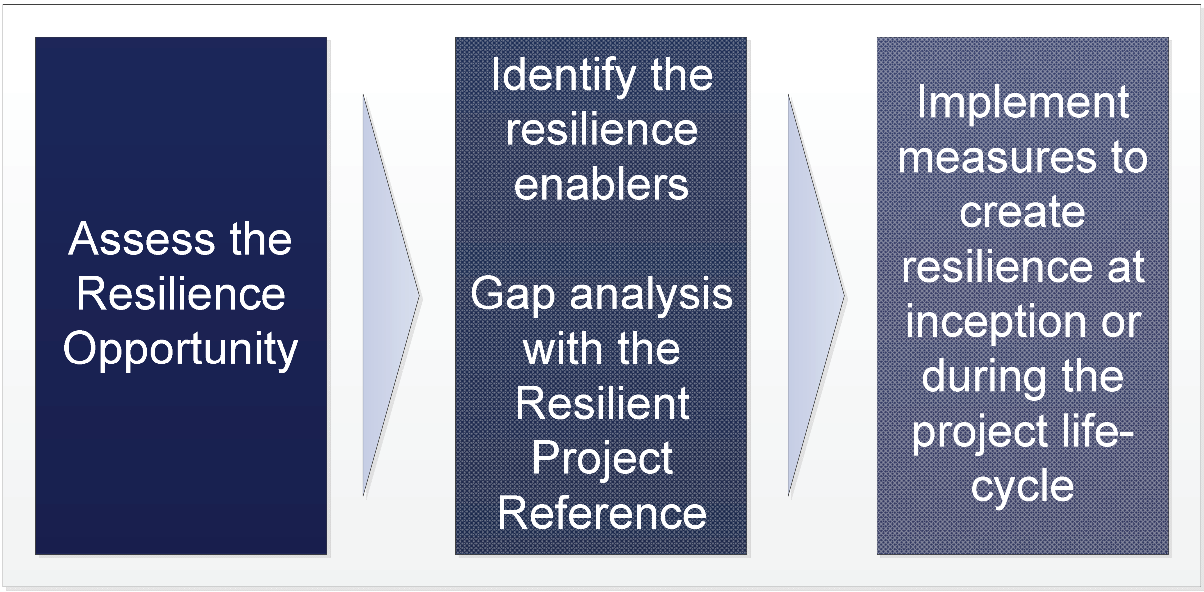

Figure 7-1: Resilience Building Process

The first step is assessing the "resilience opportunity" in a given project. The term "opportunity" refers to an evaluation of the need to build resilience. Using the NRLA case study, we identify the critical events likely to occur by nature. We then estimate the likelihood that the risk will occur and identify financial consequences by projecting the unfolding critical event into the project system. The systematic projection will help in identifying the “key” risk drivers and the priorities for the risk management’s investment. The opportunity to build resilience is driven by the number of high impact, low probability risks and the project actors’ willingness to prepare the project system for previously thought events. In this phase, tools and methods specific to the project management process should be used (scenario analysis, experience, learned lessons, and benchmarking with similar projects).

We illustrate this step with the example of critical events due to geological surprises in the NRLA project (Figure 7-3).

The systemic representation of critical event impact on the project system indicates this event as a key driver risks. Its occurrence will impact the technology and process levels. May engender unknown changes of work process and lead to work stops.

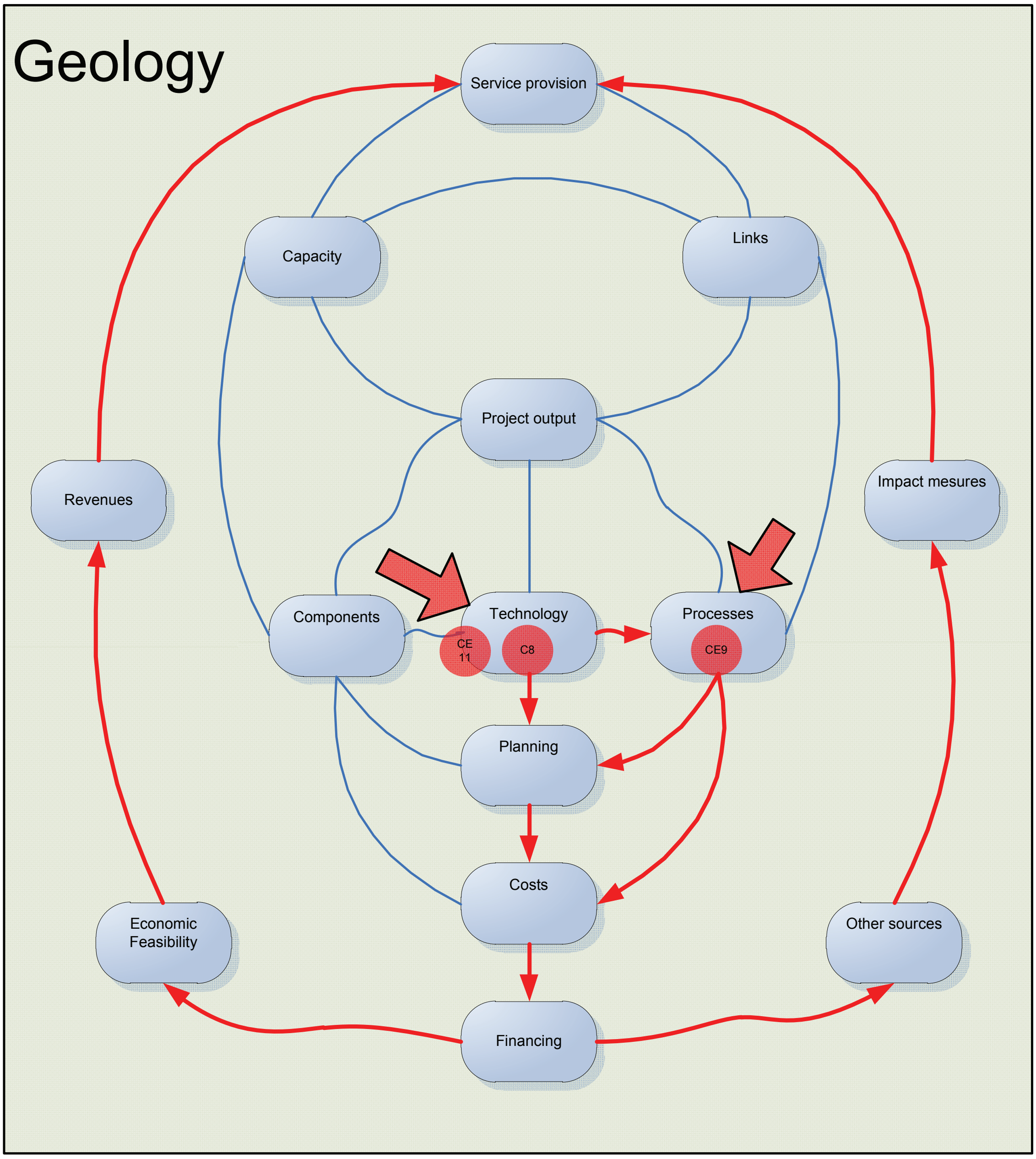

Figure 7-2 : Building Resilience Process _ Step 1: Evaluate the Resilience Opportunity

This systemic representation could be customized for any given project. In synergy with other methods (scenario analysis) it can be used to assess the related financial impact and evaluate the “opportunity for resilience”.

The second step is to benchmark the resilient capabilities already existent within the project organization against the ideal case. The resilient project reference is presented in Figure 7-4, which reunites the identified resilience enablers and the assigned levels of resilience.

