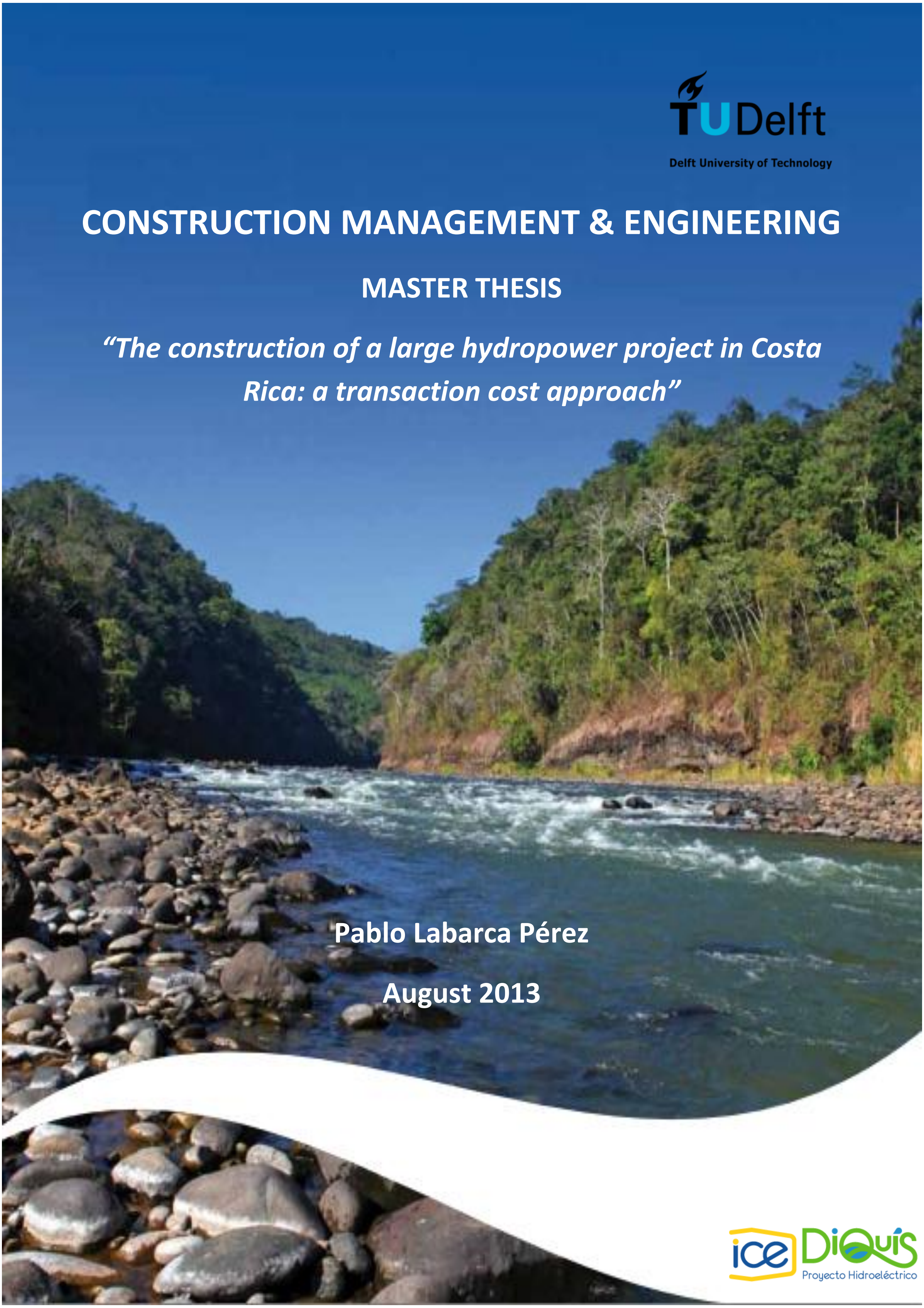

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"The construction of a large hydropower project in Costa Rica: a transaction cost approach"

Pablo Labarca Pérez

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The construction of a large hydropower in Costa Rica: a transaction cost approach

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Disclaimer: This is a final thesis´ report for the master of Construction Management & Engineering (CME) at the Delft University of Technology. The research was performed by P. Labarca Pérez based on a case study provided by the *Instituto Costarricense de Electricidad* (ICE). The author remains responsible of the statements here included. The investigation aims to contribute in the theoretical development of transaction costs of economics in the context of the construction industry, while providing useful insights to ICE that may help it to improve its performance. It is intended for general use, offering analytical tools to others researchers willing to investigate about the organization of construction processes. Nevertheless, the latter should be aware of its limitations and adjust them accordingly to their own purposes.

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To Caro,
For her endless
supply of patience
and affection.

August 2013

Preface

Construction management and engineering is a vast and fascinating area of expertise. One of the biggest challenges a prospective graduate student faces when approaching the end of his studies is to choose among a myriad of possible and interesting thesis´ topics. Taking a good decision is anything but trivial; after all, months of efforts will be devoted to it. In my case several were the reasons that motivated the selection of this particular topic. First, it satisfied my personal interest to know more about the theory of transaction costs of economics (TCE) and its potential in the organization of construction projects. In my opinion the major problems faced nowadays in the construction of infrastructure are not technological, but related to the adequate selection of the project´s governance structure. TCE provides as no other theory a rich framework for this purpose, which additionally can be adjusted to different institutional environments. Second, it gave me the opportunity to apply during the course of the investigation my work experience in what represents a major area of interest: the planning and construction of power generation facilities. This condition granted me a particular grip in the subject that would have been difficult to achieve otherwise. Third, even though this is a theory oriented research it has also practical relevance for the *Instituto Costarricense de Electricidad* (ICE), the organization here examined and the main player in the development of electric power facilities in Costa Rica. Important insights are derived from this investigation which I believe can give a new perspective to ICE about how to organize its projects in a better way. Last but not least, the topic contributed to the scientific knowledge of TCE in the context of the construction industry, providing valuable analytical tools to other researchers venturing in similar endeavors.

This thesis represents the culmination of two years of studies in the Netherlands, a long way from home. Much I have to thank, for it is an experience to which most of my countrymen do not have access. ICE´s support as one of the sponsors of my studies has been instrumental. I hope a humble retribution is found in this work. The same can be said about my family and others that have supported me during this process. Finally, my graduation committee deserves recognition for their valuable opinions and recommendations along these last months. For this I am most grateful.

Executive summary

Transaction costs of economics (TCE) has become a standard framework for the study of organizations, helping to explain not only the existence of the firm, but also its scope and dimensions (Ménard and Shirley, 2005). Transaction costs are plain and simple the cost incurred in using the market. TCE sustains that there is a direct relationship between the governance structure selected to organize a transaction and the intrinsic characteristics of the latter and this is based mainly in the minimization of transaction costs. Conceptually TCE belongs to a broader analytical framework where it operates under the constrains imposed by both formal and informal institutions (Williamson, 1998), the former comprised by legal rules and regulations and the later by rooted cultural values and norms.

This theory has been repeatedly used to analyze the organizational decisions made in a wide variety of industries, of which construction is not the exception. Nevertheless, the attempts made in the latter to test its applicability have been rather discrete and have opted for breadth instead of deepness. The main objective of this thesis was to contribute in closing this gap by making a theory oriented research based in a single case study: the construction of El Diquís Hydropower Project (EDHP) in Costa Rica. Based on the insights derived from this process, opportunities for improvement were recommended to the *Instituto Costarricense de Electricidad* (ICE), a public utility company an EPC contractor responsible of the project´s construction.

Five main research questions guided this study: 1) *what hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?* 2) *What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?* 3) *What are the main characteristics of the EDHP´s institutional framework?* 4) *What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?* 5) *What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?* A qualitative and interpretative approach was adopted to answer these questions, relying on triangulation of sources to eliminate the chance of subjectivity.

Williamson (1979) was the first to formally set up the critical dimensions relevant for the study of transactions: asset specificity, uncertainty and frequency. Asset specificity is associated to the degree of idiosyncratic investments required to conduct a specific transaction. Uncertainty emerges as the combination of complexity and bounded rationality, the former associated to systems that constantly change (Arthur, 1999) while the latter is an intrinsic characteristic of human nature. A contract prepared in the combination of these two ingredients is by definition incomplete. Finally, frequency refers to the regularity of the transaction and the number of possible future exchanges between demander and supplier. It introduces social mechanism of restrain, which reduces the opportunistic behavior of the transacting parties.

At the same time, three types of governance structure can be recognized: market, hierarchy and hybrid. They can be characterized in terms of attributes such as adaptability, incentives, control instruments and contractual law (Williamson, 1991). Market is characterized by autonomous adaptation, high powered incentives, low administrative control and the use of classical contractual law (e.g. closed end provisions and self enforcement mechanisms). On the other hand, hierarchy relies on cooperative adaptation, low powered incentives, high administrative

control and the use of forbearance. A hybrid structures emerge in between with intermediate attributes and relying in neoclassical contractual law (e.g. open end provisions and complementary dispute settlement mechanisms).

Central to the origin of transaction costs is the concept of contractual hazards, which arise in the confluence of asset specificity, incomplete contracts and opportunistic behavior. When these three ingredients are low contractual hazards are negligible and the preferred governance structure is market; it is possible to rely only in the autonomous adaptation propelled by its high powered incentives as an adjustment mechanism in the case of change. If on the contrary these features are high contractual hazards become relevant and the autonomous parties cannot be entrusted anymore to efficiently steer adaptation in isolation. Additional mechanism should be incorporated to induce flexibility and to reach adjustments in a coordinated way, for which hierarchy is the most economical option. For situations in between a hybrid structure is more likely to appear. If one of the transacting parties is a public organization, third party opportunism comes into scene creating probity hazards for both the public agent and private party, which in response increase the specificity and rigidity of the contractual procedures (Spiller, 2008). This reduces the potential for informal adaptation, further enhancing the contractual hazards in the presence of unanticipated events.

For the purpose of this thesis the actor of interest is the engineering, procurement and construction (EPC) contractor. It has been assumed that ICE has the overall capacity to fulfill this role and that it should decide regarding the organization of the transactions composing the construction process. Acknowledging the fact that TCE is developed in the context of Western capitalistic societies, where the social framework offers conditions supportive of its causal explanation, the research hypotheses were deliberately supported in three assumptions that provided ideal market conditions: *1) ICE has the freedom to organize the transactions following mainly a profit maximization function. 2) The market works well and offers production cost advantages in comparison with vertical integration 3) The boundaries between the governance structures conform to the cost proportions introduced by the research hypotheses*.

Based on these conditions, three research hypotheses were proposed: 1) *when asset specificity is low, transactions are better organized in the market, regardless of the level of frequency.* 2) *When asset specificity and uncertainty are high and there is a low level of frequency in the exchanges that neither contributes to articulate more complete contracts or to introduce social mechanism to restrict opportunistic behavior, hierarchy is the preferred governance structure.* 3) *In situations in between some nuance of hybrid structure is more likely to appear.* The conclusions regarding the theory´s applicability should be underpinned by an analysis of both the extent of the predictions provided by these hypotheses, as well as by the validity of the supportive assumptions in the light of the specific characteristics of the environment in which this project is embedded.

The case study (EDHP) is a large hydropower project located in the southern region of Costa Rica. It has a capacity of 650MW and a total cost of approximately USD$ 2.1 billion. The construction stage is expected to start in the second half of 2014 and to last for seven years. Because it is a structurally complex system, to keep the research within its practical scope the boundaries were set to include just the project´s permanent works: dam works, intake works, conduction works, generation works and reservoir works. In addition, five major trades were selected: concretes, earthmoving, tunneling, electromechanical works and metal works, each of them further divided in a total of eleven sub trades. More than 120 potential transactions (PTs) emerge from the intersection of main parts and sub trades.

Based on the characterization of these PTs it can be asserted that the dominant type of asset specificity is temporal, which is high for those transactions with a slack smaller than the replacement time. Human asset specificity is in general medium, an outcome of a production process demanding learning by doing experience but that can be used in other transactions of the same trade. As expected from an industry characterized by the use of standardized parts and equipments, physical specificity is in general and with few exceptions low. No transaction exhibits dedicative specificity higher than medium, indicating that if no capacity is found in the local market it could either be expanded and used elsewhere after the transactions is finished or provided by international contractors. Site specificity is low in every case because either proximity or the installation costs of the production facilities are irrelevant.

With regards to uncertainty, a high level can be attributed to all the transactions included in the trades of tunneling and earthmoving, mainly influenced by unforeseen geological conditions and unpredictable weather events. Due to the conjunction of structural complexity and the need for local adaptations this classification is also shared by the electro mechanic assemblies. The existing project´s designs and baseline studies are detailed enough so as to expected no relevant changes in the original conditions related to other trades, whose level of uncertainty is medium or low. Finally, with few exceptions frequency is consistently low because ICE is a public company subjected to competitive tendering procedures and therefore the same provider is generally not expected in future projects.

Viewed from the perspective of the research hypothesis, these results point toward vertical integration in the tunneling and earthmoving operations involved in the main conduction tunnel, dam and diversion works, as well as in the electro mechanical assemblies of the latter and of the spillway´s gates. Due to its short construction time and low interrelation with successive works, as well as its low level of uncertainty, the metal works' fabrication and assemblies of the bottom discharge are the only transactions were a pure market structure was predicted. Some form of hybrid structure was envisaged for the remaining transactions, getting closer either to market or to hierarchy in function of the specific combination of the three critical dimensions.

Meanwhile, the study of the institutional framework consisted of two parts: the characterization of the governance structure selected to organize the transactions implicit in the EDHP´s construction process and the exploration of the social framework (i.e. formal and informal institutions) in which the project is embedded and that imposes constraints to the theory´s causal explanation. In order to conduct the first part the transactions were divided in two groups: those organized under ICE´s direct administration and those outsourced. This second group was further separated in market or hybrid by making a comprehensive analysis of the provisions included in the contracts used by ICE for the procurement of construction works to conclude what kind of adaptation and enforcement mechanisms were included. From this characterization process it can be concluded that a mixed make-buy scheme was selected to organize the project´s construction, in which three main procurement packages can be distinguished: dam site works, metal works and electro mechanic fabrications. While the first one encompasses activities related to more than one trade, thus representing a sub system for which ICE ceded its responsibility as the system integrator, the other two are trade specific. In general the analyzed contracts comply with the characteristics of a hybrid governance structure, relying in open end provisions and complementary dispute settlement mechanisms.

Taking into consideration that decisions made in the present are affected by past choices (Liebowitz and Margolis, 1995) and that projects are temporal endeavors which are embedded in the long term history of the executing organization (Ruuska et al., 2011), the exploration of the project´s social framework was guided by an examination of the main institutional constraints at which ICE has been historically confronted when organizing this type of projects. Four sub-cases encompassing the total sample of large hydropower projects conducted by ICE in the last two decades were used as a basis for this purpose. From this exploration, three main institutional constraints were identified: financial, time and integration related. First, ICE is not only a capable contractor but also the owner of the infrastructure. Vested in this second role financial entities demand from it certain conditions to secure the funding that limit the space it has as a main contractor to organize the project´s construction. Second, ICE has to comply with national expansion plans and a lack of synchrony is perceived between their goals and the level of maturity of the projects. As a consequence construction is started without having secured all the funds, introducing uncertainty that favors the selection of organizational forms that have work in the past. Finally, ICE is subjected to lengthily procurement procedures that are full of challenging instruments, thus open to the hazards of third party opportunism. This hinders its abilities to efficiently integrate the system relying on procuring discrete parts of it to trade providers. In overall, it can be concluded that the organization ICE chose for EDHP´s construction is strongly shaped by these constraints.

After confronting the predicted with the selected governance structure it was possible to confirm that in general the research hypotheses were not effective in predicting the organizational arrangement selected by ICE for the construction of EDHP. Even though some decisions seem to fit well with the theory, as for example the choice to organize in-house the tunneling works and to procure the electro mechanic fabrications, other decisions such as the vertical integration of trades with low contractual hazards, like concrete and aggregate production, as well as ceding the integration of a system which is full of transactions that exhibit high levels of uncertainty and temporal asset specificity, such as the dam site works, are difficult to explain following just the logic outlined by TCE. Of all the analyzed transaction, only 37% were organized as it was predicted.

This result is nevertheless not surprising, for the theory was developed in the context of free capitalistic market. The circumstances in which this project is conducted are of a different nature and for several reasons it is possible to conclude that the assumptions used to support the research hypotheses were not effective in providing a reliable representation of the conditions in which the decisions were taken. First, ICE is not free to organize the transactions following majorly a profit maximization function due to the pervasive effects of the constraints imposed by its institutional environment, which introduce conditions that are not of an economic nature but that nevertheless play a dominant role in the organization of the construction process. Second, very limited information is available to support the assertion that the construction is taking place in a well functioning market that provides production cost advantages. Third, the boundaries set between the three generic governance structures are not irrefutable and different results could be obtained if they were set differently. Therefore, the theory is applicable in the context of this case study as long as it is placed in a broader analytical construction, in which the surrounding environment is properly taken into consideration. In essence, there is no reason why a construction company operating in Costa Rica or elsewhere would not find TCE a useful theory to study the organization of construction activities, even one of public character such as ICE.

Finally, a conceptual model to improve ICE´s performance as an EPC contractor was proposed to mitigate the effects of the institutional constraints and increase the degrees of freedom it has to organize the construction process. Three levels of action are contemplated. First, a better integration of the projects´ phases and gradual maturation of their governance structure during the development stage should be assured. This would provide protection during the execution stage against any organizational uncertainty that could have been decided beforehand when the space for maneuver was greater. Second, institutions should be customized in order to increase ICE´s abilities to act as a system integrator. For this purpose an abbreviate procurement process based on a register of certified contractors and preapproved unitary prices was suggested. In addition, alternative dispute resolution mechanisms other than arbitration could be customized to provide a smother progression in the escalation of conflicts and to improve the manner ICE exerts the governance of the contractual relations. Third, the construction process should be organized as much as possible as a redundant system in which additional capacity is decoupled from a specific transaction to be conveniently activated if the latter fails to fulfill its original promises. This could contribute in reducing the impacts of delays in the procurement processes of different and independent parts of the supply chain by decreasing the temporal asset specificity of the transactions.

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List of abbreviations

AHP	Angostura Hydropower Project
APL	Administrative procurement law
CABEI	Central American Bank of Economic Integration
CAFTA-DR	Central America and Dominican Republic Free Trade Agreement with the U.S.
CCC	Costa Rican Chamber of Construction
CFRD	Concrete Face Rockfill Dam
DAB	Dispute Adjudication Board
EDHP	El Diquis Hydropower Proyect
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement & Construction
FEED	Front end engineering and design
FIDIC	*Fédération Internationale Des Ingénieurs-Conseils*
GCR	General Comptroller of the Republic
ICE	*Instituto Costarricense de Electricidad*
IDB	Interamerican Development Bank
IRENA	International Renewable Energy Agency
JBIC	Japanese Bank of International Cooperation
LSMI	Law of strengthening and modernization of ICE
MIDEPLAN	Ministry of National Planning and Economic Policies
MINAET	Ministry of Environmental, Energy and Telecommunications
NDP	National Development Plan
NEED	National Energy Education Development Project
NEP	National Expansion Plan
NIE	New Institutional Economics
NPE	National Plan of Energy
PHP	Pirris Hydropower Project
PTs	Potential Transaction
RCC	Rolled Compacted Concrete
RHP	Reventazón Hydropower Project
TCE	Transaction Costs of Economics
UEN CENPE	National Center of Electricity Planning
UEN PySA	ICE´s Unit of Projects and Associated Services

1. Introduction

The theory of transaction cost of economics (TCE) represents a shift from the neoclassical economical notions that individuals possess perfect information and unbounded rationality and transactions are costless and instantaneous. It is derived principally from the work conducted by Ronald Coase, Oliver Williamson and Douglass North and is part of what it is known today as the New Institutional Economics (Rutherford, 2001). Under this framework the transactions, defined "*as the exchange of goods and services between technologically separable entities"* (Williamson, 1981, p. 550) are the prime focus of analysis when assessing the better way of organizing economic activities.

In simple terms the transaction costs represent the costs incurred in participating in the market. According to TCE the optimum governance structure to support an economic exchange is related to the particular attributes thereof and should strive at minimizing the transaction costs. This theory has become a standard framework for the study of organizations, being vertical integration (i.e. the make or buy decision) its archetypical problem (Williamson, 1998). Even though TCE has been recognized as a useful perspective to analyze the construction process, the attempts made to explicitly test its applicability have been rather discrete and have opted for breadth rather that deepness. This thesis´ main objective is to contribute in closing this gap by analyzing the applicability of TCE as an explanatory theory for the governance structure chosen to organize the transactions implicit in the construction of a large hydropower project in Costa Rica. Based on the insights derived from this process, opportunities for improvement are also recommended to the *Instituto Costarricense de Electricidad* (ICE), a public utility company an EPC contractor responsible of the project´s construction.

This report has been divided in seven main parts. First, in chapter two the research design is presented, explaining in detail the context of the investigation, the research problem and the manner this thesis contributes towards its solution. In addition, the research objectives, framework and main questions are depicted, as well as the followed strategy and main sources of information. Next, in chapter three a thorough exploration of the main theoretical precepts and general machinery of transaction costs of economics is provided, including a custom made methodology to make the theory operational in the context of this case study. Important characteristics of the construction industry which are relevant for this study are also incorporated, finalizing in the proposition of the hypotheses and main assumptions that guided the course of this investigation. Subsequently, the study of the main transactions involved in the construction of EDHP is presented in chapter four. Included here is the project´s description, the establishment of the system boundaries, the selection and definition of the transaction of interest and finally the characterization thereof and their alignment to a theoretical governance structure. Afterwards, the institutional framework is explored in chapter five. This yields a characterization of the governance structure selected in reality to organize the project´s transactions, a description of the main institutional constraints imposed by the social framework in which the project is embedded and an outline of the rationality behind the chosen organization. With this as a background, in chapter six reflections are drawn about the applicability of TCE in the context of this case study, thus fulfilling the thesis´ main objective. Based on the insights derived from this investigation, ideas to improve ICE´s performance as an

EPC contractor follow in chapter seven. Finally, the main research´s conclusions are presented in chapter eight.

A set three of research hypotheses were formulated in this thesis in order to provide a theoretical connection between transactions and governance structures. In general it can be asserted that these hypotheses were not effective in predicting the organizational arrangement selected by ICE for the construction of EDHP, but that nevertheless this is not an indication of theoretical failure because the main assumptions used for their construction, which deliberately introduced ideal market conditions, were not effective in providing a reliable representation of the social framework in which the decisions were taken. It was concluded that the theory is applicable in the context of this case study as long as it is placed in a broader analytical construction, in which the surrounding environment is properly taken into consideration.

2. Research design

The research design for this thesis was elaborated based on the guidelines suggested by Verschuren and Doorewaard (2005) and it is divided in five sections. First the context of the research project is presented, explaining the research problem and how this study intends to contribute towards its solution. Afterwards the objectives of the investigation are outlined. This is followed by the research framework, where the intended results, research perspective and research objects are introduced, leading to the definition of the central question and sub-questions in the fourth section. Finally, in the fifth section a brief summary of the research strategy and main sources of information are presented.

2.1 Project context

TCE has become a standard framework for the study of organizations, helping to explain not only the existence of the firm, but also its scope and size (Ménard and Shirley, 2005). From all its areas of application vertical integration, or in more common terms the make or buy decision, has been the archetypical problem for TCE (Williamson, 1998). Why do some firms choose a vertically integrated structure, while others specialize in one stage of the production and outsource the remaining stages to other firms? Since Coase´s ideas were revived by Williamson in the 1970´s this question has been the base of an important body of scientific research, for which a good recapitulation is provided by Klein in the Handbook of New Institutional Economics, edited by Ménard et al.(2005). As it can be stated the framework has repeatedly been used to analyze the decisions made by organizations in industries such as automotive (Monteverde and Teece, 1982, Gordon and Weber, 1984, Masten et al., 1989, Langlois and Robertson, 1989, Ramon Casadesus-Masanell and Daniel F. Spulber, 2000) aerospace (Masten, 1984), and electricity (Joskow, 1985, Saussier, 2000). These are just but a few samples of the total compendium of empirical literature on the subject.

But what place does the construction industry holds in the development of this body of knowledge? It cannot be denied that there are many aspects in which construction industry differentiate from many other economic activities, including to some degree the ones formerly mentioned. Most of the work is organized as projects, each of them specified to meet the particular requirements of discrete clients and therefore unique in many aspects. The products of such projects are systems composed of a large number of interacting components. The tasks required to be delivered are undertaken to a high degree on the site, each time under different conditions and in a low controlled environment. The scope of the work is not fully defined at the outset of the projects, and therefore the stability of the assumptions taken by the parties is rather low, resulting in unpredictability and uncertainty. Large construction projects can be characterized generally as being complex in both structural and dynamic dimensions (Whitty and Maylor, 2009).

Despite these particularities construction industry holds a basic similarity with any other production process. Considering the building itself as the final product and outcome of the construction project, its creation involves the succession of several processing and assembly activities (i.e. a chain of supplies) with a clearly defined interface between them. As it was noted by Coase (1937) in his seminal paper “The Nature of the Firm” the boundary of the firm is under this condition a decision variable for which an economic assessment is needed and for which TCE can be used as a valid analytical framework.

The usefulness of TCE approach to analyze the construction activity has not been unnoticed and several researchers have adopted it as a theoretical lens for their studies. The application of TCE as a viable conceptual framework to study the governance of both construction projects and firms has been acknowledged by authors such as Eccles (1981b), Reve and Levitt (1984), Winch (1989, 2001, 2006), Walker and Wing (1999), and Zerjav et al (2011) just to name a few. It has also been related specifically to topics such as choices of contracting and procurement (Lingard et al., 1998, Lai, 2000, González-Díaz et al., 2000, Bajari and Tadelis, 2001, Turner and Simister, 2001), nature of the supply change (Hobbs, 1996, London and Kenley, 2001), and cost optimization (Li et al., 2012), among others.

Within all this scientific activity there have been some attempts to expressly test the application of the theory in the construction industry, although these have been rather discrete in the context of the research agenda. For instance Masten et al. (1991) used econometric methods to analyze the organization of a sample of components from a large naval construction project and to test the transaction cost arguments. Despite being a shipbuilding project, the authors argued that it resembled more to a traditional construction project than to any other manufacturing operation. The results supported some but not all the standard TCE arguments, although the authors recognized that limitations in the available data may have affected the outcome.

González-Díaz et al.(2000) used data on a panel of 278 firms in the Spanish construction industry over a six year period to examine the factors driving the subcontracting decisions and to explain the reasons of vertical integration. A set of hypothesis were proposed and tested using a multivariate regression model. It was concluded that the application of the TCE theory was partial, although the test did not have full statistical significance and the authors recognized that important information regarding the specific characteristics of the studied firms was lacking.

More recently and using as a case study the implementation phase of two contemporary nuclear power plants, Ruuska et al. (2011) analyzed the governance structure selected for their construction. Despite not being a study addressed directly at testing the TCE approach, it includes the framework as an important part of the assessment suggesting that the market-hierarchy dichotomy do not fully grasp the mechanism putted in practice for such projects. Further research about the selection of governance structures for large construction projects was recommended by the authors.

Despite these efforts it is clear that more research is needed in order to test the applicability of the transaction cost approach in explaining the dynamics of the construction industry. Most of the studies fail to provide an in depth identification and description of the transactions involved in the construction process and to characterize the institutional framework in which the decisions are taken. Therefore, this research aims to contribute in closing this gap by making a theory oriented research based on a single case study: the construction of El Diquís Hydropower Project (EDHP) in Costa Rica. As was noted by Chang and Ive (2007a, p. 394) *“the case study methodology can complement the econometric testing that is currently predominant in TCE* *empirical literature because, by examining the details of the contracting, the arguments in transaction cost reasoning can be put under more focused scrutiny".*

This specific project was chosen for two main reasons. First, the author directly participated in the construction planning as part of the project´s front end engineering and design stage (FEED). This grants him privileged knowledge about the case. Second, the project is going to be constructed by the Engineering and Construction Division (UEN PySA) of the *Instituto Costarricense de Electricidad* (ICE), a public utility company legally responsible of satisfying the country´s electricity demand. Being a public entity ICE is considerably more open to share information that would be difficult to obtain from a private contractor, thus further contributing to the goal of reaching a level of detail in the analysis not achieved before.

2.2 Research objectives

2.2.1 Main objective

To contribute with the theoretical development of TCE in the context of the construction industry by testing its applicability as an explanatory theory of the governance structure chosen to organize the transactions implicit in the construction process of a large hydropower project in Costa Rica.

2.2.2 Secondary objective

To propose opportunities for improvement to ICE, using as a basis the insights derived from this investigation.

2.3 Research framework

For this thesis a theory oriented research perspective was adopted. A study of TCE, complemented with a revision of the main characteristics of the construction industry, yielded a set of hypotheses which provided a theoretical connection between the transactions´ attributes and the governance structures. By means of these hypotheses the transactions involved in the construction of EDHP were aligned to a theoretically favored governance structure and then confronted with the real one, resulting in a set of conclusions regarding the applicability of TCE as an explanatory theory for the chosen organization. Based on the insights derived from this study, opportunities for improvement were recommended to ICE. A detail of the followed research framework is presented in **figure 2.1**.

As it is implicit in this framework the case study consisted of two separate research objects: the transactions involved in the construction of EDHP and its institutional framework. The latter encompasses not only the governance structure that was selected to organize those transactions, but also the social framework (i.e. formal and informal institutions) in which the project is inserted and that imposes constraints to the theory´s causal explanation. Taking into account that today´s decisions are affected by past choices (Liebowitz and Margolis, 1995) and that projects should be perceived as temporal endeavors which are embedded in the long term history of the executing organization (Ruuska et al., 2011), the study of the social framework was guided by the investigation of four sub-cases representing the total sample of large hydropower projects conducted by ICE in the last two decades.

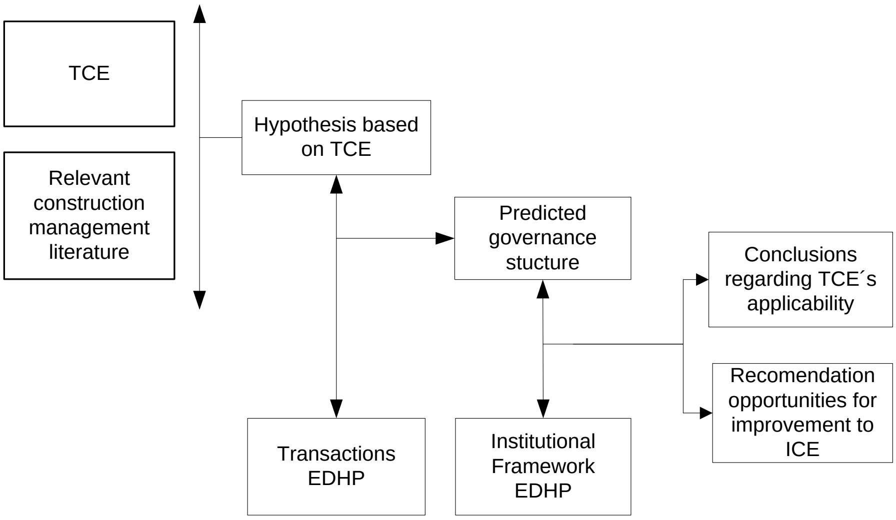


Figure 2.1: **research framework**

2.4 Research questions

Based on the defined research framework the following central questions and sub questions were used to steer the execution of this study:

1. **What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?**
    1.1 What level of analysis does the theory provides in the study of organizations?
    1.2 What are the main theoretical precepts of TCE relevant for the purpose of this investigation?
    1.3 How can the theory be operationalized in order to extract from the study objects the information needed to test the hypotheses?
    1.4 What are the main limitations commonly attributable to TCE?
    1.5 What characteristics of the construction industry are relevant for this investigation?
2. **What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?**
    2.1 What are the main characteristics of EDHP?
    2.2 What are the boundaries of the system under investigation?
    2.3 What transactions should be used as a basis for the analysis?
    2.4 How are these transaction characterized according to TCE?
3. **What are the main characteristics of the EDHP´s institutional framework?**
    3.1 What are the characteristics of the selected governance structure?
    3.2 What institutional constraints are relevant for this investigation?
    3.3 What is the rationality of the chosen organization?

4. **What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?**
5. **What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?**

2.5 Strategy and main sources

This thesis can be characterized as being an in depth case study in which a qualitative and interpretative approach was adopted. The research perspective consisted in a set of hypotheses constructed using as a theoretical framework the theory of transaction cost of economics. In addition, analytical tools were customized in order to extract from the study objects the required information. For this purpose the project started with a desk study in which a content analysis regarding TCE and the general characteristics of the construction industry was conducted. The main source of information for this initial stage was relevant journals and books found within the TU Delft Library´s collections and subscriptions.

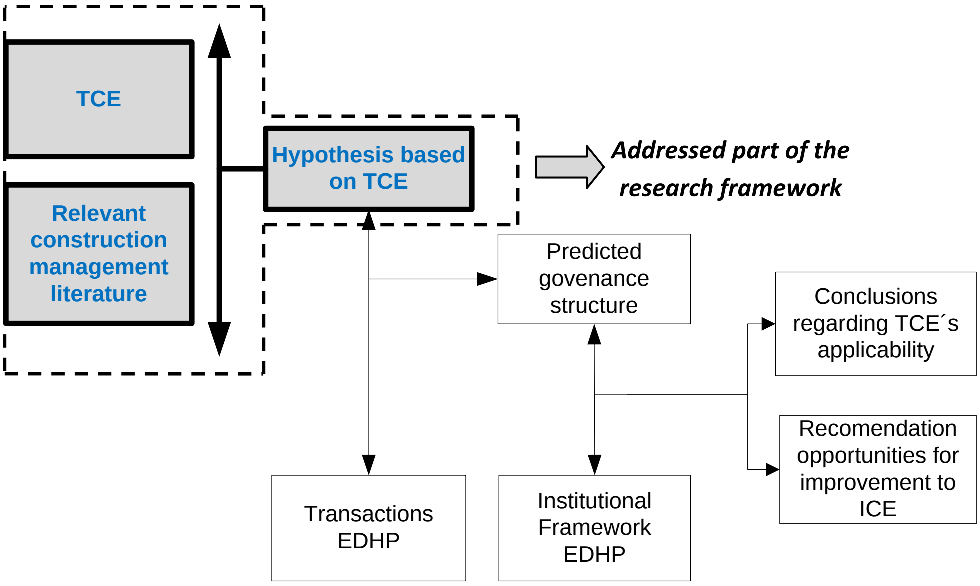
The general strategy used for the study of the research objects was to rely on triangulation of sources to eliminate chance and subjectivity as much as possible, as it is usually recommended when the study is dealing with a single case (Verschuren and Doorewaard, 2005, Yin, 2009). The main source of information used for the study of transactions was documentation regarding the project´s front end engineering and design, technical specifications and construction plans. This information was provided by ICE in digital form and was complemented by the author´s participatory observation in the project planning an in similar construction processes. In addition, the opinion of several specialists was asked in specific points in which reaffirmation or additional knowledge was necessary.

Meanwhile, the study of the institutional framework was divided in two parts. In the first a documental analysis of the project management plan and several contracts used by ICE for the procurement of construction works was conducted in order to extract the information required to characterize the EDHP´s governance structure. Afterwards four sub cases (including EDHP) were studied to distill the decision factors leading to the selected governance structures and to infer base on that the main institutional constraints that currently influence ICE´s decision making process. This was based on the analysis of several documents provided by ICE (e.g. project management plans, final construction reports, etc), semi structured interviews to the key players involved in the decision making process, as well as the researcher´s participatory observation in two of the analyzed sub cases.

More detail regarding the specific methodology followed in each part of the investigation is appropriately introduced later on in this report.

CHAPTER 3

THEORETICAL FRAMEWORK AND RESEARCH HYPOTHESES



Thesis´ main research questions:

1 **What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?**

2 What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?

3 What are the main characteristics of the EDHP´s institutional framework?

4 What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?

5 What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?

Research question to be answered

3. Theoretical framework and research hypotheses

This chapter is divided in three main sections. First the most important theoretical precepts and general analytical machinery of TCE are presented. This includes a description of its level of analysis, required adjustments in order to incorporate a public contracting party, a proposed methodology attuned to the characteristics of the case study in order to make the theory operational, as well as the main limitations commonly attributed to the theory. Afterwards, in the second section a general characterization of the construction industry is provided. The analysis here is focused on those elements that are relevant in the light of TCE, including some important traits of the segment of construction at which the case study pertains. Finally, in section three a synthesis of the hypotheses and main assumptions that guided the course of this investigation is presented.

3.1 Transaction cost of economics

One of the main precepts of neoclassical economic theory is that an economic system requires no central control; it is steered by an automatic adjustment of supply and demand, in a process that is both responsive and resilient (Coase, 1937). The manner in which human activities are organized makes, nevertheless, the digestion of this assumption a rather problematic affair. As it was noted by Coase (1937), if production is regulated solely by the price mechanism there is no reason for the existence of any organization, inasmuch as production could be carry out without them. This reasoning evidently is not valid and the main motive to establish an organization appears to be linked to the fact that sometimes there is a cost of using the price mechanism (Coase, 1988).

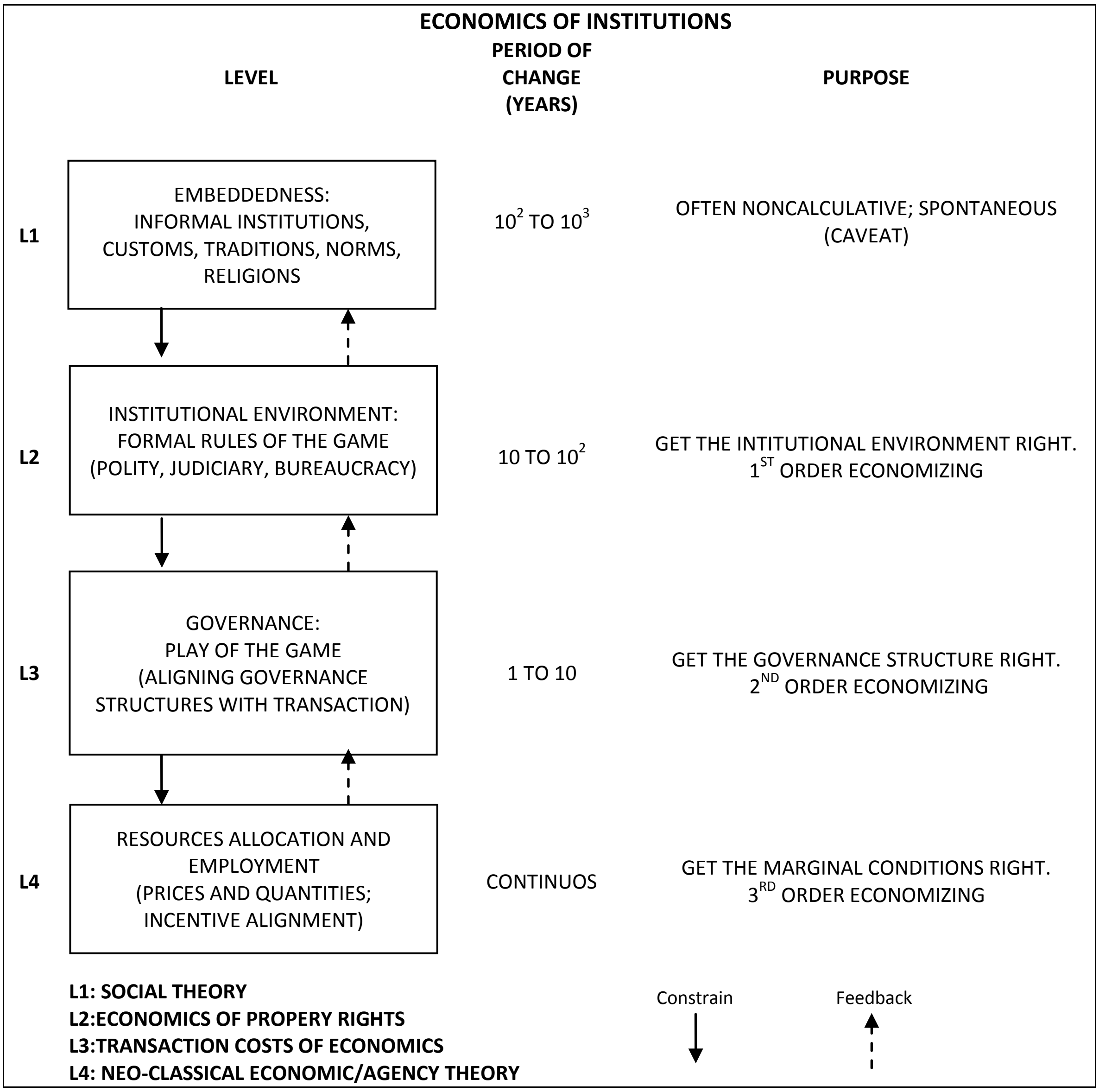
Transaction has been defined by Williamson (1981, p. 550) as "*the exchange of goods or services between technologically separable entities"*. The question of what exactly is a transaction cost naturally emerges at this point, being the simple affirmation of *"are the cost of running the economic system"* (Arrow, 1969, p.59) insufficient for the inquisitive mind. Williamson (1981) uses the analogy of a mechanical system and the lost of energy do to the frictions between its components, arguing that in the economic counterpart that friction is represented by the transaction cost. If an exchange is carried out by the parties as a harmoniously (friction free) operation, the cost associated to the action of trading should be lower than if there are regular misunderstandings and quarrels that lead to breakdowns, delays and other malfunctions (high friction). Taking as an assumption that in order to conduct a transaction a contract between the parties is needed, the transaction costs are plain and simple the costs of making and enforcing that contract. For reasons that will be explained later on in this chapter these costs are higher for some types of transactions than for others, which brings us to the most important theoretical principle in the context of this study. TCE holds that transaction cost economizing is central to the study of organizations. In other words, there is a direct relationship between the governance structure selected to organize a transaction and the intrinsic characteristics of the latter, and is based to a large extent in the minimization of the transaction costs.

This is not to suggest that production costs are irrelevant and that transaction cost is the only decision factor involved in the selection of organizational arrangements. Production costs are indeed important, and as noted by Williamson "*transaction cost economizing needs to be* *located within a larger economizing framework and the relevant trade-offs need to be recognized (1981, p. 552)"*. What is important to understand is that both concepts are complementary and that decisions based solely on one of them are by definition incomplete. Even thought the theoretical framework chosen for this thesis resides mainly on TCE, conceptually production costs are also incorporated. It is therefore necessary for the integral understanding of the subject in question to elaborate a bit more on this last point. Nevertheless before doing this it is convenient to further advance in the exposition of the theory of TCE, beginning with a description of the level of analysis the latter provides. The query about how production costs fit in the current analysis is resumed in section 3.1.5.

3.1.1 Level of analysis

Transaction cost of economics doesn't stand in isolation. Conceptually it belongs to a broader framework and its position within this framework should be recognized in order to understand its practical limits. Essential for this purpose is the meaning of the term institutions, which according to North (1990) are the rules of the game that define and restrict the set of choices of individuals in a society. As it was noted by Jong et al. (2002, p. 19-20) despite the significant volume of literature striving to describe and define institutions in fields as diverse as institutional economics, political science, law, sociology, anthropology and history; the common denominator in most writings is the distinction between formal and informal institutions. The former are the *"legal rules of the game telling who is allowed to undertake what actions and under what conditions"* while the latter are *"social practices and rituals based on underlying cultural values and norms*".

Formal and informal institutions give shape to the social framework in which TCE is circumscribed, as is shown in **figure 3.1**. The upper a level of analysis is in this framework, the more levels below it constrains. Informal institutions, characterized by social embeddedness, are at the top of the list. According to Williamson (2000) this kind of institutions have many times spontaneous origins and once adopted display great inertia . Changes at this level occur very slowly and the analysis is mainly undertaken by social scientists. At a second level and constrained by the cultural norms and values, formal institutions appear. This is referred by Williamson as institutional environment and is characterized by formal rules, as for example property rights and contract laws. In democratic regimes changes in this level also occur slowly and are difficult to articulate, even though the rules can be consciously molded in order to improve the institutional environment. The third level, institutions of governance, is constrained by both formal and informal institutions. This is the level at which transaction cost of economics operates by making a discrete analysis of the best manner to organize transactions. Below this point is level four, the realm of neo-classical economics and agency theory. The firm is seen as a production function in which marginal analysis of benefits and costs using as a main variable prices and output, as well as incentive alignment are the principal concerns. This level is at the same time constrained by all the levels above.



Souce: (Williamson, 1998, p.26)

Figure 3.1: social framework and levels of analysis

It should be noted that the research hypotheses introduced later on in this chapter as a mean to provide a theoretical connection between transactions and governance structures are based entirely in the third level of analysis mentioned above. Economic theories of the firm, such as TCE, have been developed thinking majorly in the context of the U.S., in which the market is controlled by private parties and the government confines itself to intervene only in case of market failure (Hamilton and Biggart, 1988). In other words, the social framework is one that provides conditions that support the logic outlined by TCE. The project analyzed here is nevertheless carried out in Costa Rica and conducted by a public company. This company is additionally acting as the main contractor of the construction process, a role that worldwide has traditionally been played by private parties. It is acknowledged that under these conditions an outcome different to the one predicted by the research hypotheses alone should not cause any surprise, nor it should be an immediate indicator of theoretical failure.

What is important here is to place these predictions in the institutional context of this specific project. To accomplish this, an integral part of this investigation is the study of the social framework pertinent to the case study, the constraints it imposes on ICE´s operations as a main contractor and the effects it has on the validity of the assumptions used to support the research hypotheses, which are distinctive of Western capitalistic economics. Only then can the applicability of TCE as an explanatory theory of EDHP´s organizational arrangements be assessed. More about this will be discussed later on in section 3.3.

3.1.2 Characterization of transactions

In simple terms transactions are all the processes involved in the production of a specific product that are divisible in terms of technology (i.e. methods, knowledge and tools) and for which a specialization of work is possible. Williamson (1979) was the first to formally set up the critical dimensions of transactions relevant for the evaluation of governance structures, which he synthesized in three: asset specificity, uncertainty and frequency. These dimensions are interwoven, residing the nodes in specific elements of human nature that have been usually neglected by mainstream economic models. An explanation of the reasoning behind this categorization, as well as the links between the different dimensions, is of paramount importance.

Asset specificity is associated to the degree to which transaction specific investments are necessary (Williamson, 1981). It could be the case for instance that in order to provide an specific component the supplier has to invest in specialized equipment, facilities or knowledge that employed in a second use would yield much smaller value than original intended. Under these circumstances both supplier and buyer are to some degree tied to the transaction because the former cannot find a second comparative alternative use to profit from the investment, and the latter cannot obtain a better price in the market for the demanded provision. Williamson (1979, p. 241) refers to this effect as a *“bilateral monopoly”* and concludes that it has important contracting consequences. Idiosyncratic investments are meaningful if there is a relatively safe earning prospect. For both parties there is a need to assure that the integrity of the transaction will be kept as planned and for sufficient time to meet the original expectations.

The introduction of the concept of bounded rationality is relevant at this point. The type of rationality often assumed in economy is one of flawless, rational and deductive nature. It is capable to precisely allocate production factors in its best economic use without mistake, delay or hesitation. Nevertheless this behavior does not match with the human nature because *“beyond certain level of complexity human logical capacity ceases to cope”* (Arthur, 1994, p.406). Bounded rationality is connected to the fact that there are limits for human ability to adapt to complex environments (Simon, 1991) and that under situations of complicated or ill-defined nature the dominant method of reasoning is inductive rather than deductive. Internal models are built by individuals to reduce complexity and they are by definition both subjective and incomplete.

A further exploration of the term complexity is required to make a conceptual bond between the critical dimensions proposed by Williamson. Complexity has been defined by Whitty and Maylor (2009) as a function of both the number of components with emergent behavior in a system (i.e. structural complexity) and the dynamic nature of their interactions (i.e. dynamic complexity). Complex systems are those that *"constantly evolve and unfold over time"* (Arthur, 1999, p.107). It is the combination of complexity with unbounded rationality what leads to uncertainty regarding the course of action of human activity.

As it was previously argued when the investment of specialized assets is required in order to provide a good or service, interdependency is born between buyer and supplier. In order to protect their interests a contract is created to define the terms of the exchange in a manner that satisfy both parties. Because human rationality is not without limits, in the presence of complexity not every possible contingency will be established from the outset of the relation and the contract is necessarily incomplete. Such transaction can therefore be described as uncertain.

The optimal behavior of the exchange system in the presence of incomplete contracts is that characterized by adaptation, in which any contractual gap is automatically filled on the light of the circumstances in a balanced and impartial way. This ideal however denies another highly relevant human characteristic. Given the chance individuals may exhibit opportunistic behavior in order to increase their gains. The more specific are the assets involved in the transaction, the higher is the prospective gain of incurring in this behavior because there is a bigger difference between the actual use of the investment and its second best use[1]. This cause an increase in the costs of contracting while making more attractive vertical integration as a mean to economize in the cost of avoiding or minimizing the risk of post contractual opportunistic behavior (Klein et al., 1978). The appealing of vertical integration is therefore related to the increase of flexibility and adaptability to cope with uncertainty. As was noted by Williamson (1971, p.117): *"integration harmonizes differences and permits an efficient decision process to be utilized".*

The last dimension proposed by Williamson is frequency and it refers to the regularity of the transaction and the number of possible future exchanges between the parties. If a supplier has the prospect of future collaboration with the buyer it may restrain to act opportunistically, because by doing so it would condemn future gains. Jones et al. (1997) further define frequency in transactions as a requirement for the appearance of social mechanisms to coordinate and safeguard exchanges, such as restricted access, macro cultures (i.e. shared assumptions, values and knowledge), collective sanctions and reputation. These social elements are the basis for the relational contracts, defined by Baker et al. (2002, p.39) as "*informal agreements and unwritten codes of conduct"*, and usually mentioned by Williamson as an alternative for situations in which keeping the original agreement as the reference point does not offer the required flexibility to the parties to adapt to changing circumstances, and therefore a shift to rely more in the relation itself is preferable. In addition if a transaction is conducted regularly, the identification of factors that need to be adapted as well as the direction of those adjustments improves (Ménard, 2000).

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[1] Klein et al. (1978) refer to this difference by the name of quasi-rent.

3.1.3 Characterization of governance structures

The analytical power of TCE relies on the principle that transactions (with different attributes) are aligned to governance structures (with different costs and competences) so as to minimize the transactions costs (Williamson, 1988). According to Williamson (1991) in general terms there are three generic forms of governance: market (i.e. to buy), hierarchy (i.e. to make) and hybrid[2]. Moreover, these generic modes can be characterized by four main attributes: adaptability, incentives, control instruments and contractual law. These attributes are first going to be explored and afterwards matched accordingly to each form of governance.

In Williamson (1991) perspective there are two types of adaptability relevant for the transaction cost analysis. The first is the autonomous adaptation of individual buyers and suppliers, for which the price mechanism suffice and additional coordination is not required. In other words, both parties respond independently to market changes following a profit maximization function. The second type of adaptability, referred by Williamson as cooperative adaptation, concerns the premeditated efforts to create adaptive instruments, needed when parties interpret the same situation in a different manner, decisions of suppliers and buyers are not taken separately (e.g. bilateral monopolies) and changes are not induced automatically by market variations.

The second attribute is incentives, which is divided by Williamson (1985) according to their level of intensity in high powered and low powered. High powered incentives directly link payment with output in a manner that only profitable activities are conducted (Lazear, 2000), in other words, it makes reward to be a function of performance. On the other hand, when incentives are low powered remuneration may be just weakly (or not at all) dependable of the outcome of the production process. Individuals involved in the exchange may be promoted or receive an increase in salary, but normally they do not benefit directly from trading earnings (Frant, 1996).

High powered incentives promote efficiency, because parties profit directly from an improvement in the production process and a reduction in costs. Nevertheless, too powerful incentives also encourage opportunistic behavior, especially in those situations in which considerable gains can be derived from such acting (e.g. in transaction involving high asset specificity, incomplete contracts and low frequency). It is theoretically desirable to reduce the intensity of incentives if the increase in production costs produced by a drop off in efficiency is offset by the reduction of costs derived from opportunistic behavior. By definition transactions in the market can be characterized as high powered, while within the firm as low powered.

According to Tadelis and Williamson (2010) administrative control is an indication of the administrative right to intervene in the production process to correct any possible misalignment. In practical terms there is not much distinction between ownership and control (Grossman and Hart, 1986), inasmuch as that who owns the assets has the power to exert control. Grossman and Hart (1986, p.695) further state that the owner of the asset has *"the right to control all aspects of the asset that have not been explicitly given away by the contract"* (i.e. residual rights). Administrative control has a direct and positive connection with the cooperative adaptability discussed above.

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[2] Also buy, but with additional contractual provisions.

Contract law was defined by Esser (1996, p.608) as a *"body of legal principles enforcing obligations explicitly consented to by the parties in an agreement".* Those obligations are embodied in contracts, which emerge as means for organizing transactions and for coordinating and controlling the parties involved in the exchange. There is no universally accepted typology of contracts (Ménard, 2000), nevertheless the threefold classification proposed by Williamson (1979, 1985) and derived from MacNeil (1974, 1978) in which contracts are classified according to their legal tradition in classical, neoclassical and relational is useful in terms of its operational capacities. A fourth type, forbearance (Williamson, 1991), should be added to describe the coordination mechanisms within the firm.

A classical contract is first of all of a discrete nature; it plans a particular transaction apart from all other transactions in the near future term (Esser, 1996). All relevant future contingencies pertaining to the supply of goods and services are adequately provided (i.e. the contract is complete). Because there are no consequential differences between *ex ante* and *ex post* circumstances, simple self enforcement mechanisms can be introduced at low cost (e.g. automatic clauses of adjustments, hostage clauses, guarantees, etc). It corresponds to the ideal market transaction in which the identity of the parties is irrelevant, because there is a weak interdependency between them. In addition, the agreement is carefully delimitated (i.e. no open terms are left), governed by strict formalities (i.e. formal terms supersede informal ones) and any modification would be as good as a new contract.

In the presence of bilateral dependency between autonomous parties and long term agreements executed under conditions of uncertainty, classical contract is incapable to cope with the adaptation requirement and gives rise to different contracting forms. Neoclassical contracts deal with the situation in which it is not possible or practical to define from the outset all future contingencies associated to the exchange (i.e. incomplete contracts) by incorporating a set of mechanism to create flexibility and fill the contractual gaps during the *ex post* stage. It envisages for instance the inclusion of credible commitments (e.g. informal rules) as a complement to formal clauses to induce adaptation and reinstate efficiency (Williamson, 1991, Ménard, 2000). The settlement machinery goes beyond the simple self enforcement apparatus used in the classical contracts and includes the intervention from third parties (e.g. arbitration) and solutions exogenous to the clauses of the contract. In addition, its scope is extended to include not only discrete transactions in a near future but also a succession of isolated transactions extending over a longer period of time (Esser, 1996). In synthesis, the contract in the neoclassical tradition works as an adjustable framework for the exchange (Williamson, 1991, p. 272).

The third kind of contract proposed by Williamson (1979, 1985) makes the relation between the parties the reference point for affecting adaptation, instead of the original agreement as it is the case for the neoclassical system. Relational contracts constitute an evolution in terms of contractual traditions to an agreement that goes beyond discrete transaction and open term conditions in which long term relations are used as a device for governing exchanges. These agreements are based on inter firm cooperative processes by which the terms of the exchange are negotiated during the *ex post* phase (Esser, 1996), providing maximum flexibility to the parties. It relies heavily in social mechanisms to restrain the parties from acting opportunistically, which are foster by the perspective of future gains during the term of the agreement.

To close the description of contractual typologies forbearance appears as the implicit contract law of internal organizations (Williamson, 1991, Ménard, 2000). It refers to arrangements in which fiat[3]becomes the main coordination mode. Transactions within this scheme are regulated by a hierarchical system characterized by the capacity of taking discretionary decisions. Within the constraints imposed by the legal environment, this system remains *"its own court of ultimate appeal "* (Williamson, 1991, p. 274) when there is a need to fill the gaps of an internal contract. In other words, parties participating in an internal exchange can settle any discrepancy by themselves and if fail submit it to the hierarchy for a final decision, making such a system the more flexible form of organization.

Having explored the main attributes relevant for the characterization of governance structures each of the three generic modes proposed by Williamson can be defined in terms of their intrinsic qualities. As it is shown in table 3.1, market and hierarchy are the polar modes, with hybrid displaying intermediate values in every feature.

Table 3.1: characterization of generic governance structures by their intrinsic attributes

Attribute		**Governance structure**		
		Market	*Hybrid*	*Hierarchy*
Adaptability	*Autonomous*	High	Intermediate ⟺	Low
	Cooperative	Low		High
Power of incentives		High		Low
Administrative control		Low		High
Contract law		Classical	Neoclassical	Forbearance

3.1.4 Public contracting

Up to now the exploration of the theory has been principally orientated towards transactions between private parties. As the organization analyzed in this study is state owned, it is necessary to introduce what implications this condition has for the TCE´s theoretical framework. In essence the same construction can be used as a basis to explain the exchanges between public and private parties, but it has to be expanded to include those elements that are not present in the private domain.

According to Spiller (2008, p.5) public contracting is intrinsically different from private one because *"it is exposed to a larger set of hazards"*. First it has to confront the opportunistic behavior of the transacting party, just as it occurs in the private realm. It this sense the

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[3] The authority of agents to give orders regarding how and when an action should be undertaken

theoretical framework presented so far is completely applicable. Nevertheless, in Spiller´s perspective two additional types of opportunism are relevant when one of the contracting parties is a public entity: governmental and third party. They present potential hazards to both sides of the transaction.

Governmental opportunism refers to the ability of governments to opportunistically change the conditions of an agreement subscribed with a private party by using its governmental powers once the required investments are in place (Levy and Spiller, 1994, Spiller, 1996, 2012). This kind of opportunism is especially relevant in utilities, where high sunk investments are required and the expected returns occur during a long period of time. The intensity of this kind of behavior is conditioned by the control the executive power may exert over legislation, as well as the degree of independency of the judiciary system (Spiller, 2008).

In comparison with private contracting, and in the presence of governmental opportunism, stronger safeguards will be demanded by the private party. This includes the elaboration of more detailed contracts and rigid procedures to eliminate the scope for subjective interpretations. If judiciary interdependence is weak, high doses of potential governmental opportunism may lead to the payment of considerable upfront rents or simply to the public integration of the transactions (Spiller, 2008). As can be easily inferred the party most affected by this type of opportunism is the private, which is subjected to the governmental powers.

Being funded with money from tax payers, public organizations are usually subject to the principle of publicity. Their actions are exposed to public scrutiny, which is commonly channeled through comptroller´s agencies. This can be seen as a normal condition to avoid corruption in relatively well organized societies (Spiller, 2008). There is nevertheless a hazard factor implied in the fact that the public is a vast stakeholder with an average low level of information regarding the particularities of the public bureau´s operations. Well informed parties may use their privileged knowledge to misrepresent the real characteristics of public actions in a manner beneficial to their own interests. This is known as third party opportunism and was framed by Spiller (2008, 2012) as mainly propelled by political competition. A similar approach was followed by Frant (1996), who recognized that in essence both parties private and public have high powered incentives, relying the difference not in the lack of motivation but in the nature of the stimulus (economical for the former, political for the latter). Despite these purely politically centered perspectives it should be recognized that incentives rising eminently from the economic sphere are also prime motivators for this kind of behavior. In general, the more complex a transaction is, the bigger the information asymmetry is and the more prompt third party opportunism tends to appear.

As with the case of governmental opportunism, third party opportunism is likely to affect the manner in which contracts are conceived mainly because it introduces what Williamson (1999) has called probity hazards. Spiller´s (2008, p. 12-13) remarks are relevant:

> *“The exposure of third party opportunism increases the risk of both public agent and private party contracting with the state. In response, both will have incentives to increase the specificity of these contracts as compared to equivalent contracts among private parties. Moreover, to mitigate the risk of third party opportunism,*

> *these contracts are likely to demand more rigid procedural processes, including formal procedures for renegotiation."*

Whether this increase in specificity has any relevant consequence in the degree of effective completeness of the contracts is debatable, what is plausible to assume is that the exacerbated formality and stiffening of procedures have a negative effect in the potential to introduce flexibility in the agreements. Entering in a close relation with a provider could be perceived as a lack of probity by the public agent. In addition the use of negotiated contracts is also problematic (Ghertman and Ménard, 2009). This imposes a restriction to the existence of relational agreements, commonly mentioned as alternatives to induce adaptation and reduce transaction costs under conditions of uncertainty (Williamson, 1985, Esser, 1996, Jones et al., 1997, Artz and Brush, 2000, Cannon et al., 2000, Baker et al., 2002). Moreover the inclusion of high powered incentives in the contract may increase the risk for public agents to be challenged by third parties, and therefore they could be motivated to reduce their intensity to suboptimal levels in comparison with private contracting. Opposite to the case of governmental opportunism, which is foster by centralization of power, third party opportunism requires some degree of political division and contestability to properly germinate (Spiller, 2008).

3.1.5 Selective alignment

Based on the theoretical construction elaborated so far a causal diagram was built to serve as a unified framework in order to ease the understanding of the dynamics involved in the creation of transaction costs (see **figure 3.2**). Williamson´s concept of the levels of social analysis introduced in section 3.1.1 was used as a basic template. The third level of analysis in which the discriminative selection of governance structure occurs, has been further divided in two domains: private – private and public – private, depending upon the origin of the transacting parties. As it can be noticed the second is inclusive of the first.

Beginning with the private-private domain, it can be noted that central to the origin of transaction costs is the concept of contractual hazards, which rises in the confluence of bilateral monopoly, incomplete contracts and opportunistic behavior. The simultaneous presence of these three ingredients is required for the existence of transaction costs. Incomplete contracts in the company of opportunistic behavior but without the presence of asset specificity to create a bilateral monopoly would mean that the parties can easily and with little cost recur to the market to find a substitute for the transaction. Likewise, a bilateral monopoly in conjunction with opportunistic behavior but confronted with a perfectly complete contract would mean that all the required provisions for adaptation were incorporated in the agreement from the outset, leaving no space for appropriation of quasi-rents. Finally, if opportunistic behavior was suppressed from the exchange even in the presence of contractual gaps and bilateral monopoly the transaction would be subject to fair adaptation, in which neither of the parties would feel tempted to increase their gain at the expenses of the other.

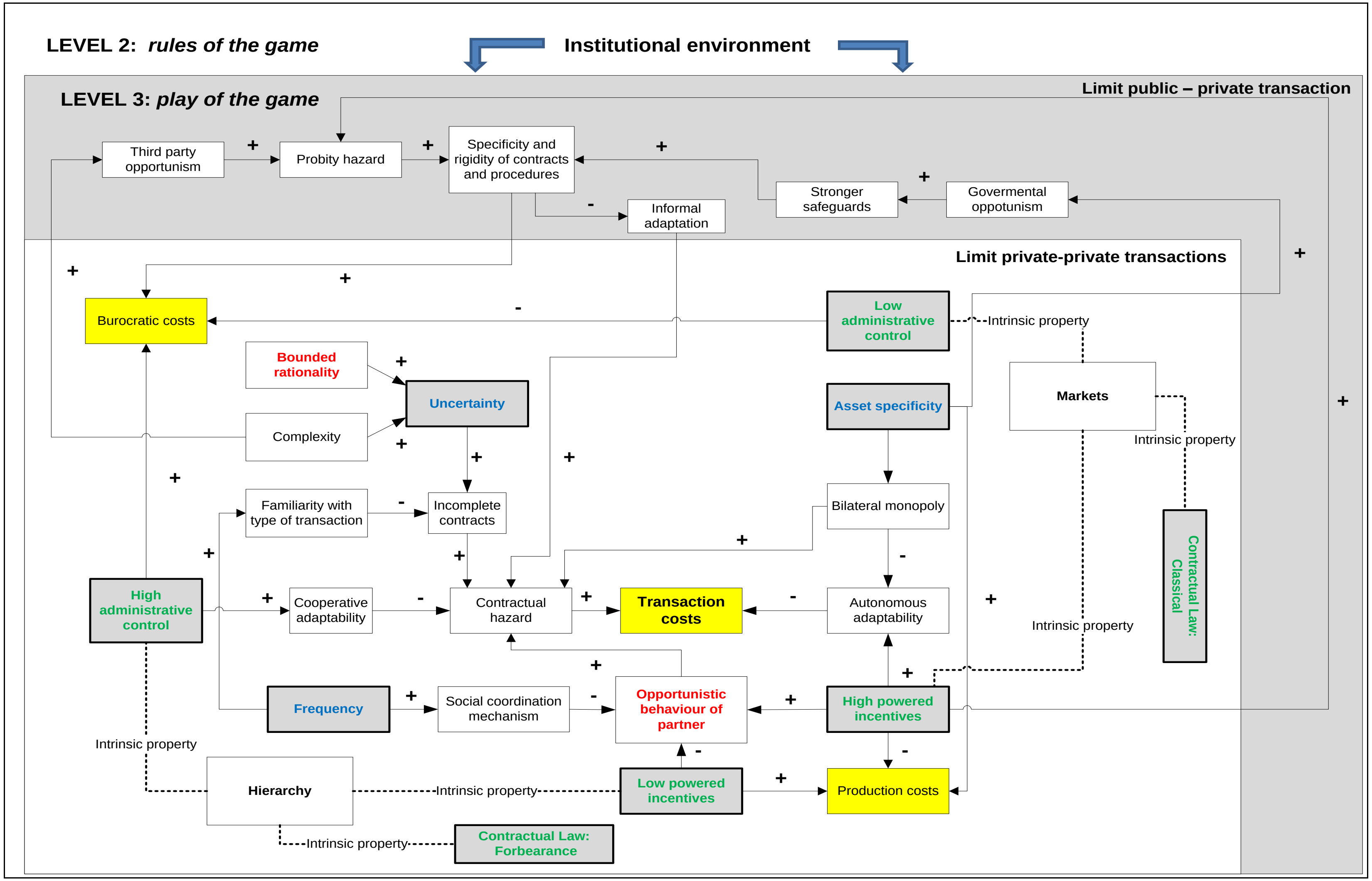


Figure 3.2: causal diagram transaction costs.

As introduced in the previous section, if one of the transacting parties is a public organization, the limits of this system are expanded to incorporate two additional classes of opportunism. The first is governmental opportunism, which is foster by high sunk investments with a long payback period as well as by centralized governmental power and weak judicial apparatus. In the other hand, in the presence of complexity and political fragmentation, third party opportunism is prompt to appear, causing probity hazards for both public agent and private party. These two new types of opportunism increase the specificity and rigidity of the contractual procedures, resulting in a direct increase of the transaction costs and in a reduction of the potential for informal adaptation, further enhancing the contractual hazard in the presence of unanticipated events.

As it was mentioned before an analysis just focusing in transaction costs is truncated in the sense that neglects the existence of other sources of cost which should also be taken into consideration when deciding about the optimum organizational arrangement. In **figure 3.2** two additional types of cost are introduced, restricting transactions cost to those expressly incurred in using the market. First, production cost is theoretically and directly affected by the intensity of the incentives. Driven by a profit maximization function, market with its inherent high powered incentives provides the strongest motivation to minimize production cost and introduce improvements in the production process. This motivation however comes at the price of a consequent increase in the tendency to act opportunistically and to trigger a raise in the transaction cost under conditions of bilateral monopoly and incomplete contracts. The latter can be mitigated by enhancing the cooperative adaptation of the system with an increase in the levels of administrative control, but this at the same time boost the bureaucratic costs linked to such administration. An increase in the rigidity of contractual procedures induced by governmental and third party opportunism could also be expected to amplify the latter. As it can be inferred it should be possible to reach an optimum at the point in which a reduction in transaction costs is perfectly offset by an increase in production and bureaucratic costs.

A graphical example taken from Williamson (1989, p. 150-154) will be provided to illustrate this effect. For the sake of simplicity asset specificity (*s*) will be assumed as the principal dimension explaining vertical integration and therefore the only variable included in the analysis, assuming a constant and middle level of frequency and uncertainty. Transaction, bureaucratic and production costs are denoted as *T(s)*, *B(s)* and *P(s)*, respectively. Moreover, only the two polar modes of governance are taken into consideration. Production cost is assumed to apply both to market and hierarchy, while transaction cost applies to the former and bureaucratic cost to the latter. The total cost of a good or service provided by using the market or hierarchy is given by the following formulas:

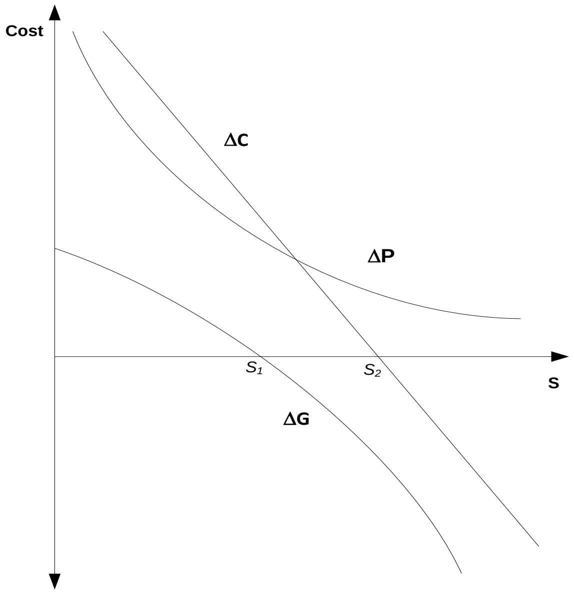
$$C(s)_h = P(s)_h + B(s) \qquad \textbf{(Eq.1)}$$

$$C(s)_m = P(s)_m + T(s) \qquad \textbf{(Eq.2)}$$

The total difference in cost by using one mode of governance instead of the other one can be expressed in the following manner:

$$\Delta C = C(s)_h - C(s)_m = [P(s)_h - P(s)_m] + [B(s) - T(s)] = \Delta P + \Delta G \qquad \textbf{(Eq.3)}$$

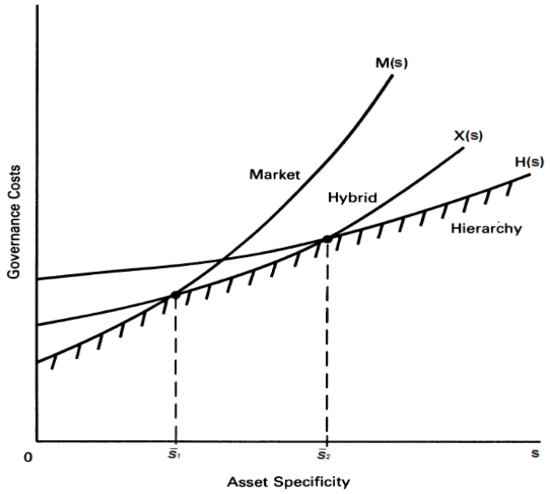
In this expression ∆P and ∆G are the differential production and governance costs, respectively. Each of these differentials, including the total cost, is plotted against asset specificity in **figure 3.3**. Several simplifications and assumptions should be remarked. First, it has been assumed that market always yields lesser production costs than hierarchy, and that this difference tends to be smaller for higher asset specificity due to the lost in economies of scale. In addition, after certain level of asset specificity (S_1) the organization of the transaction is cheaper by hierarchy than by market, because of the intrinsic contractual hazards and need for cooperative adaptability. The breakeven point for the total cost of the good or service occurs at S_2, when it is in overall more economic to opt for vertical integration.



Source: (Williamson, 1989, p.153)

Figure 3.3: **cost differentials vs. asset specificity.**

Considering the governance costs as the central point of analysis, an example is taken from Williamson (1991, P. 282-284) to make a theoretical comparison between the governance costs of the diverse organizational structures when confronted with different levels of asset specificity. As it is shown in **figure 3.4** when the latter is low the preferred governance structure is market. At this point the contractual hazards are negligible enough so as to efficiently rely only in the autonomous adaptation propelled by the market´s high powered incentives as an adjustment mechanism in the case of changes. Nevertheless when the asset specificity increase further than S_1 those contractual hazards created by the bilateral dependency become sufficiently relevant and the autonomous parties cannot be entrusted anymore to efficiently steer the adaptation in isolation. Additional mechanisms should be incorporated in the agreement to induce flexibility in the presence of variations to the original conditions so as to reach adjustments in a non automatic and coordinated way. Finally, when the asset specificity is too high (i.e., bigger than S_2) the contractual hazards created by the prospective appropriation of quasi rents are too costly for parties to act as autonomous entities. Hierarchy, in which the independence of buyer and supplier is replaced by fiat, becomes the most cost efficient form of organization.



Source: (Williamson, 1991, p. 284)

Figure 3.4: **governance costs as a function of asset specificity**

So far and to simplify the analytical exercise uncertainty and frequency have been assumed to be constant and to hold a middle level of intensity. Despite the fact that the predictive power of TCE has been placed more heavily in asset specificity than in any other dimension, these two attributes have an importance in the selection of the optimum governance structure that cannot be neglected. It is convenient to represent them as attenuating or amplifying factors to the need of induced adaptability in the relationship between the parties. As it can be seen in **figure 3.5**, at very low and very high levels of asset specificity market and hierarchy respectively are best structures to organize transactions because of their already discussed intrinsic properties. The zone in between is ruled by the hybrid organization, with boundaries that are not fixed and that move in function of these complementary dimensions. Under low levels of uncertainty and high frequency of exchanges the market is able to efficiently cope with higher levels of asset specificity, because opportunistic behavior is restrained by social mechanisms and contracts can be completed more easily in the presence of lower system complexity and familiarity with the nature of the transaction. In the same manner, if uncertainty is high and frequency is low it can be expected from contracts to be less complete and parties more tempted to opportunistically increase their short term gains at the expenses of the other. In this case, the efficient zone of hierarchy is extended to cover lower levels of asset specificity.

Following the line of reasoning exposed so far in this chapter it is possible to venture in the anticipation of the plausible effects of introducing public contracting in the model delineated above. Taking as a starting point that public contracting tends to have more rigid contractual procedures as well as restrictions to relational agreements, it is to be expected the adaptation mechanisms to be fewer in comparison with contracting in the private domain. These limitations in the adjustment capacities should lean to vertically integrate at lower levels of asset specificity than an equivalent private organization would do (i.e. an organization which follows exactly the same purpose). The effects in the boundaries between market and hybrid structures are less obvious but ceteris paribus it could also be expected for a hybrid arrangement to be adopted at lower levels of asset specificity, principally because social mechanisms should be less effective in restraining opportunistic behavior when there is less possibility for the parties to develop a close and long term relation.

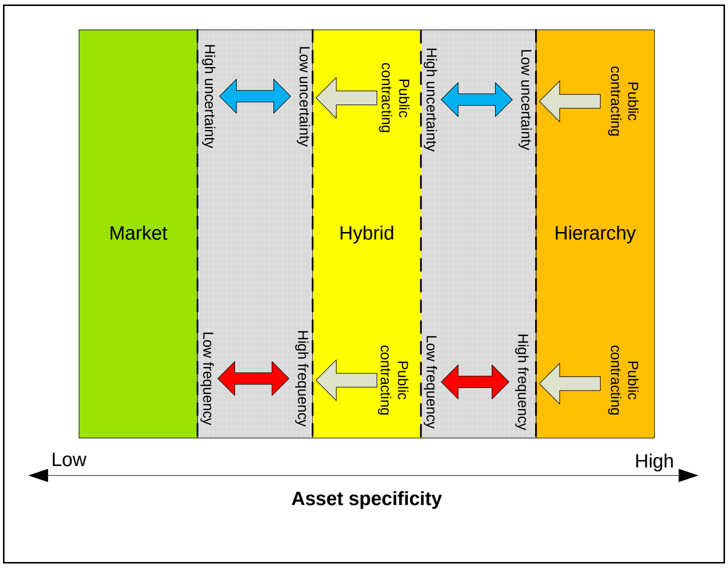


Figure 3.5: conceptual boundaries for governance structures

3.1.6 Operationalization

For the purpose of this research it was essential to extract from the case study a characterization of the transactions and the selected governance structure. Because the theory is lacking of a uniform operationalization of its main constructs (David and Han, 2004) a set of tools were designed to facilitate this process, as it is presented below.

Study of transactions

Three attributes have been distinguished as relevant for the study of transactions: asset specificity, uncertainty and frequency. Despite the extensive literature concerning the first of them, so far asset specificity has been just loosely defined; it has multiple dimensions for which a straightforward measurement mechanism is lacking (De Vita et al., 2011). To overcome this an analytical framework was crafted using as a starting point the different kinds of asset specificity proposed by Williamson (1985, p. 55): human, physical, site and dedicative. In addition to this a fifth type proposed specifically in the context of construction operations by Masten et al. (1991), temporal specificity, was also included.

Physical specificity refers to the degree an investment in physical assets (e.g. equipment and tools) is tailored to fit a specific transaction and its alternative uses are few (Joskow, 1988). One simple way to analyze the extent of physical asset specificity is to measure the uniqueness of equipments and tools required to undertake a production process (i.e. design specific characteristics). Intrinsic to this approach is the assumption that the degree of customization is an indicator of the ease to find a replacement in the market if a disturbance between supplier and demander occur, less customization meaning more offer.

Human specificity is related to the extent unique skills and experience are required to conduct a specific transaction. This attributes commonly arise from learning by doing (Williamson, 1985), and may have little value outside the ambit of the transaction (Masten et al., 1991). It has also being related to the extent that the knowledge required to conduct a transaction can be easily standardized (Sridharan and Akroyd, 2011). For instance, for low levels of human asset specificity clear guidelines can be implemented to conduct the work and used to evaluate performance, while for high levels of specificity this ex-ante prescription is not easily achieved and specific solutions should be crafted based in specialized transaction specific knowledge. Therefore human asset specificity can be described not only in terms of the degree of idiosyncratic knowledge needed to conduct a transaction, but also how difficult it is to transfer this knowledge.

Site specificity arises when proximity is important in order to reduce process related costs (De Vita et al., 2011) and when the assets are highly immobile (Joskow, 1988), in other words, when there is a high cost attached to their relocation. As was noted by Shelanski and Klein (1995) many authors use the distance between contracting firms as a proxy for site specificity. Nevertheless, it is fair to say that this approach has at least two major flaws. First physical proximity may be just circumstantial and does not give a clear indication of the real importance closeness have in the context of the transaction. Second, specificity should be an intrinsic dimension of the transaction and not the dependent variable of the particular selection of transacting party. It is reasonable to infer that a better proxy is the relative significance transportation costs holds in the total cost of the supply. A scale can be provided based on the geographical extent at which transportation becomes the major cost contributor. In order to have a complete perception of this type of asset specificity the latter should be analyzed in conjunction with an indicator of the importance attached to the relocation costs of the production facilities.

Temporal specificity is represented as the difficulty of replacing a supplier, which introduces the possibility of strategic holdups (Masten et al., 1991). It has also be linked to transactional relationships where timing and coordination are critical (Lamminmaki, 2005). It can be noticed that this two definitions explain different attributes of the transaction, but are nevertheless interrelated. For a strategic holdup to occur not only there should be an impossibility of a soon replacement of the provider, but the late supply should as well have the potential to cause a serious disturbance in the production process (i.e. no slack). No studies were found in which to base the parameterization of these attributes in the context of a construction project. For this reason and supported in the researcher´s experience, as well as the criteria of consulted experts, a measurement method was proposed based on the slack of the transaction, as well as the replacement time of the provider in terms of the project´s total duration.

As was noted by De Vita et al. (2011) the difference between dedicated specificity and physical specificity is hard to articulate and it refers to investments in general purpose assets (i.e. not specialized) which rationality is associated to the prospect of a long term relationship with the transacting party. This may derive in a situation in which a surplus of capacity would be left to the provider in case the contract is ended before time (Joskow, 1988). The extent to which new capacity is required from the market to support the transaction can therefore be taken as a proxy to measure this type of asset specificity.