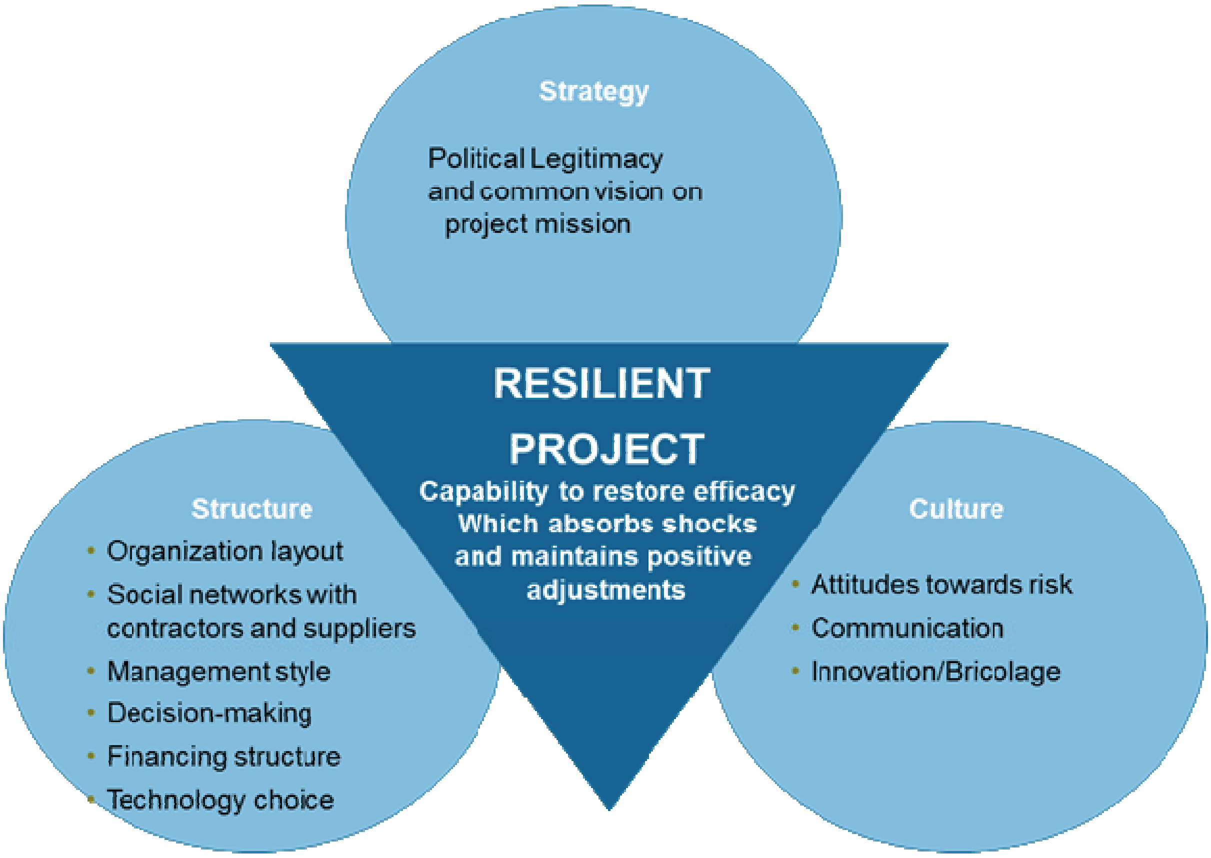

Figure 7-3: Building Resilience Process _ Step 2: The Resilient Project Reference

This results in a gap analysis. The appropriate measures need to be decided upon and implemented in the third step. This will maximize the efficiency of intervention strategies and confer resilience to the project's system in the case of critical events.

In the NRLA case study, examples of resilient capabilities that already exist are project legitimacy, comprehensive risk management processes, flexible contracting practices and positive work relationships. Resilient capabilities resulted from the development of the capacity to adapt in the face of critical events. Those adaptations were laws that changed the project environment and mitigated the negative effects of exogenous critical events; such as environmental claims or award of sections' execution claims. As a general note, the continuous handling of critical events led to measures that made the project organization more resilient than it was at the project's inception. The collateral effect was an improved capability to estimate costs and time needed to complete the project. This was reflected in the last three year's reports that costs and scheduling were kept on track.

8 CONCLUSIONS, LIMITATIONS, FURTHER RESEARCH

8.1 Conclusions

*Knowledge for whom? Action for what? (*Suchman, 1971)

Infrastructure projects deal with unexpected events all throughout their project life-cycle. There is a scale within an event, which can be handled as part of a normal management process, where unexpected events present both opportunities and risks. However, very often events move beyond this scale. Under these circumstances, there is a greater uncertainty about the project system's ability to maintain performance and the consequences of the potential impacts. In this study, we set out to investigate how projects cope with the inherent critical events that occur at some point in their life-cycle. We chose to do this by developing an exploratory case study concerning the execution of one of the most important infrastructures of this century, The New Rail Link through the Alps.

This study has several contributions to project management theory and practice.

8.1.1 Theoretical Contributions

The first contribution is, the appropriateness of accommodating the concept of project resilience when studying a project system's behavior when confronted with critical events. In addition, the factors and conditions enabling project resilience were found to be constructive in maintaining project performance after the critical event. However, it was shown that both projects did not behave the same when confronted with similar events. This could be partially explained by the differences of the parent organization's structural attributes in their project systems (organization layout, communication channels, and contracting practices). These new concepts emerged from empirical research and form the basis for a mid-range theory of resilience in a temporary setting, an infrastructure project. Midrange theory is understood by Merton (1968), "as a theory which is not derived from general abstract theories but is consistent with, and provides important empirical evidence for one or more general theories, and contributes therefore to bridging scientific knowledge." The discussion of empirical findings highlights the fact that resilience enablers either endorse recurrent themes in other studies of resilience, or are new to the theory of resilience, with project organization as a unit of analysis. However, they overlap and complete with existent research over critical success and failure factors in project management. The NRLA example demonstrates that resilience is a “keystone” on the list of the critical success factors and could enable “project performance survival” after the critical event.

The methodological approach - the use of critical events to highlight behavior-based issues within the context of an exploratory case study - is to our knowledge, relatively novel in project management research and may be useful in further exploration. Along with this exploratory case study of a major infrastructure project, a step is made toward the better understanding of the troubled project behavior phenomenon. Currently, this is an underexplored area in project management studies.

8.1.2 Contributions to Project Management Practice

Exploration into the NRLA project highlighted the usability of the resilience perspective in temporary organizations with advanced and comprehensive risk management processes. The main argument is that resilience offers project actors the opportunity to manage critical events, which are “unknown unknowns”. They are risks that have not been thought of, and therefore cannot be assessed and mitigated. Derived from the empirical analysis of project system behavior in the face of critical events, we propose three general strategies. These strategies contribute to the development of project resilience that, in turn, help a project to maintain its performance after the critical event. These strategies are enhanced by risk-focused, resource-focused, and protection-focused measures. They are not necessarily costly, but are contingent to the organizational layout and management processes inherited from the parent organization. These measures relate, on one hand, to the effective management of critical events. Effective management is done through: 1) ensured project legitimacy and goal alignment, 2) face-to-face and informal communication channels, dialogue with partners, and 3) enforced risk management and safety culture. On the other hand, they refer to the ability to restore a system’s efficacy after the critical event. The NRLA experience proved that this can be achieved through 1) flexibility in work processes, enhanced by technology selection and contracting practices, 2) operational slacks for anticipated problems (proactive planning), 3) diversity of skills and capabilities, and 4) positive work relationships.

The case study revealed a synergy between resilience and the risk management process. This led to another practical application, consisting of a three-step tool that can be used to assess the resilience in any given project.

The first step is assessing the “resilience opportunity,” where “opportunity” denotes an evaluation of the need to build resilience. This step could be carried-out along with the normal risk management process. It consists of identifying high impact, low probability risks which are too costly to be addressed. From a resilience perspective, they become critical events and could be treated as such. Their potential impact on a project’s system is evaluated by projecting the unfolding critical event into the project system, as explained by the tool in chapter 6. This “way of doing” enables project managers to tradeoff efforts to address some unknown risks with resilient measures. They could decide to go beyond the traditional risk management process and protect the project system against “costs to address risks.” This is done by taking measures in building (reinforcing) project resilience. However, as previously explained, in practice these measures are not necessarily costly, but may be difficult to implement given that they refer to inherited project structural attributes.

The implications of this study for project management practice are described in Figure 7-1 below. It highlights the differences between the resilience approach and the traditional methods.

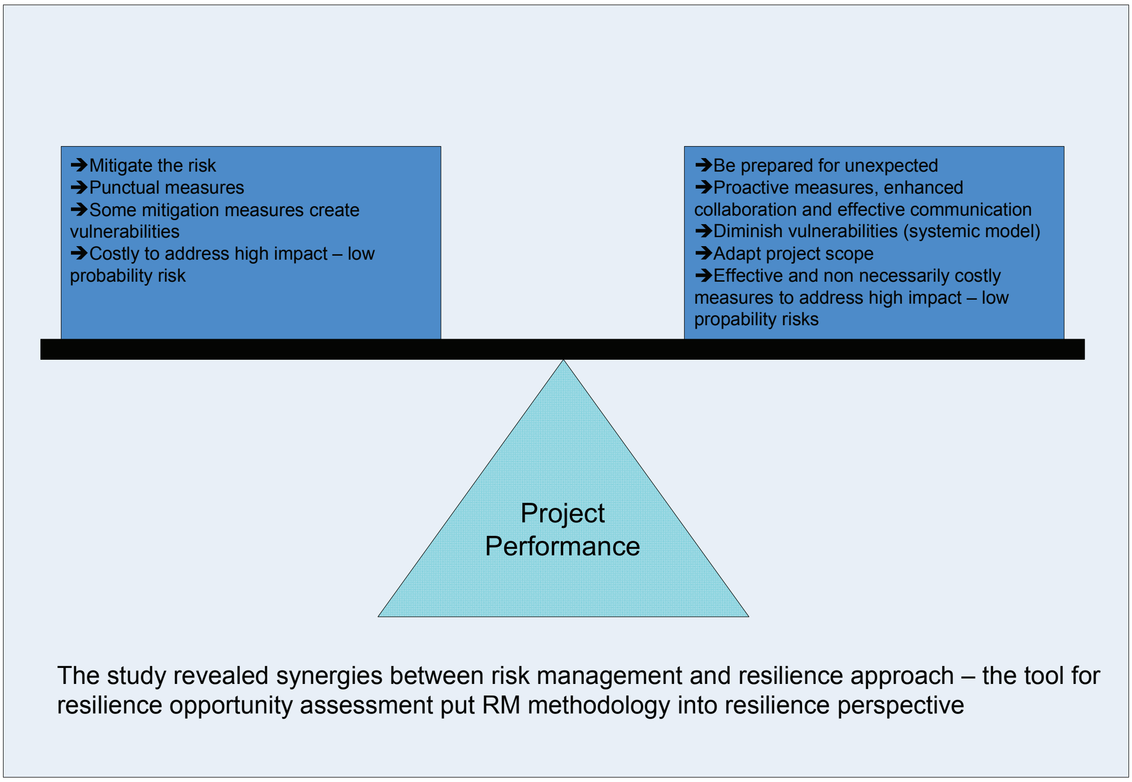

Figure 8-1: Resilience Approach vs. Traditional Methods

8.2 Limitations and Further Research

> *"You cannot generalize from a single case"* some would say... One reason is that *"in general, formal generalization is overvalued as a source of scientific development, whereas '**the force of example**' is underestimated." Flyvbjerg, 2006*[70]