The second relevant attribute is uncertainty, which was framed earlier as the result of bounded rationality and complexity. The former is a human quality and therefore for the sake of simplicity will be considered as a constant. In this manner the variable that should be directly measured as an indicator of uncertainty is complexity. In the context of project management Whitty and Maylor (2009) have divided complexity in two categories: structural and dynamic. Structural complexity refers to systems that consist of a large number of interacting components, while dynamic complexity refers to the extent that the elements and interactions of the system are subject to change. This thesis subscribes to the idea that change and adaptation are the essential problems in economic organizations (Tadelis and Williamson, 2010, p.7) and that while important for the management of the system structural complexity in isolation has relatively stable qualities (Maylor et al., 2008). The attention should be focused therefore to identify those dynamic features that could change the specifications of the transactions in a manner that could not be anticipated in the original contract. A qualitative scale is provided for this purpose.

Frequency is the last dimension and has two main effects that are relevant for this study. First a frequent interaction between the transacting parties is expected to activate social mechanism to restrain opportunistic behavior, with a corresponding reduction of transaction costs. Secondly it should make the contracting party more familiar with the type of transaction, which in turn is conductive to more complete contracts and with a consequent reduction in the contractual hazards. Therefore the nature of this dimension is twofold and its parameterization should be based in the measure of both components.

Based on this argumentation, a synthesis of the analytical framework that has been constructed to operationalize the study of transaction is provided in **table 3.2**. As it can be stated each type of attribute is measured in low, medium and high according to a set of qualitative criteria.

Table 3.2: analytical framework for the study of transactions.

Dimension		Criteria	Low	Medium	High
Asset specificity	Physical	Customization of physical assets	No customization of equipment and tools	Partial customization of equipment and tools	Fully customized equipment and tools
	Human	Idiosyncratic skills, knowledge and experience	Required skills, knowledge and experience are of general use in construction operations	Required skills, knowledge and experience are specific to this type of operation, but could be applicable to other transactions	Required skills, knowledge and experience have limited applicability to this specific transaction.
		Difficulty of knowledge transfer	Work can be easily standardized. Time required to transfer knowledge is negligible in terms of the project duration.	Not every element of the work is subject to standardization. Learning by doing and/or other type of formal training is required. Time required for knowledge transfer may take a relevant percentage of the project´s duration.	Work is not subject to standardization. Extensive learning by doing and/or formal training is required. Time required for knowledge transfer may exceed the duration of a single project
	Site	Importance of proximity	Transportation cost is negligible in comparison to production cost.	If produced outside the country the transportation cost becomes more important than the production cost.	If produced outside the region the transportation cost becomes more important than the production cost.
		Relocation cost	Mostly mobile production facilities easily re-deployable in other setting with negligible installation cost	Mostly fixed production facilities, its deployment could be feasible in the context of this project only, but their installation cost is not longer negligible.	Fixed production facilities, which installation cost cannot be justify in terms of this project only
	Temporal	Time criticality	Activity with total slack of more than 5% of project´s total duration	Activity with a total slack of less than 5% of project´s total duration	Activity is in critical path
		Difficulty to arrange replacement	Time to have replacement operational less than 1% of project´s total duration	Time to have the replacement operational between 1% and 5% of project´s total duration	Time to have the replacement operational more than 5% of project´s total duration
	Dedicative	Market capacity	Local capacity is sufficient to support the transaction without any adjustment.	Local capacity needs to be increased, but could be at least partially used in other transactions. If the works are big enough, international providers can also be used as an alternative	Either local or external capacity needs to be increased and its use is exclusive to this specific transaction
Complexity		Likelihood of non-anticipated changes in conditions	All the relevant changes that could affect the specification of the transaction can be anticipated from the outset	Not all relevant changes that could affect the specification of the transaction can be anticipated from the outset, but in normal conditions their possibility of appearance is fairly low and therefore not a major cause of concern.	Not all relevant changes that could affect the specification of the transaction can be anticipated from the outset. In normal conditions their possibility of appearance is relevant enough to make these potential changes a major cause of concern.
Frequency		Transacting party	The provider is not expected to interact again with the organization.	The same provider is expected again in the future, but does not holds exclusivity	The same provider is expected in every construction project conducted by the organization.
		Type of transaction	Novel	Recurrent in some construction projects conducted by the organization	Recurrent in every construction project conducted by the organization

Study of governance structure

By now it should be clear that adaptability is central to the theory of transaction costs of economics. As it was explained in section 3.1.3 each type of governance structure have intrinsic qualities regarding the manner in which adjustments are conducted in the production process, and these qualities are the ones that guide the discretional selection of the optimum transaction cost economizing organization. From previous sections it can also be extracted that the fundamental difference between the three generic governance structures resides not only in the nature of the adaptation process, but as well in the enforcements procedures. In this sense this study subscribes to Ménard´s (2000) perspective of contracts as frameworks for organizing and coordinating transactions, in which enforcement mechanism are not only essential but also directly associated to different governance structures.

Consequently, adaptability and enforcement mechanisms are used as the main criteria to classify the selected governance structure. From the perspective of the organization under study the foreseen agreements[4] to be established between demander and supplier[5] to conduct the transactions should be analyzed in terms of the planned provisions with regards to these two aspects. A further detailing of the elements that should be extracted from these foreseen agreements is pertinent to make this strategy operational.

Following the line depicted in section 3.1.3 regarding the relevant contract law traditions, adaptation can be induced in the agreements by means of the following three mechanisms:

- ***Closed end provisions:*** confronted to change adaptation is either not possible or restricted to the limits imposed by closed end provisions that specify from the outset the scope for the adjustments. This level is associated to classical contract law.
- ***Open end provisions:*** the possibility to make adjustment to ongoing exchange to unforeseen circumstances is included in the agreement by means of gap filling provisions, such as good faith, reasonable commercial standards, prior dealing, customary industry practices (Cannon et al., 2000), or others open to interpretation. This level is associated to neoclassical contract law and relational agreements.
- ***Discretionary decisions:*** adjustments are coordinated directly by a hierarchical system with the capacity of taking discretionary decisions to fill any gap of information in the agreement. This level is associated to forbearance.

Likewise three different enforcement mechanisms can be introduced in the agreement: self enforcing, complementary dispute settlement and internal private ordering. Until this point these mechanism have been just briefly discussed, and therefore a further explanation has been deemed relevant.

According to Telser (1980) a self enforcing agreement is one in which if one party in an exchange fails to fulfill his obligations the only option for the other party is to end the agreement. In other words, there is no intromission of courts or any other third party. The

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[4] The contracts to be used have not been fully written yet. The foreseen agreement is the closest proxy available, as will be explained in section 5.1.

[5] In this case the demander is the organization under study (ICE) and the supplier could be either the same organization (i.e. vertical integration) or an independent party.

sanctions for deferring the agreement are of private nature and mainly consist of the direct losses of finalizing the exchange and reputational damage within the market (Klein, 1996). Ménard´s (2000, p. 242) definition of self-enforcement is nevertheless more extensive:

> *" Self enforcement [is] understood as a set of clauses based on mutual consent among partners with no arbitrariness in their implementation and, therefore, no need for intervention of a third party (for example, penalties for delays are automatically implemented)"*

The set of clauses mentioned above are meant to rearrange the private enforcement capital[6]in a manner that reduces the possibility of breaches in the agreement, as for example by *"allowing valuables to be held hostage"* (Clague et al., 1999, p. 187). Another element that can be extracted from Menárd´s definition is the lack of subjectivity of the enforcement mechanism; it is formal, complete and easy to apply. Any divergence with the contractual terms can be easily measured, which makes less probable a recursion to courts or other third party for dispute settlement.

It should be noted that contract completeness is not a requisite for the application of self enforcement mechanism. This mechanism is trusted even when performance cannot be verified by direct measures, in which case parties rely mainly in what Scott (2003, p.1645) has called *"reciprocal fairness*". Nevertheless for the purpose of the categorization proposed in this section only those procedures which imply an objective measure agreed beforehand by the parties are taken as to be self enforced.

When asset specificity and uncertainty increase relying solely in self enforcing mechanisms may result insufficient to support the exchange. This calls for the inclusion of complementary dispute settlement mechanisms which may involve parties external to the contractual ambit (Ménard, 2000). These third parties include not only public courts, but also other disputes settlement services provided by the private sector, such as arbitration. The incorporation of the latter mechanism is what Williamson refers as *"trilateral governance"* (1985, p. 74-75), which offers advantages over litigation in providing flexibility, gap filling and continuity to the exchange.

The last type of enforcement mechanism is the internal private ordering that occurs by mean of hierarchy when the transactions are vertically integrated in the same organization. Within the legal limits managers have the discretionary power to settle any discrepancy between the parties and to enforce any course of action considered appropriate for the transaction to follow.

Based on the above characterization of adaptation and enforcement mechanisms, the analytical framework for the classification of governance structures is finally presented in table 3.3. As it can be stated every generic governance structure is matched to a pair of mechanisms, which nature can be directly deducted from the transactions´ foreseen agreements.

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[6] Private enforcement capital is defined as the cost for a partner to break a contract.

Table 3.3: analytical framework for the study of governance structures

Criteria	Governance structure		
	Market	***Hybrid***	***Hierarchy***
Adaptation	Closed end provisions	Open end provisions	Discretionary decision
Enforcement	Self enforcing	Complementary dispute settlement mechanism	Internal private ordering

3.1.7 Limitations

As was noted by London and Kenly (2001) transaction cost of economics appear to have as many detractors as supporters . An exposition of the theory would therefore be incomplete if a recapitulation of the main limitations usually attributed to it is not as well provided. Williamson (1991) himself recognized four main objections that are commonly made to his exposition of transaction costs of economics. The first is related to the levels of analysis presented in section 3.1.2. An apparent disconnection is argued between the institutional environment, which analytical framework is of a broader spectrum, and the institutions of governance at which TCE subscribes and that is characterized by its micro analytical qualities. The second grievance is about relying on just two polar modes (i.e. market and hierarchy), although hybrid structure has been clearly introduced as a middle level governance mode. The third is that a disproportionate attention has been given to the dimensioning of transaction while governance structures have been left comparative behind. The last complain is that it has been mostly developed with reference to Western capitalist economics, as it was mentioned before in section 3.1.1, even though aspires to be of universal application.

According to Masten (1996) transaction cost are difficult to distinguish and measure because many hazards, such as litigation for bad performance or the failure to adapt to new circumstances, are inherent or concealed in the transaction, while others are simply hard to quantify. Several authors (David and Han, 2004, De Vita et al., 2011) have also noted that the theory is lacking of a uniform operationalization framework, which at the end may have added to the confusion concerning its empirical status. In specific David and Han recognized that the theory is too malleable and that even though this has contributed to its rapid dissemination, it has also lead to a relevant amount of misapplication.

Zajac and Olsen (1993) claims that transaction cost of economics focus on the cost minimization of just one party in the transaction, thus neglecting the interdependence between transacting parties in the chase of shared value. In addition, Robins (1987) argued that the theory has been over ambitiously applied in the study of organizations, even when it relies in an unconvincing model of causal explanation. Applied in a more modest manner, the theory is recognized as promising in giving relevant insights into the organizations´ activities. Pitelis (1998) also expressed his skepticism by arguing that the theory has unstable foundations and that it is short of dynamics and history. Chiles and McMackin (1996) argued that TCE focus mainly in opportunism and bounded rationality as the principal behavioral assumptions, thus ignoring the importance risk preference has in the overall framework. It is claimed that many of the contradictions found in the past empirical research can be addressed by integrating this additional behavioral assumption into the model.

According to Madhok (1996, p.577) transaction costs of economics is “*fundamentally incapable of being a complete theory of economic organization”* because *“the notion of the firm as a bundle of contracts ignores the essential notion of the firm as a bundle of knowledge”.* In other words, it does not acknowledge the fact that bounded rationality also constraints the firm capabilities because it may not possess the necessary knowhow to conduct the production process efficiently. This neglecting of the production side of the firm was also noticed by Langlois and Foss (1999).

In the context of the construction industry, Koskela and Ballard (2006) openly criticized Winch´s (2002) economic based theory of construction management, of which transaction cost is a major ingredient. Three major claims were raised. First, it is stated that transaction cost is just one among many sources of waste during the production process and that production should not be organized based on reducing a specific kind of waste only. Second, in the authors’ perspective the behavior of the supplier affects the production costs in complex manners, although this is not taken into consideration in TCE. Finally, it is noted that the goal of an organization is not restricted to produce cheaply; continuous improvement is also important. In this sense TCE is perceived as taking a static view on production limited to a single contract.

3.2 The construction industry

After having presented in the last section the main theoretical precepts of transactions costs of economics, in this section a brief description of the construction industry is provided. Using as a guideline the principal transactions´ attributes introduced in the last section, three topics are considered of interest: complexity, nature of the interaction between the parties of the supply chain and characteristics of the assets involve in the production process. In addition some peculiarities of the construction segment at which the case study belongs are also presented. The exploration of these points is important in order to assure that the hypotheses proposed in the next section are consistent with the nature of the economic activity under study, as well as to provide a basic understanding of the production process necessary for the proper interpretation of this work.

3.2.1 Complexity in construction

Uncertainty rise from the combine effect of bounded rationality and complexity. Given the fact that construction projects are among the most complex endeavors of any industry (Baccarini, 1996) and that they can be regarded as the temporal locus in which construction firms interact to create the building environment (Winch, 1989) it is plausible to conclude that construction industry is one plagued with uncertainty. The question that naturally follows from this reasoning is what are the specific characteristics of construction projects that make them such complex endeavors?

Complexity is a term much used in construction, but that does not enjoy of a uniform definition among scholars (Gidado, 1996). This research is subscribed to Whitty and Maylor´s (2009) perspective of complexity as an intrinsic attribute of systems composed of a large number of interacting components, in which those components as well as their interaction are subject to change. Acknowledging the fact that large civil engineering projects are by definition structurally complex, our attention will shift to the dynamic dimension of complexity.

Construction is different from other industries in many aspects. First of all every project is designed to meet the requirement of very specific clients and is constructed every time in a different place (González-Díaz et al., 2000). Contrary to other industries characterized by mass production and controlled manufacturing environments, the conjunction of site and requirements specificity makes the construction process one in which traditionally the bulk of the production system is mobilized and adjusted to each construction site (Gann, 1996). The components of the building systems and construction techniques should be adaptive enough to deal with local adjustment, which explain why in comparison with other industries it is unusual to find manufacturers with specific products adapted to particular contractors or construction sites (Dubois and Gadde, 2000). The standardization is mainly of parts (i.e. construction materials or highly adjustable components) produced in large scale by manufactures which enjoy of economies of scale (Dubois and Gadde, 2002). All this elements have lead to the generalize idea that every construction project is a unique endeavor (Vrijhoef and Koskela, 2000, Bassioni et al., 2004, Puddicombe, 2012)

The elements introduced above have various implications that must be analyzed. First if a construction project is created to meet the expectations of a discrete customer, and if the customer has little knowledge about the system under construction, even with the inclusion of a consultant to supply the missing expertise it is plausible to expect an incomplete translation of the client´s requirements into a concrete list of specifications from the outset of the exchange, which lead to changes during the construction process. There is plenty of prove in the construction management literature that this indeed is common (Love et al., 2002, Sun and Meng, 2009) and that construction is an industry mark by the dissatisfaction of clients that at the end don’t perceive value for their money (Egan, 1998). Much of this dissatisfaction comes from the incapacity to cope with changes of perception during the construction process (Ridder and Vrijhoef, 2007).

Even if the client is knowledgeable in the particularities of the requested system, making a perfectly complete design is usually not economically and technically feasible and therefore some level of variation during the construction process is always expected due to changes in the original specifications. In addition the fact that the production process is every time taking place in a different context makes the construction activity always subject to the external factors imposed by an unknown environment. An important element of this environment which is particularly difficult to predict is the ground conditions, not only because they are not evident to the naked eye, but because it is economically unfeasible to conduct a geological survey capable to clarify all possible unknowns, especially considering that its application will be restricted to the scope of a single project. Changes induced by this and many other external conditions associated to the environment, such as weather, are to be expected in any large construction project.

But the effects of site specificity are not just restricted to those changes forced by environmental factors. Being oblige to mobilize every time the production system in function of the project´s location, a spatial centralization of the production means is usually not possible.

Additionally there is little customization of systems and components and construction heavily relies on handwork to perform the integration of the system (Masten et al., 1991) starting from very basic parts and materials. So the production system is not only transferred from project to project but is also subject to the quality and quantity of the local resources, with special attention to the man power for the reasons already discussed. Important changes in the planned conditions can be expected if the contractor is unaware of the characteristics of the local resources (Uwakweh and Maloney, 1991).

Standardized parts instead of customized components and systems also mean a multitude of providers which products are meant for general use. The expected result of this condition is the requirement of site adaptation to couple parts fabricated using different technologies and not specifically designed to fit to each other. The interfaces in which these adaptations occur are often not easy to specify from the outset and demand the explicit coordination of one of the parties involved in the construction project (i.e. the system integrator).

3.2.2 A loosely coupled system

Construction industry strongly relies on competitive tendering as a standard procurement practice for selecting contractors and suppliers (Holt et al., 1995, Dubois and Gadde, 2002). In a context in which the selection is usually based in the lowest bid price, there is a fierce competition within the industry for the construction of projects and the margins of profit are usually low (Seaden and Manseau, 2001, Yeo and Ning, 2002, Bajari et al., 2006). Even though as noted by Lingard et al. (1998) this practice is considered by some as adequate to promote efficiency, much has also been written regarding the negative effects it has in innovation (Sidwell et al., 2001) and in promoting long term relationships between the different participants in the industry (Cox and Thompson, 1997). The fact that every project is seen as an isolated entity, in which today´s partners may be tomorrow´s competitors (Dubois and Gadde, 2000), have profound effects in the manner in which the network of players in the industry is interwoven. The term loosely coupled system, which was adopted to entitle this section, was taken from Dubois and Gaddle (2002) and reflects the reality of an industry whose members exhibit a low degree of interdependency in comparison with other trades.

The selection of suppliers based on lowest price is at first glance very logic and has high face validity as a plausible approach to promote efficiency. The consequences of this predilection are nevertheless far from obvious and demand further attention. Considering that every new construction project has some degree of novelty and is exposed to a wide range of uncertainties, the evaluation of the reasonableness of the tendered price is not always straightforward. There is substantial evidence that demonstrates that cost overruns are the common denominator in construction projects (Flyvbjerg et al., 2002). A fierce competitive environment with low profit margins also means that there are incentives to act opportunistically by bidding a lower than optimum price with the prospect of using the intrinsic complexity of the construction process to maximize every possible gain that can be derived from conditions not originally anticipated in the agreement. Even though construction has been rightly described as a loosely coupled system at the industry level, the high doses of local adaptation required in the construction process within projects create a temporal shift of the coupling patterns from loose in the permanent network to tight in the project domain (Dubois and Gadde, 2002). Construction at the site can be conceived as a tightly coupled chain of fabrication and assembly activities (Ballard and Howell, 1998) with intensive interaction of a wide variety of actors and trades and for which buffer inventories are not always possible (Eccles, 1981a). Under this context an ex ante condition characterized by low interdependency can perfectly well evolve in an ex post bilateral monopoly during the construction process (Voordijk et al., 2000), when the cost of hiring another contractor to finish up the work if the original contractors fails are many times prohibitive (Winch, 1989).

Tendering procedures based in the lowest price in conjunction with the focus of the project as an isolated entity also means that construction lacks of the stability required to achieve an integration of the supply chain based on long term commitments between the parties. The low customization of components and high standardization of parts discussed in the previous section is a reasonable response to this condition. It may also contribute explaining the high variability in the levels of activity experienced by construction companies and the relatively low certainty regarding future work conditions (Eccles, 1981a). This creates an environment in which the workforce has high mobility, increasing and decreasing constantly in function of the ongoing projects (Uwakweh and Maloney, 1991). It also results in an industry that is little inclined for innovation. Even though construction projects are fertile ground for novel ideas and solutions, their loose connection with the permanent network and heterogeneity of the parties involved in future endeavors difficult the diffusion and accumulation of knowledge, and with this the progressive evolution in more efficient production methods if compared with other industries characterized by centralized and more stable production systems.

3.2.3 Production assets

With the possible exception of building materials (Gann, 1997) and the equipment sector (Arditi et al., 1997), construction is an industry that exhibit comparative low levels of investment in research and development (Seaden and Manseau, 2001) and that is not commonly associated with the use of highly sophisticated tools (Laborde and Sanvido, 1994). Construction operations mainly involve the coordination of low technology and labor intensive activities (Masten et al., 1991) associated to the fabrication and assembly of components on site from standardized parts and materials. In the construction industry investment capitals and labor force are clearly the dominant factors of production (Seaden, 1996), with technology relegated to a second place.

The trend toward standardization is also displayed in the characteristics of the machinery and equipment used in the construction process. With the exception of very specific pieces[7], the levels of customization are low and construction equipment is distinguished for having a broad spectrum of uses and a capacity to be deployable further than a single project. Congruent to the decentralization of the production system, construction equipment is in general mobile and with relatively low installation costs in comparison with their capital investment.

Being a labor intensive activity it is interesting to note the scarce volume of research in construction management literature oriented toward a characterization of the industry´s

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[7] A good example is a tunnel boring machine (TBM), which is manufactured to fit the geometry and geological conditions of a specific tunnel.

workforce. In construction projects a vast array of technologies and type of works converge in the construction site (Voordijk et al., 2000). This makes of construction an activity characterized by a large number of labor specialties (Eccles, 1981b, Shirazi et al., 1996), even though a big proportion of the manpower is employed in few relatively low qualified positions (Eccles, 1981a). The variety of trades in conjunction with the uncertainty of work continuity make difficult for construction contractors to meet all possible requirements by means of permanent staff, making subcontracting specially suitable for the construction industry (Lai, 2000). The latter is provided by specialized firms that employ specialized labor and equipment across a larger number of projects in comparison with big contractors, thus providing production costs advantages (Reve and Levitt, 1984).

Roughly speaking the personnel involved in the construction process can be divided in skilled and unskilled. The former includes not only the professional staff in charge of managing, coordinating and supervising the construction process, but also other trained personnel such as foremen, mechanics, and operators. On the other hand, unskilled personnel are the ones directly in charge of the physical work. While skilled personnel enjoys a more stable condition in the construction industry, is the unskilled group the one who contributes the most to the size of the workforce[8] and that at the same time is subject to a higher degree of temporality (Wells, 2001). This is probably the group Winch (2001) had in mind when expressed that construction is notable for being one of the industries the use the most sequential spot contracts to employ staff, in which labor is hired when needed on determinate contract (Williamson, 1985) and paid flat or lump sums for the work.

From all the elements involved in the construction process labor is the most prone to show variability in function of the local conditions. For instance the construction industry in developing countries accounts for three-quarters of the world´s construction workers (Wells, 2001) and is characterized in comparison to developed ones by a large pool of untrained, unskilled labor (Uwakweh and Maloney, 1991). Manpower is also considerably cheaper in these countries and therefore from a financial perspective construction processes are less inclined to mechanization. When there is unemployment or the alternative use of labor has a lower value, there are also economical incentives to increase the manpower utilization[9].

3.2.4 Particularities of heavy construction

The term heavy construction is usually associated with the construction process of large civil engineering projects. Dams and tunnels are archetypical examples of this segment of the construction industry (Vanegas et al., 1993). They are often characterized by involving large scale earthmoving operation, extensive concrete production and placement and systematic use of drill and blast operation (Bartholomew, 2000, Singh, 2009). It represents a different class of construction than building construction, which is characterized by construction of residential,

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[8] E.g., between 60% and 70% of the total workforce estimated by ICE for the construction stage of EDHP belongs to this category.

[9] One of the main selection criteria used to choose drill and blast as methodology to excavate the Porce III Hydropower Project (660MW) conduction tunnel instead of TBM was the fact that it employed more people in a time in which unemployment was high in the region of Antioquia, Colombia. This was confirmed by the researcher during a visit in 2009.

offices and industrial buildings. Despite intrinsic differences exist between the two there is a remarkable scant volume of literature expressly addressing those divergences.

Compared to building construction heavy construction projects usually demand bigger investments and a longer construction time. The final product is frequently public infrastructure for which the government is the most common client and has some degree of knowledge about the procured system. The construction process require in average higher engineering expertise but at the same time require fewer types of trades (Eccles, 1981a, Carty, 1995). In addition it is usually composed by several simultaneous fronts of work that are often spread over a vast geographical region. It is fair to say that heavy construction projects are subject to higher risks than those present in building construction and therefore they follow more extensive campaigns of base line studies (e.g. geological, environmental, economical, etc) design and planning. Sometimes the pre-execution stage can take several years or even decades[10] and involve considerable levels of sunk costs.

The duration of the execution stage and the massiveness of the activities involved in the construction process make heavy construction operations to display characteristics closer to an industrialized production system. For instance the concrete lining of several kilometers of tunnel is a cyclic operation that requires the coordination of several processing and assembly stages which are repeated and improved during a number of years. It also makes the construction process to be heavy dependable of the availability of key local resources. The construction of a large rock fill dam requires millions of cubic meters of processed material that should met specific characteristic and that has to be extracted from quarries in a radius of no more than a few kilometers from the construction site in order to make the project economically feasible. The demand of materials with low added value during the production process is higher than in building construction, increasing the importance of proximity.

Additional characteristics are implicit in the extensive duration of these projects, as well as in their level of investment. Compared with projects in the building environment, large civil engineering projects are executed with a lower frequency. It is plausible to expect the market to be composed by bigger and fewer contractors with the capacity of operating internationally in order to expand their network. For the particular case of large power projects Reve and Levitt (1984) recognized that only a handful of contractors in the world have the financial, technical and human capabilities to directly undertake these endeavors. In an industry that is worldwide composed mostly by a myriad of very small firms (Gann, 1997), these big contractors represent just but a small fraction of the total number of organizations in the industry, even though they are able to hold a higher degree of specialization in their workforce (Eccles, 1981a). Because in construction physical specificity of the assets is directly related to the extent of the market (González-Díaz et al., 2000), some machinery and equipment used in heavy construction projects could be difficult to find in a small construction market[11].

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[10] The basic studies for EDHP began more than 30 years ago.

[11] This is not precisely because heavy construction equipment has a higher degree of customization than the one used in building construction, but rather because its large size and high production rates make their use many times not practical or economical in other kind of construction.

3.3 Synthesis of hypothesis

Up to this point the theoretical framework that supports this study was outlined, focusing on TCE and the relevant characteristics of the construction industry. Before proceeding with the synthesis of the research hypotheses, first it is pertinent to explain how the predictions derived from thereof fit the context of this investigation. As it may be recalled from section 3.1.1, the level of analysis provided by TCE is constrained by both formal and informal institutions (i.e. social framework). In addition, it was also acknowledged that the theory was developed in the context of a free capitalistic market, where the social framework offers conditions supportive of its causal explanation. Nevertheless EDHP is carried out in Costa Rica and constructed by a public company, which at first glance may raise doubts regarding the direct application of the theory in the context of this investigation. To overcome this dilemma the research hypotheses here presented are deliberately based in a set of assumptions that provide ideal market conditions (i.e. a "clean" theoretical connection between transactions and governance structures), but that later on will be checked in the light of the specific constraints imposed by the social framework in which this case study is embedded. Therefore the conclusions regarding the applicability of the theory, to be formulated in the sixth chapter of this report, will be drawn taking into consideration not only the extent of the predictions but also the validity of the supporting assumptions, as it is shown in **figure 3.6**.

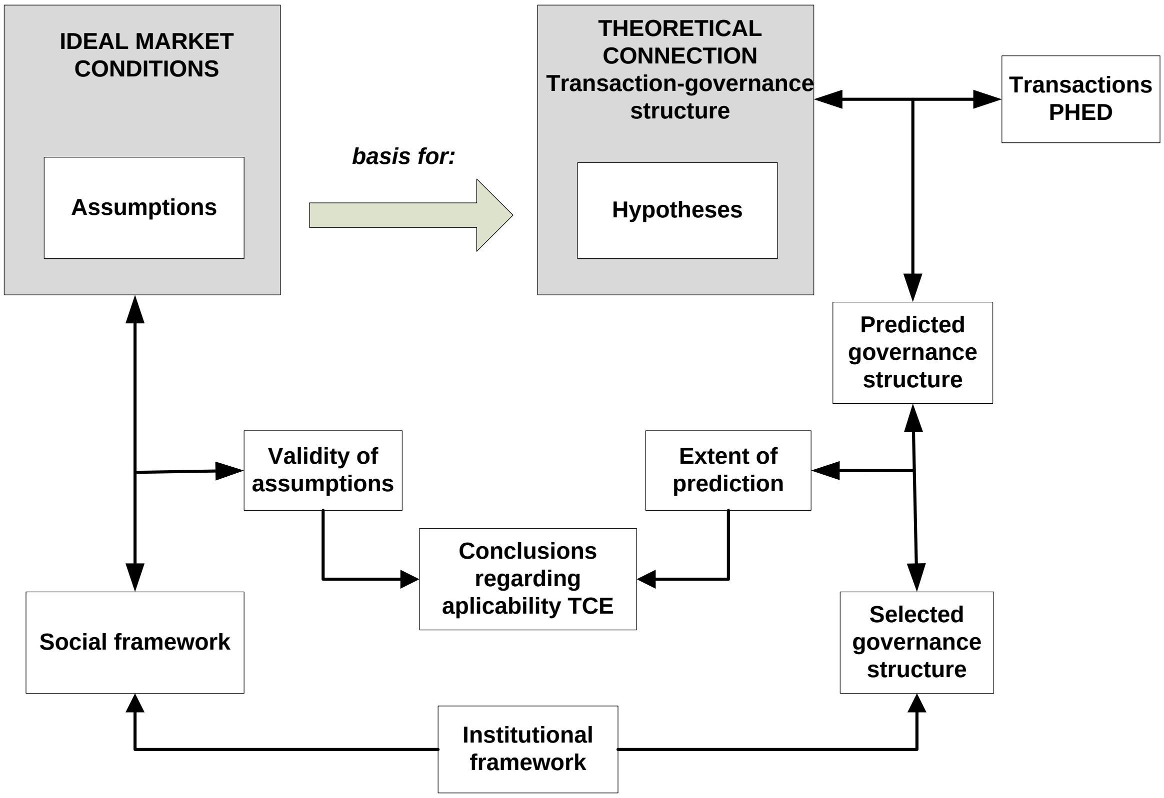


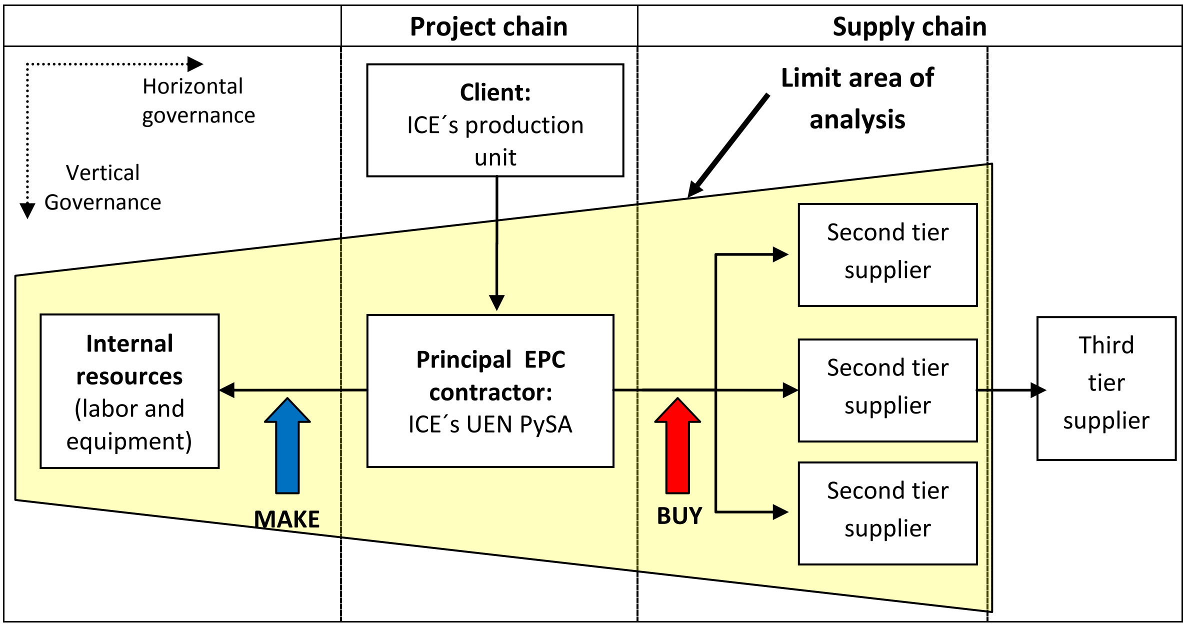
Figure 3.5: research hypotheses in the overall context of the investigation.

A final element should be clarified before starting the construction of the research hypotheses. Many actors participate in a construction project and the approach adopted for the analysis of transactions depends on which of them is the main focus of attention. For the purpose of this research the actor of interest is the engineering, procurement and construction (EPC) contractor, to which the client has commissioned the design and construction of the entire project. At this point, the first of four main assumptions drawn in this section is introduced:

> ***Assumption 1:*** *ICE has in overall the capacity to undertake the project as the main EPC contractor and should decide regarding the organization of the transactions composing the construction process.*

This assumption is important for the general logic of this study. ICE is not only responsible of ensuring that the generation facilities are designed and constructed on time, but it is also a capable design and construction contractor. This makes the decision of how to organize the project considerably different as if only was a procurement agency with no production capacity available. In addition, it matches ICE´s plans of assuming a leading role as the main design and construction contractor for EDHP, and thus the rationality of the selected organization.

A detail of the area of interest for this study is presented in **figure 3.7**. As it can be stated the main client is internal and represented by ICE´s Production Unit, which is the one in charge of giving the approval to the facilities once constructed, as well as of the operation stage. This internal client has already commissioned to ICE´s Unit of Projects and Associated Services (UEN PySA) the design and construction of the project. The basic design is already completed with enough detail to proceed with the make or buy decision. Therefore, taking ICE´s UEN PySA as the main EPC contractor, the area of interest covers the decision of to either undertake the construction process with internal resources or to outsource part of the work. The analysis is limited to the second tier supplier, because it is not possible at this point to make an evaluation further than that nor is the objective of this study to analyze organizations other than ICE. It is important to anticipate that ICE´s being both the client and the contractor has important consequences in the manner the construction process of this project was organized, as it will be extensively discussed in chapter five.



Source: (adapted from Winch, 2001, p.801)

Figure 3.7: **delimitation of the area of interest for the study of transactions.**

After having defined the position of the actor of interest in the supply chain, an ideal setting for TCE´s causal explanation can now be constructed in order to support the research hypotheses. First, in a perfect capitalistic market a firm should be free to choose the manner it organizes its operations, following majorly a profit-maximization function. Under the logic outlined by TCE, this means that it should have the liberty to analyze the transactions implicit in the production process, rank them in function of the contractual hazards and finally align them to a optimum governance structure based to a large extent in the minimization of the transactions costs. The following assumption can be introduced to emulate these conditions:

> ***Assumption 2***: *to organize the construction process ICE has the freedom to procure anything from a single transaction to a complete subsystem of the project, following mainly a profit maximization function.*

Additionally, this ideal market is one to which ICE can resort to procure any transaction implicit in the project´s construction and that offers production costs advantages in comparison to vertical integration. The next assumption follows directly from this proposition:

> ***Assumption 3:*** *the market works well and there is enough supply for the required transactions. In case the governance cost is the same for any given structure the market is preferred because its intrinsic high level incentives derive in lower production costs.*

As was noted by Lie et al. (2012), the accounting practices in the construction industry makes almost impossible a quantification of the transactions costs. This also applies to this project, for which a forecast of the total costs associated to different governance structures is simply out of the reach of this investigation. To overcome this limitation, the total cost of each transaction was assumed to conform to proportions that could be reasonably expected from the theoretical exposition presented in this chapter. These proportions constitute the last assumption taken in this section to support the research hypotheses:

> ***Assumption 4:*** *classifying each transaction attribute in high (H), medium (M) and low (L), the boundaries between each generic governance structure conform to the following proportions:*

$$T_g(S,U,F,g) = G_g(S,U,F) + P(g) \qquad \textbf{(Eq.4)}$$

Where:

$\boldsymbol{S}$ = *asset specificity*= $\{H_s, M_s, L_s\}$

$\boldsymbol{U}$ = *uncertainty* = $\{H_u, M_u, L_u\}$

$\boldsymbol{F}$ = *frequency* = $\{H_f, M_f, L_f\}$

$\boldsymbol{T}$= *Total cost*

$\boldsymbol{G}$= *Governance cost*

$\boldsymbol{P}$= *Production cost*

$\boldsymbol{g}$=*governance structure* = {M, Hy, Hi }

In addition, consider the following subsets:

$$[\,S_1=\{H_S\},\ S_2=\{L_S\},\ S_3=\{M_S\}\,] \subseteq S$$

$$[\,U_1=\{H_U\},\ U_2=\{L_u\},\ U_3=\{M_u, H_u\},\ U_4=\{L_u, M_u, H_u,\},\ U_5=\{L_u, M_u\}] \subseteq U$$

$$[\,F_1=\{L_f\},\ F_2=\{L_f, M_f, H_f\},\ F_3=\{M_f, H_f\}] \subseteq F$$

The following proportions are assumed to be valid:

$$\left. T_{M\ or\ Hy}(S_1,U_1,F_1,M_{\ or}\,Hy) - T_{Hi}(S_1,U_1,F_1,Hi) > 0 \right\} \quad \therefore \text{ Hierarchy provides lower total costs}$$

$$\left. T_{Hi\ or\ Hy}(S_2,U_2,F_2,Hi_{\ or}\,Hy) - T_M(S_2,U_2,F_2,M) > 0 \right\} \quad \therefore \text{ Market provides lower total costs}$$

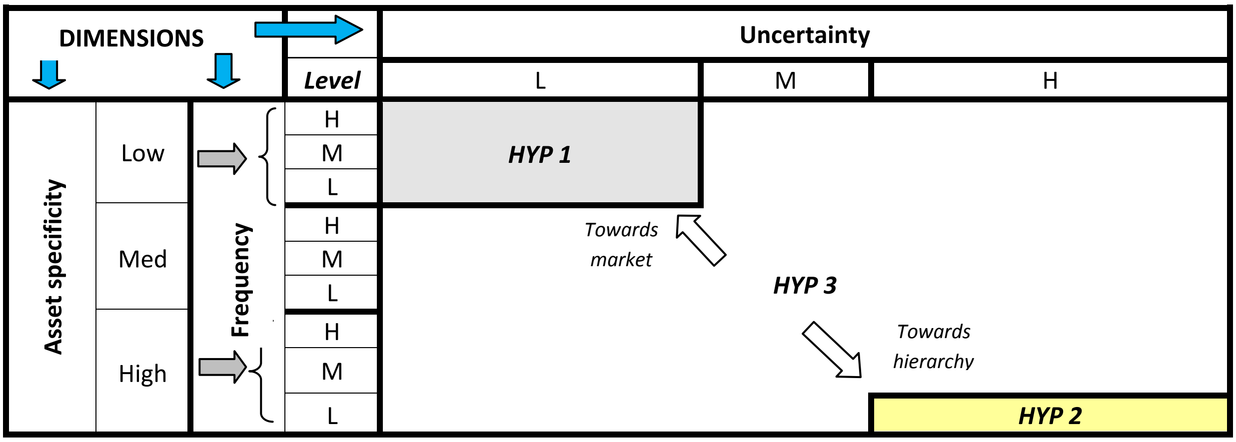
$$\left. \begin{array}{l} T_{M\ or\ Hi}(S_2,U_3,F_2,M_{\ or}\,Hi) - T_{Hy}(S_2,U_3,F_2,Hy) > 0 \\ T_{M\ or\ Hi}(S_3,U_4,F_2,M_{\ or}\,Hi) - T_{Hy}(S_3,U_4,F_2,Hy) > 0 \\ T_{M\ or\ Hi}(S_1,U_1,F_3,M_{\ or}\,Hi) - T_{Hy}(S_1,U_1,F_3,Hy) > 0 \\ T_{M\ or\ Hi}(S_1,U_5,F_2,M_{\ or}\,Hi) - T_{Hy}(S_1,U_5,F_2,Hy) > 0 \end{array} \right\} \quad \therefore \text{ Hybrid provides lower total costs}$$

The research hypotheses follow naturally from these proportions:

> ***Hypothesis 1****: when asset specificity and uncertainty are low, transactions are better organized in the market, regardless of the level of frequency.*
>
> ***Hypothesis 2****: when asset specificity and uncertainty are high and there is a low level frequency in the exchanges that neither contributes to articulate more complete contracts or to introduce social mechanisms to restrict opportunistic behavior, hierarchy is the preferred governance structure*
>
> ***Hypothesis 3****: in situations in between some nuance of hybrid governance structure is more likely to appear.*

A graphical representation thereof is provided in **table 3.4**.

Table 3.4: synthesis of hypothesis.



DIMENSIONS			Level	Uncertainty		
				L	M	H
Asset specificity	Low	Frequency	H	*HYP 1*		
			M			
			L			
	Med		H	*Towards market*		
			M		*HYP 3*	
			L			
	High		H			*Towards hierarchy*
			M			
			L			*HYP 2*

Without any doubt these hypotheses offer a very simplistic model. First, the level of intensity assigned to each transactions´ attribute (i.e. low, medium or high) is determined in this study using qualitative criteria (see section 3.1.6), thus cannot pretend to provide a perfect correlation with the costs. In addition, governance and production cost does not contribute in the same manner in the total cost of every possible transaction. In reality if a cost optimization function is followed the boundaries between each governance structure are not as tightly delineated as is represented by these proportions. Nevertheless, what is of interest here is to identify those transactions that show extreme divergences with the proposed hypotheses. For instance, it should not be expected for a transaction with the characteristics described by the first hypothesis to be organized as a hierarchy, unless there is an important breach in the assumptions taken along this section.

The intrinsic characteristics of the construction industry in general seem to confirm the direction of this set of hypotheses, but some caution is required. As was introduced in section 3.2 a wide variety of trades are involved in a construction project and at the same time there is a high level of uncertainty of work continuity. The industry is usually perceived as being composed by a number of smaller specialized firms that enjoy more frequency of work and hence production cost advantages in comparison with main contractors, which in return find subcontracting an attractive option instead of continually hiring and firing workers. All these elements seem to support assumption 3, in terms of a well functioning market which offer production cost advantages in comparison with vertical integration.

Despite this there are three elements that may cause a disruption in the logic of this argumentation. The first arises from the characteristics of heavy construction projects, which as was explained by several authors (1981a, Carty, 1995), require fewer types of trades and exhibit considerable lower levels of subcontracting. This is also influenced by the fact that contractors involved in this kind of construction are bigger, fewer and with more capability of holding a higher degree of specialization in their workforce.

The second element is the capacity of the local market. As was introduced before, contractors involved in heavy construction projects have international projection. In addition, the physical assets in construction are highly movable; hence the boundaries of the local market may not be so relevant in a project such as EDHP. Still, for a contractor that is already deployed in the country having capable suppliers within its operation range could offer cost incentives which may not be so attractive if it has to resort to international suppliers.

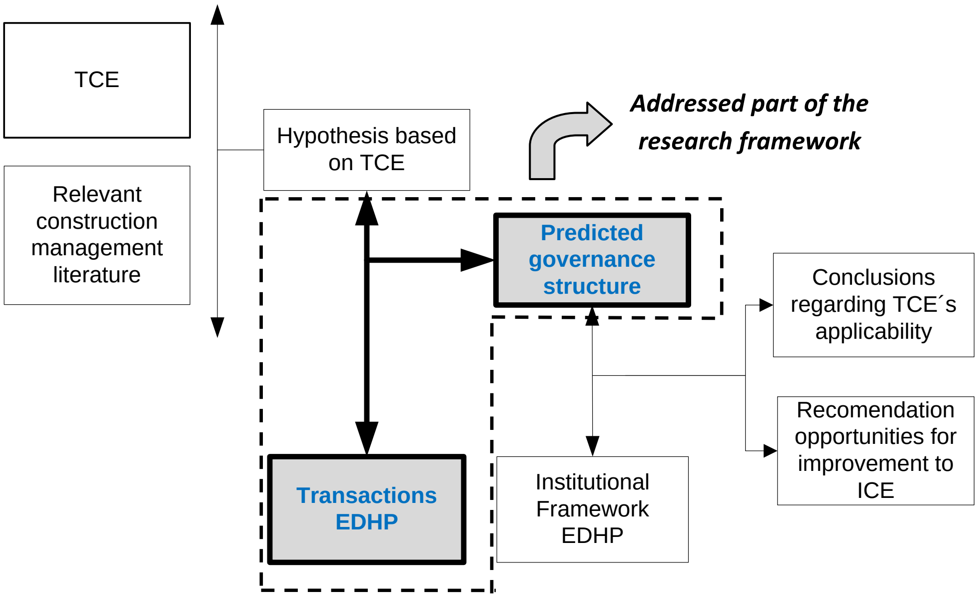
The final disruptive element is the uncertainty of future workload, which was described as being strongly conditioned by the followed procurement strategy. If a procedure other than competitive tendering is systematically used, there may be more certainty regarding future demand and therefore the firm may be less forced to recur to subcontracting as an alternative to balance prospective labor requirements and to commit to fixed capital investments. In essence, these three elements may affect the validity of both assumptions 3 and 4.

A final remark is apposite. The need for local adaptation was also referred as an intrinsic characteristic of construction projects. At the same time, structural complexity has been mentioned so far as inherent to large civil engineering projects, yet its effect in the analytical framework has not been explicitly included. The conjunction of these two elements may have relevant consequences that are necessary to elucidate. A high structural complexity means that the system consist of a large number of interacting components, and between those components there are interfaces, which is precisely where the local adaptations occur.

Understanding transactions as the *"exchange of goods and services between technological separable entities"* (Williamson, 1981, p. 550), by definition interacting transaction could be provided by different parties and therefore analyzed separately following the analytical framework suggested in this chapter. Nevertheless the management of the interfaces may require such a close level of communication between the providers that at the end is more convenient to cluster them in just a single transaction held with the dominant supplier. This effect will be taken into consideration when defining the system boundaries for the study of transactions in the next chapter.

CHAPTER 4

CHARACTERIZATION AND ALIGNMENT OF TRANSACTIONS



Thesis ‘main research questions:

1. What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?
2. **What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?**
3. What are the main characteristics of the EDHP´s (in)formal institutional framework?
4. What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?
5. What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?

Research question to be answered

4. Characterization and alignment of transactions

Having introduced in the previous chapter the main theoretical precepts in which this study is based, in the present chapter the main transactions involved in the construction EDHP were characterized and aligned to a theoretical governance structure. From a methodological point of view three steps were followed in order to conduct this process appropriately, as it is shown in **figure 4.1**. First the study of the research object was accomplished by a thorough analysis of the project documentation, complemented with the researcher´s participatory observation in the project´s planning stage. Of special interest for this purpose was the study of the project´s Feasibility Studies (Ingetec, 2005), the Front End Design´s drawings, specifications and technical reports (Ingetec and ICE, 2010), the Construction Planning and Budged Report (ICE, 2013c), which includes relevant technical elements of the construction process, as well as the Project Management Plan (ICE, 2013b). All these documents, together with others such as Gantt charts, were provided by ICE in digital format to the researcher. To assure the study remained within its practical scope, in the second step the system was broken down and the boundaries set to include just the most relevant parts for the purpose of this investigation. In addition the transactions were clustered and defined in a manner that facilitated their analysis. The final step was the characterization and alignment of the transactions, for which the analytical machinery proposed in section 3.1.6 and the research hypotheses were the principal tools. Triangulation of sources was the main strategy employed to gather the required information, relying on the already discussed documental analysis and participatory observation, as well as interviews with several experts regarding specific points in which reaffirmation or additional knowledge was considered to be relevant.

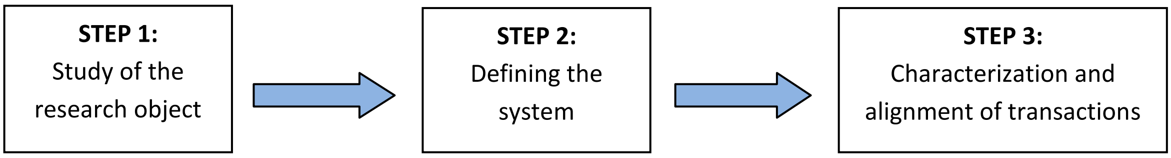


Figure 4.1: **steps followed in the transactions´ characterization process.**

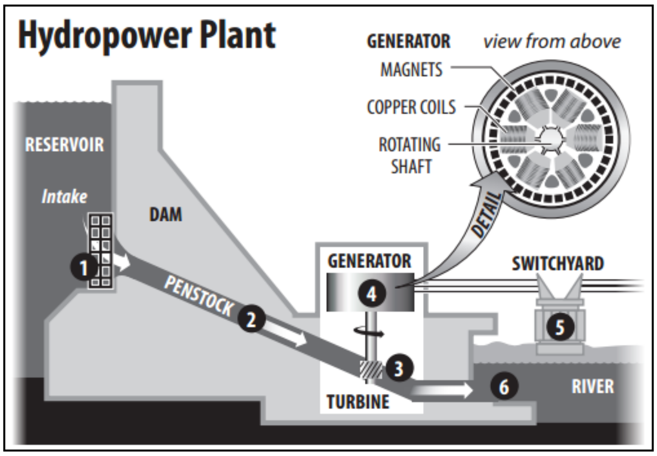
In terms of structure this chapter is divided in two sections. First a description of the most relevant characteristics of the case study project is provided. This includes an explanation of the functioning and main components of a typical hydropower plant, as well as a general overview of EDHP. This first section is complemented with a comprehensive technical data sheet of the latter, which can be found in **annex A.** Afterwards, in the second section the study of transactions is presented. This section synthesizes the results of the second and third steps of the characterization process introduced above, including the system´s boundaries, the selection and definition of the transactions of interest and finally the characterization and alignment thereof to a theoretical governance structure. Two annexes accompany this section. In **annex B** a detailed description of those components of the system selected for this study is provided, while **annex C** is a memory in which the reasoning followed to characterize the transactions is presented in great detail.

4.1 Project description

4.1.1 Type of project

Hydropower projects transform the kinetic energy of falling or flowing water into electricity and currently represent the largest available renewable source of energy. More than 15% of the world´s electricity comes from hydropower and the sector is experiencing rapid growth in regions with high potential like Africa, Asia and Latin America (IHA, 2012). A project with a capacity over 100MW is considered to be a large hydropower project (IRENA, 2012).

The water head[12] and flow are the two main factors that define the capacity[13] of a hydropower plant. The specific configuration of a project is heavily dependable of how these two variables can be conjugated within the possibilities given by the topographical conditions of a selected site. In **figure 4.2** a simplified layout taken from NEED (2012) has been deemed adequate to explain the general operation of a hydropower plant. As it is possible to state the system mainly consists of a dam that creates an obstruction to the natural course of water, which may be accumulated in a reservoir before captured by an intake structure **[1]**. From this point the water travels through a penstock **[2]**, a tunnel, a channel or a combination of all the aforementioned until it reaches a powerhouse in which the force of the water spins a turbine **[3]**. This turbine is connected to a generator **[4],** inside of which the shaft spins coils of copper wire within a ring of magnets, producing electricity. The electricity is then sent to a switchyard **[5]**, where a transformer increases its voltage, allowing it to travel through the electric grid. After used the water flows out of the powerhouse into the downstream river **[6]**.



Source: National Energy Education Development Project, 2012

Figure 4.2: **simplified scheme of a hydropower plant.**

The project layout shown in **figure 4.2** is fairly compressed, being the powerhouse positioned at the base of the dam. In order to increase the water head in many hydropower projects it is common to locate the powerhouse at some distance from the dam site, taking advantage of the local topography and thus extending the length of the conduction works. Large hydropower

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[12] Water head is the distance from the highest level of the dammed water to the point where it goes through the power producing turbine (or the discharge level, for the specific case of a vertical axis Fracis type generating unit).

[13] Capacity (kW) = η x γ xF x (ΔH-h), where η is the efficiency of the generation units, F is the water flow (m3/s), ΔH (m) is the water head, h (m) is the energy loss suffered during the operation of the system and γ (9.81kN/m^3) is the specific weight of water.

projects are usually characterized by covering a vast territorial extension in which the main works are widely dispersed. This is precisely the case of EDHP, as it will be explained in the next section.

4.1.2 General overview

El Diquís Hydropower Project (EDHP) is located in the southern region of Costa Rica and it is one of the government´s top alternatives to satisfy the country´s increasing electricity demand. The project also represents a valuable opportunity for the development of the southern region, which has been characterized by problems such as low productivity and lack of organizational capacity. EDHP is linked to the studies conducted by ICE in the *Grande de Térraba* river´s basin since the 1960´s, decade in which its potential was identified. From the vast amount of studies conducted since then, the feasibilities studies (Ingetec, 2005) and front end designs (Ingetec and ICE, 2010) are the most recent ones.

A general layout of the project is shown in **figure 4.3**. As it can be seen, it is spread over a large geographical region. The dam site is located in the *General Superior* River, approximately 10.5km southeast of *Buenos Aires* city, in the province of *Puntarenas*, between the communities of *Térraba* and *Paraiso*. The reservoir starts from this point and covers approximately 6 800 hectares. Its normal operation level oscillates between 300 and 260 meters above sea level (m.a.s.l), with a maximum level at 310 m.a.s.l. This includes a containment zone for eventual extraordinary floods. The reservoir´s level is controlled by means of a spillway structure placed in the right bank of the dam.

The water intake is located 14.0 km west from the dam site, in what today is known as *Pilas* community. This is where the water conduction starts, with a tunnel of approximately 11.3Km long and an internal diameter of 9.8m that passes across the *Fila Brunqueña* mountain system to exit 3.0 Km north from the town of *Palmar Norte*. The last section of the conduction is composed by a double penstock of approximately 1Km length, which bifurcates in the last segment and connects directly with each of the four Francis generation units located in the powerhouse. The total generation capacity provided by this set of units is of 623MW. Afterwards the water is finally evacuated from the powerhouse to the *Grande de Terraba* River by means of a 2km long channel. A general profile of these works is shown in **figure 4.4**. In addition, a small powerhouse is located in a cavern at the right bank of the dam to take advantage of the environmental discharge[14], contributing with 27MW. The total capacity of the project is therefore of 650MW.

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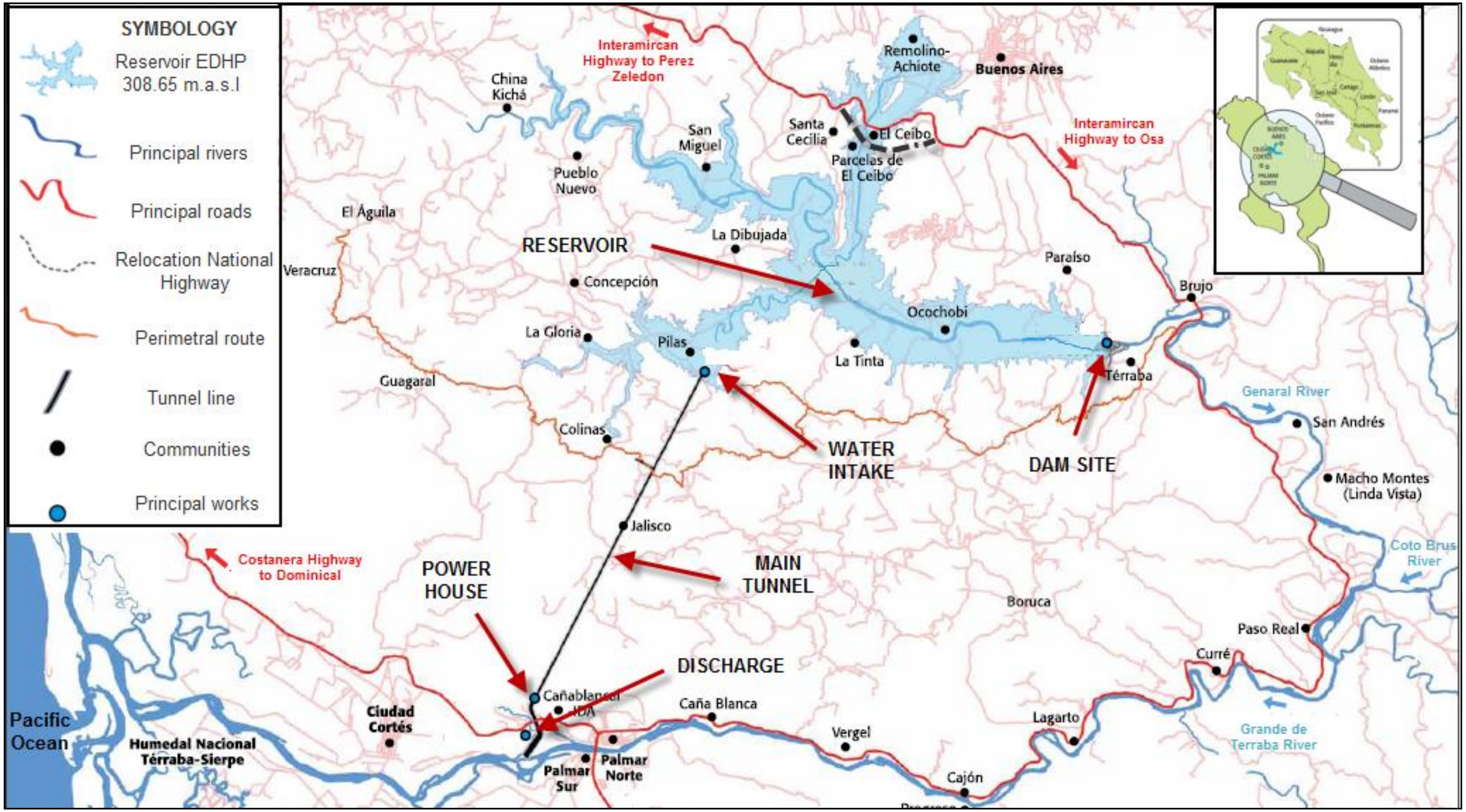
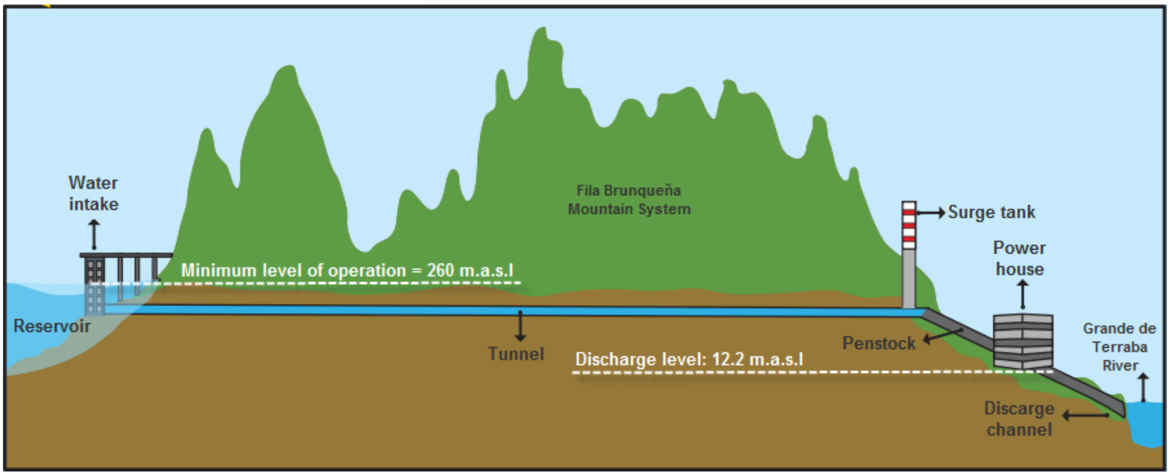
[14] Environmental discharge is the minimum amount of water that is required to support the biodiversity and main human activities downstream of the dam.



Source: Costa Rican Institute of Electricity, ICE

Figure 4.3: **general layout El Diquís Hydropower Project**



Source: Costa Rican Institute of Electricity, ICE

Figure 4.4 profile water intake, conduction system and generation works.

The works described above are part of what is considered to be the project´s permanent works: those physical components strictly necessary for the system to meet the purpose for which it was designed. In addition to this, some facilities or temporary works need also to be constructed in order to support the construction process. In general terms these facilities are comprised by camps, access roads and distribution lines and are undertaken in the earliest of the construction phase. For this project and due to its spatial extension, four camps have been envisioned to support the construction activities, as well as several kilometers of access roads and distribution lines.

It will also be necessary to conduct an extensive program of mitigation and compensation works as part of the commitments included in the environmental impact assessment. The reservoir will flood ten small communities and therefore it will be necessary to resettle approximately 1500 persons. Moreover it will also disturb the current land connectivity between several towns in the area and flood approximately 3.6 Km of the Interamerican National Highway. These will result in the construction of approximately 10 km of new road and in the improvement of over 50 Km of existing one, including a new 1Km bridge over the reservoir to reconnect the national highway. In addition to these, a myriad of smaller construction works will be also conducted, such as water supply systems, communitarian centers, etc.

At present the project´s environmental impact assessment is being conducted, even though a preliminary evaluation was included as part of its feasibility studies (Ingetec, 2005) with favorable results. It currently has a highly detailed front end design (Ingetec and ICE, 2010) which is being used as a basis to prepare the project´s contractual documents. In addition a project management plan (ICE, 2013b) is also available, in which the main elements of the organization chosen by ICE to undertake the project are described. The expected date to start the construction stage is in the second semester of 2014. A total of seven years has been estimated from the moment in which the environmental license is granted to the commercial operation of the last generating unit. The total cost of the project is of USD$ 1.3 billion, without taking into consideration escalation of prices, financial expenses during the construction stage and the transmission system[15]. Taking into consideration the latter the total cost associated to this project reaches approximately USD$ 2.1 billion. A complete technical data sheet of the project is presented in **annex A**.

4.2 Study of transactions

4.2.1 System boundaries

Normally a complex system is broken in a number of subsystems, which can be decomposed further until a division is reached for which its inner workings are not necessary to understand; this is called element (Nicholas and Steyn, 2012). Taking as a starting point Williamson´s definition of transaction as *"the exchange of goods and services between technologically separable entities"* (1981, p.550), a complex system such as EDHP can be divided in thousands if not millions of interacting elements that theoretically speaking fulfill this criterion. In order to keep this research within its practical scope it is first necessary to conveniently break down the system and to select the boundaries of the area of interest in a manner that just those elements that are relevant for the purpose of this study are taken into consideration.

A construction project can be broken down following many different criteria: physical parts, geographical location, phases of development, processes in the chain of production, etc. For the purpose of this thesis it has been deemed appropriate to define the research space in the conjunction of two different breakdown strategies: physical parts and trades involved in the construction process. In essence both divisions meet a different purpose. While the first is useful to map the different parts of the project and guarantee no element of importance is being left behind, the second is a convenient way to cluster the main transactions involved in the project´s construction. Once broken, the system boundaries can be placed in order to selectively restrict the scope of the study. The transactions of interest are those in the intersection of trades and parts and within the research space, as is conceptually represented in **figure 4.5**.

From the three categories of works introduced above, the attention of this study will focus just in the permanent works, which are composed by five major subsystems: dam works, intake works, conduction works, generation works and reservoir works. Together these subsystems account for approximately 90% of the total project´s budget (ICE, 2013b). This selection reduces significantly the scope of the study, while assuring that the most relevant and representative works of a hydropower project are being taken into consideration. The breakdown structure of the entire system and the selected boundaries are presented in **figure 4.6**. A detailed description of each of the five selected subsystems is presented in **annex B.**

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[15] The transmission works associated for this project consist mainly in the construction of 130Km of a new two circuit's 230KV transmission line, and the reconstruction of approximately 100Km of existing single circuit lines two adapt them to a double circuit. This is organized by ICE as a separate project..

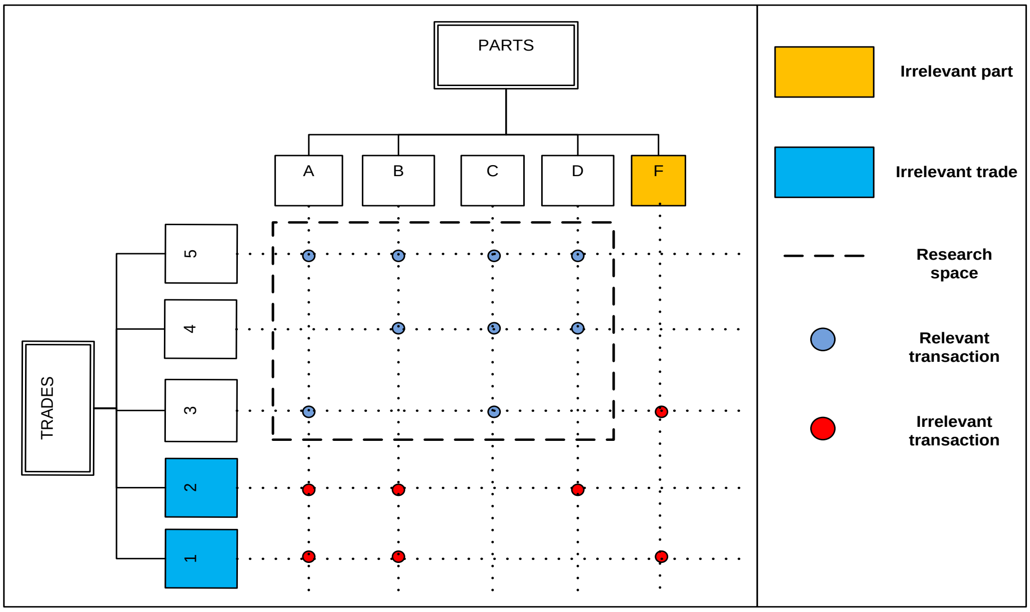

Figure 4.5: **definition of research space.**

As introduced in section 3.2 the practice of subcontracting in construction has the characteristic of being organized in specialized trades. Heavy construction has, for the purpose of this study, the advantage of involving fewer types of relevant trades (Eccles, 1981a) in comparison with building construction. In general terms and focusing on the main works attached to the construction of a large hydropower project, five main trades are of importance: concretes, earthmoving, tunneling, electromechanical works and metal works. This division is congruent with the characterization of heavy construction operations provided in several relevant sources (Bartholomew, 2000, Singh, 2009). Besides these there are also other trades that are required to a lesser extension, as for example finishing works within the operation facilities, landscaping of the project´s area, information technologies for the interconnection of the different facilities to the control center, among others. Nevertheless the works included within these secondary trades represent less than 5% of the total project´s budget (ICE, 2013b) and have been considered not relevant for the purpose if this study. A detail of the selected trades and their main division in presented in **figure 4.7**. Each sub trade has been allocated in those parts of the system in which they will be required for the construction process, as presented in **table 4.1**. For the purpose of this study each individual allocation should be considered a potential transaction (PTs).

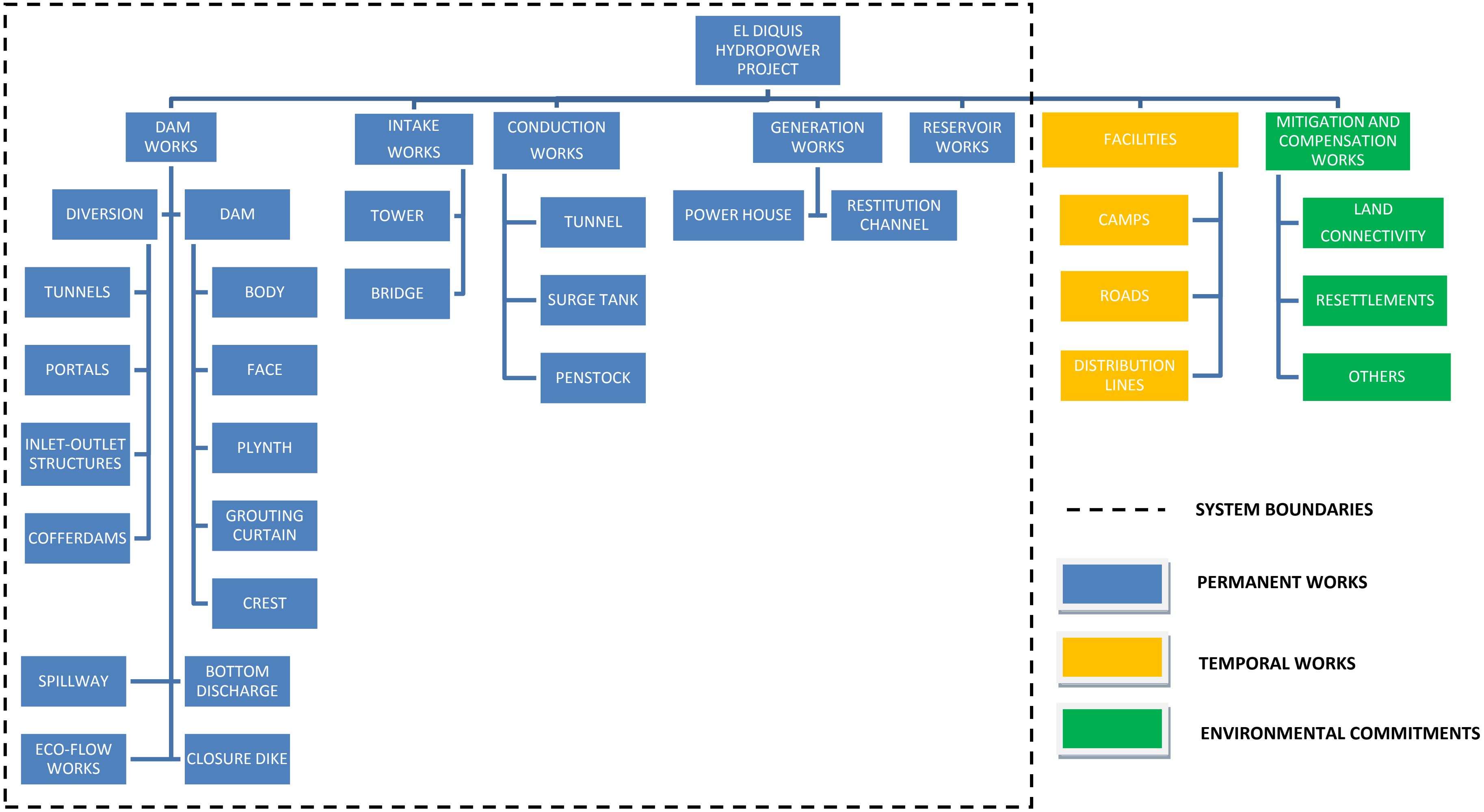

Figure 4.6: El Diquís Hydropower Project´s system breakdown structure and selected boundaries

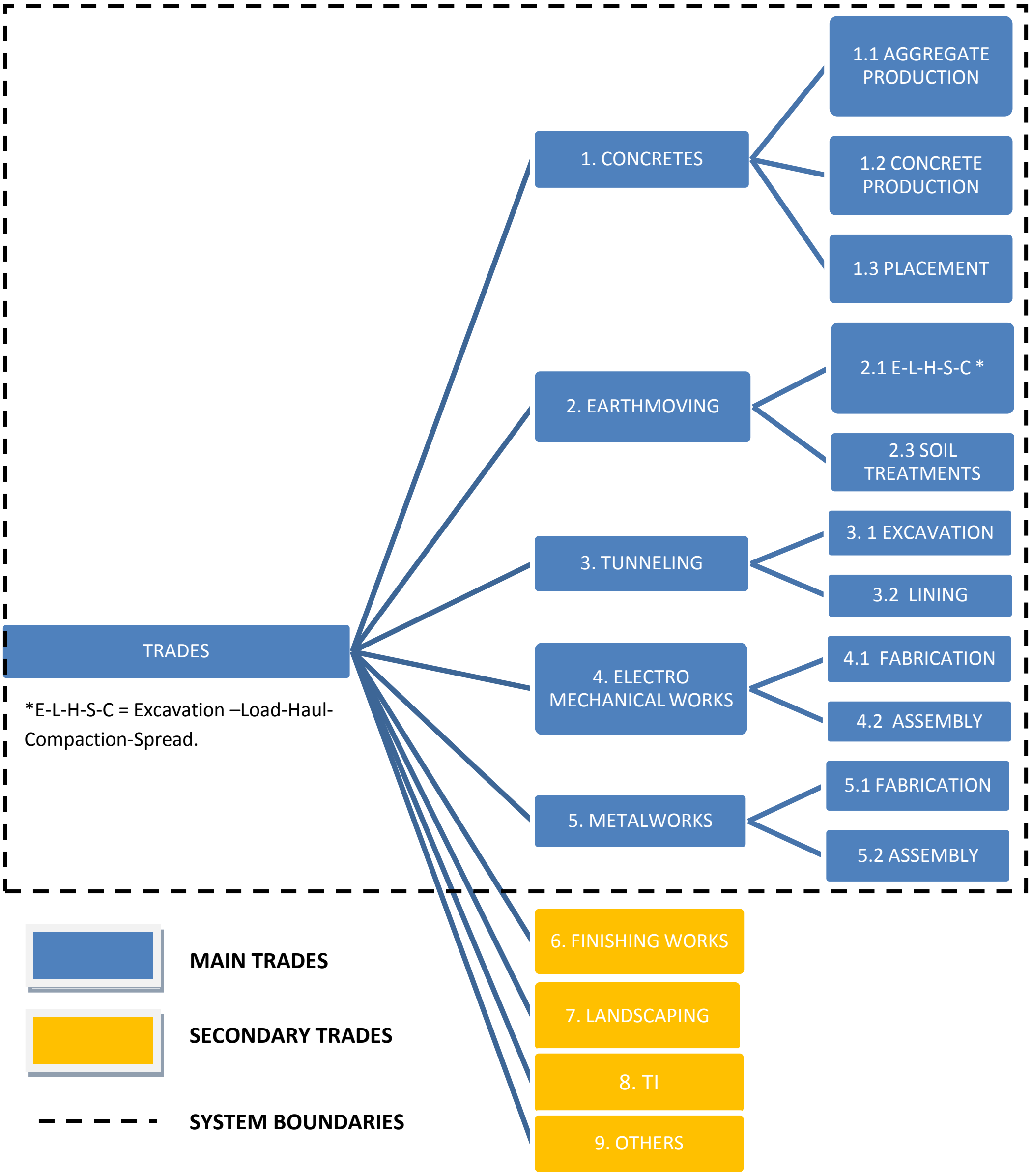

Figure 4.7: main trades involved in the construction of a large hydropower project.

Table 4.1: allocation of trades per subsystem and definition of research space.

ID	SYSTEM BREAKDOWN STRUCTURE (SBS)	TRADES										
		Concretes [C]			Earthmoving [EM]		Tunneling [T]		Electro mechanic works [EW]		Metal works [MW]	
		C.1	C.2	C.3	EM.1	EM.3	T.1	T.2	EW.1	EW .2	MW.1	MW.2
DW	**Dam Works**											
DWA	Diversion											
DWA1	*Tunnels*	X	X				X	X				
DWA2	*Portals*				X	X						
DWA3	*Inlet-Outlet structures*	X	X	X					X	X		
DWA4	*Cofferdams*	X	X	X	X	X						
DWB	Dam											
DWB1	*Body*	X			X	X						
DWB2	*Face*	X	X	X								
DWB3	*Plinth*	X	X	X	X	X						
DWB4	*Grouting curtain*					X						
DWB5	*Crest*	X	X	X								
DWC	Spillway	X	X	X	X	X			X	X		
DWD	Bottom Discharge	X	X	X	X	X	X	X	X	X	X	X
DWE	Closure Dike				X	X						
DWF	Eco-Flow Works	X	X	X	X	X	X	X	X	X	X	X
IW	**Intake works**											
IWA	Tower	X	X	X	X	X			X	X		
IWB	Bridge	X	X	X	X	X						
CW	**Conduction works**											
CWA	Tunnel	X	X		X	X	X	X			X	X
CWB	Surge Tank	X	X		X	X	X	X			X	X
CWC	Penstock	X	X	X	X	X					X	X
GW	**Generation works**											
GWA	Power House	X	X	X	X	X			X	X		
GWB	Restitution channel	X	X	X	X	X						
RW	**Reservoir works**				X	X						

4.2.2 Definition of transactions

According to the classification made above, in the selected research space there are approximately one hundred and twenty potential transactions. Nevertheless, in general all the transactions clustered within a specific sub trade can be characterized in similar terms using the analytical framework proposed in section 3.1.6, with the exception of temporal specificity for which the place each transaction has in the project planning is of relevance. A general description of these clusters is necessary before proceeding with their formal characterization. Unless otherwise indicated each of these transactions comprises the installation, operation, management and control of the production system, including as well the procurement of all the inputs required for the production process.

Concretes

In every concrete work three main sub trades are involved: aggregate production, concrete production and concrete placement. In essence the product of each of these sub trades could be delivered by different providers, as discrete outcomes can be distinguished and different technologies are used during the production process.

Aggregate production includes all the activities required to transform the raw material extracted from quarries into usable aggregates for the production of concrete, as well as for those dam´s fillings in which processed material is required. The production system is usually composed by several stationary equipments such as crushers, screens, conveyors and grinders that are arranged following a specific configuration in order to obtain the demanded composition of aggregates. The exploitation of the quarries is excluded from this sub trade because it is within the domain of earthmoving operations. The final product of these transactions is the processed material delivered to the next step of the construction process. Three different aggregate production facilities have been envisioned for this project with a total production exceeding 2 million cubic meters.

Similarly to the aggregate production, the concrete production is undertaken in centralized production facilities. The production system consists of semi-automated stationary equipment which dispenses the concrete constituent materials in the right proportion and then stirs the mixture until it reaches the required consistency. The final product of these transactions is the concrete delivered to the construction site. For this project four different locations have been foreseen for the installment of concrete plants, each of them no more than a couple kilometers away from the main construction works. The total production of concrete has been estimated in 1.5 million cubic meters.

The final sub trade of this category is concrete placement and includes not only the pouring of the concrete but also the fabrication and placement of reinforcement and formwork. An exception is made regarding the concrete lining of underground structures such as tunnels and shafts, that although essentially are also concrete placement operations the working conditions are substantially different from those in exposed structures[16], making it an activity more related to the trade of tunneling. The final product of these transactions is the concrete structure built according to the plans and specifications.

Earthmoving

In large engineering projects earthmoving works go beyond simple load and haul operations to include other specialized activities that involve different technologies and methods but that nevertheless are strongly interrelated. In the context of this project two relevant sub trades can be distinguished: excavation-load-haul-spread-compaction (E-L-H-S-C) and soil treatments.

E-L-H-S-C operations are conducted in any project in which open pit excavations are required for the construction of structures and the extracted material must be transported off the site and wasted in selected dump locations. Likewise they are also needed for the construction of embankments, in which case the material is usually extracted from other locations and then loaded and transported to the site for its final spread and compaction. Included in this sub trade is any drill and blast operation that may be required in order to remove material that

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[16] For instance, the work is undertaken in highly confined conditions and the contractor has to confront situations that are not typical in exposed concrete operations, such as management of underground infiltration, ventilation systems and potential instability of the surrounding excavation.

cannot be extracted by simple mechanical means (i.e. rocks), the exploitation of quarries, the management of dump sites and the construction of the dam´s fillings, which in essence is a large scale embankment. The production system is highly mechanized and composed mainly of earthmoving machinery. The final products of these transactions are the excavated material adequately disposed in the dump site, an embankment constructed according to the specifications and the material extracted from quarries and transported to the aggregate production facilities. The total volume of material to be extracted in this project has been estimated in near 30 million cubic meters.

Soil treatments operations are mainly undertaken to guarantee the stability of slopes as well as the structural integrity of works founded in ground with suboptimal mechanical conditions. This includes among others the placement of passive and active anchor bolts, installation of drainage systems, systematic treatment of slopes with shotcrete and wire mesh and the construction of grout curtains for those works in which water infiltration can cause structural damages (e.g. embankments). As it can be inferred, the final outcomes of these transactions are stabilized slopes and improved grounds.