According to Yin (1994) one should not try to generalize to other case studies but one should generalize case study findings to theory, analogous to the way a scientist generalizes from experimental results to theory. Consequently, the basis of the generalization in our case would not be on typical points of the project but on the existence of particular factors (attributes, processes) that influence the behaviour of troubled projects; in the sense that they could enable projects to respect the committed budget and time lines. These attributes and processes

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[70] Five Misunderstandings About Case-Study Research, Qualitative Inquiry, Volume 12, 2, 219-245

were revealed through the analysis of project behaviour from an original perspective, which is the resilience approach. In this light, the analytical generalization in this study leads to a *middle range theory on the applicability of the resilience construct in the management of infrastructure projects and conceptualization of troubled project behaviour. As explained, this theory contributes to an increase of the understanding of those conditions and factors which account for the positive adjustment when a project faces critical events (resilience enablers).*

Therefore the practical recommendations presented could be understood as general and not domain specific. While the results of this study might be generalizable to other projects there are several limitations that should be acknowledged.

Given the nature of the method used, it is difficult to generalize to other major project's developed in different cultural or political settings. Yet, this study raises several important questions for further research. For example, what is the appropriate balance between centralization and decentralization in a project organization in order to enable effective communication for efficient critical event management? Which enablers contribute most to the development of resilience and what is their relative importance during the project's life-cycle? Further, future confirmatory studies are required to validate the viability of these resilience enablers as indicators of resilient functioning that can be relied upon. This research creates the context for continuing this valuable line of research. Although not explored in great details in this study, the relationships identified between risk management and resilience are an emergent consideration and could potentially trigger significant benefits for both the literature and practice by developing greater understanding of the synergy between these performance enhancing mechanisms. Finally, we invite further exploration of the conditions in which virtuous circles between enablers of resilience and structural attributes of a project's organization are created and sustained. Another avenue for future research is in helping project organizations assess their capacity to handle critical events and develop systems to signal when the capacity is affected by traditional project management trade-offs (e.g. contingency plans vs. additional costs; safety vs. efficiency).

Encountering what they still know nothing about, places project's actors in a context which does not tell that critical events are avoidable but rather implies the need to create a project system flexible enough to adapt and handle crisis. This research proves that resilience is a multidisciplinary concept which could help project actors to address this challenge.

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« La réouverture rapide du Gothard n'a rien résolu: le trafic des camions dans les Alpes nous mène dans une impasse. Le transfert au rail est loin d'être réglé et les habitants des vallées alpines sont de plus en plus exaspérés. Aucune solution n'est en vue et le problème ne peut qu'empirer avec.. ».

Gothard, le chantier du siècle **,** Émission du 26 juillet 2001

« Voyage au centre de la terre. C'est en effet par un puits central de 800 mètres de profondeur que les ouvriers et les machines pénètrent dans le chantier titanesque du tunnel du Gothard, au coeur de ce massif mythique. Ils participent à la construction du plus long tunnel ferroviaire au monde, 57... »

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ANNEX 1: PRE-INTERVIEWS (NOV 2006 – FEB 2007)[71]

List of practitioners and roles

NAME, FUNCTION	*INSTITUTION*	ROLE IN PROJECT
Niklaus Scheerer Global Wealth Management & Business Banking	UBS AG	Project Financing
Daniel Wild Responsible for large infrastructure projects	« Secrétariat d'Etat à l'Economie » (Seco)	Project Developer (design, feasibility)
Dieter Rothenberger PPP Responsible for water-related infrastructures	« Secrétariat d'Etat à l'Economie » (Seco)	Legal, Contracting
Massimo Florio Professor of Economics of European Integration (Jean Monnet Chair), University of Milan	CSIL, Centre for Industrial Studies, Milan	Appraisal Methods for Infrastructure Projects
Sorin Geambasu Project Manager	Nestlé Nespresso SA	Project Management

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[71] N.B. The questionnaire layout reflects the actual "thinking" at the moment when the pre-interviews were realized; until the end of this study this "thinking was refined" and the objectives of the study redefined.

Questionnaire outline

Research topic: The concept of resilience in infrastructure projects

The objective of this questionnaire is to understand what you think about resilience, its applicability in the management of infrastructure projects, and what you think about the long record of costs overruns and scheduling delays during the implementation of infrastructure projects.

Our approach: Explain the “non-performance” in terms of overruns and delays by using the concept of resilience; specifically, the project’s resilience in the face of unexpected critical events inherent in its life cycle.

Definitions of Resilience (to be given after the first concept question/discussion “per se”):

In material science: resilience is the physical property of a material that can return to its original shape or position after a deformation that does not exceed its elastic limit.

In psychology and child development: resilience is commonly used to describe the ability of people to cope with stress and catastrophe.

In ecology: resilience has been defined in two ways, which show two contrasting aspects of stability, one focuses on maintaining efficiency of function (engineering resilience) and one focuses on maintaining existence of function (ecological resilience).

In today’s business environment: resilience is widely used to characterize an organization’s ability to react to unexpected disruption and to restore normal operations (Coutu, D.L. “How Resilience works,” Harvard Business Review - May 2002).

This research embraces the resilience approach and hypothesizes that in a long run project the probability of not having planned changes, shocks, or disruptions is high. The project’s viability will depend on its resilience, meaning its ability to amortize shocks and anticipate and adapt the changes to fit the infrastructure’s objectives.

From this perspective, the challenges will:

- Formulate the concept of resilience in infrastructure projects, determine its variables, and assess their importance for actors and the project's overall success
- Create metrics so that resilience can be measured and eventually contrasted with risks and performance indicators
- Propose a tool that will enable the decision makers to trade-off between the benefits and costs of resilience, and will reinforce sponsors' motivation to invest in a project with traditional project appraisal methods

Objective 1: The Resilient Qualities

Contrary to risk approach, looking at the risk factors causing the projects' failure and trying to mitigate them, we focus on identifying those strengths that enhance the project's success. Specifically, we would like **to identify those qualities, assets, or protective factors** that help a project survive the winds of unplanned changes.

1. What are the qualities needed in order for a project to succeed?

Objective 2: The Resiliency Process

By resilience process, we mean the process of coping with changes which normally result in an identification and enrichment of resilient qualities. Specifically, we would like to know **how the resilient qualities are acquired**.

1. How did you overcome obstacles in past projects?
2. If we imagine a disruption followed by a reintegration and we think, how is the reintegration state different from the one before disruption, does it make any sense to discuss:

- Resilient reintegration – reintegration to a state superior of the one before disruption, in which the resilient qualities are stronger
- Reintegration to homeostasis – reintegration back to the state before the disruption
- Reintegration with loss (whatever loss may mean)
- Dysfunctional reintegration

In an affirmative case, can we validate this classification with concrete examples?

This portion was only discussed among people with a scientific background, as it was too abstract for people with other backgrounds. It's results come, in part, from biographical references.

Objective 3: Resilience as an Intrinsic Propensity

In order to reintegrate resiliently, a project needs resources. Therefore we would like to know **what and where are the resources and motivation needed to reintegrate resiliently**.

1. If you could change one thing in an abandoned project, what would it be?
2. Imagining a project like a system with the poles: DEMAND, OFFER, FINANCING STRUCTURE, and ORGANIZATION, which one of these poles is much more likely to intervene in order to reintegrate resiliently.

The answers to these questions depend on the interviewed person's profile and their role in the project's life cycle. Their agreement that the project's organization could be a means for factual decision-making and flexibility in liberating resources when needed was the common denominator.

ANNEX 2: CRITICAL EVENT INTERVIEW METHOD

The critical incident technique is a procedure designed to collect important information about human behaviour in defined situations. The roots of the method can be traced back to 18th century studies by Sir Francis Galton. The technique can best be regarded as "an outgrowth of studies in the Aviation Psychology Program of the United States Army Forces in World War II" (Flanagan, 1954). The Aviation Psychology Program was established in the summer of 1941 to develop job analysis procedures for the selection and classification of aircrews. The main objective of these procedures was to determine critical requirements. These have been demonstrated to have made the difference between success and failure in carrying out an important job assigned in a significant number of instances. The characteristics of the techniques developed for defining these job descriptions, are the best explained in Flanagan (1953):

To obtain valid data on the truly critical requirements for success in a specific assignment, techniques were developed in the Aviation Psychology Program for making systematic analysis of causes of good and poor performance. Essentially, the procedure was to obtain first-hand reports, or reports from objective records, of satisfactory and unsatisfactory execution of the task assigned. The cooperating individual described a situation in which success or failure was determined.

This technique is seen to be highly reliable because only simple judgements are required from the observer. Only reports from qualified observers are included and all observations are evaluated by the observer against an agreed statement for the purpose of the activity.