Tunneling

Tunneling is a trade related to the construction of underground works such as tunnels, shafts and caverns. For the purpose of this study it has been divided in two main sub trades: excavation and lining. In general the excavation methodology chosen in this project for the construction of underground works is drill and blast, which means that excavation and lining are in its entirely sequential operations. Even though both of this sub trades are usually performed by the same contractor they still have intrinsic differences in their production process that deserve to be treated separately.

The excavation of linear underground works such as tunnels is a cyclic operation. When using drill and blast as the main construction methodology, a normal cycle includes mark of holes in the tunnel face, drilling, loading explosives, blasting and ventilation, load and haul of debris, scaling of loosened rocks, ground support, surveying and extending services. It may be required in function of the quality of the material being excavated to include additional stabilization measurements such as grouting curtains to avoid undesirable infiltrations in the excavation front. In the case of shafts and caverns, excavation may also be conducted using a raise boring to drill a pilot hole, and then expanding the excavation either by using explosives or normal mechanical means. Even though the production system relies strongly in the use of equipment and machinery, labor is still an important factor of production and the work can be described as physically challenging, requiring the participation of numerous working crews in a confined environment in which dangerous materials such as explosives need to be directly manipulated. The final product of these transactions is a tunnel, shaft or cavern excavated and stabilized for the next step of the construction process.

The lining provides both a smooth surface for water to travel and a permanent support for the excavation. When drill and blast methodology has been used for the excavation stage of these works there are basically two principal types of linings: casted on site concrete lining and steel lining. The former is mainly constructed using movable formwork systems while in the latter steel tubes are fabricated elsewhere and transported and assembled on the site. Steel lining is not considered within this sub trade because the fabrication and assembly process resembles more other metal works such as penstocks and surge tanks[17], which are classified as a different kind of trade in this thesis. In addition, for the purpose of this classification the production and transportation of concrete to the site is also excluded from this sub trade, because it is no different to those operations already included as part of the concrete trade. An exception most be made regarding those operations required to assure the quality of the interface between lining and rock, as for example filling and consolidation grouting, which are included in this sub trade indistinctly of the type of lining constructed. The shafts and tunnels lined according to the specifications are the final products of these transactions.

Electro mechanic works

In this study the electro mechanic works have been divided in two main sub trades: fabrications and assemblies. In hydropower project it is normal to divide the equipments within this category in mechanical and electrical. The former includes main components such as gates and valves, turbines, overhead traveling and gantry cranes as well as other minor auxiliary systems[18], while the latter is composed by generators, power transformers, grounding systems, excitation systems and control systems among others. Metal works such as penstocks are sometimes included within the group of mechanical components. Nevertheless for the purpose of this study they are taken as a separate trade. The reason for this decision is that there are fundamental differences in the level of technology implicit in the fabrication process. Metal works in general demand a significant lower level of sophistication than the required for the production of the other components introduced in this section. As a result of this characteristic the manufacturing facilities are considerably cheaper to set up, thus increasing the number of possible suppliers. In addition the knowledge required for the assembly process is also of a different nature.

It should be noted that not all the electro mechanical components mentioned above need to be fabricated by the same provider, even though some of them have the capacity to supply all the main equipments at once. It is also possible to procure them individually if there are sufficient cost incentives to do so, provided that the interfaces between technologies are adequately managed in order to avoid any compatibility problem. Nevertheless, for the sake of simplicity in this study they are analyzed all together.

It is assumed here that the sub trade of fabrication includes the final design, manufacturing and the delivery of the equipment to the construction site, as well as the provision of technical support to the party in charge of the assembly operations, which assumes responsibility of the equipment´s installment once on the site. For both sub trades the final product of the transactions is the equipment operating in a commercial regime.

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[17] Normally the same manufacturing facilities are employed and the work is commissioned to the same contractor.

[18] In a powerhouse of a hydropower project there are five main auxiliary systems: ventilation, cooling, drainage, fire fighting and compressed air.

Metal works

The final trade included in this study is metal works and just as with electromechanical works it has been divided in fabrications and assemblies. The main works within this category are the penstock, surge tank and the steel lining in the tunnel´s final section, which pertain to the last segment of the conduction system and are directly connected to each other[19]. To avoid any contractual problem arising from both the physical interfaces between the components as well as of the overlapping use of facilities and support services and to benefit from economies of scale in the production process they are usually commissioned to the same party, although this is not strictly necessary.

The fabrication process is carried out in centralized manufacturing facilities in which the steel plates are transported, cut and beveled in the junctures. Afterwards each element is rolled to the correct curvature and joined to other elements by means of longitudinal and circumferential high precision welding. A tube segment is thereby formed, the length of which is limited in order to facilitate the posterior manipulation and assembly[20]. Each tube is then smoothed by means of sandblasting, painted and finally delivered to a collection center before its final mobilization to the construction site. Because once in operation the tubes will be subject to very high pressure, quality control is of prime importance during the manufacturing process and is applied to both the steel plates and finished tubes by means of techniques such as penetrating liquids, ultrasound and x-rays, among others. Sometimes the manufacturing facilities are set up adjacent to the construction site, if the work is big enough and savings in transportation cost so warrants[21]. The final products of these transactions are the tube segments transported to the site and ready to be installed.

Even though the fabrication of the tube segments follow more or less the same procedure for any of the three works mentioned above, during the assembly operations there are some variations mainly attributable to differences in the nature of the interface between the tubes and the supporting elements. The penstock´s tubes are installed on the open in previously constructed concrete pedestals and mounts in which plates and anchors are left embedded by the concrete provider. Once the tubes are in place a second stage of concrete is required for embedding them in the concrete anchor blocks. On the other hand both the assembly processes of the steel lining and to some extent of the surge tank are conducted as underground works, the first inside a tunnel and the second partly confined in a shaft. A direct relation is born in this case between the metal work and tunneling contractors, being the latter usually in charge of filling with concrete the gaps between the tubes and the preliminary lining, as well as of any posterior treatment required to assure the mechanical quality of the interface with the rock. In all the mentioned assemblies high precision welding and accurate topographical control is

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[19] The steel lining is connected to the penstock at the exit of the tunnel, as well as to the surge tank on the inside.

[20] The longer the fabrication length of each segment, the faster the installation process because it means less on site welding. Nevertheless, normally each segment should weight no more than 20Ton - 25Ton in order to ensure its adequate manipulation during the assembly stage.

[21] The steel plates without alteration occupy less volume than after been rolled. For example in the context of this project and considering the geometric characteristic of the penstock segments, as well as the country´s regulations regarding the mobilization of heavy goods by land, twice the weight of unaltered plates can be transported per freight in comparison to rolled sections.

required, as well as a strict quality control. The final products of these transactions are the penstock, surge tank and steel lining installed and ready to conduct water**.**

4.2.3 Characterization and alignment

Based on the clusters defined in the previous section, the transactions included within the selected research space were characterized using the methodology proposed in section 3.1.6 (see table 3.2) and then aligned to a theoretical governance structure by means of the research hypotheses. An exhaustive memory of the characterization process is provided in **annex C**, including the reasoning followed to reach each of the assigned categories. In **table 4.2** the main results are presented. The transactions are shown here broken according to the subsystem and trade at which they pertain. In this way the analytical clusters are decomposed in order to present those singularities which are intrinsic to each part of the system. The theoretically preferred governance structures, as defined by the research hypotheses, are also indicated in the table using a key of colors. In addition, the type of specificity which is dominant in the analysis (i.e. which scored the highest) is incorporated as part of the nomenclature used to represent each transaction. A thorough exploration of these results is presented below, one dimension at a time. Afterwards, a concise summary is provided.

Asset specificity

From **table 4.2** it is evident that the prevailing type of asset specificity is temporal. This is congruent with what was observed by Masten et al. (1991, p.19), who concluded that temporal is the critical type of asset specificity in the context of construction operations. In this project two critical paths can be distinguished: the dam, beginning with the diversion works, and the main conduction tunnel. Most of the transactions involved in their construction have a high temporal specificity. The remaining works have a shorter construction period and their location in the overall planning is conditioned by other factors such as balance of resources and performance warranties[22]. For the purpose of this study not only the transactions included in the critical path were defined as having high temporal specificity, but also those for which the available slack was smaller than the replacement time. This explains why some of the transactions associated to other works not in the critical path can also be found in the lower third of **table 4.2**. Meanwhile, those transactions associated to works in which the slack was bigger than the replacement time but for no more than 5% of the project´s duration were classified as having a medium level of temporal specificity. The remaining transactions were classified as having low temporal specificity.

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[22] Although it may be possible to conclude the construction of both powerhouses several months in advance the electromechanical equipments need to be tested with water in the conduction system. Too much anticipation even if possible is not recommended because the equipment warranty may expire before they are tested as they should.

Table 4.2: characterization of transactions and predicted governance structures

DIMENSIONS			Uncertainty		
Asset specificity	Frequency	Level	L	M	H
Low		H			
		M			
		L	MW.1DWD, MW.2DWD	C.1DW,C.1IW, C.1CW,C.1GW,C.3 DWD	
				TOWARDS MARKET	
Med		H			
		M			
		L	C.2IW-(T,D), C.2DWD-(D), MW.2DWF-(T), MW.2CWC-(T).	C.3IW-(T), C.3GW-(T).	EMDWC-(T,H,D), EMCWC-(T,H,D), EMGWA-(T,H,D), EMDWD-(H,D), EMDWE-(H,D), EMDWF-(H,D), EMIW-(H,D), EMCWB-(H,D), EMRW-(H,D), T.1DWF-(T,H,D), T.1DWD-(H,D), T.1CWB-(H,D), T.2DWF-(T,H,D,P), T.2DWD-(H,D,P), T.2CWB-(H,D,P), EW.2DWF-(T,D), EW.2GW-(T,D), EW.2DWD-(D), EW.2IWA-(D)
			TOWARDS HIERARCHY		
High		H			
		M	EW.1DWA-(T), EW.1DWC-(T), EW.1DWD-(T), EW.1DWF-(T), EW.1IWA-(T), EW.1GWA-(T),		
		L	C.2DWA-(T), C.2DWB-(T), C.2DWC-(T), C.2DWF-(T), C.2CWA-(T), C.2CWB-(T), C.2CWC-(T), C.2GW-(T), MW.1DWF-(T), MW.1CW-(T), MW.2CWA-(T), MW.2CWB-(T).	C.3DWA-(T), C.3DWB-(T), C.3DWC-(T), C.3DWF-(T), C.3CWC-(T).	EMDWA-(T), EMDWB-(T), EMCWA-(T), T.1DWA-(T), T.1CWA-(T), T.2DWA-(T), T.2CWA-(T), EW.2DWA-(T), EW.2DWC-(T).

▨ **Market**
☐ **Hybrid**
🟨 **Hierarch**

$\underbrace{EM}_{1}\underbrace{DWA}_{2}-\underbrace{(T)}_{3}$

1 = Trade
C: Concretes
EM: Earth Moving
T: Tunneling
EW: Electro mechanic
MW: Metal Works

2 = ID SBS
DW: Dam Works
IW: Intake Works
CW: Conduction Works
GW: Generation Works
RW: Reservoir Works

3= Dominant specificity
(P): Physical
(H): Human
(S): Site
(T): Temporal
(D): Dedicative

As can be noted, the replacement time is central in the analysis of temporal specificity. The precise estimation of this parameter is nevertheless a complicated affair; it is dependable of many factors that are not only difficult to predict far in advance, but that to a certain degree are affected by the selected organizational arrangement. For instance, confronted with a contractual breach the time required to replace a particular sub contractor can be substantially reduced if the main contractor has himself available production capacity associated to that specific trade, or if he can get it from another sub contractor already engaged in the project. In other words, the replacement time is dependable of the level of redundancy with which the production system was conceived. A good example of this is the production of aggregates, which is decoupled from the project´s critical path because each of the three aggregate production plants that will be required for the construction of the project could be procured to different providers and because an amount of aggregates are usually produced in advance and stored for later use.

In addition, temporal specificity is conditioned by factors such as whether the potential contractual rupture is total or partial[23], the flexibility and celerity in the main contractor´s procurement procedures, the availability in the market and within the organization of the required inputs, the time needed to restart the production process, among others. Three assumptions were taken in this regard to support the characterization process, which were added to the four already outlined in section 3.3:

> ***Assumption 5:*** *Any contract rupture will be assumed as total (i.e. no production assets or supply contracts are kept)*
>
> ***Assumption 6:*** *ICE has constantly during the project´s execution the capacity to plan and coordinate the production process of any sub trade included within the project´s scope*[24]*. In case of a contract rupture it has the alternative to resume the works by direct administration if this proves to be the most convenient option, for which it maintains the control of the main temporal facilities (distribution lines, water supply, camps, etc).*
>
> ***Assumption 7:*** *at the time of the replacement (if the supplier is replaced by direct administration) ICE does not count with sufficient operational staff, equipment, machinery and stock of materials to fully cover the requirements.*

Based on the conducted analysis, in general the fastest option for ICE to arrange a replacement if confronted with a contract rupture is to resume the construction by direct administration. In this case it has been concluded that the replacement time varies from 3 months in those activities in which machinery and equipment[25] are the dominant production factor (e.g. earthmoving operations) to 12 months or more when the dominancy shift to materials, being the latter demanded in such a rate that a full tender procedure is the only feasible procurement option[26]. In conditions in between when materials, labor and equipment are equally relevant

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[23] A partial rupture represents the case in which the construction process is no longer conducted by the sub contractor but an arrangement is reached with the main contractor so as to keep the key assets of production and supply contracts.

[24] The fabrication of electromechanical equipment is an exception to this assumption.

[25] ICE is subscribed to an abbreviate procedure for the rental of equipment and machinery. The three month period has been estimated in order to anticipate any difficulty finding the required equipment and to include the minimum time necessary for the professionals in charge to take control of the production process.

[26] The steel plates for the metal work´s fabrication and the cement for the production of concrete are good examples.

and therefore some basic inputs need to be acquired[27] or staff recruited in order to resume the production process (e.g. concrete placement and tunneling operations) a period of six months has been deemed appropriate.

The fifth assumption introduced above is also relevant when assessing the importance human specificity has in the context of this analysis. With few exceptions[28] the trend is transactions that exhibit a medium level of human specificity. This is the result of a production system that requires, specially at coordination level, formal training or learning by doing experience only possible to obtain through a long period of time (i.e. difficult to transfer) but that at the same time is required in general basis in any project of this kind (i.e. it is trade specific not transaction specific). Nevertheless, it is proposed here that for the particular case of ICE this type of asset specificity is not relevant because it already posses the knowhow to undertake any construction activity within the project´s scope. Consequently no transaction was positioned in **table 4.2** using human specificity as the only determinant factor, even though it was included in the transaction´s code when the level with which it was characterized was shared with other types of asset specificities.

In section 3.2 it was argued that the construction industry is one characterized by the use of standardized parts and equipments, thus exhibiting a low level of customization in comparison with other industries. This statement was proven in the present analysis, from which it can be concluded that the level of physical asset specificity implicit in the construction process of this project is consistently low. With very few exceptions and mostly related to the customization of formwork systems[29] the production process can be characterized by using fully standardized and mass produced construction equipments and materials. In some cases in which it was detected that the local market is short of capacity to provide the required physical assets, having low levels of customization in turn moderates the dedicative asset specificity of those transactions. For instance, it was concluded that it may not be possible to find in the local market all the required earthmoving equipments at the same time[30]. Nevertheless, because these equipments are fully standardized if the market capacity is increased once the transaction is finalized the equipments can be used in other projects, or alternatively their salvage value recovered. In any case, the construction operations are large enough to attract international providers. For this reason even in transactions for which no local provider is available (e.g. tunneling) the level of dedicative specificity was not considered to be higher than medium, in accordance to the conventions established in this study.

With regards to site specificity, as it was expected its level is low for all the analyzed transactions. The project´s production systems can be characterized as easily deployable, many times movable by their own means once in the site. Even though fixed physical assets are

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[27] It is assumed in this case that a full tender procedure is not required to start up the production process. Materials in stock and purchases in process complemented with abbreviate acquisition procedures are sufficient for this purpose.

[28] The only exception is concrete production, a highly automated process in which the knowledge required is easily transferable.

[29] The formworks for the tunnels´ lining and for the dam´s face and plinth are two examples.

[30] This is explicitly illustrated in annex C with the example of the trucks required to transport the dam´s filling materials, which because of their number, type and size may be difficult to arrange in the current local market.

always required, in general their relocation costs are not relevant in comparison with the total production costs. Nevertheless, a few exceptions deserve recognition. Electro mechanical equipments are produced in centralized facilities that benefits from economies of scale and therefore their relocation cannot be justified in terms of one single project. This condition is however irrelevant because the production cost of these equipments is considerably high, thus transportation is not a critical factor.

An interesting case to observe more closely is the fabrication of metal works. There may be economical reasons to mobilize the manufacturing facilities to the site, although unlike most of the transactions analyzed in this study the installation cost cannot be considered as negligible[31]. In the specific case of EDHP it has been concluded that the savings in land freights compensate the installation costs of the manufacturing facilities and therefore the best option is to install the pipe factory on the construction site. This however does not mean it was unfeasible to bring the elements already manufactured from elsewhere, even from outside the country. In no setting the transportation costs would outweigh the production costs, thus site specificity is low.

A different situation can be observed in the production of both aggregates and concrete, in which proximity to the construction site is of great importance. For aggregates the production costs are outweighed by transportation costs within a radius of a couple of kilometers. Nevertheless, the importance of this condition should not be overweighed. What is vital is not the control of the extraction and production processes, but of the exploitation site itself. The assets used in the former are easily replaceable, while extraction sites that meet the requirements of quality and quantity demanded by a project of this scale are usually very limited and can mean the difference between a feasible and an unfeasible project. The production facilities are installed as close as possible to the extraction site because there is always a percentage of material wasted[32] and therefore the transportation between the aggregate plant and the extraction site should be minimized, but provided that that who owns the production facilities does not holds the property rights of the extraction site as well, the replacement of the former should not be a major concern.

With regards to concrete production, proximity is relevant because of two factors. First transportation costs can be a major contributor to the total cost of the supply, especially when roads´ conditions impose speed restrictions. Secondly, quality requirements limit the transportation time in average to no more than one hour[33]. This is the main reason why despite several concrete plants are spread all over the project´s area, this was not considered to be a redundancy in the production system that could attenuate its level of temporal asset specificity, as it is the case with the production of aggregates. Despite this, as long as the control of the production facilities and suitable installation sites are not exercised by the same party, the site specificity of the transactions associated to concrete production is rather low because the

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[31] According to ICE estimations (2013b) it represents 5% of the total production cost (including assembly).

[32] Generally it is not possible to adjust the plant to produce aggregates exactly in the composition demanded. Unused remaining is normal in this process.

[33] The exact time depends on the type of concrete, use of additives and weather conditions. For this project it is reasonable to assume a maximum transportation time of 60-90min for conventional concretes and 45min for RCC.

production facilities are relatively easy to relocate. An additional assumption should be introduced:

> ***Assumption 8:*** *ICE holds the property rights of the most suitable quarries and sites to locate aggregate and concrete production facilities.*

Having presented the characterization of the project´s transactions in terms of the different types of asset specificity, the attention now focus in the evaluation of their level of uncertainty.

Uncertainty

There are several reasons why the objective assessment of the transactions´ level of uncertainty is a particularly difficult endeavor. To a large extent the examination of asset specificity can be based on content analysis of the project´s documentation, the researcher's participatory observation and interviews with experts regarding specific points in which complementary information was apposite. Nevertheless, the likelihood and relevancy of not anticipated changes in the original conditions is something that depends on a multitude of variables and therefore not easily extractable from the project´s documentation. The opinion of experts involved in the project procurement and construction processes can still be asked and is indeed an important source of information, but it must be recognized that if changes are not predicted in the first place is because to some extent the rationality of those elaborating the contracts may be bounded, which intrinsically hinders their possibilities of making a plausible forecast of how likely a not anticipated change is ready to appear. Additional research about what conditions elicit changes in construction projects was necessary in order to underpin the assessment of this dimension.

Changes in the original conditions of a contract are triggers of disputes between the parties participating in an exchange, which in the context of large construction projects are inexorably present (Sai On and Tak Wing, 2006). Even though a plurality of studies have focused on investigating their causes, most of them have failed in providing a complete and systematic overview on the subject (Sun and Meng, 2009). What is clear from this collectivity of research effort is that in construction changes depend of a myriad of factors which are to a large extent project specific and therefore difficult to generalize. Despite this, a careful literature study makes it possible to conclude that the potential for unforeseen variations in the original conditions of the construction contracts appears to be strongly correlated to the quality and level of detail of the information used to define the project´s baseline. Several authors seem to agree that changes in the design yielding from initial mistakes or omissions, in the site and ground conditions due to an inadequately conducted or intrinsically limited research campaigns, as well as those propelled by unpredictable weather events are among the most significant causes of claims and disruptions in construction contracts (Semple et al., 1994, Kumaraswamy, 1997, 1998, Yogeswaran et al., 1998, Al-Momani, 2000, El-Rayes and Moselhi, 2001, Hsieh et al., 2004, Wu et al., 2004). A closer look to these conditions in the context of this case study is pertinent.

As was mentioned before, EDHP is the outcome of over four decades of studies. In the words of the EDHP´s chief engineer of the design department[34] *"never in more than 20 years of experience in this type of endeavors I have been involved in a project with greater baseline studies and design prior to the construction stage than in this one"***.** Both the feasibility studies (Ingetec, 2005) and front end designs (Ingetec and ICE, 2010) were conducted in association with a consultancy firm with extensive design experience in this type of projects. Knowing that as any other large hydropower project the environment is a major variable to consider, ICE has been focused in recent years on developing a environmental impact assessment in which, according to the EDHP´s Director Franklin Avila, *"all the required resources and time are being devoted to meet the highest international standards".* This process has given an unusual impasse of several years to undertake a proper planning using as a basis very detailed basic information. The following assumption can therefore be introduced:

> ***Assumption 9:*** *EDHP counts with a very complete set of designs and baseline studies to use as a basis for the procurement process, for which enough time and resources are being devoted.*

This condition means that changes due to suboptimal design and lack of initial information should remain minimal. Despite this, there are still some uncertainties that cannot be completely eliminated. As was introduced earlier, unexpected geological conditions are among the most important causes of claims and disruption in construction contracts. Even the most comprehensive research´s campaign cannot aver to give an exact prediction of what is going to be found in the subsoil during construction operations. As will be introduced below, there is considerable evidence that this condition is a headache for contract managers.

According to Wu et al. (2004) one of the most serious problems at which civil engineering projects involving extensive earthmoving and tunneling operations are confronted is the sprout of frequent change orders majorly stemming from geological causes. For this same reason and based on a comprehensive review and analysis of the recorded change orders of over 90 public work projects executed in Taipei during a period of ten years (1990-2000), Hsieh et al. (2004) concluded that tunnel construction presents the highest average frequency of change orders among all the analyzed categories. These is consistent with the results obtained by Charoenngam and Yeh (1999) in the context of hydropower projects, who based on a survey conducted to experienced professionals from the main parties involved in the construction process concluded that the subsurface condition of geology is perceived as the major risk factor associated to this kind of endeavors.

Therefore underground works have to deal on regular basis with problems derived from unpredicted geological conditions (Riemer, 2006) and as it was noted by Smirnoff *"no other form of construction results in more disputes, large claims and judgments for differing site conditions and defective specifications (2002, p.183)".* An almost identical opinion was expressed by Wildman who stated that despite law commonly allocate the risk of unforeseen conditions to the contractor, at the end the employer often finds itself *"mired in endless litigation over claims regarding unforeseen conditions or claims that the plans and specification*

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[34] M. Varela, see annex C.

inadequately described the sub-surface conditions (2004, p.171)". It appears that unexpected changes are almost an intrinsic property of underground works, as can be clearly extracted from the following comment of one of ICE´s underground works specialist[35]: *"in practical terms I cannot remember a job where things went as we had originally planned".*

Even though as was noted by Wu et al. (2004) earthmoving operations are also susceptible to changes due to unforeseen subsoil conditions, at first glance this factor appears to be less critical if compared with underground works. It is considerably easier to predict the geological conditions to be encountered in a punctual work with a relatively superficial excavation than to do the same in eleven kilometers of tunnel with coverage of several hundred meters. Nevertheless, earthmoving operations are especially susceptible to the third relevant condition of change introduced above: weather. Weather related events are not only one of the main causes of claims and disruptions in construction projects, but it appears to be the one which is most often granted to the contractors or subcontractors (Yogeswaran et al., 1998),commonly resulting in transaction related costs for the client as well[36]. From all construction activities, earthmoving is the more affected by rainfall (El-Rayes and Moselhi, 2001), which in tropical countries such as Costa Rica tends to be unpredictable and a major cause of concern.

Based on the arguments sketched above, some general outlines regarding uncertainty can be provided. First, it is not realistic to expect complete contracts to regulate the transactions within the trade of tunneling and in normal conditions the possibility of relevant not anticipated changes to appear is high enough so as to become a major cause of concern for the employer, thus matching the criterion for high level of uncertainty. Likewise, the conjunction of prospective unforeseen geological conditions and high susceptibility to unusual weather events make of earthmoving a trade with a great potential to suffer variations in the original conditions that may lead to continuous claims and disruptions during the construction process.

A less critical scenario looms in the transactions within the trade of concrete. Beginning with the sub trade of concrete placement, even though concrete structures are also susceptible to changes in the ground conditions this usually translates in variations of effort within previously accepted ranges of work included in the contract´s bill of quantities[37]. Despite the fact that not all relevant changes can be predicted from the outset[38], considering the high level of detail in the design of this project it is reasonable to conclude that their possibility of appearance is low and should not be a major cause of concern. A similar condition is presented by the production of aggregates, in which changes are not likely to appear but are always possible if the raw material extracted from the quarries is too different from what was originally expected. Both concrete placement and aggregate production fit well in the category of medium uncertainty.

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[35] D. Campos, see annex C.

[36] These costs are associated with items such as supervision and delays. They represent a cost for the client despite the fact that, as the authors acknowledge, it is normally considered as a discussable non-compensable cause of disturbance (except in very abnormal circumstances).

[37] A unit price reimbursement mechanism has been assumed in this statement. This is not only the common practice for ICE but a plausible conjecture as well for any construction work characterized by having a well defined scope but for which the exact quantities cannot be exactly predicted from the outset.

[38] Unforeseen geological conditions in the Dam site of Pirris Hydropower Project forced to completely change the configuration of the diversion works from an exposed channel to a tunnel, a change difficult to predict from the outset.

Even less critical is the sub trade of concrete production, whose level of uncertainty has been classified as low. The reason for this stems from the fact that the production process takes place in a well controlled environment. Even though the design and composition of the concrete mixture depends of the characteristics of the inputs materials, which are to a certain extent subject to change, the payment items included in the contract usual takes this into consideration by recognizing the production process separately from the input materials. A relevant change not predictable from the outset of a contractual relation is hard to imagine.

The fabrication of both electro mechanic and metal works are also perceived as being transactions with a low level of uncertainty. In general electro mechanic equipments are fabricated using functional specifications, such as flow and water head, for which no relevant changes are expected. This was confirmed by one of ICE´s specialists[39] who stated that *"in all the years [more than 20] that I have been involved in the electro mechanic works of hydropower projects I cannot remember any case in which we have experienced problems with a supplier due to relevant omissions in the original agreement"***.** Exactly the same argumentation is valid for the fabrication of metal works.

With regards to the assembly operations, a difference becomes evident between metal works and electro mechanic works. In one hand, the assembly of metal works can be characterized as a type of transaction with a low level of uncertainty. It implies the integration of a system with few interactive parts, usually installed one piece at the time and once all the associated works (e.g. excavations, mounts and stands) are finished. The interfaces with other trades are of a very discrete nature and relevant local adaptations are normally not required. On the other hand, electro mechanic assemblies can be described as highly uncertain. They entail the integration of systems with a large number of elements, many times fabricated using different technologies and with interfaces that are deeply rooted in the construction process of other trades. Local adaptations difficult to specify from the outset are almost intrinsic to this type of operations.

Frequency

The last dimension included in the characterization of the projects´ transaction was frequency. As can be recalled from section 3.1.6, when analyzing this dimension the interest focuses on two different types of frequency: the first is how frequent are the interactions between the transacting parties, while the second is how often is the type of transaction required by the contracting party. The results of the characterization process are marked by a sharp contrast between the two. On one hand hydropower projects are systems that to some extent are composed by the same elements, hence the same type of transactions can be expected in practically any project of this kind. On the other hand, ICE is a public company that most submit all future works to competitive tendering. In general sufficient amount of capable contractors are available worldwide so as to conclude that the same provider is not expected to interact again with the organization. This conclusion can be confirmed by ICE´s procurement history[40]. Therefore the frequency with regards to the interaction between the transiting parties is in general low. The electro mechanic fabrications represent the only exception to this condition,

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[39] J.M. Castro, see annex C.

[40] Only once ICE has had the same contractor involved in the construction of different projects: Sandillal Hydropower Project (1992) and Pirris Hydropower Project (2011) , whose dams were commissioned to the Italian Astaldi.

because only a handful of suppliers in the world are capable of manufacturing the electromechanical equipment of a large hydropower project. The same provider can be expected in future projects, even though exclusivity cannot be assured. The level of frequency in the interaction between demander and supplier is in this case medium, according the adopted conventions.

This thesis subscribes to the idea that opportunistic behavior as an intrinsic human quality is a central concept in the theory of TCE and therefore it has been assumed that from both types of frequency the one associated with the interaction between transacting parties is dominant. This explains the reason why all the transactions in this study were classified as having a low level of frequency, with the only exception of electro mechanic fabrications for the aforementioned motive.

Before ending this chapter, a summary of the main results of the characterization process, as well as an overview of the theoretical governance structure predicted by the research hypotheses, is pertinent.

Summary

With regards to the characterization of the transactions, it can be concluded that the dominant type of asset specificity is temporal, high for those transactions with a slack smaller than the replacement time. Human asset specificity is in general medium, an outcome of a production process demanding learning by doing experience but that can be used in other transactions of the same trade. As expected from an industry characterized by the use of standardized parts and equipments, physical specificity is with few exceptions low. No transaction exhibits dedicative specificity higher than medium, indicating that if no capacity is found in the local market it could be expanded and used elsewhere or provided by international contractors. Site specificity is consistently low because either the proximity or the installation costs of the production facilities are irrelevant. Uncertainty is high in the transactions included in the trades of tunneling and earthmoving, mainly influenced by unforeseen geological conditions and unpredictable weather events. Due to the conjunction of structural complexity and the need for local adaptations this classification is also shared by the electro mechanic assemblies. The existing project´s designs and baseline studies are detailed enough so as to expected no relevant changes in the original conditions related to other trades, whose level of uncertainty is medium or low. Finally, with few exceptions frequency is consistently low in all transactions because ICE is a public company subjected to competitive tendering procedures and therefore the same provider is generally not expected in future projects.

Viewed from the perspective of the research hypothesis, it can be concluded that vertical integration is expected in the tunneling and earthmoving operations involved in the main conduction tunnel, dam and diversion works, as well as in the electro mechanical assemblies of the latter and of the spillway´s gates. In all these cases high temporal asset specificity conjugates with high complexity and low frequency. Due to its short construction time and low interrelation with successive works, as well as its low level of uncertainty, the fabrication and assembly of the metal works associated to the bottom discharge are the only transactions were a pure market structure is predicted. In all the remaining transaction some form of hybrid structure is envisaged, getting closer either to market or to hierarchy in function of the specific combination of the three critical dimensions. A detail of the predicted governance structure for each of the potential transactions is presented in **table 4.4**.

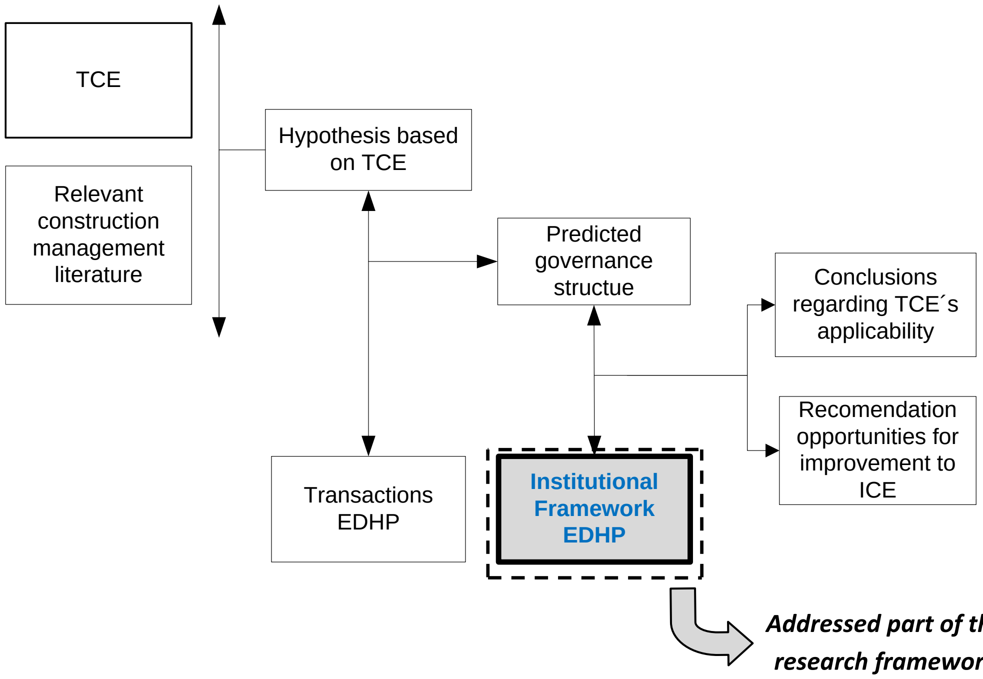
Table 4.1: governance structure predicted for each of the potential transactions.

ID	SYSTEM BREAKDOWN STRUCTURE (SBS)	TRADES										
		Concretes [C]			Earthmoving [EM]		Tunneling [T]		Electro mechanic works [EW]		Metal works [MW]	
		C.1	C.2	C.3	EM.1	EM.3	T.1	T.2	EW.1	EW.2	MW.1	MW.2
DW	**Dam Works**											
DWA	Diversion											
DWA1	*Tunnels*	X	X				🟨 X	🟨 X				
DWA2	*Portals*				🟨 X	🟨 X						
DWA3	*Inlet-Outlet structures*	X	X	X					X	🟨 X		
DWA4	*Cofferdams*	X	X	X	🟨 X	🟨 X						
DWB	Dam											
DWB1	*Body*	X			🟨 X	🟨 X						
DWB2	*Face*	X	X	X								
DWB3	*Plinth*	X	X	X	🟨 X	🟨 X						
DWB4	*Grouting curtain*					🟨 X						
DWB5	*Crest*	X	X	X								
DWC	Spillway	X	X	X	X	X			X	🟨 X		
DWD	Bottom Discharge	X	X	X	X	X	X	X	X	X	▨ X	▨ X
DWE	Closure Dike				X	X						
DWF	Eco-Flow Works	X	X	X	X	X	X	X	X	X	X	X
IW	**Intake works**											
IWA	Tower	X	X	X	X	X			X	X		
IWB	Bridge	X	X	X	X	X						
CW	**Conduction works**											
CWA	Tunnel	X	X		🟨 X	🟨 X	🟨 X	🟨 X			X	X
CWB	Surge Tank	X	X		X	X	X	X			X	X
CWC	Penstock	X	X	X	X	X					X	X
GW	**Generation works**											
GWA	Power House	X	X	X	X	X			X	X		
GWB	Restitution channel	X	X	X	X	X						
RW	**Reservoir works**				X	X						

▨ **Market** ☐ **Hybrid** 🟨 **Hierarchy**

CHAPTER 5

INSTITUTIONAL FRAMEWORK



Addressed part of the research framework

Thesis ‘main research questions:

1. What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?
2. What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?
3. **What are the main characteristics of the EDHP´s institutional framework?**
4. What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?
5. What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?

Research question to be answered

5. Institutional framework

In the previous chapter the most relevant transactions involved in the construction of EDHP were characterized and the theoretical governance structure predicted based on a set of research hypotheses. In this chapter the focus shifted to the study of the institutional framework surrounding EDHP, which according to the research framework (see section 2.3) is comprised of two parts: the governance structure selected for EDHP´s construction and the social framework that constrains the theory´s causal explanation. Based on this the rationality of the chosen organization was exposed, providing the final element needed to reflect in the next chapter about the applicability of TCE in the context of this case study.

The methodology that was followed to fulfill this part of the investigation is presented in **figure 5.1**. Bellow it will be explained, referring appropriately to each of the shown steps. The first component of the institutional framework, the governance structure selected for EDHP, was characterized using as a basis the analytical tool crafted in section 3.1.6 (**step 1**). This means that the contractual conditions that regulate the execution of the project´s works were analyzed in terms of the included adaption and enforcement provisions in order to conclude which of the three generic governance structures (i.e. market, hybrid or hierarchy) was selected in reality to conduct the transactions within the scope of this investigation.

With regards to the study of the second component of the institutional framework, the social framework in which this case study is embedded, the route followed is considerably more complicated and demands further explanation. As was explained in section 3.1.1, the social framework at which TCE is circumscribed is composed by both formal and informal institutions. In the case of an organization such as ICE, this represents a broad and somewhat abstract referential milieu. Without a proper gating, when embarking in its study the risk existed of being adrift in a vast ocean of irrelevant information. Hence the strategy used to avoid overabundance of information was to define from the outset what were the points of interest which the analysis should be focus. The latter provided a study perspective to extract in a selective manner from the project´s social framework those elements that may have constrained the decision making process in ways not necessary obvious at first glance and external to TCE´s causal explanation.

Because the decisions made in the present are affected by past choices (Liebowitz and Margolis, 1995), and taking into consideration that projects are temporal endeavors which are embedded in the long term history of the executing organization (Ruuska et al., 2011), it was not sufficient to extract these points of interest only from the context surrounding the decision making process of EDHP. Therefore, the examination was enriched by the study of a bigger sample of large hydropower projects executed in the past by ICE. A period of twenty years was established as adequate to define the sub-cases of study because in a broader context the gathering of information from direct participants could be limited. Additionally, the projects are recent enough to have digital documentation. Apart from EDHP, three projects were analyzed: Angostura Hydropower Project (AHP, 172 MW), Pirris Hydropower Project (PHP, 141 MW) and Reventazon Hydropower Project (RHP, 306 MW).

Considering that the final goal of this part of the investigation was to understand the rationality of the selected governance structure, the points of interest to guide the study of the social framework were extracted directly from the final step of the decision making process´ chain of events: the make or buy decision itself. A backwards analysis was undertaken from this point, beginning with an inquiry about what were the key factors that motivated the projects´ organizational arrangements (**step2**). The examination of these decision factors was based on triangulation of sources: documental analysis, participatory observation[41] as well as semi structured interviews to the key players involved in the decision making process. Once collected, all the decision factors were synthesized (**step 3**) and allocated in its corresponding level of analysis: informal institutions, formal institutions and selective alignment (**step 4**). Those decisions factors allocated in the first two levels were translated in the aforementioned points of interest (**step 5**), which were confronted with the social framework in order to define the main institutional constraints (**step 6**). Having elucidated the principal social conditioners, as well as those decision factors pertaining to the logic drawn by TCE (i.e. allocated in third level of analysis), the rationality of the governance structure selected in EDHP was finally outlined (**step 7**).

In terms of structure, this chapter is divided in three sections. In the first the EDHP´s governance structure is presented and characterized, thus summarizing the results of step 1. Afterwards, in the second section the social framework is explored. This includes the distillation of the points of interest that guided the investigation (step 2 to step 4), as well as a description of the main institutional constraints (steps 5 and 6). With these elements as a basis, the rationality of the selected organization is finally explained in the third section.

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[41] This applies only in the sub-cases of PHP and EDHP.