ANNEX 3: PRIMARY AND SECONDARY DATA SOURCES

N°	*NAME AND POSITION*	*CRITICAL EVENT LINK*	**SOURCE**[72]
1	Michel Béguelin, Conseiller aux Etats; président de la commission Suisse du transport	1 to 11	**CE- I**
2	Adolf Oggi, conseiller fédéral et ancien ministre du transport	1, 2, 3, 4	**TSR-I**
3	Moritz Leunberger, conseiller fédéral et ministre du transport	5, 6, 11	**TSR-I**
4	Otto Stich, ancien ministre des finances	1, 2, 3, 4	**TSR-I**
5	Maura Moretti, Directeur général des chemins de fer italiens	11	**TSR-I**
6	Peter Testoni, President Alptransit Gothard	7, 8, 9, 11	**TSR-I**
7	Andrea Hämmerle ; conseiller socialiste et spécialiste dans la politique de transport	1, 2	**TSR-I**
8	Daniel Blaser, Leiter Management Services, BLS AlpTransit AG	1, 2, 6, 7, 8, 10 and organizational issues	**CE-I**
9	Elmar Lambrigger, Abschnittsleiter Süd	1, 2, 6, 7, 8, 10 and organizational issues	**CE-I**

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[72] TSR-I are interviews obtained through “la Television Romande Suisse”; CE-I are unstructutred interviews realized with the “critical event interview technique”

N°	NAME, POSITION	CRITICAL EVENT LINK	SOURCE[73]
10	Heinz Ehbar, Leiter Tunnel und Trasseebau GBT, Mitgleid der Geschäftsleitung	1, 2, 6, 7, 8, 10 and organizational issues	**CE-I**
11	Giovanni Lombardi*, designer, did the feasibility studies for Alp Transit Gothard	Geology related problems Risk Management aspects	**CE-I**
12	Philippe Arnold der Beauftragte Sicherheit in Loetschberg Projekt (Sicherheit)	Sicherheit	**CE-I**

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[73] TSR-I are interviews obtained through “la Television Romande Suisse”; CE-I are unstructutred interviews realized with the “critical event interview technique”

ANNEX 4: INTERVIEW LAYOUTS (2008-2009)

1. Introductory statement:	**We are carrying out a study on the behaviour of troubled projects. By this, we understand the process and we believe that you are especially well qualified to explain to us about how the decisions were made after the (name the critical event).**
2. Request for the general aim: (lengthy explanation)	What would you say the primary purpose of the decision making process after the (name the critical event) is?
3. Request for summary:	In a few words, how would you summarize the general aim of the decision making process in the context of (name the critical event)?

Outline for interview to establish the goal description

Questions and topics dicussed were adapted to the interviewed person's role and expertise. Listed here are examples of questions and topic discussions:

Data related to the formal organization

By the organization's formal structure we understand the chart describing normative relationships, chains of command, and subdivisions or grouping elements.

We would extremely appreciate if you could:

- Confirm the mission of each "box" in Figure 5.
- What are the precise responsibility boundaries for each box?
- How does each box precisely report to one another (regular meetings, flexible meetings based on the necessity, formalized communication channels)?

Data related to the informal organization

By informal organization we understand the unpublished "chart," one that describes the relationships that evolve through the interaction of people.

- From your knowledge, did the project organization develop special communication channels beyond the formalized ones? If yes, in what circumstances and how were they used?

Data related to unexpected events

From secondary data, your web site and materials we received from you, the following events have been identified. Their nature is either geological, technological or executional related. We would extremely appreciate if you could provide us with a brief description of each event, including information on:

- How are the occurred unexpected events communicated?
- How were the unexpected events solved?
    i. Who participated in finding the solutions?
    ii. How long did it take?
    iii. What impact did the event have on planning?
    See remarks on geology and execution.
    iv. What kind of measures did you take in order to keep the scheduled timetable or overcome incurred delays?
    Change in the general construction schedule
- Did you make use of the claim management procedures in relation to your subcontractors?

ANNEX 5: LIST OF THE PROJECT'S CRITICAL EVENTS IN CHRONOLIGICAL ORDER[74]

1983	
	The Federal Council endorses the construction of a trans-alpine rail route, but deems that a decision to construct it would be premature.
1985	
March 22	Fuel Tax Law
May 1	International Rail Traffic Convention (COTIF) enters with force.
November 20	Cheaper piggyback conveyance - reduction in the price of car loading (subsidized by the Confederation)
1986	
	Commencement of planning (EWI Elektro-Watt Ingenierung, the Confederation, SBB and BLS) Examination of five planning scenarios: - Lötschberg-Simplon - Gotthard base line - Splügen 1 - Splügen 2 - Ypsilon (Gotthard)
October 8	National Council passes a motion, the decision-making foundation is set for a "New Rail Link through the Alps" incorporating the Y proposals on the Gotthard and taking into account the possibilities for expansion of the Simplon line
November 24	EVED (now UVEK / DETEC) sends a letter to cantons in search of cooperation and active support for the four transalpine routes: - Gotthard - Splügen - Y line route - Lötschberg base line (-Simplon)

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[74] This is based on data found on BLS Alp Transit web site (2007); the content is endorsed by data collected from primary sources and triangulated with data from other secondary sources

December 2	Rawil is deleted from the national road network (120:60)
1987	
December 6	Rail 2000 referendum: 57% vote yes
1988	
June 29	Founding of TransAlp 2005 (now CISL) (Cantons VD, VS, GE, NE, FR, JU, BE)
1989	
October 24	Federal Council decides on an improved service offering to piggyback transport
1990	
October 17	Proposal of the Republic and canton Valais for a Lötschberg base tunnel with a Y solution to Mundbach and Susten
1991	
March 13	AlpTransit's decree accepted by the National Council (88:15)
May	Valais compromise proposal: Y solution to Raron and Mundbach
August	Proposal by the state council to the canton of Valais through the publication of the brochure: "Valais' proposal for the Lötschberg base tunnel"
Sept, 18	AlpTransit's decree accepted by the Council of States (27:1)
October 4	Settlement of differences regarding the AlpTransit decree, National Council (118:18), Council of States (25:1)
December 1	AGTC Agreement (European Agreement on important lines of international combined transport and associated infrastructures). Approved by parliament on 16.12.1992
1992	
	The European community calls for a road corridor through Switzerland for 40-ton trucks.
May 2	Transit contract concluded (approved by parliament 16.12.1992)

September 27	Referendum on AlpTransit's decree, 63.5% vote yes
December	First Lötschberg information sheet is published by the Federal Office of Transport (FOT) containing information about the project and organization
December 1	Confederation decision: the first credit commitment for Lötschberg of CHF 250 million
1993	
February 19	BLS board decides to found BLS AlpTransit AG as a subsidiary
June 8	Foundation of BLS AlpTransit AG, share capital CHF 100,000: 100% BLS
August 12	BLS AT tenders for mandates for project engineers and project geologists
September 1	Confederation transfers responsibility as a client to BLS AlpTransit AG
September 27 - October 29	BLS AT plans submission for exploratory tunnel at Kandertal and Mitholz lateral audit
October 4	BLS AT starts a submission for an exploratory tunnel and lateral audit in Kandertal
December 8	The agreement between the Confederation and BLS over the construction of the Lötschberg base line is signed
December 23	Federal Council awards contract to BLS for construction of the piggyback corridor for the transportation of trucks with 4m corner height (value CHF 158.5 million)
1994	
January	Transport study by canton Valais construction department "Transport and infrastructure planning in Valais"
February 20	Referendum on Alpine Initiative: acceptance vote, 52.0% yes
February 28	BLS AT submits a pre-project to the Federal Office of Transport
March 22	Press conference over the pre-projects by BLS AlpTransit

April 12	First sod on the Kandertal exploratory tunnel turned by Federal Councilor Ogi and cantonal government representatives (Berne and Valais). It was done together with the public.
April 30	Award for the construction work on the Kandertal exploratory tunnel (9.5 km), by the board of BLS AT
May 18	Board of BLS AT awards the new mandates for project designs
July 25	Commencement of construction at the Mitholz lateral audit
August 1	**In an interview on Radio Suisse Romande, Federal President Stich announces that the Gotthard alone will be sufficient**
August 10	Commencement of the construction of the exploratory tunnel in Frutigen
August 10	**Board of BLS AT decides to intervene with communications and a set of arguments for the necessity of the Lötschberg tunnel**
August 17	**Notwithstanding the program to rationalize federal finances, the Federal Council decides not to defer to Lötschberg**
August 18	**Press conference by cantonal government representatives Ramseier (GE), Schaer (BE), Bornet (VS), and national councillor M. Béguelin, all against the cancellation of Lötschberg**
September 14	Federal Councilor Ogi informs the media of the status on the NRLA project
October 15	**National councilor Béquelin resigns as vice-chairman of the board of BLS AlpTransit AG**
November	ARENA broadcast National councillor Ed Belser versus National councillor Chr. Wanner, Lötschberg side presents a united front
December 1	TransAlp 2005 (now CISL) organizes active political support through a permanent secretariat
December 9	Mrs Yvette Jaggi, city president of Lausanne, is elected to the BLS AT board
December 30	**Luzerner Zeitung reports that Director Max Friedli favours the Gotthard, if there is not enough money, the Lötschberg will not be built**

1995	
January 19	Inspection, with BUWAL and Federal Office for Area Planning, of the pre-project and materials management of the Lötschberg base line
February	Study by Coopers & Lybrand on the economic feasibility
February 3	Transalp 2002 (now CISL) organizes a policy meeting at the Berne Rathaus. 400 personalities from the world of politics and economics take part. Manifesto from representatives of the seven cantonal governments of western Switzerland to the Federal Council
February 10	ARENA broadcast National Councilor Chr. Blocher versus Cantonal Government Councilor Dori Schäer and City President Yvette Jaggi
February 19	Closed Federal Council meeting over the NRLA project
February 19/20	**Federal Council retains network variant.** **Instructs EVED (now UVEK / DETEC) and EFD to draw up financial models.** **Car loading on the Lötschberg to be examined**
February 20	**Presidents of parties and fractions are invited to a discussion with representatives of the Federal Council: consisting of Federal President Ogi and Federal Councillor Stich (financing problems)**
April 5, 12	**Federal Council decides on a second credit of CHF 855 million.** **Releases Sedrun intermediate working point, but blocks Amsteg, Faido, and Ferden intermediate working points.**
April 12	**Federal Council approves Lötschberg pre-project**
June 20	**Council of States approves Bloetzer application (23:3); CHF 50 million released for Ferden**
June 27	Federal Council sets up a working group for the financing of public transport.
June 30	Additional applications to Federal Council to be submitted with conditional project, including Steg-Baltschieder pre-project
August 25	**Public transport finance working group presents a report to the media.** **Variant 5: simultaneous construction of both base tunnels, but**

	Lötschberg to be only a single-track. **Variant 8: staggered construction first Gotthard, then Ceneri, and then Zimmerberg**.
August 31	BLS AT submits project for Ferden lateral audit to BAV
August 31	North and south the projects for Lötschberg are deferred (meanwhile, Gotthard is allowed to submit all)
September 13	Federal Council decides on public consultation regarding public transport finance proposals to be due on November 15, 1995
September 20	BAV commissions BLS AT to examine proposed variants five and eight
September 20	**National Council decides on the second credit of CHF 855 million, including CHF 50 million for the Ferden intermediate working point (according to Bloetzer application in the Council of States)**
October 3	**BLS receives authorization from EVED (now UVEK / DETEC); according to which the Ferden lateral audit can be submitted.** **However, the planning approval procedure for the base tunnel north-south is deferred until a later date. (Gotthard allowed to submit plans)**
November 1	**Federal Councilor Leuenberger becomes chairman of EVED (now UVEK / DETEC) and replaces Federal Councilor Ogi**
November 13 - December 13	Planning approval procedures for the municipalities of Ferden, Gampel, and Steg
December 23	**BLS AlpTransit AG is allowed to present its position on variant five to the Public Transport Finance Working Group**
December 23	BLS AT presents EVED (now UVEK / DETEC) with the results of the evaluation commissioned on September 20
1996	
January 17	First meeting of the representatives of the Public Transport Finance Working Group, Gygi, and Friedli with the federal party's parliamentary working group. **This working group, voting 6:2, proposed the simultaneous construction of the Lötschberg according to variant five, to the Federal Council.**

February 12	"Regio Sempione" is founded in Brig
February 27	**BLS can present itself to Federal Council Leuenberger (incl. BLS AlpTransit AG)**
March 12	BE/VS: NRLA manifesto for the Lötschberg-Simplon axis is signed by federal and cantonal parliamentarians, heads of fractions, governors, prefects, and mayors of the municipalities
March 22	**In Berne, 130 politicians, at municipality, cantonal, and federal levels, as well as business and tourist organizations, demand the full construction of the Lötschberg branch**
April 24	**Federal Council decides on the simultaneous commencement of both base tunnels in a re-dimensioned form.** **At Lötschberg, the Niesen flank tunnel, Frutigen by-pass, and car loading are deferred. Modified variant 5.1 is envisaged**
June	Preliminary construction work starts on the Ferden lateral audit
June 26	Federal Council passes a motion over the construction and financing of public transport infrastructure.
June 26	Ecoplan economic feasibility study of the Lötschberg-Simplon axis is carried out on behalf of TransAlp 2002 (now CISL)
July 2	Federal Council passes a motion on the financing of public transport to Parliament
December 10	**Council of States decides, after a repeated vote 23:22, against the application of the consultative commission to build the Lötschberg and Gotthard at the same time. The Commission wanted to defer the Lötschberg**.
1997	
February 4	Kandertal exploratory tunnel is fully driven at 9.45 km
March 3	Commencement of pre-project approval procedure for the Raron tunnel portal
April 17	BLS AlpTransit AG reports on the Lötschberg-Simplon tunnel system (The Lötschberg base tunnel and Simplon tunnel combined are shorter than the Gotthard base tunnel)
April 22	**Business meeting of the Berner Oberland chamber of commerce;** **400 participants adopt a resolution in favor of the Lötschberg base**

	tunnel.
May 9	National Council Transport Commission retains a network variant but wishes to give preferential treatment to the Lötschberg, Zimmerberg, and Ceneri tunnels.
June 3	Planning approval decision by EVED (now UVEK / DETEC) for the Ferden lateral audit
June 18	National Council adheres to network variant with (124:35)
June 19	National Council decides to chronological sequencing of the NRLA by votes 95 to 48. First the Lötschberg, Ceneri, and Zimmerberg tunnels will be built
September	Competition launched for design of the bridges over the Rhone at Raron
November 5	**Federal Council releases two tranches of credit of CHF 55 million for the Lötschberg (Ferden and Mitholz lateral audits)**
December 1	Federal Council adopts funding regulations for major rail projects to get the attention of Parliament
December 6	At their meeting in Domodossola, authority representatives from Italy and Switzerland highlight the importance of the goods transport axis to the Genoa port (TransAlp 2002, now CISL)
December 9	**Council of States retains the Gotthard and Lötschberg network variant; the Ceneri and Zimmerberg tunnels are envisaged for the second phase**
1998	
February 13	Call for tenders for driving the Ferden lateral audit.
April 20 – May 19	Public planning submissions for project modifications in the municipalities of Steg, Niedergestelns and Hohtenn (displacing the tunnel portal approx. 100 m west)
September 27	**Referendum vote for the mileage-related heavy vehicle tax with a 57.2% vote yes**
October 29	**Information event by the Berner Oberland economic commission on financing public transport (FinÖV)** **Chair: National Councilor Seiler** **Participants:** **State Councilor W. Schnyder VS - For**

	Ignaz Reutlinger (Com. FinÖV - Against) **National Councillor H.U. von Allmen - For**
November 29	**Referendum on the construction and financing of the public transport infrastructure: a 63.5% vote yes**
December 4	Public invitation to tender for the major construction phase of the north base tunnel and the Steg lateral audit's west base tunnel
1999	
June 25	Obtained planning approval for the south base tunnel (canton boundary to Steg)
July	Public invitation to tender the Raron tunnel phase
July 5	**First blasting operation in the Mitholz base point to drive the Lötschberg base tunnel project**
October 19	BLS AlpTransit board awards construction phase contracts for the Steg lateral audit/base tunnel and the material management centre at Raron
December 6	**Fatal accident in the Ferden lateral audit**
2000	
January 1	BLS AlpTransit moves from Berne to Thun
February 15	Contract awarded of the for the north base tunnel phase (in Mitholz) and the mandate for publicity work by the board of BLS AlpTransit
May 4	Official opening of the Eya construction site at a rail station in Raron
May 30	Award of the Raron-Ferden base tunnel phase contract given by the board of BLS AlpTransit AG
July 28	Official delivery of the first tunnel boring machine for the Steg phase in Schwanau to the Herrenknecht's company premises
August 11	Christening ceremony for the north Lötschberg base tunnel at the Mitholz base point with tunnel sponsor Dori Schaer-Born
August 14	Arrival of the TBM drilling head at Steg/Niedergesteln
September 18	Completion of the Ferden lateral audit according to schedule, Ferden base point phase is given an extension

September 22	Commencement of the tunnel driving operations with the first TBM in Steg/Niedergesteln and the christening of the Steg lateral audit with the tunnel sponsor, Marlies Schnyder. Simultaneous unveiling of the BLS AlpTransit locomotive
September 28	Award of the Rhone bridges contract and work on connection to the Rhone valley line is given by the board of BLS AlpTransit
September 29	Board of BLS AlpTransit assigns the Ferden construction phase contract
2001	
February 22	Delivery of the second tunnel boring machine, for the Raron-Ferden phase, arrives at the Herrenknecht's company premises
May 1	Commencement of the tunneling work from the Ferden base point
May 1	Assembly of the second TBM in front of the south portal at Raron
May 28	Public planning order for the line route between the north portal and the base line link to the original BLS line in Wengi-Ey
June 7	Opening of the BLS AlpTransit Information Centre in Raron
July 4	Tunnel christening and commencement of tunnel driving operations using the second TBM begins in Raron with tunnel sponsor, Ruth Kalbermatten
August 24	The contract for the preliminary Frutigen phase is awarded by the board of BLS AlpTransit AG
September 28	The Raron TBM rotates into the Triassic tunnel
October 25	Opening day at the construction site in Raron
November 14	***First information is given to the St. German population about lowering the ground level***
December 12	***Stabilization of the settlement in St. German.*** ***A joint group, consisting of BLS AlpTransit, local authorities, and private representatives, handles damage; remedial measures are introduced.***