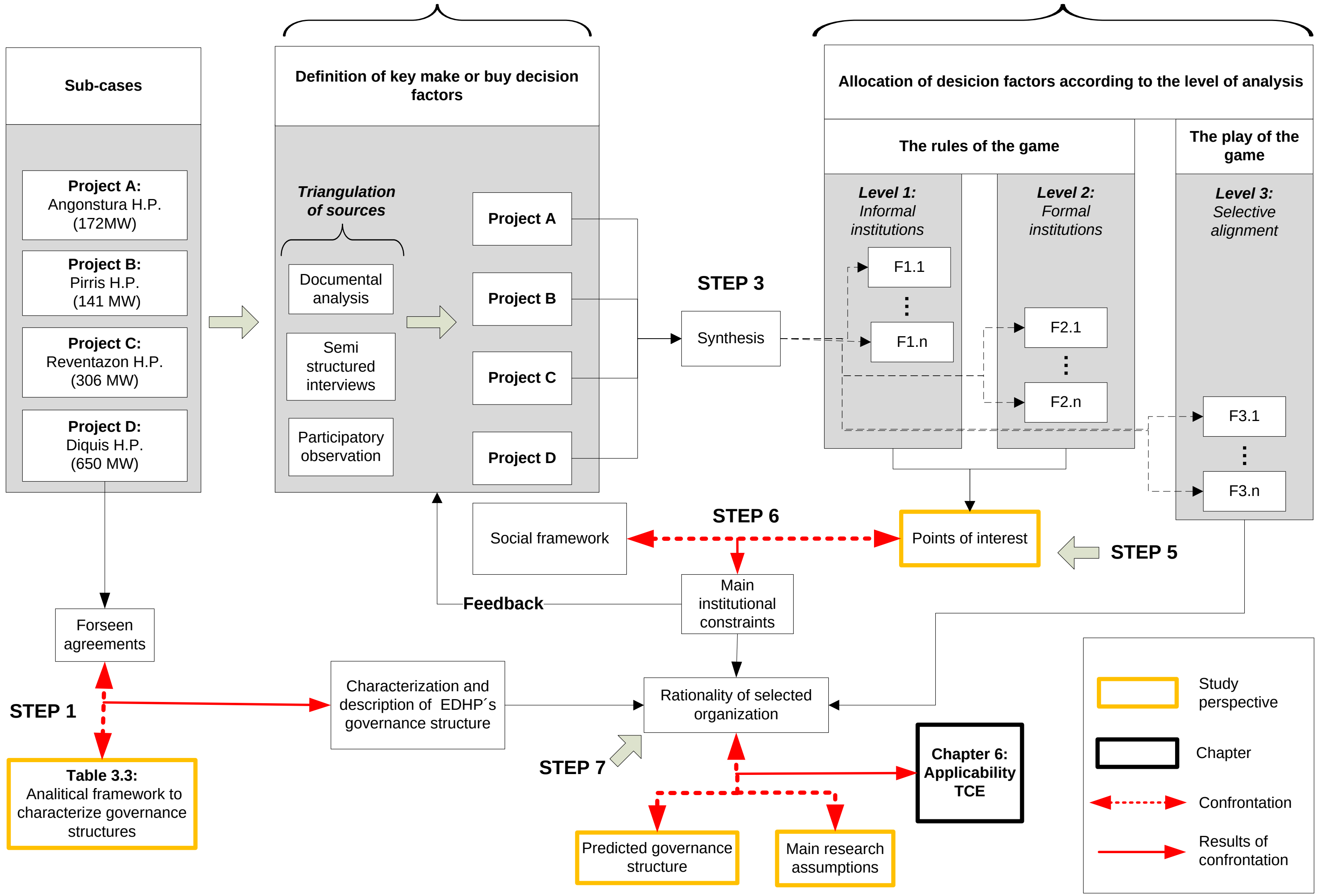


Figure 5.1: methodology for the study of the institutional framework.

5.1 Governance structure

5.1.1 Characterization

The first step of the characterization process is to divide the transactions in two groups: those to be conducted relying in ICE´s own internal resources (i.e. make) and those to be contracted to a third party (i.e. buy). The former correspond to a hierarchy type governance structure, while the latter has to be further divided in hybrid or market. To achieve this division the provisions included in the transaction´s foreseen agreements were analyzed in detail in terms of the adaptation and enforcement mechanisms. The characterization process followed in this section is graphically represented in **figure 5.2**.

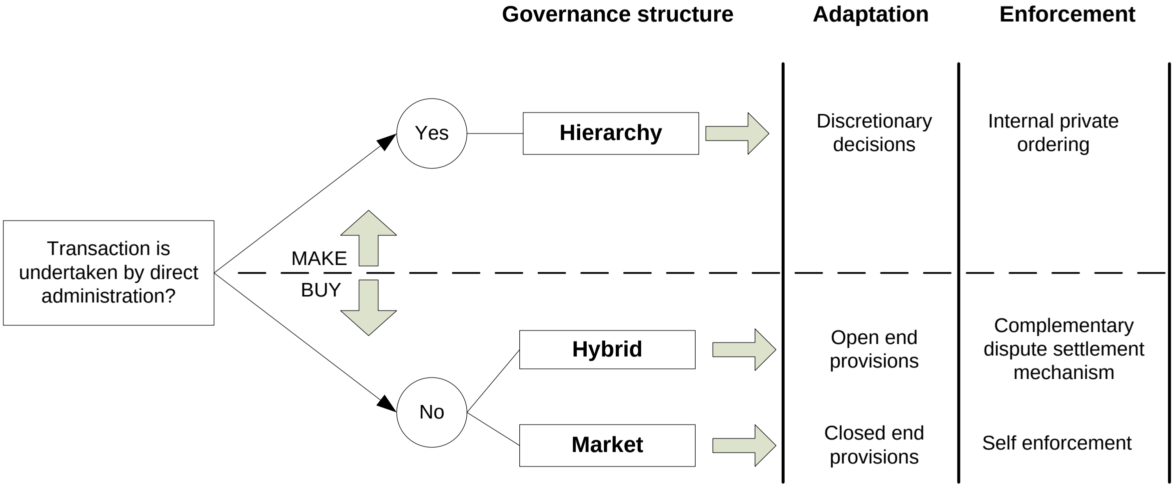


Figure 5.2: governance structure characterization process.

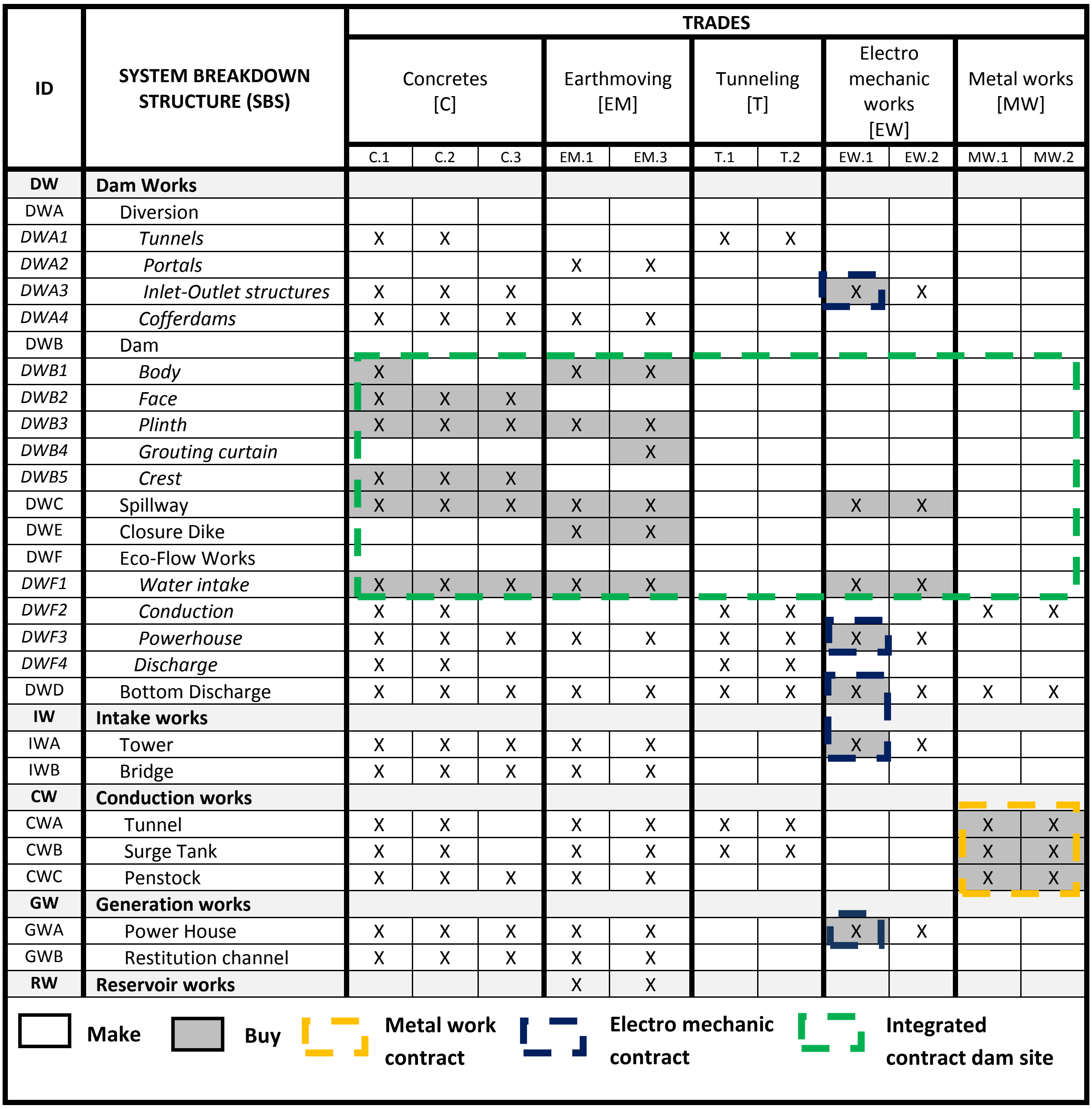
According to the project management plan (ICE, 2013b) EDHP will be constructed using a mixed make-buy scheme. This division is shown in **table 5.1**. The contract represented by a green line was called integrated contract of the dam site because it covers activities pertaining to more than one trade, thus assigning to the contractor the responsibility to integrate the system. The remaining procurement packages are trade specific: four contracts for the fabrication of electro mechanic equipments and a fifth one for the fabrication and assembly of the penstock, surge tank and steel lining of the tunnel´s final segment. All the works not included in one of the mentioned contracts are going to be constructed by ICE´s direct administration.

The documents to be used in EDHP for the procurement of these works are not fully written yet; hence a proxy was needed in order to conduct the analysis. The direct candidates for this purpose were the contracts used in Pirris Hydropower Project (PHP), which followed an almost identical organizational arrangement and that corresponds to the most recent project conducted by ICE with full contractual documentation available. The documents selected as foreseen agreements were the following:

- Contract conditions of the dam site´s construction works (ICE, 2005)
- Contract conditions for the design, fabrication and installation of the penstock and steel lining of the final segment of the conduction tunnel (ICE, 2006a)

- Contract conditions for the fabrication of electro mechanic equipment and associated services (ICE, 2006b).

Table 5.1: make-buy scheme selected for EDHP´s construction.



ID	SYSTEM BREAKDOWN STRUCTURE (SBS)	TRADES										
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DWA3	*Inlet-Outlet structures*	X	X	X					X	X		
DWA4	*Cofferdams*	X	X	X	X	X						
DWB	Dam											
DWB1	*Body*	X			X	X						
DWB2	*Face*	X	X	X								
DWB3	*Plinth*	X	X	X	X	X						
DWB4	*Grouting curtain*					X						
DWB5	*Crest*	X	X	X								
DWC	Spillway	X	X	X	X	X			X	X		
DWE	Closure Dike				X	X						
DWF	Eco-Flow Works											
DWF1	*Water intake*	X	X	X	X	X			X	X		
DWF2	*Conduction*	X	X				X	X			X	X
DWF3	*Powerhouse*	X	X	X	X	X	X	X	X	X		
DWF4	*Discharge*	X	X				X	X				
DWD	Bottom Discharge	X	X	X	X	X	X	X	X	X	X	X
IW	**Intake works**											
IWA	Tower	X	X	X	X	X			X	X		
IWB	Bridge	X	X	X	X	X						
CW	**Conduction works**											
CWA	Tunnel	X	X		X	X	X	X			X	X
CWB	Surge Tank	X	X		X	X	X	X			X	X
CWC	Penstock	X	X	X	X	X					X	X
GW	**Generation works**											
GWA	Power House	X	X	X	X	X			X	X		
GWB	Restitution channel	X	X	X	X	X						
RW	**Reservoir works**				X	X						

☐ **Make** ▨ **Buy** **Metal work contract** **Electro mechanic contract** **Integrated contract dam site**

The construction of the works within these contracts was funded through a loan with the Japanese Bank of International Cooperation (JBIC), requiring the application of FIDIC´s contractual forms. More specifically, the fourth edition of FIDIC´s Conditions of Contracts for Works of Civil Engineering Construction (1992), commonly known as red book, was in general the used guideline. At present there is a newer version of these conditions, FIDIC´s new red book (1999), which ICE has chosen as the standard to be use in EDHP[42]. An analysis of the differences between these two versions is apposite to conclude how adequately the contracts selected as a proxy for this investigation represent the real ones.

A comparison between both versions of FIDIC´s contractual forms was performed by Swiney (2006), who concluded that even though most of the variations are cosmetic there are some changes of substance with regards to two aspects: the distribution of risks between transacting parties and the role of the engineer (i.e. the contract manager). Regarding the former, the author further concluded that because in this newer version the risks shifted from both sides the impacts on the overall balance of the contracts are difficult to predict. Consequently, for the purpose of this thesis this variation was not taken into consideration. The change in the role of the engineer, on the other hand, could have the potential to affect provisions relevant for this study, thus demanding a closer look.

Traditionally the engineer has had in construction a duality of functions: in one hand as the agent of the employer and in the other as an independent party responsible of keeping the balance between the parties. The new red book strives to change this condition by favoring the first role over the second. In specific, the employer has now more control over the engineer, the latter´s duty to act impartially was eliminated and a dispute adjudication board (DAB) was introduced (Ndekugri et al., 2007). Nevertheless, three conditions explain why these changes don't have any real effect in the context of this case study. First, ICE is both the engineer and the employer and therefore its role as the former can hardly be described as impartial. Second, Costa Rica is a civil law country and *"the concept of the engineer as an independent and impartial party is unknown in continental and other civil law systems under which the contract administrator is an agent of the employer in all aspects (Ndekugri et al., 2007, p. 792)"*. Third, ICE has to comply with national legislation regarding alternative dispute resolution[43], according to which in practice the implementation of alternative dispute resolution mechanisms other than arbitration appears to be restricted to private parties only. Consequently, it can be concluded that the selected contracts are good approximations of the real ones.

Having proved their adequacy for the purpose of this investigation, the contracts were thoroughly reviewed to determine the nature of the included adaptation and enforcement provisions. A complete recapitulation of the findings is presented in **annex D**. As it can be stated, to some extent all the agreements rely on open end provisions to deal with not anticipated situations. A good example of this is the force majeure clause, which establishes that a contractor has the right to an extension in time and recognition of extra costs in case of an event or exceptional circumstance for which he could not have taken "*reasonable precautions"* before subscribing the agreement, that if arising could not have been "*reasonably avoided or overcome*" and that cannot be "*substantially attributable"* to the other party. As was noted by Swiney (2006), this clause as framed by FIDIC is completely open ended and could potentially cover any not anticipated human cause. Examples such as these can be found all along the three analyzed contracts, most of them applying variations of the same open ended

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[42] This is a well justified decision, given the fact that most of the multi-lateral development bank´s contractual forms are in most respect identical to this standard (Swiney, 2006).

[43] Law N° 7727 "Alternative conflict resolution and promotion of the social peace"

terms. These terms, as was noted by several authors (Ndekugri and McDonnell, 1999, Swiney, 2006, Hillig et al., 2010), are clearly subject to different interpretations.

With respect to the enforcement provisions, the FIDIC´s 1992 red book included a three layered dispute settlement mechanism: the engineer´s decision, amicable understanding between the parties and finally arbitration (Rahman and Kumaraswamy, 2002). Apart from these, an additional layer was included in the analyzed contracts: the project´s director, who has the final word before exhausting the administrative remedy. This should give the contractor some protection against a clearly flawed judgment by the engineer, even though impartiality can never be assured because the project director is also subjected to the employer´s hierarchy[44].

In synthesis, the contracts can be characterized by the use of open end provision and complementary dispute settlement mechanism, hence matching the parameters of a hybrid governance structure. This does not mean that self enforcing provisions are not included. On the contrary, just as was noted by Klein (1996) self enforcing provision are used jointly and represent an important element in the overall logic of the agreements. As it is usual in construction contracts (Clough et al., 2005), several types of securities were incorporated in order to assure that the contractor comply with its obligations. The first of these provisions is a performance guarantee, which represents a security backing the contractor´s completion of the work. The inclusion of this guarantee is recommended by FIDIC conditions, compulsory according the Costa Rican Procurement Law (article 34) and a common international practice when engaging a main contractors (Meng, 2002, de la Cruz et al., 2006), but less frequently used by main contractors in their contractual relations with sub contractors (Shash, 1993, Fayek et al., 1999, Arditi and Chotibhongs, 2005). Retention of partial payments was also included as an additional guarantee that could be used by the employer to pay fines, damages, repairs, etc.

To be used in conjunction with these guarantees, several bonus and penalty clauses were incorporated. This includes a clause of liquidated damages for delays, which introduces the possibility of charging a fine to the contractor if the agreed finish date is not met, as well as a bonus for early termination. Additionally to these, a fine for contractual breaches was also included in case the contractor failed to comply with any provision included in the contract. This penalty went from a daily fine to the suspension of payments. Finally, special warranties were included in the electro mechanic contract if after being tested the efficiency, capacity and level of noise of the equipments were inferior to those initially offered by the manufacturer. Most of these clauses could be applied by simple verification of the engineer and deducted from any submitted guarantee or future payment.

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[44] The lack of neutrality of the employer´s agent has been perceived by contracts´ users in both common law and civil code jurisdictions (Hughes and Shinoda, 1999) and explains the main motivation for the introduction of DAB in the new red book (Swiney, 2006) as a neutral and temporal determination procedure that generally prevents disputes to escalate into arbitration (Gaitskell, 2007), thus creating a fine balance between quick resolution and preservation of good contractual relationships (Seifert, 2005). The application of a DAB, despite its apparent benefits, appears to be limited in most civil law countries (Jaeger, 2010, p. 409-410).

5.1.2 Additional considerations

Beyond the characterization provided above, more can be extracted from the study of these contracts that is relevant for the purpose of this investigation. Three elements are particularly interesting to discuss: the mechanisms by which the governance of the contractual relations is exerted, the congruency between ICE´s role in the project´s chain and the overall balance of the selected contractual forms, and the manner in which the transactions have been allocated in the procurement packages. The exploration of these elements provided valuable insights of the way in which ICE intends to exercise the governance of the project´s construction, which were especially useful for the formulation of a strategy to improve ICE´s performance in the construction process, to be presented in chapter seven of this report.

Governance of the contractual relation

As discussed in section 3.1.6, self enforcement clauses are meant to arrange the private enforcement capital in a manner that reduces the possibility of contractual breaches. Many infrastructure projects, of which power generation is not the exception, are time driven in the sense that delays seriously reduce the project´s value for the client[45]. An unfinished infrastructure project has little use, regardless of the level of progress and of the amount of money invested on it. In a rather clear manner Chang and Ive (2007b) demonstrated that in construction projects the quasi rent[46] is always greater for the client and owner of the infrastructure than for the contractor. The inclusion of provisions such as guarantees and retentions is therefore a normal response to this condition in an attempt to level up the private enforcement capital of the parties, thus creating an optimal self enforcement range and reducing the hold-up potential (Klein, 1996).

At the same time, from **annex D** it becomes evident that the engineer is granted with considerable faculties to steer the contractual relation. For instance, it is entitle to provide supplementary instructions and corrections that should be considered as part of the original agreement, as well as to unilaterally define the preliminary price of a modification. Williamson (1985) defined his role as one of trilateral governance, distinguished by a third party that facilitates the governance of the transaction. Winch (2001) further described him as an independent control actor that verifies the performance of the contract, facilitates negotiations and provides a first line of dispute resolution. Even though both perceptions are not entirely correct, because as was explained before the engineer acting as a contract manager can hardly be considered as neutral, it cannot be denied that the faculties granted to the engineer by the contractual terms are important to assure the continuity of a time driven production process characterized by having high temporal asset specificity. The self enforcement range mentioned by Klein (1996) is no more than the extent the original conditions can change without deriving in hold up problems, which in the context of construction projects is the space in which the engineer can exert an effective governance of the contractual relation.

Nevertheless, the enforcement range and the effectiveness of the engineer´s power are not without limits and become considerably blurred if change turn into the norm rather than the

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[45] The lost of value does not only derives from a delay in the infrastructure´s income stream, but also from the fact that loans have finite grace period (i.e. the loan most be repaid when the asset is still not giving any revenue).

[46] As can be recalled from section 3.1.2 this refers to the difference of value an investment has between its actual use and its second best use (Klein et al., 1978).

exception (Chang and Ive, 2007a). The problem arises from the opportunistic behavior of the contractor, the natural difference between his and the client´s quasi rent and from the specific configuration of what has been called by several authors as the dispute resolution ladder (Ng et al., 2007, Menassa et al., 2009, Song et al., 2012). In a construction project the first level of this ladder is always the engineer and the last one litigation, with several possible steps in between (e.g. mediation, adjudication, arbitration, etc). If the gap between the successive steps is too large, the information asymmetry between the conflicting parties and the dispute solver may introduce non verifiability issues (Berends, 2007) that could foster the opportunistic behavior of a contractor tempted by the clients´ higher quasi-rent. Relying just in the engineer and a high level dispute resolution such as court or even arbitration[47] in a large infrastructure project were frequent changes are expected does not contribute in improving this condition. A smoother progression in the escalation of conflicts is preferred because it reduces conflict[48], extends the self enforcement range of the contract and improves the efficiency of the provisions included to arrange the parties´ private enforcement capital. Such progression does not appear to be present in the contracts envisaged for EDHP, majorly because the current legal framework does not support its implementation.

ICE´s role and balance of the selected contractual forms

Because an unfinished piece of infrastructure has little alternative use, the quasi-rent for the client is always represented by the cost of switching contractors (Chang and Ive, 2007b). In a normal condition the client does not have construction capacity available and replacing a contractor is a particularly difficult and time consuming endeavor. Consequently the client´s quasi-rent is rather high and the contractual terms are crafted to arrange the private enforcement capital accordingly. Nevertheless, the role ICE plays in the project´s chain is not typical; in one hand it is the owner of the infrastructure and in the other it is a contractor with a considerable amount of construction capacity deployed in the project. As was demonstrated in the previous chapter, if confronted to a contractual disruption ICE´s most favorable option is to resume works by direct administration; hence its appropriable quasi rent should be significantly lower than that of a normal client[49]. Taking into consideration that the overall balance of the FIDIC´s new red book conditions has been conceived to support transactions with a normal client-contractor quasi-rent differential, the question remains whether this contractual form still optimally fits the purpose in the context of this project, despite being its application a standard requirement of many financial entities.

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[47] Many consider that arbitration has become a method of conflict resolution not significantly cheaper or more expeditious when compared with litigation (Hamon, 2003).

[48] Ng et al. (2007) successfully demonstrated that the level of conflict is significantly reduced if the two step dispute resolution (engineer-arbitration) is expanded to include a layer of mediation by a neutral third party.

[49] In theory it should be possible to further reduce this quasi rent if the project organization is designed as a redundant production system. This redundancy is plain and simple additional capacity decoupled from a specific transaction that can be conveniently activated if the latter fails to fulfill its original promises (e.g. aggregate production facilities, see section 4.2.3). In essence it meets the same purpose as the contract´s self enforcement clauses in balancing the private enforcement capital of the transacting parties, but instead of increasing the capital of the supplier the one of the demander is reduced. This is an interesting concept that so far as the author knows has not been addressed in the construction management literature.

Allocation of transactions in the procurement packages

A final remark is necessary regarding the manner the transactions were distributed in the EDHP´s contracts and what this may have to say about ICE´s role in the construction process. Normally a main contractor has in charge the integration of the system, outsourcing discrete parts of it to specialized trade providers. This position is clearly not assumed in the dam site contract, were the responsibility to integrate the system was ceded to the second tier supplier. At first glance and from the perspective of ICE as an EPC contractor with the capacity to carry out the construction of the whole project this decision does not makes much sense. There is no regional[50] contractor with the capacity to undertake this contract, thus an international contractor is the only option. But the latter not only has larger overhead costs than trade providers do, which should be added to the ones ICE has regardless of the chosen organization, but also is confronted to the risk of undertaking a large project in an unknown environment, a risk to which ICE is exempt. Additionally, an international contractor has indeed not much prospect of future gains with a client such as ICE, nor is the latter a relevant player in the market of international heavy construction projects. Under these conditions it is reasonable to doubt about the effectiveness reputation and other social mechanism have in affecting the equilibrium of the parties´ private enforcement capital. Given this general picture, the next question naturally follows: why was the integration of the system ceded instead of relying more in trade providers to conduct the work? To answer this question the main institutional constraints imposed by the project´s social framework and the key decision factors that prevailed in the selected organization should be explored. This is the topic of the next section.

5.2 Social framework

This section is divided in two parts. First, the points of interest that guided the study of the social framework are presented. Afterwards, based on these points the main institutional constraints at which ICE is confronted when organizing the construction process are revealed.

5.2.1 Points of interest

As was mentioned earlier, the points of interest that steered the study of the social framework (i.e. formal and informal institutions) were extracted directly from the decision factors that guided the selection of the governance structures in a sample of four large hydropower projects. The study thereof began with a documental analysis. This was necessary in order to extract the main technical characteristics of the projects, the specific organizational arrangement selected for their construction, as well as any other piece of information that could help the author to prepare the interviews. Of special importance was the study of the project´s final reports[51] (ICE, 2000, 2012a) for those projects already constructed (i.e. AHP and PHP) as well as the project management plans (ICE, 2010, 2013b) for those under construction or yet to be constructed (i.e. RHP and EDHP). Once finished the documental analysis, some of the main stakeholders involved in the decision making process were contacted providing a general description of the objective of this study and an explanation of the purpose of the

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[50] In the context of this argumentation a regional contractor should be understood as one with frequent operations in the country.

[51] ICE has as a standard practice the elaboration of a comprehensive recapitulation of the most important aspects pertaining the planning and construction stages at the end of every project. This proved to be valuable source of information for this thesis.

consultation. Semi structured interviews were organized in which some basic questions related to the decision factors involved in the selected organization were formulated[52]. Depending on how the conversation evolved, additional inquiries were added. The contacted sources included projects´ directors, ICE´s general coordinator of projects, ICE´s former CEO (2009 – 2013) and general director of UEN PySA, as well as other actors with first hand information of the selection process or historical knowledge about the organization. In general the time of each interview was between 30 and 45 minutes.

A summary of the projects´ principal characteristics, the selected organizational arrangements and the main decision factors collected from interviews and documental analysis are presented in **annex E**. An element that deserves to be highlighted is the remarkable similarity the analyzed sub cases exhibit with regards to the selected governance structures. In general a mixed make-buy scheme was selected in each project, including three main contract packages: dam site works, fabrication and assembly of metal works and fabrication of electro mechanic equipments. The only exception for this is RHP, the biggest project conducted so far by ICE and currently under construction. This project is being constructed almost entirely by ICE´s direct administration using its own internal resources. Only the fabrication of electro mechanic equipments and some minor works are commissioned to third parties, thus representing an exception among the analyzed sample.

In a manner consistent with the organizational arrangements, the decision factors are similar in every case. Taking into consideration that all the respondents were approached independently, that the interviews were structured to avoid the introduction of judgment elements preconceived by the author and that in general the findings match what was expected by the latter in function of his participatory observation in two of the analyzed projects, it is fair to conclude that the findings possess high face validity. A synthesis thereof is provided in **table 5.2**. As it can be seen, each factor has been allocated according to the level of analysis at which it pertains. A closer look to those factors assigned to the first and second level makes it possible to distinguish three main types of constraints that have a central importance in explaining the genesis of the selected organizations: financial constraints, time constraints and integration constraints. These are the points of interest that guided the exploration of the social framework relevant for this investigation. The decision factors synthesized in table 5.2 are better explained as part of this exploration course, hence their description was arranged in the following section. Whenever reference is made to any of them a distinction is included so as to make them clearly recognizable.

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[52] The interviews in general began with a direct inquire regarding what factors in the opinion of the interviewee motivated the organizational arrangement selected for a specific project. This was formulated in an open manner so as to avoid limiting the research space to those factors preconceived by the author´s participatory observation. This question was followed by an exercise in which the interviewees were asked to describe the main reasons other hypothetical organizational arrangements were not selected. During the interviews notes were taken which were afterwards synthesized in the main decision factors shown in **annex E**.

Table 5.2: main decision factors and points of interest for the study of institutional constraints

ID	Decision factor	Level of analysis		
		Level 1 Informal institutions	**Level 2** Formal institutions	**Level 3** Selective alignment
D.1	Historical inertia	●		
D.2	Lack of synchrony between development stages		●	
D.3	Financial related limitations		●	
D.4	Time criticality imposed by national expansion plans		●	
D.5	Rigidity of procurement procedures		●	
D.6	Foreseen contractual hazards			●
D.7	Experience differential			●
D.8	Economies of scale			●
D.9	Available capacity			●

1) **Financial constraints**
2) **Time constraints**
3) **Integration constraints**

POINTS OF INTEREST

5.2.2 Institutional constraints

5.2.2.1 Financial constraints

Financial related limitation *[D.3]* seems to be the decision factor that came first to the mind of all the interviewees when asked regarding the rationality of the selected organization. It is precisely here where the division between ICE´s roles in one hand as the owner of the infrastructure with the legal responsibility for its timely development and in the other as a capable design and construction contractor starts becoming blurred, making this duality of functions hard to separate. The notion of a public construction company is not only unusual but also is seen with suspicious by some financial entities. Multi Lateral Development Banks, such as the Inter American Development Bank (IDB) and the Central American Bank of Economic Integration (CABEI), are prime participants in the funding of this types of projects in the region and their initial position is that the infrastructure should be built in its entirely by private parties.

A campaign of persuasion is usually undertaken by ICE´s officials in order to convince these entities, based on its past record of successfully constructed projects, that the organization has the technical capacity to undertake these endeavors. But in essence the reluctance of granting ICE resources for the construction of the projects by direct administration is not necessarily related to doubts regarding its qualities as a main contractor. It is also a matter of practicality in the control of the disbursements and of satisfying the bank´s vested interests. It is quite less demanding for a bank to control that the resources are being used efficiently when the payments are made to a contractor which in theory assumes the risk for any cost overrun[53] based on a unit price reimbursement mechanism than to do the same when the resources are being used to pay materials, labor, equipments and other inputs of the production process. In addition these financial entities also have to answer to their shareholders, which many times are member countries that want to see their economic interests taken into consideration. Several of the questioned sources recognized some degree of pressure from the banks in order to organize contracts in which international companies pertaining to the bank´s subscribed countries where able to participate.

The negotiation process usually ends with the banks acknowledging that ICE is technically a capable contractor (i.e. accepting its participation as a main actor in the construction process) but conditioning funds to specific uses. The restrictions are by no mean standard; some entities as the IDB limit the use of the funds to the contracting of works only, while others such as the CABEI are more open in its application and support some level of in-house construction activities. The JBIC, one of the main lenders involved in the construction of PHP, allowed using the funds not only to commission works to third parties but also to buy materials such as steel and cement, as well as construction machinery and equipment. Other items such as labor were expressly banned and the bank demanded the permanent presence in the project of a consultancy company directly appointed by it to approve the procurement processes.

It is fair to say that the aforementioned restrictions are not new; they already existed long before the execution of these projects, as was confirmed by some of the interviewees with historical knowledge about ICE, exerting a profound influence in the manner projects are currently organized. The starting point has been to achieve an overall make-buy balance that emulates the normal equity-debt ratio, which is around 50/50. The ambit of this allocation process has been delimited by two very clear poles. At one extreme is the fabrication of electro mechanic equipments, which is undertaken in centralized facilities that benefit from ***economies of scale*** *[D.8]* and that exhibit a low level of uncertainty regarding non anticipated changes in initial conditions, thus obviously the first candidate to be arranged as a contract. In the other extreme are all the activities pertaining to the trade of tunneling, at which ICE assign high doses of ***contractual hazards*** *[D.6]* and consequently gives practically for granted that they represent transactions that should be governed by means of hierarchy. This notion is congruent with what was concluded in section 4.2.3 regarding how unexpected changes are almost an intrinsic property of underground works. In essence the selection of both poles follows closely the logic outlined by TCE.

The electro mechanic equipments of a hydropower project such as EHDP scarcely contribute to 20% of the total cost and therefore additional works should be commissioned in order to facilitate the project´s funding. The combination of dam site works - metal works was selected around three decades ago, as was acknowledged by one of the interviewees involved in those

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[53] This corresponds to the common and somewhat idyllic perception that when developing large construction projects the cheapest option for the client is assigning all the construction risk to the contractor. Davis et al. (2009) provide an interesting overview of how, based in an extensive research of global mega projects, the BAA (British Airport Authority) decided to radically change the approach in the construction of the USD$ 8.5 billion London Heathrow Terminal 5 by using an innovative type of cost-plus incentive contract in which it assumed full responsibility for all the construction risks. The project was delivered within the original budget and schedule.

times in the organization of ICE´s projects, because they represented *“work packages interesting enough [i.e. with sufficient prospect of profit] so as to attract the attention of international contractors in conformance with the bank´s desires and that together with the electro mechanic equipments fulfilled the share of debt provided by the latter[54]”.* After this point the tendency was to systematically repeat this arrangement every time funding from multi lateral development banks was needed, reaching a point in which decisions are taken partly motivated by a condition of ***historical inertia*** *[D.1]*.

From this condition it is also possible to notice some shades of path dependency, because an ***experience differential*** *[D.7]* has growth over time between the works usually commissioned to third parties and those always built in house. Nevertheless, this does not represents the classical lock in situation (Arthur, 1989) in which a historical event restrict the choices of economical exchanges to one not necessarily optimal alternative. The capacity exists to construct the project entirely by direct administration[55], but as was explained by ICE´s General Coordinator of Projects when asked for the reasons why the construction of the PHP´s dam was commissioned to a third party: “the *time came in which we had to negotiate with the bank which works we insisted in doing in-house and which ones we were willing to organize as contracts. We had more experience constructing powerhouses and tunnels than large scale RCC dams, which we envisioned as technically challenging. Therefore, we chose to build the first ones by direct administration and cede the second to a private contractor “.* At the end a force majeure event in conjunction with sub optimal performance of the contractor forced ICE to partially rescind the contract before the first cubic meter of RCC was placed and to assume the construction of this work.

But the financial restrictions at which ICE is confronted now a day are not only derived from the specific preferences of the multi lateral development banks. ICE´s debt capacity is not without limits and the government is strongly encouraging the organization to use alternative ways of funding its projects other than the traditionally used financing scheme [56] (Aguero, 2012), which is based on equity plus debt from multi lateral development banks. Of special importance for this purpose are the provisions included in the Law N°8660 , commonly known as the law for the strengthening and modernization of ICE and issued in the year 2008 in order to relax the regulatory framework governing the institution and its companies to compete with other operators in an open market[57] (Vindas, 2008). Through this law ICE is entitle to engage in

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[54] According to Roberto L. Prado, chief engineering of ICE´s planning and control department in the 1980´s and author of this quote, this specific scheme was first applied for the construction of Ventanas-Garita Hydropower Project (97.4 MW, in operation since 1987).

[55] This is currently being demonstrated in RHP.

[56] In order to fulfill its legal duty of satisfying the country´s electricity demand ICE is entitled to borrow as an autonomous entity using its assets as collateral. Nevertheless, according to the article 12 of the Law N°8660 (Strengthening and Modernization of ICE) the maximum allowable level of debt is 45% of its total assets (art.12). By the end of 2011 ICE reported in assets approximately USD$ 9 600 million (Moody´s, 2012). According to ICE´s last available financial statements (September 2012) and without taking into consideration the short term liabilities (as indicated by law) the total assets – liabilities ratio was of 0.36. The government believes that this condition does not represent a problem yet, but calls to seek new financial schemes in order to support the ambitious development plan envisioned by ICE for the next decade.

[57] Costa Rica ratified the free trade agreement with the U.S., Central America and the Dominican Republic (CAFTA-DR) on January the 1st 2009. One of the commitments included in this agreement was the opening of the telecommunication market, a monopoly previously controlled by ICE. The law N°8660 was created with the purpose

strategic alliances in or out of the country with any private or public company undertaking activities related to those it performs (art. 7). In addition, ICE is allowed to subscribe trust funds agreements locally or internationally (art. 10) and to issue securities based on its current and future income or assets (art. 13) in order to fulfill its legal duties.

However the creation of a strategic alliance as a mean to ensure off-balance funds for the construction of a power project in Costa Rica is not as easy as it might seem. Restrictions imposed by the current regulatory framework make of this a quite complicated process, as became clear from the recent experience in designing the financial scheme and raising funds for the construction of RHP. Following the directives given by the government ICE devoted considerable time and efforts to attract parties that were interested in forming an alliance and contributing with capital for the construction of this project. Negotiations were held with several companies such as Electrobras and Synohydro. Nevertheless, two major factors prevented the realization of ICE´s intentions[58]. First, the alliance involved the creation of a legally independent company which ICE must possess at least 51% of the share capital (Art. 5, Law N° 8660). This was not favored by any of the approached companies. Second, a common requirement was to have a percentage of the total electricity production available to be sold to the wholesale market. But Costa Rica does not have such a market, being the generation of electricity organized under a single buyer model in which the totality of the production should be sold to ICE. At the end the negotiation failed and ICE was forced with little time available to resort to a complicated financial scheme consisting of equity, debt subscribed with Multilateral Banks (IDB and CABEI) and a trust fund with the contributions of a myriad of local and international banks. This scheme was additionally tailored to fit the context of a project that was already under construction by ICE´s direct administration relying majorly on its own capital and pushed by the ***time criticality imposed by a tight national expansion plan*** ***[D.4]***. This represents one of the main decision factors distinguished in all the analyzed projects, as will be explained in more detail in the following section.

5.2.2.2 Time constraints

One of the fundamental responsibilities ICE has with regards to the Costa Rican electric power sector is to ensure the balance between supply and demand and to prevent any risk of electric shortage[59], a common problem in other Central American countries. The planning tool used for this purpose is the yearly realization of a national expansion plan (NEP) that within a time horizon of ten years defines which projects should be constructed following economic and environmental criteria and according to the policies and guidelines given by the National Development Plan (NDP) and the National Plan of Energy (NPE), issued by the Ministry of National Planning and Economic Policies (MIDEPLAN) and the Ministry of Environment, Energy and Telecommunications (MINAET), respectively. The NEP is develop by the National Center of Electricity Planning (UEN CENPE), a unit of ICE´s electricity division, and constitutes the

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of preparing ICE for this new condition. Although the opening of the electricity market was not a commitment expressly included in CAFTA-DR, the application of this law is not restricted to the telecommunication sector only and favors the electricity sector as well.

[58] This was confirmed by the Chief Engineer of the Planning and Control Department, L.Diego Baltodano. See annex E.

[59] This responsibility is defined in the Law N°449: Establishment of the Costa Rican Institute of Electricity, 1949.

framework of reference for all the participants in the country´s electric power sector (ICE, 2012b).

The private participation in the development of power generation infrastructure in Costa Rica is restricted by law[60]to projects with a capacity of less than 50MW and a total contribution of no more than 30% of the national capacity. This means that the responsibility to develop larger projects such as the ones analyzed in this section relies entirely on ICE. In practical terms and for all those endeavors that do not qualify for private development the NEP becomes the work schedule for ICE´s Unit of Projects and Associated Services (UEN PySA). The main objective of this unit is therefore to ensure that the projects are finished on time and according to the goals defined in the NEP. Nevertheless, there appears to be a ***lack of synchrony*** ***[D.2]*** between the level of maturity of the projects and the ambitions reflected in the NEP. The construction phase starting without having defined the projects´ financial scheme is the clearest example of this condition[61].