2002	
January 17	The board of BLS AlpTransit awards a contract for the construction of the Widi bridge
February 27	The hazardous geological zone, at the Jungfrau wedge, also at the base tunnel level in Ferden, was crossed successfully
April 2	Commencement of silo demolition in Frutigen
April 8	***Start of remedial measures in St. German***
April 11	**Meeting with ARGE Ferden, GBI, Syna, SUVA, and BLS AlpTransit in Thun to resolve the conflict situation at the Ferden site**
April 11	**Because of rock containing asbestos, driving with the tunnel boring machine in Steg is stopped**
April 13	**The TBM in Steg starts up again. SUVA gave the green light after cleaning the machine and based on measurements**
April 18	**Work stopped on the Ferden construction site by the GBI trade union**
May 2	Half of the Lötschberg base tunnel has been driven
May 14	The board of BLS AlpTransit awards the contract for the final large construction phase of the Lötschberg base tunnel - the Engstlige open-cut tunnel
June 01	**A drilling jumbo on the Ferden site catches fire.** **The fire was extinguished and only material damage was caused, no-one was injured**.
August 5	A proposal from various sources to excavate the short section between Mitholz and Frutigen (the west tube), during the first phase of construction, is given while the contractors and installations are still on site Constructing this section of the tunnel, about 6 km in length, would be considerably costlier after the completion of the first phase The corresponding report is sent to the Federal Office of Transport
September 13	The first TBM arrives at its destination After driving 8,925m, it has reached the connection to the Ferden

	section
November 8	The new bridge over the Widi is brought into service and opened to traffic
Nov, 12	The DETEC grants planning permission for the dual-tube Engstlige tunnel; this means all permissions for the construction work on the Frutigen link have been granted
December 13	The first breakthrough at the Lötschberg base tunnel between Ferden and Steg is celebrated. The breakthrough is made at km 38.647, between the tunnel blasted from Ferden and the tunnel driven by TBM from Steg
2003	
January 29	The cavern for the Adelrain fork is excavated
March 28	The new 132 kV line between Wimmis and Frutigen is brought into service
April 2	The tunnelers on the east tube cut through the Ferden carboniferous zone The tunnelers from the south, in Ferden, have successfully conquered a geologically difficult area
April 11	In Ferden, the west tube towards the south, the workers place the concrete as the first element of the tunnel's inner lining
May 5	Work starts on the Lötschen fork cavern
May 14	In the Frutigen-Mitholz west tube, a breakthrough is made successfully
June 30	At the end of the six-month period, with three exceptions, all contracts for the technical rail infrastructure were awarded
July 22	The Federal Office of Transport approves the changes to be made to the track installations in the Frutigen station area
September 10	In the Raron east tube, the tunnelers set another world record for TBM tunnel-driving through hard rock at this diameter: 50.1m in 18 hours
September 20	In September, the tunnelers driving south from Mitholz reached the highest point of the tunnel in the west tube on September 20 and the highest in the east tube on September22

October 2	The tunnelers working south from Ferden had reached the contract phase boundary on April 2, 2004. Then, on October 29, 2003, the TBM from Raron made the breakthrough at this point
October 31	About 80% of all materials required for building the embankment in the Wengi Ey had been delivered by the end of October
November	In the Ferden west tube, in the southern direction, concreting of the side strips commences. Work starts on the Galdi channel cable duct block
December 12	The breakthrough between Frutigen and Mitholz is made successfully in the east tube
December 12	The dismantled TBM (from the Raron east tube) passes through the portal and is then fully disassembled outside the tunnel
December 17	The Lötschen crossover meets the east tube The breakthrough from the Hundsprung shaft to the Mitholz lateral audit is made successfully
December 18	The west tube, being driven north from Ferden, reaches the boundary between the cantons of Valais and Berne
December 31	**At the end of 2003, the south tunneling operations in Mitholz unexpectedly encounter sedimentary rock** **This had not been predicted. The length of the sedimentary zone is as yet unknown** **By the end of the year, a large proportion of the implementation projects were in the approval phase while some had already been approved**
2004	
January 7	At the Eya installation area in Raron, BLS AlpTransit hands over the area previously used to make tunnel lining rings to the TU ABL
January 13	**Due to the risk of avalanches, the Ferden construction site had to be evacuated twice and tunneling operations suspended (January 13-15 for 48 hours and January 20 for 8 hours)**
January 28	The access and ventilation tunnel in Ferden opens up into the west tube at the Ferden north crossover
January 31	**The geological conditions for the tunneling teams heading south from Mitholz deteriorate throughout January with no improvement in sight. After the modifications and repairs to the**

	crushers, carried out over Christmas 2003 on the Ferden north tunneling operations, the tunneling teams get back up to speed **In the last week of January, the tunnellers manage to achieve a fantastic result of 65 m dug**
February 11	The Raron TBM is dismantled. The last element of the TBM leaves the Raron site
February 24	In the east tube of the Mitholz-Frutigen section, the concreting teams place the first elements of the inner lining
March 7	**In the Lötschberg branch, a drilling jumbo catches fire. The cause: a defective hydraulic hose, luckily no-one is injured**
March 15	**On March 15, in the sedimentary rock, which had been a problem since January, additional and ever larger anthracite deposits are encountered** **The tunnel driving rate drops dramatically and a breakthrough by the end of 2004 is no longer possible.** **In the Raron east tube (TBM), the first element of the inner lining is placed at the boundary of the contract section**
March 29	Raron portal and operations centre’s work on the west head wall begins
April 24	The two tunneling teams driving south from Mitholz come to a standstill because of problems with the rock. The trial bore that had been started, has to be aborted
April 30	The inner lining in the Ferden-Lötschen west tube is completed
May 14	The head of the Hundsprung shaft is completed
May 16	Tunnel-driving operations is resumed in south Mitholz
May 6	Raron east tube TBM: concreting the inner lining begins
June 17	In the Mitholz south tunnel-driving operations, a trial bore about 50m long is drilled No change in the rock is discovered and the average driving rate is only about 1.7m per working day. (For comparison: in November 2003, the average daily driving rate through granite was 9.3m)
June 20	**During the excavation work on the Widi tunnel, the construction crew encounters a rock line which is substantially higher than the geological survey had predicted**

	In order to ensure that the completion date of "July 2006" can be met, it is crucial to revise the construction schedule, with a considerably more intensive construction program **The result: additional expenditures on construction and logistics, leading to increased costs**
June 30	At the end of June, the work on the technical rail infrastructure can be summarized as follows: Production of the mechanical and electro-technical components is proceeding apace The modified ventilation concept for the outfitting stage is available On June 30, in the Wengi Ey, about 700,000m3 of material had been delivered The material is being used to build the embankment for the displaced original BLS mainline section and for landscaping. This means that virtually all the material required for completion has been placed. The interior finishing work (on the tunnel lining) on the Ferden south tunnelling operations is now complete
July 1	Just over half of the Engstlige tunnel carcass has been completed (1362.5 meters of tunnel, or 53%) The Engstlige underpass's south side's concrete is done Interior finishing work on the Ferden south tunneling operations in the east tube is complete, apart from 240m of side strip
July 20	Despite a minor rock-fall, tunneling work in the Ferden north section is making satisfactory progress; as well as the interior finishing work
July 26	**The Mitholz south tunneling team is still stuck in the carboniferous rock**
July 31	**Towards the end of July, serious damage to the Mitholz avalanche protection tunnel is reported. The tunnel has to be closed off for safety reasons and traffic is routed via an emergency road. The civil engineering department for the canton of Berne is the contractor for the tunnel**
August 16	**The results of the trial bore, on August 5 (length: 251m), in the Mitholz south section of the tunnel indicate a slight improvement in the rock (good-quality sandstone and grey wacke)**
August 30	**Both tunneling operations have to stop for safety work** **Resumption is envisaged for mid-October, 2004**
September 20	The carcass of the southern bridge in Raron is complete and is handed over to the Lötschberg base tunnel general contractor