One of the drawbacks of this is that ICE is restricted by law to initiate a procurement process without having first the funds[62]to fulfill its contractual obligations. Therefore starting the construction phase relying on its own capital as a manner to avoid delays in the expansion plans also mean that ICE is precluded to initiate any purchasing process exceeding this contribution. Because ICE has the capacities of a main contractor, normally it has a number of ***resources already available*** ***[D.9]*** at the offset of the construction projects (e.g. equipments, facilities, etc) and therefore can initiate the construction process without hesitation and with considerably less capital than if contracted to a third party. Even with the funds to support such a contract, ICE still would have to wait the duration of the tender procedure in order to have the contractor in place and ready to produce. Both the main dam site works and the metal works of the conduction system are two work packages whose construction starts rather late in the project´s execution[63]. It is not coincidence that none of the analyzed projects envisioned any contract for works within the first two years of the construction stage.

This condition may additionally provide a valid justification for the historical inertia recognized by many of the interviewees as central in the selection of the projects´ organizational arrangement. As was previously demonstrated there are a number of limitations that are intrinsic to the specific financial scheme selected for a project and the fact that this scheme is not clear from the outset of the construction stage introduces high doses of uncertainty to the project management team. In uncertain environments where the optimal strategy is unknown

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[60] General Law of Public Works Concession (N° 7329, 1993), Law of Parallel Electricity Generation (N° 7200, 1990), Modification of Law of Parallel Electricity Generation (N°7508, 1995).

[61] This is not restricted to the aforementioned case of RHP. For instance, the approval of the loan contract subscribed with JBIC for the construction of PHP was given in July 2001, while the construction activities began in 1999 with the construction of the project´s facilities (ICE, 2012a).

[62] This restriction is defined in both the Administrative Procurement Law (Law° 7494, art 8) and the Law for the Strengthening and Modernization of ICE (Law° 8660, art 22).

[63] In order to start the construction of the dam it is required first to finish the diversion works, which depending on the project size can take several years (2.5 years in the case of EDHP). Likewise before the assembly of the metal works related to the conduction system it is first necessary to have completed the tunnel and penstock trench´s excavation, a process that takes an important percentage of the project´s duration.

or difficult to predict decision makers recur to heuristics (Gigerenzer, 2008), hence the choice of ICE´s project directors to use arrangements that have worked in the past is not without logic.

The asynchrony mentioned above is not only restricted to the definition of the project´s financial scheme. The lack of basic designs was seen by the management team of RHP as an impediment for the procurement of works. According to the interviewed sources the construction of the project was organized from the beginning entirely by ICE direct administration because in this manner the construction process could proceed while the designs were being elaborated. But theoretically speaking not having a high level of detail in the designs is not an insurmountable impediment to commission a construction work. There are contractual forms and mechanisms that can be used for this purpose[64]. It is nevertheless an insurmountable impediment if the management team in charge of taking the decision gives it for granted that the design should be prepared in-house and that a bid-build contractual form based in unit prices is the only acceptable option. From personal experience the author knows that this represents a tacit organization constraint. Late designs in conjunction with delays in the definition of the financial scheme lead to a situation in which the only option to deliver RHP on time was to organize its construction relying in ICE´s own capacity.

There is yet another reason that may contribute in explaining why RHP was not organized in the same way as the other sub cases. To a certain level it is possible to notice a lack of clear guidelines from ICE´s senior management regarding which is the preferred organizational arrangement, thus generating inconsistencies in the structures chosen by different project directors to develop projects with very similar characteristics. Extending the analysis beyond the four sub cases, it is possible to confirm that RHP´s project management team has a work history that transcends this single project. Before, they were also involved together in the construction of two smaller hydropower projects[65] whose construction was financed entirely by means of a trust fund, having in general good results. This was the first time this financial scheme was used by ICE to support the construction of power projects and has the advantage that in practical terms ICE is contracted by the trustee to design and construct the project. This means that the funds can be used to support normal expenses of a construction company which are restricted in other more traditional financial schemes. RHP was therefore the third project in a row constructed by the same project team, who confronted by the aforementioned uncertainties resorted to a well known formula. It should be noted that this is an inference made by the author and does not respond to the opinion expressed by any of the interviewees. What can be asserted without the risk of being wrong is that RHP and EDHP have in terms of technology and scale of the construction operations almost identical characteristics. ICE would be wise to critically revise the organizational arrangement selected for the construction of EDHP in the light of the experience and lessons learned in RHP, especially with regards to how accurately are the current institutional constraints represented by the premises used as a basis for such selection.

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[64] For example a design and build contract or a cost plus reimbursement mechanism, which is well suited for situations where the level of information at the outset of the contractual relation is low.

[65] Cariblanco Hydropower Project (82 MW, in operation since 2007) and Toro III Hydropower Project (49 MW, in operation since 2013).

The lack of synchrony between the national expansion plan and the level of maturity of the projects represent a valid explanation of why ICE usually assumes on its own the construction of the works included within the first years of the execution stage, but does not offer a convincing explanation of why it rely so little in outsourcing work to specialized trade providers. It is acknowledged that the dam site works represent an interesting prospect for any private contractor, but if the intention is to involve private parties in the construction process there are other works besides these that could be outsourced, in compliance with the time restrictions and without giving away the responsibility a main contractor usually has to integrate the system. The ***rigidity of the procurement procedures*** *[D.5]* at which ICE as a public party is subjected may provide a valid explanation for this, as it will be outlined in the following section.

5.2.2.3 Integration constraints

In section 3.2 it was argued that even though construction has been rightly described as a loosely coupled system at the industry level, at the project level in can be conceived as a tightly coupled chain of fabrication and assembly activities with intensive interaction of a wide variety of actors and trades. Being an efficient system integrator means being able to orchestrate this myriad of interdependent actors so that the input required by one is timely delivered by the other. The answer to the dilemma of whether it is on ICE´s best interests to cede the integration of a subsystem such as the dam site works or to the bear the responsibility for its integration relying partly on trade providers is closely related to the abilities it has to cope with the coordinative demands involved in putting all the parties in unison to play the same tune.

All Costa Rican public bodies are subject to the Administrative Procurement Law (APL, Law N° 7494). In ICE´s particular case, this law is contingent upon the law of strengthening and modernization of ICE (LSMI, Law N° 8660) and the institution also needs to comply with internal procurement regulations (ICE, 2011). The path it must follow to buy any good or service is considerably more lengthily and cumbersome than the one private parties need to follow. According to the LSMI and APL three procurement procedures are possible: full tender, abbreviate tender and direct purchase. These procedures are presented in descending order in terms of the number of required steps and maximum purchase amount. The threshold for their application varies between public entities in function of their reference budget. ICE has the second largest reference budget in all the Costa Rican public sector and for the current year the General Comptroller of the Republic (GCR) has set the maximum and minimum limits for an abbreviate tender procedure in approximately USD$10 500 000 and USD$115 000, respectively (CGR, 2013). Constructing a multibillion dollar project such as EDHP following these regulations means that a significant percentage of the procurement processes should be organized following either a full or an abbreviate tender procedure. The former if used to commission construction works can well last two years, being its award subjected to the approval of the GCR. In addition, during the process several impugnment mechanisms can be applied (art. 23, LSMI). The challenge may be brought by any potential bidder or party whose interests are affected by the adjudication. This means that although due care was taken, when engaging a tender procedure ICE is not only following a rather lengthily process, but also one vulnerable to delays propelled by third party opportunism (see section 3.1.4). Therefore, the abilities ICE has to efficiently integrate the system relying on commissioning parts of it to trade providers are not only affected by the natural tendency public agents have to increase the specificity of the contracts to avoid probity hazards, thus reducing the space for local adaptation during the production process, but also by the uncertainty in the duration of the procurement process of different and interdependent parts of the supply chain.

From documental analysis it was possible to confirm that this condition was taken into consideration to justify the organizational arrangement selected for the construction of Angostura Hydropower Project (AHP). The concrete and electro mechanic works related to the construction of a powerhouse are usually activities that are preceded either by a large open pit excavation or by the excavation of a cavern. Therefore they are in a similar condition with regards of its late location in the overall planning of the construction stage as the main dam site and metal works are. The problem envisioned by the AHP´s decision makers was the risk of not being able to match the programming of both contractual processes, as it can be extracted from one of the analyzed documents (ICE, 1993, p.11-12):

> *"The main objection ICE has regarding this option is that two contracts would be needed for the powerhouse´s construction: one for the concrete works and the other for the fabrication and assembly of the electro mechanic equipments, both of them confronted to the possibility of having objections and appeals during the procurement process… Because of the conditions imposed by the APL it is impossible to accurately predict the date each contract will be signed. Given the fact that both procurement processes follow an independent path, there is no guarantee that their progress will allow setting the interlocking provisions needed to solve in the best manner interference problems. The date of entry into operation is under this condition difficult to ensure."*

The argumentation given above is a bit harsh in the sense that if generalized it may preclude the contracting of any pair of interrelated works that follow independent procurement processes. Subcontracting is still possible and even AHP´s former project director believes that *"this condition, even though relevant, is not sufficient to justify the exclusion of any form of outsourcing in the construction process".* Following the recommendations made by technical consultants, some specialized activities related to the construction of RHP´s dam were subcontracted[66], even though it is fair to say that these are rather discrete in the context of the entire work and that they are not directly connected one to the other. While the option to outsource parts of the system and then take responsibility for their integration remains open, it is possible to conclude that this contractual rigidity does represent an obstacle that ICE´s decision makers, having at their disposal the capacity to do everything in-house, are not very eager to confront.

5.3 Rationality of the selected organization

From the exploration of the social framework surrounding the construction of the large hydropower projects executed by ICE in the last two decades it is possible to confirm the pervasive effect that the institutional constraints have had in the manner the construction process has been arranged. It appears that these constraints have been present even from

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[66] The formwork system for the construction of the dam´s concrete face, as well as the placement of the cofferdam´s membrane, was arranged as subcontracts.

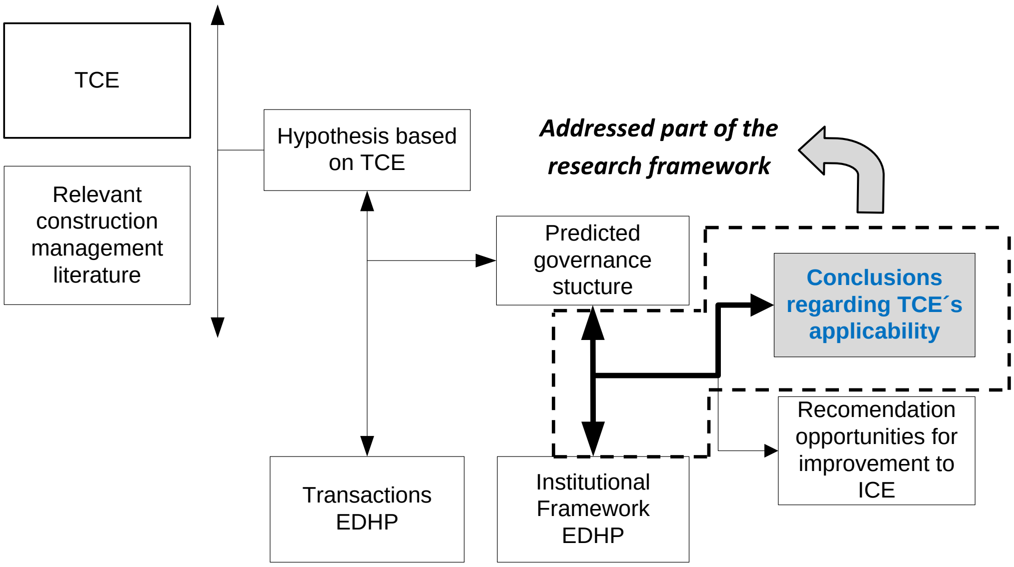
before the study period and that they are today deeply rooted in the organizational practices of ICE; to some extent they are accepted as a given condition, which has lead to a well defined pattern in the organization of projects.

EDHP is not an exception and the rationality of the selected governance structure can be depicted using similar arguments as the ones introduced in the previous section to explain the decisions made in other projects. In simple terms, the reasoning for the chosen organization is as follows. The permits to start the project´s construction are foreseen for the second half of 2014. According to the National Expansion Plan (NEP) the project has to be operational in 2021. Because of its scale, it is technically unfeasible to complete its construction in less than seven years; hence construction should start without hesitation once the permits are granted relying on ICE´s existing capacity. So far the project´s financial scheme has not been defined. This poses a dilemma: in one hand the possible governance structures are dependable of the selected financial scheme and the interests and requirements of lenders and shareholders, but on the other if the make or buy decision is not taken in advance the procurement processes may not be executed on time. To deal with this lack of definition the project management team resorts to a recipe the has work in the past: a 50/50 make-buy ratio, in which metal works and electro mechanic fabrications are outsourced and the integration of the dam´s subsystem ceded to a private contractor, with the exception of the tunneling operations and any work conducted in the first two years of the construction stage, the first because of the foreseen contractual hazards and the second because is not possible to have the suppliers on time. Anticipating the participation of Multi Lateral Development banks the contracts are prepared using FIDIC standards, thus following a hybrid structure. Finally, the rigidity of public procurement processes imposes a barrier to outsource discrete parts of the remaining sub-systems that ICE, having construction capacity available, chose not to confront.

After having completed the study of the project´s institutional framework, the next question naturally follows: what can the results of this chapter tell about the extent of the theoretical predictions and the validity of the assumptions in which they rely? It is clear that ICE is considerably limited to organize the construction process due to the effects imposed by its social framework. Based on the insights provided in this investigation, what could be proposed to improve its efficiency as an EPC contractor? These and other important issues are going to be addressed in the next two chapters.

CHAPTER 6

APPLICABILITY OF TCE



Thesis 'main research questions:

1. What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?

2. What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?

3. What are the main characteristics of the EDHP´s institutional framework?

4. **What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?**

Research question to be answered

5. What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?

6. Applicability of TCE

Before presenting the results of this chapter, it is pertinent first to make a brief recapitulation of the research´s main objective and the course that was followed to fulfill it. As it may be recalled from section 2.1, this thesis aims to contribute with the theoretical development of TCE in the context of the construction industry by testing its applicability as an explanatory theory of the governance structure chosen by ICE, in its position of EPC contractor, to organize the transactions implicit in the construction process of EDHP. To accomplish this, the research was divided in three main blocks. First, in chapter three the theoretical foundation of this investigation was built by means of an extensive exploration of TCE and of the most relevant characteristics of the construction industry. Based on this exploration, a tailor made methodology to operationalize the theory was crafted (see section 3.1.6) and a set of hypotheses proposed to make a theoretical connection between transactions and governance structures. These hypotheses were in turn based on assumptions that provided ideal conditions to apply the theory´s causal explanation. Afterwards, in the fourth chapter the most relevant transactions involved in the construction of EDHP were defined, characterized and aligned by means of the research hypotheses to a theoretical governance structure. Finally, in chapter five the institutional framework surrounding the construction of EDHP was studied in detail, yielding a characterization of the governance structure selected in reality to organize the project´s transactions, a description of its social framework and main institutional constraints and an outline of the rationality of the chosen organization.

With this as a background, the main purpose of this sixth chapter is to finally conclude about the applicability of TCE in the context of this case study. As shown in **figure 6.1**, the analysis is composed of four parts. First, the theoretical and selected governance structures are confronted and the extent of the predictions provided by the research hypotheses is evaluated. Afterwards, the validity of the main assumptions taken during the course of this investigation is revised in order to conclude about the reliability of the structure used to support both the research hypotheses and the transactions´ characterization process. Next, the effects of elements that were not directly addressed by the research perspective, but that nevertheless are relevant for the purpose of this investigation, are analyzed. Two elements are of particular interest: the effects of culture and the development of the local capacity of human resources. Finally, underpinned in all the elements mentioned above, reflections regarding the application of TCE´s in the context of this case study are provided, thus fulfilling the main objective of this thesis.

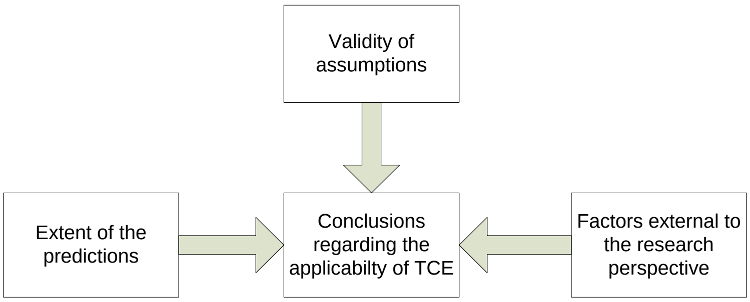


Figure 6.1: main parts of the theory´s applicability analysis.

6.1 Extent of the predictions

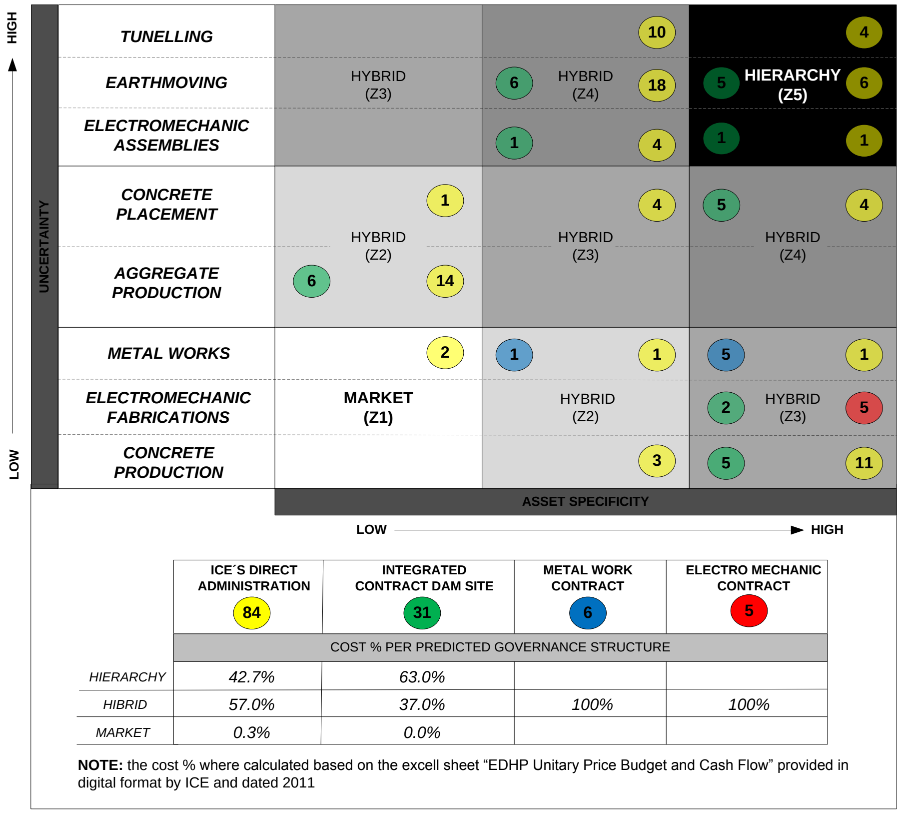
In **figure 6.2** the theoretical governance structure as predicted in chapter four and the one selected in reality according to the characterization made in section 5.1 are confronted. As was concluded in section 4.2.3, frequency is low in almost all transactions; hence this dimension was not included in this representation. The theoretical governance structure is displayed by means of a matrix in which the levels of asset specificity and uncertainty are the two main variables. The main construction trades used to cluster the transactions in chapter four are listed and ranked accordingly. At the same time, the real organization of the transactions is represented by a set of circles with a key of colors to indicate whether it correspond to one of the three main procurement packages (i.e. hybrid) or to ICE´s direct administration (i.e. hierarchy). Within each circle a number specifies how many potential transactions (PTs) are represented in each position. In total there are over 120 PTs. Even though the normal condition would be to outsource not one but a bundle of PTs to the same trade supplier, the individual allocation of these transactions still provides interesting information to conclude about the tendencies of the chosen organization. Finally, a table in the lower part of the figure shows the decomposition of the total cost of all PTs included in each of the four selected organizational arrangements according to the theoretical governance structure at which they pertain.

The examination of **figure 6.2** should start with a general indication of the research hypotheses´ predictive qualities, leading afterwards to a closer scrutiny of the information. An adequate and simple measurement of these qualities can be provided by analyzing how many PTs were organized as it was predicted. An overall prediction factor (OPF) can be defined for this purpose as follows:

$$OPF = \frac{\sum Predicted\ PTs}{\sum PTs} \qquad \text{(Eq. 6.1)}$$

In total 47 PTs were organized as predicted, resulting in an OPF of 0.37. In general, it is fair to conclude that the research hypotheses´ predictive qualities are far from satisfactory.

Additional to this, several elements can be extracted from this figure. First, looking at the manner the PTs within ICE´s direct administration are distributed, it is possible to notice that only 11 transactions (i.e. 13.1%) are allocated in the predicted quadrant of hierarchy (Z5). If this analysis is expanded to include as well the closest hybrid zone (Z4) the total PTs increases to 47 (i.e. 56.0%). Meanwhile, 31 PTs (i.e. 36.9%) are organized by ICE direct administration, even though they correspond either to market or to the closest hybrid level (Z2). Additionally, those transactions predicted as hierarchy contribute to 42.7% of the total cost, whereas the highest contribution is made by those PTs predicted as hybrid with a 57.0%. When looking to each trade separately, it is possible to note that ICE assumes by direct administration all the transaction included in the trade of tunneling, as well as outsource all the project´s electro mechanic fabrications. Apart from these, the transactions directly executed by ICE are distributed in almost every matrix´s quadrant, making difficult to discern a clear trend.



	ICE´S DIRECT ADMINISTRATION 84	INTEGRATED CONTRACT DAM SITE 31	METAL WORK CONTRACT 6	ELECTRO MECHANIC CONTRACT 5
	COST % PER PREDICTED GOVERNANCE STRUCTURE			
HIERARCHY	*42.7%*	*63.0%*		
HIBRID	*57.0%*	*37.0%*	*100%*	*100%*
MARKET	*0.3%*	*0.0%*		

NOTE: the cost % where calculated based on the excell sheet "EDHP Unitary Price Budget and Cash Flow" provided in digital format by ICE and dated 2011

Figure 6.2: confrontation between selected and predicted governance structure.

With regards to the integrated dam site contract, it can be stated that 6PTs (i.e. 19.4%) are allocated in the hierarchy quadrant. When the area of interest is prolonged to include the closest hybrid zone (Z4), the total number of PTs increases to 18 (i.e. 60%). Contrary to what could have been expected based on the research hypotheses, in terms of cost distribution the transactions included in the hierarchy quadrant represent the major share: 63%. The remaining 37% of the cost is accounted by those transaction predicted under a hybrid structure, thus matching the selected organization. It is also possible to observe how this contract includes transaction pertaining to almost all the analyzed trades, thus constituting a cluster of transactions for which ICE ceded its responsibilities as the system integrator. A different case is represented by the two remaining procurement packages, which are trade specific and whose selected governance structures match the predictions.

By simple inspection of the information provided above it is possible to assert that the set of proposed hypothesis are not effective in predicting the organizational arrangement selected for the construction of EDHP. It is necessary to recognize that there are some decisions that fit well in the general logic outlined by TCE. For instance, the selection poles mentioned in section 5.2 as the departure point used by ICE to organize the transactions seem to be well justified by these hypotheses. At one extreme of these poles, and anticipating important levels of contractual hazards, ICE decided to undertake by direct administration all the transactions included in the trade of tunneling, which are predicted as hierarchy or fairly close to it. In the other extreme the fabrications of electro mechanic equipments are the first transactions to be organized as a contract because they enjoy of economies of scale and low level of uncertainty. Furthermore, the contracts were organized following a hybrid structure, in line with the predictions.

Nevertheless there are other decisions that cannot be explained by means of the research hypotheses. For instance, there is a lack of outsourcing in some trades with low level of uncertainty and asset specificity. In all the project´s subsystems in which ICE assumed the role of system integrator the production of both concrete and aggregates is organized by means of hierarchy, while according to the overall logic outlined by the research hypotheses these transactions appear to be among the first candidates to be outsourced. But perhaps the clearest divergence with respect to the theoretical predictions is the integrated contract of the dam´s site itself. This procurement package is full with transactions that contain high levels of uncertainty and temporal asset specificity. Seen from the perspective of a main contractor with the overall capacity to integrate the system, and following the rationality sketched by the research hypotheses, the outsourcing of these transactions does not appear to be the most reasonable decision, much less to cede the responsibility for their integration.

Despite these results, and as was already mentioned in section 3.1.1, the fact that the research hypotheses were not successful in predicting the governance structure selected for this project should not be a cause of surprise or an indicator of theoretical failure, for the theory was developed thinking majorly in a context of a market controlled by private parties driven majorly by the maximization of profits and with significant freedom to transact. The assumptions taken to support the research hypotheses were also oriented in this direction, providing an ideal environment for the theory´s causal explanation. But the construction of EDHP is embedded in a different social framework, which as was demonstrated in the previous chapter introduces constraints not necessarily of an economic nature but that nevertheless play a predominant role in the organization of the project´s transactions. In order to provide good conclusions regarding the applicability of TCE in the context of this case study, it is first necessary to reflect upon the validity of the main assumptions taken to support the predictions and the characterization process. This is the topic of the next section.

6.2 Validity of main assumptions

A summary of the main research´s assumptions is provided in **table 6.1**. Included here are the assumptions used as a basis for the construction of the research hypotheses in section 3.3, as well as those taken in chapter four to support the transactions´ characterization process. Below their validity in the light of the results of this investigation is discussed.

Table 6.1: recapitulation of main research´s assumptions.

N°	Subject	Description	Validity
1	Research hypotheses	Capacity to undertake the project as the main EPC contractor.	✓
2		Freedom to organize the transactions following mainly a profit maximization function.	⚠
3		Well functioning market with lower production costs	⚠

4		The boundaries between governance structures conform to the cost proportions given by research hypotheses	⚠
5	Characterization of transactions	Any contractual rupture would be assumed as total	✓
6		ICE has capacity to plan and coordinate the production process	✓
7		Limitation of resources if organizing a contractor´s replacement	✓
8		ICE holds property rights of quarries and sites to locate aggregate and concrete production facilities	✓
9		Very complete set of designs and baselines studies provide a strong basis for procurement process	✓

Assumption N°1: ICE capacity as an EPC contractor

Once constructed, EDHP will become in terms of investment the largest infrastructure project in Costa Rica. It is without a doubt a technically challenging project and the works included within its scope surpass in size any other constructed in the past by ICE. Under these conditions, doubts may be raised about ICE´s capacity to undertake by its own the construction of this project, thus questioning the validity of the first assumption used to support the research hypotheses. Despite this, a very simple consideration is taken to sustain the soundness of this statement. In terms of technology and scale of the construction operations, there are no significant differences between RHP and EDHP. As was mentioned in section 5.2, the former is currently being constructed relying almost entirely on ICE´s internal resources. To this date, RHP has a progress of over 50% and so far as the author knows no problems other than typical have been confronted. Hence, it is plausible to assume that ICE is capable to act in the same manner for the construction of EDHP.

Assumption N°2: freedom to organize transactions

Normally the owner of an engineering project does not possess technical capabilities for the design and construction of the infrastructure and therefore should procure them to a competent third party. Several procurement alternatives are available, of which an EPC contract is one of the favorites choices in major construction projects (Loots and Henchie, 2007). But there is a long way before awarding the project´s construction to an EPC contractor. Prior to this is what Green (2009) has called development stage. This stage includes the design of the financial model, planning, permitting requirements, preparation of the procurement documents, among others, and culminates with the project´s financial close when all the conditions have been met to the lender´s satisfaction. Only after this point the EPC contract becomes effective. A contractor chosen following this development route is considered to be competent and accepted by both the owner and the funders, thus explaining why the interference of the latter in the matters concerning the construction process is usually low (Huse, 2002). This condition allows the contractor to fully exert its role as system integrator, freely organizing the transactions implicit in the project´s construction as it considers more appropriate.

The context in which ICE operates is clearly different to the one illustrated above. To begin with, ICE is not only a competent EPC contractor with substantial capacity available, but also it is the owner of the infrastructure and it has the legal responsibility to ensure the balance between the demand and the supply of electricity in Costa Rica. This condition alone should not imply particular restrictions when fulfilling its role as the system integrator, provided that the correct progression is kept from the development stage to the construction stage and that this role is well understood and accepted by the project´s stakeholders. From the study of EDHP´s social framework, it became evident that this is not the case. The current condition is one in which the level of maturity of the projects´ development stage is not congruent with the goals defined in the national expansion plan (NEP). To comply with the deadlines defined in the latter, the construction phase starts relying majorly in ICE´s existing capacity, without having reached the financial close and mostly applying organizational arrangements that have work in the past as a manner to cope with this uncertainty. Elucidating the reasons of this condition demands further research, sufficient is to say that the flexibility provided by building bridges between stages come at the cost of a reduction of the space ICE has available to maneuver as a normal EPC contractor, space that is additionally shrunken by the effects of the integration constraints imposed by its condition of public entity subjected to the principles of public procurement law.

From the exploration of the social framework surrounding the construction of EDHP and briefly depicted above it is clear that there are considerations other than economical which have a central role in the manner the construction of this project was organized. As it is shown in **figure 6.3**, if compared to an EPC contractor operating in normal conditions the scope ICE has to organize the transactions relying in TCE´s causal explanation is significantly reduced by the institutional constraints at which it is confronted. Therefore, the assumption that ICE has freedom to procure any part of the project following mainly a profit maximization function is far from real.

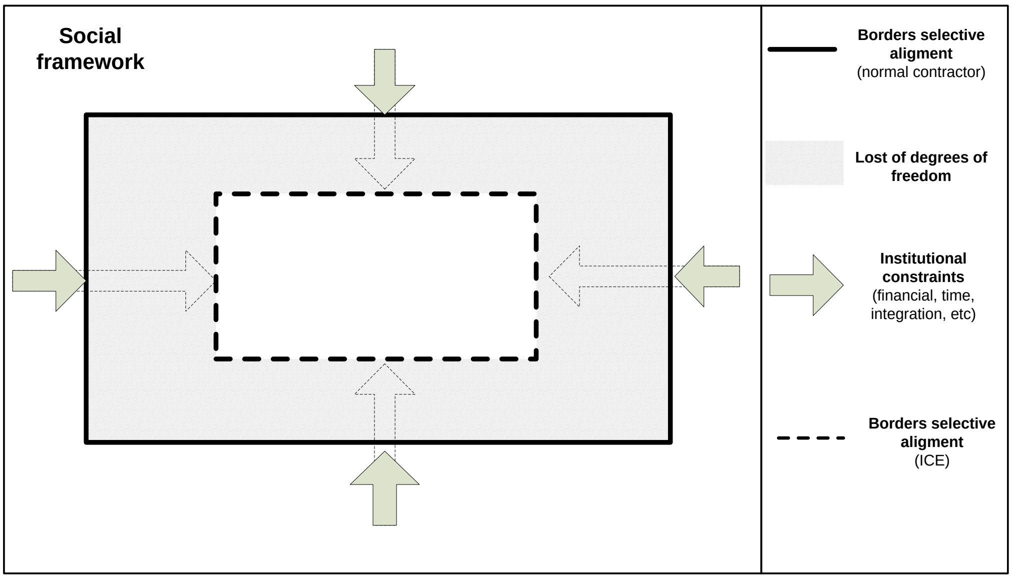


Figure 6.3: ICE´s scope to organize transactions.

Assumption N°3: market performance

As was introduced in section 3.2, in general a wide variety of trades are involved in a construction project. At the same time, there is a high uncertainty about work continuity. These two factors help to explain why the industry is usually perceived as being composed by a number of smaller specialized firms that enjoy more frequency of work and hence production cost advantages in comparison with main contractors, which in turn find subcontracting an attractive option instead of continually hiring and firing workers. These characteristics seem to support the assumption of a well functioning market which offer production cost advantages in comparison with vertical integration. Despite this, three disruptive elements were anticipated in section 3.3 with the potential to affect the logic of this argumentation: particularities of heavy construction projects, capacity of the local market and followed procurement strategy. It is pertinent now to analyze them based on the outcomes of this investigation and to conclude regarding their effects in the validity of this assumption.

Heavy construction requires fewer types of trades and exhibit lower levels of subcontracting if compared with other segments of the construction industry (Eccles, 1981a, Carty, 1995). In addition, the market is composed by bigger and fewer contractors which are able to hold a higher degree of specialization in their workforce and that generally have the capacity to operate internationally in order to expand their network. These contractors often have operations in developing countries, many of them experiencing considerably economic growth and heavily investing in infrastructure. But construction industry in developing countries is many times faced to a context of resource shortage and institutional weaknesses (Ofori, 2000). The availability of resources and trustworthiness of local partners are perceived as major sources of risk by main contractors and other participants in the projects´ development (Wang et al., 2004). Under these conditions a contractor may not always find production cost advantages in resorting to the local market to find specific trade providers, which may contribute in explaining why heavy construction contractors accustomed to work in a global environment have a tendency towards vertical integration.

In the context of this case study, very limited information was found regarding the conditions of the local construction market. For instance, in order to support the characterization of the transactions in terms of dedicative asset specificity (i.e. market capacity) information was asked to the Costa Rican Chamber of Construction (CCC) about general indicators of the national construction market and the characteristics of the local firms. Even though CCC was very supportive in providing the information that was within its reach, including indicators of utmost importance such as levels of economic activity, employment and granted building permits (CCC, 2012a, 2012b), it is still difficult to make inferences about the local or regional construction capacity with the information available. Therefore the characterization was based in the author´s experience and in the opinion of several consulted experts. This is a regretful limitation that any researcher conducting a study such as this in a developing region must confront, since the vast majority of the research efforts in construction are devoted in the context of developed nations.

It is true that the boundaries and capabilities of a local construction market should not be an impediment to develop projects in the context of an industry that is able to mobilize the required capacity from any part of the world. But while it is not an impediment to the development of infrastructure, in the context of this case it may have implications in the validity of this third assumption. When working in a not familiar location, especially if this is a developing country, multinational contractors tend to increase their prices if compared with more familiar or less uncertain environments in order to take into consideration the inherent risk of this condition (Jaselskis and Talukhaba, 1998). It is plausible to assume that a technically capable local contractor would have cost advantages if compared to an international counterpart. Having construction capacity available, a difference exists therefore for ICE if it can count with a regional pool of competent trade providers, or if on the contrary it should recur to the international construction market to fill the gap of local resources. In other words, a well functioning market for the purpose of this study should be one in which the main contractor can find available trade providers within its own operation range and from which to take cost advantages of a comparative higher degree of specialization. For the reasons explained above, this condition remains to a certain extent unclear in this investigation.

In addition to this, subcontracting is also affected by the uncertainty in future workload. Contractors can resort to it as an alternative to constantly increase and decrease their capacity in function of the changing market´s conditions. In turn, future workload is strongly affected by the followed procurement strategy. The widespread use of competitive tendering procedures is a major reason of why contractors are not able to accurately predict the prospective use of their capacity. But ICE´s condition is different, because the current legal framework grants it exclusivity in the development of the larger power generation projects. Moreover, the legal provisions that allow the existing degree of private participation were introduced in the 1990´s, while ICE operations in design and construction began almost about the same time it was founded in 1949. Therefore ICE has had during its history a remarkably high certainty about future work; as it was said before the national expansion plan is its portfolio of projects. This has allowed it to keep a strong technical base in almost all trades included in the design and construction of this type of projects, which remains unmatched by any regional contractor.

Based in the argumentation provided above, it is fair to conclude that the assumption of a well functioning market which offers production cost advantages in comparison with vertical integration remains, in the context of this project, open to contestation.

Assumption N°4: boundaries between governance structures

A limitation commonly attributable to TCE is that quantifying the costs implicit in the analysis is a remarkably difficult endeavor (Masten, 1996). This case study was not the exception and in order to overcome this condition artificial boundaries were set between the three generic governance structures based on theoretical cost proportions. Because an exact calibration of the frontiers between each governance structure would require information about the costs associated to every combination of levels of intensity of the transaction´s attributes, not mentioning the fact that the analytical machinery used to characterize the transactions is based in qualitative criteria, the assertion that the total cost conforms to the proportions given by the research hypotheses provides a simplified model essential for the purpose of this thesis but that nevertheless has intrinsic limitations in its predictive qualities.

Other assumptions

As shown in table 6.1, additional assumptions were taken to support the transactions´ characterization process, but in general these enjoy of higher face validity if compared with the statements used to support the research hypotheses. Taking into consideration the level of detail of the EDHP´s designs and baselines studies and the standby time derived from the environmental studies currently underway, it is reasonable to suppose that sufficient care in the preparation of the procurement documents will be taken so as to achieve a level of completeness congruent with that of the information used as a basis for their preparation. Additionally, the ownership of the most suitable quarries and sites to locate production facilities is ICE´s common practice and even though it is not usual to have resources easily available during the construction stage to undertake works that were not planned in advance, the capacity to plan and coordinate the production process of any sub trade remains during this period as one of the most important assets of ICE´s design and construction division. Finally, contractual ruptures are not necessarily total but this is the most reasonable conjecture a decision maker can formulate when making a prediction of the contractual hazards implicit in a transaction. It is important to note that assumptions different to these would lead to a different outcome of the characterization process.

6.3 Beyond the research perspective

The intention of this thesis was to provide a holistic view of the rationality that prevailed in the organization chosen for the construction of EDHP. For this reason, the study was not only restricted to the possibilities offered by TCE´s causal explanation, but expanded to include the effects of the social framework to which this project is circumscribed. To give structure to the analysis and keep the investigation within its practical limits, the adopted research perspective consisted in points of interest directly extracted from the factors that guided the make or buy decision in a sample of four large hydropower projects. This was based on documental analysis, participatory observation and to a large extent in semi structured interviews with key participants in the decision making process. Although this strategy facilitated an efficient distillation of institutional constraints that are central in explaining the manner the transactions of this project were organized, it cannot claim to be exhaustive in exposing all the aspects of the social framework that are relevant for the purpose of this investigation. Of all the elements that may have been left out, the author wishes to draw attention to two in particular: the effects of culture and capacity building in developing countries. Below they will be briefly addressed.

6.3.1 The effects of culture

The theory of TCE has been built with the contribution of authors such as Ronald Coase and Oliver Williamson, whose work has been mostly developed in the context of the U.S. But this thesis analyzes the organizational decisions of a project conducted in Costa Rica, a small country included in the cluster of Latin American societies. Cultural differences exist between these two settings that are difficult to unmask just by interviewing a few subjects. An interesting framework useful to overcome this limitation is provided by Hofstede et al. (2010), who empirically derived a set of six cultural dimensions from an IBM survey data and other sources such as the World Value Survey (WVS) database. These dimensions are briefly explained in **table 6.2**, including a comparison between Costa Rica and the U.S based on Hofstede et al.

(2010) and complemented by the researcher´s own knowledge about Costa Rican culture. A more extensive characterization of the latter can be found in **annex F.**

Table 6.2: cultural dimensions and comparison between Costa Rican and U.S. cultures.

Cultural[1] dimension	Description	Costa Rica	U.S
Individualism	In individualistic societies the ties between the individuals are loose and people are expected to look only after themselves or immediate family. On the other hand, in a collectivistic society people many times from birth are integrated into highly cohesive groups in which they find protection in return for loyalty.	Low	High
Power distance	In a high power distance society the members with less power expect and accept this power to be distributed inequitably.	Low	
Uncertainty avoidance	It reflects the manner in which the society copes with an uncertain future. Individuals of a high uncertainty avoidance society feel uncomfortable with unstructured, ambiguous and unknown situations.	High	Low
Masculinity	A masculine society favors competition, assertiveness and material reward for success. On the other hand, a feminine society has predilection for quality of life, caring for the weak, cooperation, modesty and consensus.	Low	High
Long term orientation	Short term oriented societies foster virtues related to the past and present (e.g. respect of traditions, fulfillment of social duties and preservation of face). On the contrary, long term oriented societies foster virtues oriented towards future rewards (e.g. thrift and perseverance)	Low	
Indulgence	Indulgent societies are more open to show emotions and have a tendency towards the search for gratification of basic human desires. On the contrary, in restraint societies these emotions and desires are constrained by strict social norms.	High	

1) According to Hofstede et al. (2010)

As can be stated from the table above, there are some cultural similarities between Costa Rica and the U.S.; both exhibit low power distance, are short term oriented and are to a certain extent indulgent. Nevertheless, fundamental differences are obvious with regards to the remaining dimensions. Costa Rica exhibits a high degree of collectivism and differently to most of Latin American countries is ranked as one of the most feminine cultures in the world. A reflection of the effects these differences have in the analytical framework provided by TCE is appropriate.