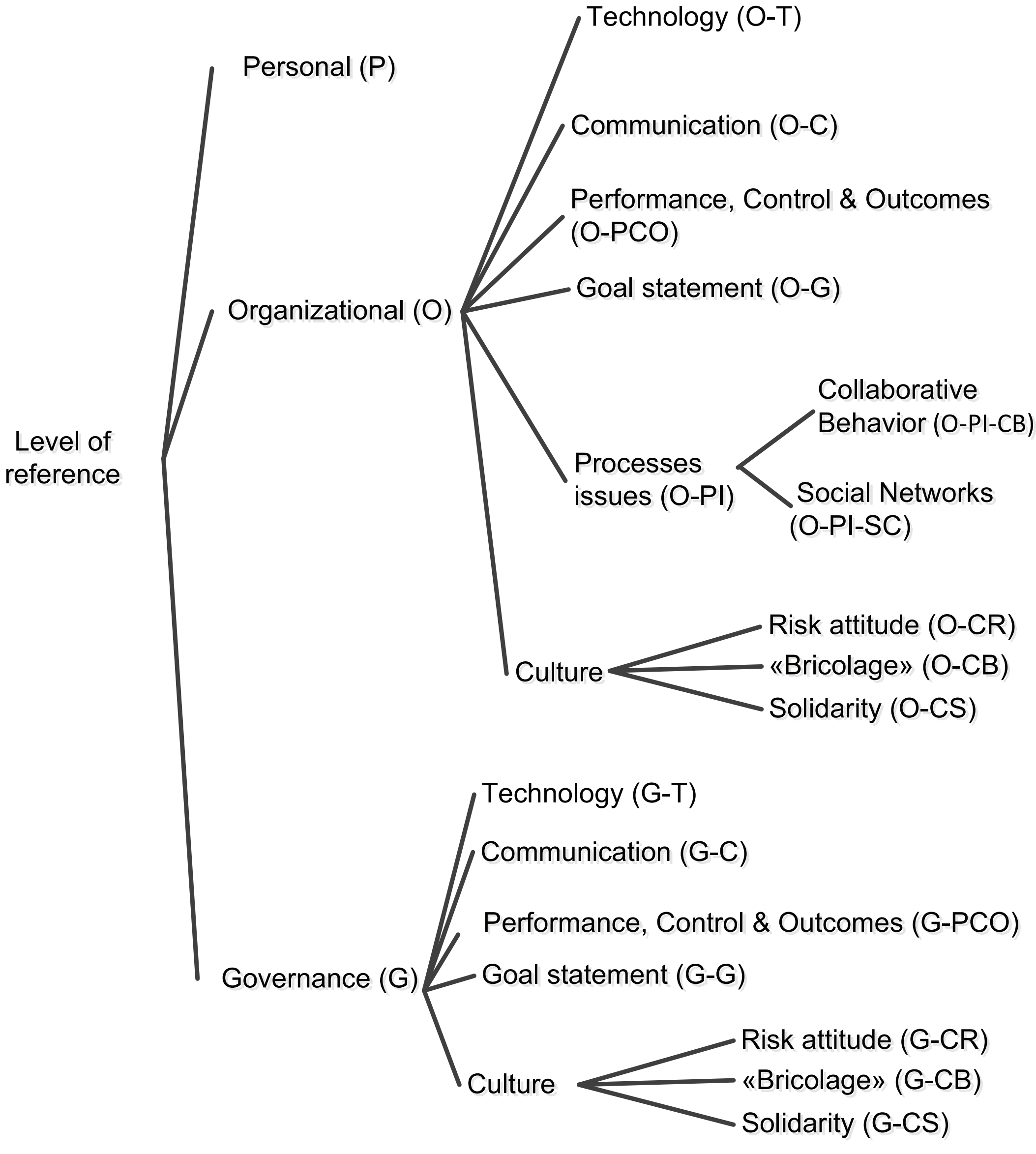
September 28	**Tunneling is resumed in Mitholz**
October 31	The west tube between Raron and Lötschen (which was being blasted) is handed over to the general contractor of ARGE Bahntechnik Lötschberg
Nov, 16	The Federal Office of Transport grants planning permission for the maintenance and intervention centre in Frutigen
December 6	Installation of the slab track begins in the west tube in Raron
December 20	Ferden north: the east tube reaches the section boundary at km 31.872
December 21	Ferden north: the west tube reaches the section boundary at km 31.647
2005	
January 15	The west tube between Lötschen and Ferden (which is being driven by the tunnel boring machine from Steg) is handed over to the general contractor of ARGE Bahntechnik Lötschberg
January 15	Construction on the maintenance and intervention centre in Frutigen begins
January 28	The Frutigen operations centre is handed over to the general contractor of ARGE Bahntechnik Lötschberg. The building houses the west and east operations centers as well as the local control centre
February 21	Work on the Steg lateral audit is completed
March 16	Mitholz: the last of the excavated material to be transported by conveyor belt is brought out of the tunnel. Trucks will be used to remove the material from the last remaining blasting operations
March 19	The work on the side strips, in the east tube between Ferden and Lötschen, is completed
April 6	The general contractor of ARGE Bahntechnik Lötschberg takes over the Tellenfeld intervention area
April 28	The main breakthrough is made at the Loetschberg base tunnel in the east tube of the Mitholz south tunneling operation. A continuous tunnel tube extending from Frutigen to Raron has become a reality

May 4	Construction of the track bed in the eastern area of the Frutigen station is complete
June 12	The new electronic signal box in Frutigen station is brought into its first stage of service
July 6	The pedestrian subway at Frutigen station is inaugurated
August 30	Tunnel contractor ABL takes over the north bridge, over the Rhone, for outfitting
September 30	The first containers are transported into the Lötschberg base tunnel (Lötschen East operations centre) The 160m long high-speed points at the Ferden North cross-over are installed
December 13	The gravel plant in Raron produces the final aggregates for the concrete In the second half of 2005, many carcass structures, which had been completed, were handed over to the general contractor ABL for outfitting Within this six-month period, most of the preparatory work for commissioning was carried out
2006	
January	The track laying teams work simultaneously on two fronts to speed up the construction process. The transitional ventilation system for the entire base tunnel starts operating
February	The tests for the tunnel control system start
February 12	The carcass of the Ferden escape tunnel system is completed
March 26	**In the Steg access tunnel near the portal, a karst penetration occurs. The portal area is inundated. As a counter-measure, an overflow pipe to the existing settlement basin is constructed**
June 1	Trial operation starts on schedule
June 6	The first electric trial run in the Lötschberg base tunnel is a success (Test Zone 3 - the section between Raron and Ferden in the east tube).
June 15	The Schwandi Ey floodplain reinstatement work is completed and accepted

July 1	Commissioning tests for the tunnel control system start in July
July 6	The last twelve containers are transported into the tunnel and installed in the Mitholz west operations centre
July 7	The gap in the track is closed almost exactly in the middle of the tunnel, in the east tube
July 24	The "golden spike" ceremony celebrates the joining of the two sections of track on July 7
September 9	The "3rd connection" is made on the north ballast track section This completes the installation work on the track of the entire Lötschberg base line
October 2	Tracklayers connect the rails from the south bridge in Raron to the SBB Rhone valley line tracks
October 4	**For the first time, a train can travel in the tunnel at a speed of 230kph (test zones 2 and 3)**
October 6	**The Federal Office of Transport grants operating approval for the 132-kV installation**
October 9	The load tests on the Rhone bridges are successful
October 13	The first ETR 470 (Cisalpino) runs in test zones 2 and 3
November	The catenaries, which run through the entire Lötschberg base line, are switched on
November	**The Federal Office of Transport grants approval for electric train journeys through the entire Lötschberg base tunnel. At 18:00, the first electric train travels through the entire tunnel**
December 16	At 00:30, the German Railway's ICE-R test train, at km 44.880 in the east tube, reaches a speed of 280kph, breaking the Swiss record During the second half of the year, the general contractor of ABL takes over numerous carcass structures for outfitting
2007	
February 11	Probably the most successful test during the commissioning process takes place. It involves checking whether the signal boxes can handle 30 locomotives simultaneously

	In all, 35 locomotives were used
March 8	The mechanical equipment in the Mitholz access tunnel is ready for the "1st partial test" This completes the installation work on the mechanical equipment
March 9	The Federal Office of Transport officially approves "operative trial operation" The first shift vehicle test is at 03:00 on March 16, 2007
April 14	Dismantling the temporary construction facilities is completed
April 17	The Mitholz mobile sub-station is in place and brought into operation at its newly-built location
May 11	An extensive rescue exercise is held inside the tunnel. 350 "injured" and "seriously injured" are rescued, cared for and evacuated
June 14	The Federal Office of Transport officially awards the operating license for the Lötschberg base line
15/16 June	**BLS AlpTransit AG hands over the Lötschberg base line to the operator, BLS AG** **Some 1,200 VIPs take part in the hand-over ceremony and the subsequent celebrations** **On June 16, 2007, the "people's ceremony" takes place; some 30,000 visitors attend**
2009	
mid-June	**Some six months ahead of schedule, the Herrenknecht Gabi 1 TBM reached its target destination of Amsteg under the Gotthard Massive of the Swiss Alps. This final breakthrough by the first machine in the Erstfeld-Amsteg section constitutes the achievement of an important milestone on the project.**
2010	
October, 15	**Breakthrough at Gotthard; Switzerland becomes the world leader in tunneling**

ANNEX 6. CODING CATEGORIES



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ANNEX 7: RESILIENCE BACKGROUND

Definitions of Resilience

The Oxford English Dictionary defines resilience as 1) the act of rebounding or springing back and 2) elasticity. The origin of word is in Latin, where "*resilio*" means to jump back. In a mechanical sense, the resilience of a material is the quality of being able to store strain energy and deflect it elastically under a load without breaking or being deformed (Gordon 1978). However, since the 1970's, the concept has been used in a metaphorical sense to describe systems that undergo stress and have the ability to recover and return to their original state.

Concept Grounding

Academic research into resiliency began 40 years ago with the studies of Norman Garmezy on why children of schizophrenic parents did not suffer psychological illness when they were growing up with parents who did. He concluded that "a certain quality of resilience played a greater role in mental health than anyone had previously suspected" (cited by Diana L. Coutu, in HBR). Since then, various theories have emerged about what makes the resilience in people, systems, and business.

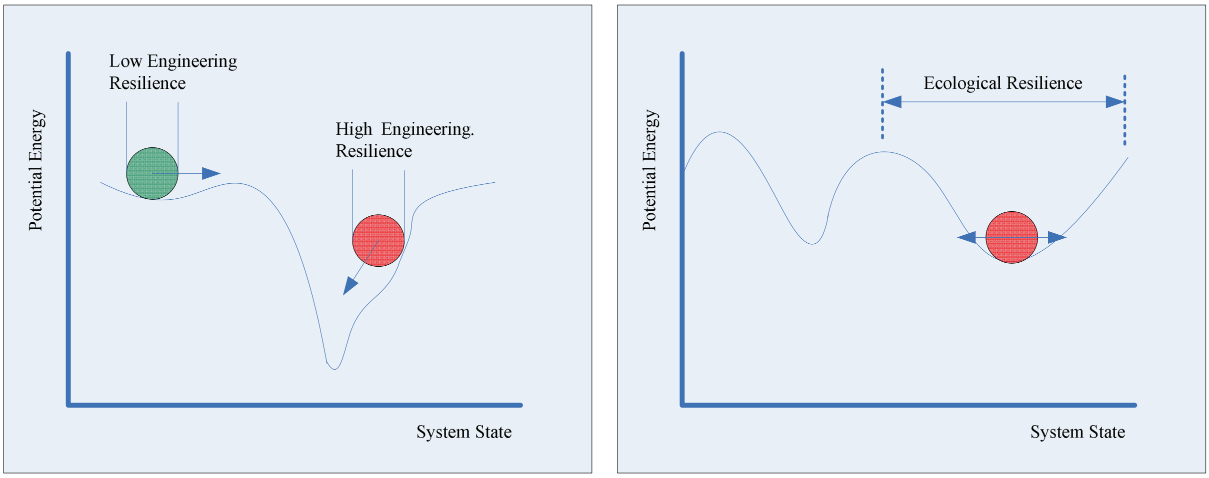
Ecological Resilience

In ecology, resilience is defined in two ways. This verified two contrasting aspects of stability, one that focuses on maintaining efficiency of function (engineering resilience) vs. one that focuses on maintaining existence of function (ecological resilience). Engineering resilience focuses on efficiency and depends on constancy and predictability – all attributes of an engineer's desire for safe design. Ecological resilience focuses on persistence. Despite change and unpredictability, all attributes embraced by evolutionary biologists and by resource managers need a safe – fail design (Gunderson 2002, p. 5-6). Holling (1973) first emphasized these contrasting aspects of stability to draw attention to the tensions between efficiency and persistence, constancy and change, and between predictability and unpredictability. In this light, the definition of engineering resilience (Holling 1996 cited by Gunderson 2006 p.4) conceives systems to exist close to a stable, steady state. Engineering resilience is then described as the speed of return to the steady state following a perturbation (Pimm 1984; O'Neil et. Al. 1986; Tilmann and Downing 1994 cited in Gunderson 2002 p. 4). The definition of ecological resilience (Walker et al. 1981; Holling 1996; cited in Gunderson 2000), conceives conditions far from any stable, steady state. It places them where instabilities can shift or flip a system to another stability domain. In this case, resilience is measured by the magnitude of disturbance that can be absorbed before the system is restructured with different controlling variables and processes.

However, the differences between the engineering resilience and ecological resilience are so fundamental that they become alternative paradigms for researchers. Table 4-2 summarizes the seminal work and contributions of these two streams. Gunderson cites them in his book <u>Resilience and the Behavior of Large – Scale Systems</u> p. 3-48.

ENGINEERING RESILIENCE	**ECOLOGICAL RESILIENCE**
➔Treats how far a system has moved from an equilibrium in time and how quickly it returns, as a measure of stability	➔Is defined as the ability of ecosystems to resist lasting change from disturbances (Gunderson et al. 1997, cited in Gunderson 2002, p. 127)
➔Is measured by the return time of an ecosystem after a disturbance (Haydon 1994, cited in Gunderson 2002, p. 127)-- There is an implicit assumption that systems exhibit only one equilibrium steady state	➔Is measured by the magnitude of disturbance that can be absorbed before a system redefines its structures by changing the variables and processes that control behaviour (Holling 1973)

The differences between the two streams are captured in Figure 4-3, in which the stability landscapes are used to represent the dynamics of a system.



A7 1: Engineering vs. Ecological Resilience

The ball represents the system state (Carpenter et al 1999; Scheffer 1998 cited in Gunderson 2002 p.5, p.255). The state can be changed by disturbances, which move the system along a stable landscape. a) Engineering resilience (speed of recovery) is a local measure and it is determined by the slope of the landscape b) Ecological resilience corresponds to the width of a stability basin.

Distinguishing between the two types of resilience is relevant in assessing which type of resilience is relevant for this study. Based on their intrinsic characteristics and declared goals of this thesis, ecological resilience is most appropriate and legitimate. Project systems are complex systems organized through the interactions of a set of elements, which is similar to ecological systems (Gunderson 2002). Resilience helps to understand the dynamisms and vulnerabilities projects go through when in face of distresses. Therefore, it would not be suitable to consider engineering resilience. This considers that only one unique equilibrium state exists and could be designed. From this perspective, the study seeks to understand the conditions of persistence and not equilibrium states.

The factors based on literature that are accountable for the increase in ecological resilience are 1) species diversity, 2) keystone species and redundancy, 3) loss and replacement of keystone species, and 4) spatial heterogeneity and refugia **(**Gunderson 2002, p.127-157).

ANNEX 8: LIMITATIONS OF PLANNING TOOLS

The table below summarizes the advantages and limits of the most commonly used tools for planning (scheduling) and controlling.

Overview of traditional tools for project planning and control (based on Nicholas, 2004)

TOOL	*APPLICATION*	*STRENGTHS*	**WEAKNESSES**
Gant Charts	➔Widely adopted in all domains which depicts the relationship between the WBS(work breakdown structure) planned and done	➔ Easy to use to monitor work in progress ➔Often maintained manually	➔Does not explicitly show the interrelationships between the different elements of projects and therefore will show neither the effect of one delayed work element on the others, nor the effect of shifting resources. ➔In large projects Requires computerized project systems
Network Scheduling Procedures	➔Is a must in large projects	➔Shows interdependencies between project elements ➔Enables planning and scheduling to be performed separately	➔Are elaborated based on the "precedence" concept meaning that shows that tasks that must be completed before others can be started. (finish-to-start networks = FS)
Precedence Diagramming Method (PDM)	Belongs to the family of methods which use networks	➔Shows interdependencies between project elements ➔Enables planning and scheduling to be performed separately ➔Besides the FS situations allows for relationships start-to-start, finish-to-start, and start-to finish and for time lags between these relationships	➔Are based on the assumption that "any projects can be defined as a sequence of identifiable, independent activities with known precedence relationship"- this is not the case in reality since the work to do cannot be always anticipated – "projects evolve as they progress"
Program Evaluation and Review	➔Is termed as critical path method because uses critical	➔Shows interdependencies between project	➔Addresses uncertainty in duration by using three time estimates (optimistic, most

Technique (PERT)	path to calculate expected project duration, and slack. ➔Developed for projects in which uncertainty is associated with the *nature and duration of activities*.	elements ➔Enables planning and scheduling to be performed separately ➔Allows incorporating of uncertainty in schedules estimations ➔the “three estimates are related through a “ßeta distribution”	likely and pessimistic) ➔Were criticized because provide overoptimistic estimates. ➔Too much focus on critical path make managers to ignore the “near critical paths” which may become critical and jeopardize the objectives ➔Assumes that activity times can be estimated and are independent, which is not always the case (e.g. shift of resources) ➔Time estimates are still “guesses” and could be biased by estimators and contractual arrangements
Critical Path Method (CPM)	➔Belongs to the family of methods which use networks ➔ Uses critical path to calculate expected project duration, and slack and gives emphasis to project costs. ➔Is deterministic and includes a mathematical procedure to estimates the trade-off between duration and cost of project.	➔Show interdependencies between project elements ➔Enable planning and scheduling to be performed separately ➔In addition to PERT allows costs to be explicitly included in scheduling	➔Requires further development to take into account the administration costs (decrease with the progress of project), the overhead costs and the incentives/penalty costs related to the contractual arrangements
Common limitations of the network scheduling methods: ➔➔No activity can be repeated and no “looping back” to predecessors are possible ➔➔The duration time/activity is limited to the Beta distribution (PERT) or deterministic (single estimate) for CPM ➔➔There is only one terminal point and the way to reach it is to complete all the activities			

<table>
<tr><td colspan="4">before.
➔➔Must be employed when potential advantages overpass the cost and time spent on using them</td></tr>
<tr><td>GERT (Graphical Evaluation and Review Technique)</td><td>➔Advanced modeling and scheduling method</td><td>➔ Surmounts the limitations of PERT and CPM
➔In addition to beta allows alternative time distribution as well as looping back</td><td>➔Requires time and costs to use it</td></tr>
</table>

The overview of the available tools, which are derived from traditional project management theories in the scope to ensure that projects will unfold according to the plan to a successful end, it becomes clear that although these methods form the necessary foundation for project management, all of them are limited to their underlying assumptions and therefore not sufficient for dealing effectively with arising risk and uncertainties in projects.

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She speaks French, English, German, Italian and Romanian (mother tongue).