The economic incentives play an important role in the main line of reasoning sketched by TCE. People are supposed to be propelled by the maximization of profits and they will act opportunistically every time they can in order to increase their prospective gains. Given equal costs of govern, market is preferred because the intensity of these incentives is higher and therefore optimization of production processes for the sake of increased earnings lead to lower costs. Nevertheless, there are incentives of a different nature that even though may have no room in the context of an Anglo-Saxon economic theory their importance in other settings should not be neglected. During his time working for ICE in the development of hydropower projects the author has experienced firsthand the feeling of pride, belonging and commitment that surrounds the people working in the construction of these endeavors. Given the country´s possibilities the achievements made by ICE´s design and construction division throughout its history are worthy of recognition. This organization is the crown jewel of Costa Rican public sector; the place in which many of the country´s finest professional and technicians aspire to work. People give the best of them not because this will lead to an increase in their personal capital, but because they perceive themselves being part of something bigger; a feeling hard to digest in a capitalistic, competitive and highly individualistic society such as the U.S. In the authors´ opinion, the assumption that ICE will find cheaper production costs if resorting to the construction market should not be so easily given for granted.

Anglo Saxon and Latin American societies are also characterized by the use of different legal families: common law in the former and French civil code in the latter. While common law is distinguished by relying in *"fact-finding by juries, independent judges, infrequent appeals, and judge-made law rather than strict codes"*, civil law is characterized by *"fact-finding by state-employed judges, automatic review decisions, and later the reliance on codes rather than judicial discretion"* (Siems, 2007, p.2). Not necessarily there is a direct relationship between the legal family in use and the country´s culture. Many societies have been subjected to exogenous shocks such as colonization in which formal institutions have been transplanted without much consideration of the cultural environment. Nevertheless, in the case that concern us a positive correlation can be observed between legal formalism and uncertainty avoidance (Licht et al., 2005). When addressing contractual issues care should be taken in not using the same formula in the two settings without any prior consideration, especially in construction where most standards have been prepared thinking majorly in a common law context. Open end provisions, central in the theoretical exposition of this thesis as a mechanism to induce adaptation, may not be so effective in a civil code country in which there is a strong tendency towards formal regulations. The effects in the range of application of enforcement mechanisms have already been discussed. A dispute adjudication board (DAB), included as an improvement in the new FIDIC standards to reduce the use of more formal mechanisms, fits well with the common law concept of independent judges, but not so much in civil code based systems. In Costa Rica its use has not been regulated and lawyers and judges would definitely have a hard time understanding it.

The tendency of uncertain avoidance societies, especially if relying in a civil code, to implement very formal rules and regulations in order to reduce ambiguity is nevertheless not external to the TCE´s causal explanation; conceptually it is possible to translate these tendencies into transaction cost differentials using the analytical machinery the theory provides. What seems to be beyond the theory is the resistance to change that is implicit in high uncertainty avoidance cultures such as Costa Rican. ICE may organize the construction of its project always in the same manner not because from the TCE point of view it is the most economical option; neither because there is a lock in situation from which it is difficult to leave, but simply because it has work in the past and shifting to a new condition introduces the possibility of confronting unknown situations that culturally speaking may be more difficult for Costa Rican decision makers to overcome than their counterparts in the U.S. Risk aversion, as was noted by Chiles and McMackin (1996), is a behavioral assumption that appears to be missing in transaction costs of economics and that is to a large extent cultural dependent.

6.3.2 Capacity building in developing countries

Common sense indicates that there is a linkage between infrastructure and economic growth and that a good infrastructure system is a fundamental condition for any nation to become developed. But even if funding was not a concern, developing countries are at a disadvantage in comparison with developed ones when trying to improve their infrastructure, not only because their institutions are weaker but because there is a lack of know-how and management skills. It is true that if lacking the capacity to develop infrastructure can be imported, but this condition is also problematic because of at least two reasons. First, people in charge of the procurement process should have some level of knowledge about the system they are procuring in order to perform efficiently. Second, the institutional framework of every country is different and solutions that are efficient in one context may not be in the next. The optimum condition is one in which the local capacity of human resource grows together with the infrastructure stock.

In this sense, the contribution made by ICE to the Costa Rican society goes beyond a reliable electric system. For more than six decades ICE has had a leading role in the development of the national human capital. Many of the most prominent engineers in the country have been trained in the light of the challenges of designing and constructing the country´s electric power infrastructure. The author has known from people involved in the development of this type of infrastructure in the region how difficult it is to get competent human resources in all the areas of expertise required to undertake these projects in other Central American countries that did not worried about building their local capacity, and how at the end this condition severely limits their progress. With an electrification index of more that 99%, over 90% of the electricity generated from renewable sources of energy, an adequate balance between demand and supply and one of the lowest rates in Central America it is difficult to deny that in a regional level the development model chosen in Costa Rica and led by ICE has been a success.

TCE has been developed in the context of well developed Western societies, in which perhaps the capacity of the country´s human resource is given for granted. In addition, it is right to say that TCE is a theory developed principally thinking in the private sector; in essence is about choosing the form of organization to reduce the costs of the exchange and therefore to maximize profits, an eminently financial consideration. Even the manner in which the theoretical framework of this thesis has introduced in section 3.1.4 the effects of having a public transacting party, mostly based of the work made by Spiller, is not exempt from this conclusion. When developing infrastructure, especially in developing countries, socio-economic considerations may overthrown financial ones and a public company most rely in more than the logic outlined by TCE to take the right decisions.

6.4 Reflections regarding TCE´s application

Conditions such as freedom to organize transactions mainly motivated by the maximization of profits and a well functioning market which offers production costs advantages due to its intrinsically high level incentives represent ideals in Western capitalistic societies. Economic theories of the firm, such as TCE, have been developed to a large extent thinking in this context, where the social framework provides an environment that supports their causal explanation. But the project analyzed here is carried out in Costa Rica and conducted by a public company, which is embedded in a social framework of a different nature. The fact that the research hypotheses proposed in section 3.3, deliberately based on ideal market conditions, were not successful in predicting the governance structure selected for the construction of EDHP does not comes by surprise.

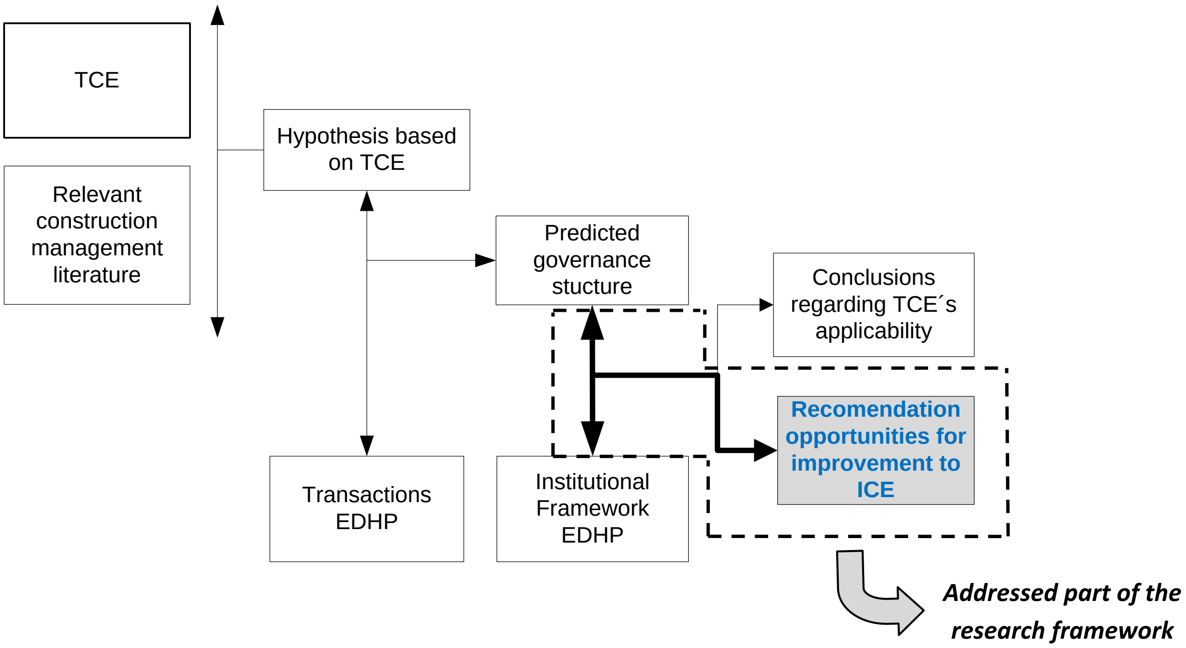
Viewed in a very simplistic manner, one may be tempted to conclude that the theory is not applicable in the context of this case study. Nevertheless, as was mentioned by Williamson (1998) TCE should be placed in a broader analytical construction composed of different levels of social analysis, all interconnected by constraints and feedbacks. The research hypotheses failed to provide an adequate prediction of the chosen organization, but as was demonstrated in the previous sections this is because the assumptions that were used to support them did not offered a good representation of the social framework in which this project is immersed. Once understood the institutional constraints at which ICE is confronted, not only those directly attached to it but also others affecting the society as a whole, it was possible to recognize that there are factors other than economical which are determinant in the manner the construction process of this project was organized.

The author will venture to conclude that the theory is applicable even in contexts divergent to the one Williamson and other authors probably had in mind when establishing its main precepts, such as the one represented by this case study, provided that it is not naively applied without taking into consideration the surrounding environment. In essence, there is no reason why a construction company operating in Costa Rica or elsewhere would not find TCE a useful theory to provide insights about the organization of construction activities, even one of public character such as ICE. One of the most interesting characteristics of this approach is the manner it combines different levels of analysis. In one hand its micro analytical qualities demand a good understanding of the technological aspects of the production process, but on the other, because it is circumscribed to a broader analytical construction, it also requires to comprehend the manner the social framework set limits to the economic activities. This by itself it’s a valuable analytical exercise for any company.

In the context of ICE´s operations as an EPC contractor the theory gives a very interesting perspective about which activities, based on their contractual hazards, are more likely to be outsourced. The author has been informed that currently efforts are been made to complete a benchmark study of ICE´s construction costs. The results of this research may provide a perfect complement to this, noting that there are other elements beside production costs that should be taken into consideration when deciding how to organize a transaction. The study also helped to uncover several institutional constraints that may not be evident at first glance, but that nevertheless affect ICE´s efficiency as an EPC contractor, limiting the scope it has available to organize the construction process. Based on the insights provided in this investigation, in the next chapter a general strategy will be outlined as a contribution to improve this situation

CHAPTER 7

OPPORTUNITIES FOR IMPROVEMENT



Thesis ‘main research questions:

1 What hypotheses can be formulated to provide a theoretical connection between transactions and governance structures?

2 What is the governance structure predicted by the research hypotheses to organize the EDHP´s transactions?

3 What are the main characteristics of the EDHP´s institutional framework?

4 What can be concluded regarding the applicability of TCE as an explanatory theory for the governance structure selected for the EDHP´s construction?

5 What opportunities for improvement can be suggested to ICE from the insights provided in this investigation?

Research question to be answered

7. Opportunities for improvement

A note of warning is pertinent before starting this chapter. It is not the objective of this investigation to conclude about the convenience of having or not a public EPC contractor participating in the development of electric power projects in Costa Rica. A study such as that would be of a different nature. ICE´s intention to continue playing the leading role in the design and construction of the power projects included in the National Expansion Plan (NEP) will be taken for granted. Based on this consideration, ideas to improve its performance are drawn from the outcomes of this thesis.

If compared with a private contractor, the degrees of freedom ICE has available to organize the construction process are significantly reduced by the effects of the institutional constraints at which it is subjected. Even though it is unreal to think that ICE will ever be able to act in the same manner as a private contractor does, steps can be taken to expand the scope it has for choosing different alternatives to organize the transactions implicit in the projects´ construction. Based on the insights provided by this work, a strategy denominated ***“bulls-eye´s approach for the maximization of freedom”*** was outlined. This conceptual model is intended to be the departure point from which additional research efforts could be organized by ICE to improve its efficiency as a main contractor.

A detail of this strategy is presented in **figure 7.1**. Three levels of action have been envisioned: integration of phases and maturation of governance structure, customization of institutions and introduction of production redundancy. The more external a level is, the more pervasive its effect in releasing the moorings that constraint ICE´s capacity to organize the construction process. A brief explanation thereof is provided in the following sections.

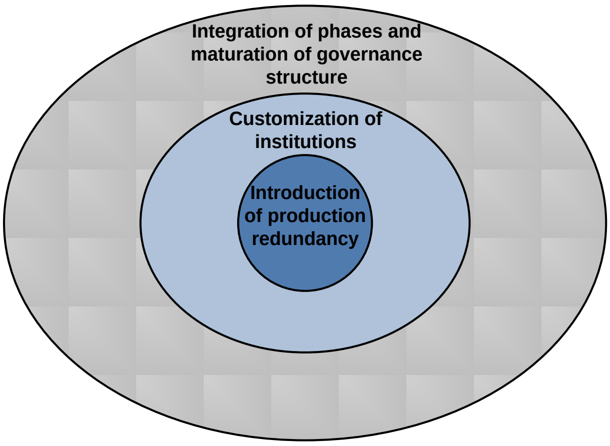


Figure 7.1: **bulls-eye´s approach for the maximization of freedom.**

7.1 Integration of phases and maturation of governance structure

As long as ICE´s duality of function remains, in one hand as the client and owner of the infrastructure and in the other as the main contractor, its activities as a contractor will be subject to the financial and time related constraints discussed in this investigation. But the effects of this condition could be minimized if an adequate progression between the development and the execution stages is kept. The selection of the project´s governance structure should be understood as something that needs to be gradually decided at the former, integrating the interests of all relevant stakeholders. It is not something that should be delegated to the project management team once the execution stage is close to start or has already started. Then the scope for selection shrinks to a few options that are not necessarily the optimal.

In **figure 7.2** a diagram of the phases normally followed by ICE to develop power projects is shown. The development phase includes the feasibility studies, the environmental impact assessment (EIA), the front end engineering and design (FEED) and finally the financial close, where the negotiations to secure the project´s funding come to an end. Identification and prefeasibility stages are left out of the diagram. Starting from this point the execution phase begins, including the project´s detailed engineering, procurement and construction (EPC) activities. For the sake of simplicity the stages are represented sequentially, even though in reality typically overlap to some extent. As it can be stated, in the current condition the project´s governance structure remains undefined until a late point of the development stage. In some cases the financial close extends well into the execution stage. The project management team in charge of the EPC, who did not have much involvement in the development stage, is the one bearing the responsibility to decide which governance structure should be followed. This is done while the financial close is underway and surrounded by a great deal of uncertainty.

This condition can be improved if from the early development stage the most favorable governance structure is progressively matured taking into consideration the points of view of the main stakeholders. The latter are not only players external to ICE such as banks and political actors, but internal as well including key members of the planning, financial, procurement and construction departments. This gradual definition is not limited to choosing which transactions should be organized in-house and which ones should be outsourced, but includes additionally the consolidation of the financial scheme that will provide the funds to construct the project under the selected structure. The idea is therefore to protect the execution stage and its management team from any organizational uncertainty that could have been decided beforehand when the space for maneuver was greater.

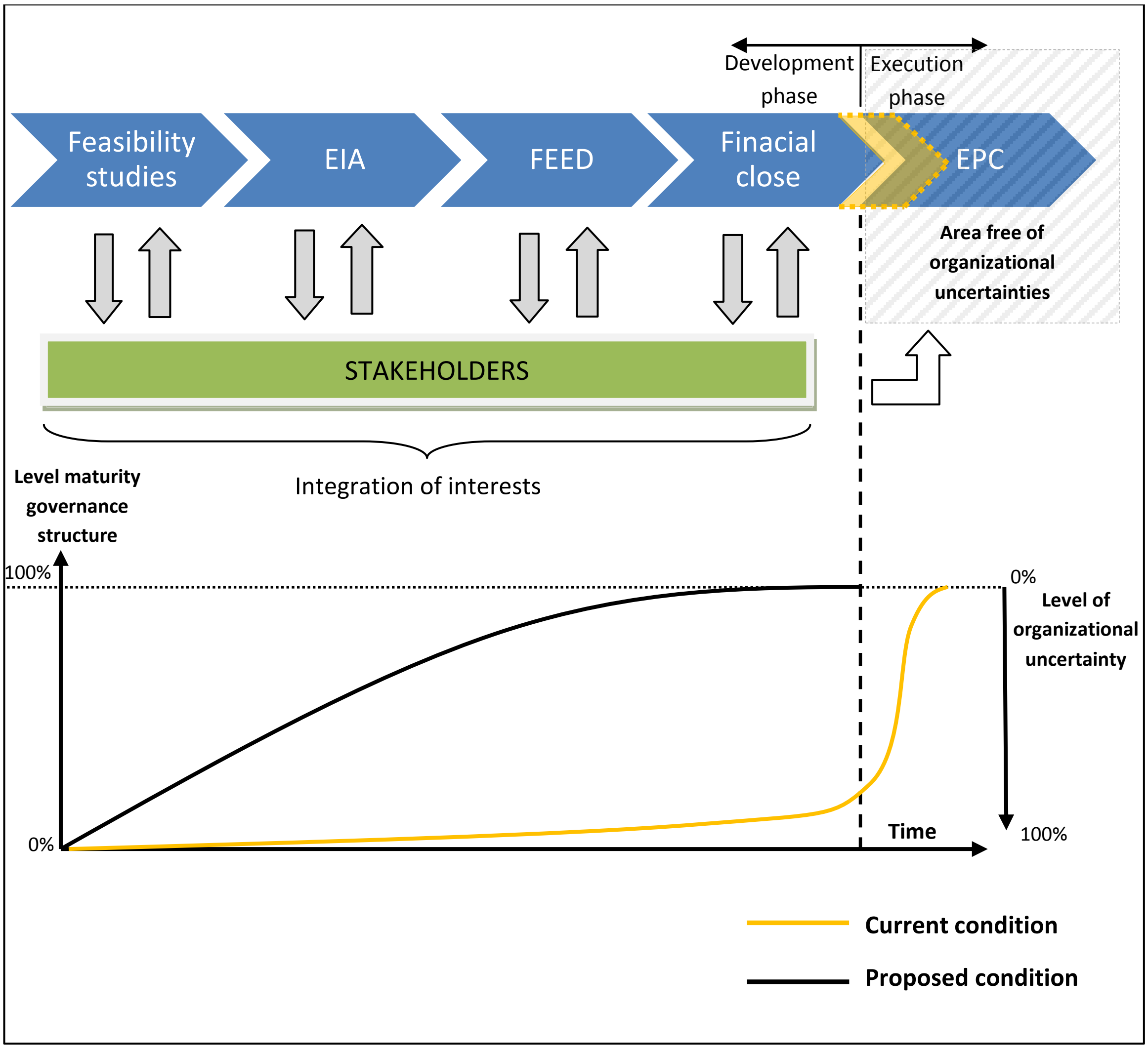


Figure 7.2: integration of phases and gradual maturation of governance structure

The integration of the stakeholder´s interest and maturation of the governance structure is a process that has to be planned and coordinated continuously during the project development. It is not something that should be disturbed every time a new stage begins. The author believes that there are great opportunities for improvement in this area because to some degree each step is currently developed independently from the rest, making difficult to perceive the bigger picture. Superior integration between stages means more time to take the strategic decisions affecting the execution phase, as well as improved feedback to and from the National Center of Electricity Planning to better attune the level of maturity of the projects with the expectations reflected in the NEP.

7.2 Customization of institutions

The processes required to undertake a construction project cannot be efficiently conducted relying in the same mechanisms used by public entities to carry out routine activities. ICE has understood this and special institutions have been crafted in order to make possible its operation as a main contractor. For instance, for the projects´ construction ICE uses a special framework for the recruitment of personnel that allows it to flexibly decrease and increase the manpower in function of the projects´ progress. This elasticity would not be possible using the normal provisions that apply to the organization of labor in the civil service. In addition, instruments have been created for the rental of construction equipment and machinery based on a tariff estimation method previously approved by the General Comptroller of the Republic, allowing in a matter of a few days to have the required assets on the site and ready for production.

Still, limitations are perceived with regards to ICE´s abilities to act as a system integrator relying on trade providers to conduct specific parts of the construction process. As it was revealed in section 5.2.2, these constraints appear to be generated from long procurement processes which are vulnerable to delays propelled by third party opportunism. In addition, procedures can also be expected to be more rigid than usual due to probity hazards. This creates a condition in which it is difficult to assure that the procurement processes of different and independent parts of the supply chain will be timely executed. But institutions need not to remain invariant and if ICE´s intention is to continue playing an active role as a main contractor there is every reason to critically analyze the current situation. Within the boundaries defined by its condition of public body, there is room to make improvements that allow it to organize more freely the construction process.

From the author´s perspective, without losing its position as system integrator there are several benefits of participating local trade providers in the construction process. First, for ICE it represents a valuable benchmark opportunity. The conditions surrounding a construction project are always different, making sometimes difficult to establish comparisons between projects. Outsourcing specific parts of the construction process introduces both a direct yardstick and healthy competition to ICE´s own crews. Second, it is also beneficial for the local construction industry, an important development engine and contributor to the national economy. One of the interviewees commented to the author that there is a big appetite from the industry to participate in a joint manner with ICE in the construction of power generation projects. This impetus may represent a window of opportunity that serves both interests. A quality assurance program could be established based on third party certification in which construction companies are encouraged to comply with minimum quality standards. As an incentive, ICE could customize an abbreviate procurement system based on a register of certified contractors. A premium mechanism can also be introduced providing tendering advantage to those suppliers that consistently achieve good quality. Because training and certification costs could be too high for medium to small enterprises to bear, a financial and technical support scheme can also be implemented with the contribution of key public and private parties[67]. Confronted to a boom of public construction projects and a perceived low quality of the local industry, a similar system was implemented in Singapore in the early 1980´s with very good results (Kam and Tang, 1997, Ofori and Gang, 2001).

The procurement scheme introduced above could also incorporate a baseline of unitary prices for those specialized works that are common in heavy construction projects, easily measurable and that are subject to a higher standardization of the production process (e.g. fabrication and

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[67] Some actors that could have a leading role in this process be are the Ministry of Economy, Industry and Trading, Ministry of Public Works, Professional Association of Engineers and Architects (CFIA) and Costa Rica Chamber of Construction (CCC), among others.

assembly of reinforcement steel, drilling and placement of anchor bolts, etc). These prices could be adjusted by ICE to the particularities of every project based on its own cost estimations and approved beforehand by the General Comptroller of the Republic. In this manner, certified contractors could compete to provide well defined services with a pre-approved ceiling price, similarly to the mechanism used to rent machinery and equipment. The quality certification by a third party and upper boundary price method provides safeguards against probity hazards and third party opportunism. In response, contracts should be considerably lighter and procurement processes shorter, making practical for ICE to outsource discrete elements of the construction process.

Another area in which institutions could be customized is in the alternative dispute resolution mechanisms currently available for the governance of the contractual relations. Even though this was not specifically acknowledged as an institutional constraint that imposes restrictions to ICE´s actions as an EPC contractor[68], from the study of the project´s main contracts in section 5.1 it was possible to note that during the ex-post stage of the procurement process there is not a smooth progression in the escalation of conflicts; if a query between ICE and a contractor cannot be solved to the satisfaction of both parties by either the engineer (i.e. contract manager) or the project director, the next step in the dispute resolution ladder is arbitration. Even though as it was already discussed (see section 5.1.2) ICE´s quasi-rent is lower than that of a normal client with no construction capacity available, problems may still be expected if changes to the original conditions sprout frequently during the contractual relation. This is the main reason why the new FIDIC contractual forms have introduced the use of a Dispute Adjudication Board (DAB) as a neutral and temporal determination procedure.

According to the current Costa Rican legal framework, the implementation of alternative dispute resolution mechanisms other than arbitration appears to be restricted to private parties only. Moreover, as was mentioned in section 6.3.1, the application of a DAB fits well in a common law jurisdiction, but not so much in civil code based systems such as Costa Rican. Despite this, it is plausible to assume that the presence of a independent party appointed at the commence of the project and that performs frequent visits to the site, regardless of the degree in which it offers binding resolutions, could be beneficial because the dispute solver in each step of the ladder should rely strongly in the resolution taken at lower levels by better informed and usually technically more competent third parties. A contractor will think it twice before resorting to the tactic of threatening deliberate delay, thus reducing conflict and extending the self enforcement range of the contract. In essence, this should lead as well to a reduction of the transactions costs implicit in the governance of the contractual relations, especially for those transactions with high levels of contractual hazards. Given the importance of this project, the technical challenges it implies and the huge investment involved in its construction, it would be a wise decision to analyze if the current legal framework should be adjusted to introduce the possibility of intermediate steps in the project´s dispute resolution ladder.

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[68] In fact, this applies more to ICE in the role of owner of the infrastructure than in the role of EPC contractor. Nevertheless, because both roles are exerted together it was considered relevant to recommend in this section the evaluation of this aspect.

Needless to say these are but some of several ideas that could be used to reduce the integration constraints at which ICE is currently confronted, as well as to improve the manner it exerts the governance of the construction process. Further analysis is required to conclude about its viability. What is important to understand is that if ICE´s decision is to continue playing a dominant role as a main contractor, logic tells that it should be proactive in shaping the institutional framework in a manner that enables it to exercise its role in the most efficient way.

7.3 Redundancy in the production system

In construction projects temporal is the dominant type of asset specificity. In response to this, as it was explained in section 5.1.2, contracts terms are crafted to arrange the private enforcement capital of the parties and to grant the engineer with sufficient faculties to steer the contractual relation so as to reduce the hold-up potential. Temporal specificity, as defined in this study, is a function of the available slack a transaction has in the construction process and the time required to arrange a replacement. While the former cannot always be increased, given the fact that there will always be a critical path that marks the project duration, the replacement time can be positively affected if the production process is organized as a redundant system.

The production of aggregates was characterized in chapter four as the only type of transaction with a consistently low level of temporal asset specificity. The reason for this condition is that if one production facility fails there are several others around the project with the capacity to meet the demand until a replacement is arranged. Also contributing to this is the fact that aggregates can be produced and stored for later use. The manner in which the production of aggregates was organized is the perfect example of what is referred here as a redundant production system. While most of the construction processes do not enjoy the advantage of being able to produce in advance for later use, there are still other ways to achieve redundancy. Additional capacity could be decoupled from a specific transaction and conveniently activated if the latter fails to fulfill its original promises. This can be done by including in the construction process for a particular trade more than one supplier and by organizing the works to be conducted in-house in such a manner that the production system could be temporarily overloaded to minimize the impact of a supplier´s failure.

The introduction of redundancy in the production system is of course not for free. Organizing transactions of the same nature under the responsibility of different providers means more contracts to coordinate (i.e. increased transaction costs) and reduced benefits from economies of scale. Moreover, having additional capacity available to endure a temporal overload also implies the cost of not being able to use this capacity elsewhere. But several benefits also become evident. As was explained earlier in section 5.1.2, being the owner of the infrastructure as well as the main contractor ICE´s quasi-rent is always represented by the cost of switching suppliers. Having a redundant production system significantly reduces its quasi-rent, thus extending the contract´s self enforcement range. In theory this condition should lead to a decrease in the suppliers´ opportunistic behavior and less stringent contractual terms, which in turns reduces the transaction costs. Because infrastructure projects are time driven, decision makers may also be willing to invest in reducing their risk perception by introducing measures to diminish the temporal asset specificity of the transactions. Based on this line of reasoning, the benefits of a redundant production system can be quantified as follows

$$\boldsymbol{B_{RS}} = [T_{RQ} + V_{RP}] - [T_{MP} + P_{ES} + C_{AD}] \qquad \text{(Eq. 7.1)}$$

Where:

B_{RS} = net benefits of redundant production system.
T_{RQ} = transaction cost savings of reduced quasi-rent.
V_{RP} = value for the owner of reduced risk perception.
T_{MP} = transaction cost increase of having multiple providers for the same type of transaction.
P_{ES} = production cost increase due to the loss of economies of scale.
C_{AD} = cost of having additional capacity ready to be activated.

A conceptual model of the optimum redundancy level is shown in **figure 7.3**. The production system is represented as a network of trade specific capacity nodes connected by transfer links. Each node may be a particular trade provider with whom a contract is signed to deliver the amount of capacity represented by the node, or well a crew within ICE´s own forces. If a capacity node fails to provide the required output, another node connected to it by a transfer link may temporarily cover this capacity while a permanent replacement is arranged. The link indicates that it is physically possible to transfer capacity from one node to the other and that this could be achieved in a shorter period of time than if importing the capacity from outside of the production system (e.g. by contracting a new supplier). In theory, several configurations could be tested in terms of the net benefits of the offered redundancy level, using a as a baseline a configuration in which all the trade specific transactions are commissioned to the same provider. In the example presented in **figure 7.3** the configuration with three capacity nodes represents the optimum level of redundancy.

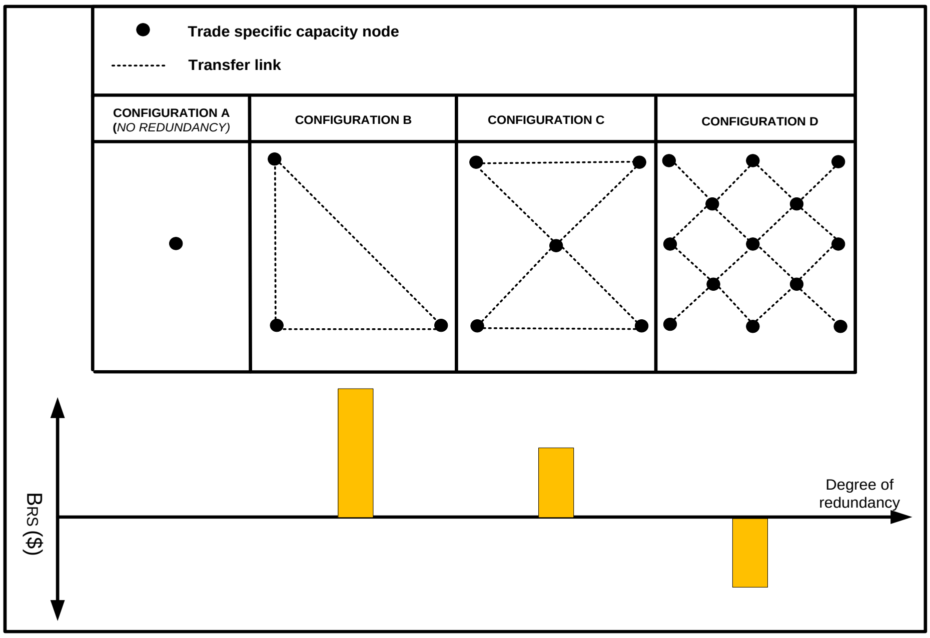

Figure 7.3: **conceptual model of optimum redundancy level.**

The introduction of redundancy in the production system could be a useful mechanism to ease the effects of the integration constraints at which ICE is currently confronted, because it reduces the impacts of delays in the procurement processes of different and independent parts of the supply chain by decreasing the temporal asset specificity of the transactions. It is also the last level of a conceptual model that integrates several ideas arising from the course of this investigation that could potentially contribute in losing the moorings that constraint ICE´s freedom to organize the construction process, thus increasing its efficiency as an EPC contractor. It demonstrates at the same time how transaction cost of economics can become a theoretical perspective from which practical benefits can be extracted when used to analyze the organizational arrangements in the construction industry.

8. Conclusions

Since Williamson gave it new life in the 1970´s, transaction costs of economics (TCE) has been the base of an important body of scientific research oriented towards the study of institutional arrangements in a great variety of industries, being vertical integration the most representative topic. Even though construction has not been the exception, the attempts made in the latter to test the theory´s applicability have been rather discrete and have opted for breadth rather than deepness. The objective of this thesis was to contribute in closing this gap by making a theory oriented research using as a single case study the construction of a large hydropower project in Costa Rica. In specific, the analyzed project was El Diquis Hydropower Project (EDHP) and the executing organization the *Instituto Costarricense de Electricidad* (ICE). Hypotheses were proposed and the congruency between the transactions´ attributes and the selected governance structure assessed in order to conclude about the applicability of the theory. Based in the insights derived from this investigation, ideas to improve ICE´s performance were proposed.

Deliberately based in several assumptions that provided ideal market conditions, three research hypotheses were formulated. First, when asset specificity and uncertainty are low transactions are better organized in the market, regardless of the level of frequency. Second, when asset specificity and uncertainty are high and there is a low level of frequency in the exchanges that neither contributes to articulate more complete contracts nor to introduce social mechanism to restrain opportunistic behavior, hierarchy is the preferred governance structure. Third, in situations in between some nuance of hybrid structure is more likely to appear.

In general it can be concluded that these hypotheses were not effective in predicting the organizational arrangement selected by ICE for the construction of EDHP. Even though some decisions seem to fit well with the theory, as for example the choice to organize in-house the tunneling works and to procure the electro mechanic fabrications, other decisions such as the vertical integration of trades with low contractual hazards, like concrete and aggregate production, as well as ceding the integration of a system which is full of transactions that exhibit high levels of uncertainty and temporal asset specificity, such as the dam site works, are difficult to explain following just the logic outlined by TCE. Of all the analyzed transaction, only 37% were organized as it was predicted.

The inaccuracy of the research hypotheses´ predictions is, nevertheless, not surprising. TCE was developed in the context of a free capitalistic market, where the social framework offers conditions that are supportive of the theory´s causal explanation. Nevertheless, from the results of this study it was possible to recognize that the social framework in which EDHP is embedded is of a different nature and that it introduces considerations other than economical that played a central role in the manner the transactions of this project were organized. Of special importance is the fact that ICE is not free to organize the transactions relying majorly in a profit maximization function due to the pervasive effects of its institutional environment, which introduces financial, time and integration constraints. So even though the research hypotheses did not provided an adequate prediction of the chosen organization, this does not represent a theoretical failure because the main assumptions used for their construction did not offered a reliable representation of the conditions in which the decisions were take.

Based on these arguments, and taking into consideration that TCE should be placed in a broader analytical construction composed of different levels of social analysis (Williamson, 1998), it is concluded in this thesis that the theory is applicable even in contexts divergent to the one Williamson and other authors probably had in mind when establishing its main precepts, such as the one represented by this case study, provided that it is not naively applied without taking into consideration the surrounding environment. In essence, there is no reason why a construction company operating in Costa Rica or elsewhere would not find TCE a useful theory to study the organization of construction activities, even one of public character such as ICE. The strategy proposed in this thesis to improve ICE´s performance as an EPC contractor, which was based entirely in the insights derived from this investigation, is a good prove of it.

After having fulfilled the objectives of this thesis, it is possible to conclude that its contribution is twofold. First, it contributes with the theoretical development of transaction costs of economics in the context of the construction industry by testing its applicability at a level of deepness generally not found in the existing empirical literature, where econometric testing is predominant. Several micro analytical tools were crafted for this purpose, which represent by themselves a valuable addition to other researchers willing to use TCE as a theoretical perspective to study the organization of construction activities. Second, a practical contribution is also made to ICE as the facilitator of the case study. Important constraints that currently affect its efficiency as a EPC contractor where reveled and in response to this ideas were proposed to increase the degrees of freedom it has available to organize the construction process, as well as to improve the manner it exerts its governance.

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ANNEX A: Technical Data Sheet EDHP

A. GENERAL INFORMATION	
Total capacity	650 MW
Average production	3 050 (GWh/year)
Total cost	USD$ 2 072 million
Current status	Conducting the Environmental Impact Assessment (EIA)
Scheduled date for the start of construction phase	Second semester 2014
Duration of construction stage	7 years (84 months)
Population resettlement	1547 persons (416 families) 10 different communities
B. TECHNICAL INFORMATION	
HYDROLOGY, SEDIMENTS AND SEISMOLOGY	
Average river flow	167 m^3/s
Maximum probable flood	22 300 m^3/s
Suspended sediment load	3 622 000 Ton/year
Maximum design earthquake	0.51 g
Basic operating earthquake	0.34 g – 0.42 g
RESERVOIR	
Maximum operation level (MOL)	300 m.a.s.l
Minimum operation level	260 m.a.s.l
Gross storage volume	2 858 hm^3
Usable storage volume	1 646 hm^3
Area at MOL	5 842 Ha
Total area including protection zone	7 364 Ha
DIVERSION SYSTEM	
Maximum design flow (Rp = 1:10 years)	4 081m^3/s
Type	Tunnel
Number of tunnels	2
Internal diameter	12.6 m
Length	618m – 688m
DAM	
Type	Concrete Face Rockfill Dam (CFRD)
Elevation of crest	310 m.a.s.l
Length of crest	854 m
Width of crest	8 m
Maximum height	173 m
Total volume	11 600 000 m^3
Thickness of concrete face	0.30 m - 0.75 m
SPILLWAY	
Design flow	22 298 m^3/s
Number and type of gates	4 - Radial
Dimension of gates (w x h)	14.5 m x 16.9 m

Elevation of the cymatium crest	284 m.a.s.l
BOTTOM DISCHARGE	
Discharge flow (at minimum operation level)	398 m^3/s
Discharge flow (at maximum operation level)	527 m^3/s
Type	Tunnel
Number and type of gates	1 Sliding + 1 Stop log
Dimension of gates (w x h)	3.1 m x 4.1 m
ECO FLOW POWERHOUSE	
Type	Underground
Dimensions (l x w x h)	42 m x 21 m x 29 m
Design net head (nominal)	123.3 m
Design flow (nominal)	20 m^3/s
Number and type of electro mechanic equipment	1 – Francis vertical axis
Capacity	27 MW
MAIN WATER INTAKE	
Height of tower	75 m
Length of bridge	214 m
Input threshold elevation	250 m.a.s.l
MAIN CONDUCTION TUNNEL	
Design flow	260 m^3 /s
Internal diameter	9.80 m
Length	11 300 m
Length of steel lining	237 m
Slope	0.3 %
Maximum coverage	600 m
SURGE TANK	
Total height	110 m
Exposed percentage	50%
Internal diameter	28 m
Total weight	2 050 Ton
PENSTOCK	
Length of each branch	1 175 m
Internal diameter	6.9 m – 2.5 m
Total weight	12 200 Ton
MAIN POWERHOUSE	
Type	Superficial
Dimensions (w x l x h)	26.5 m x 134.5 m x 25.5 m
Level assembly floor	17.1 m.a.s.l
Design net head (nominal)	263.4 m
Design flow (nominal)	260 m^3/s
Number and type of electro mechanic equipment	4 – Francis vertical axis
Capacity	155.7Mw each
RESTITUTION	
Type	Channel

Chamber level	12.2 m.a.s.l
Length 1st segment	1.0 Km
Length 2nd segment	1.4 Km
Width 1st segment	25 m (concrete lining)
Width 2nd segment	100 m (without lining)
TRANSMISSION	
Length of new 230KV line	130 Km
Length of 230Kv line to be reconstructed	100 Km
Number of new substations	2
Number of substations to be expanded	4

ANNEX B: System´s description

B.1 Dam works

The main function of the dam is to obstruct the river´s flow and to create a researvoir area in order to store water for its later use in electricity generation. In this project the works related to the dam system can be divided in six main subsystems: dam [A], diversion [B], spillway [C], bottom discharge [D], closure dike [E] and eco-flow works [F]. The latter is not directly related to the prime system´s function (i.e. to obstruct the water flow) but it is necessary for letting pass the required amount of water in order to support the wildlife and human uses downstream of the dam and in the process produce more electricity. The main components of these subsystems are shown in **figures B.1 to B.8**. Below a detailed description thereof is provided.

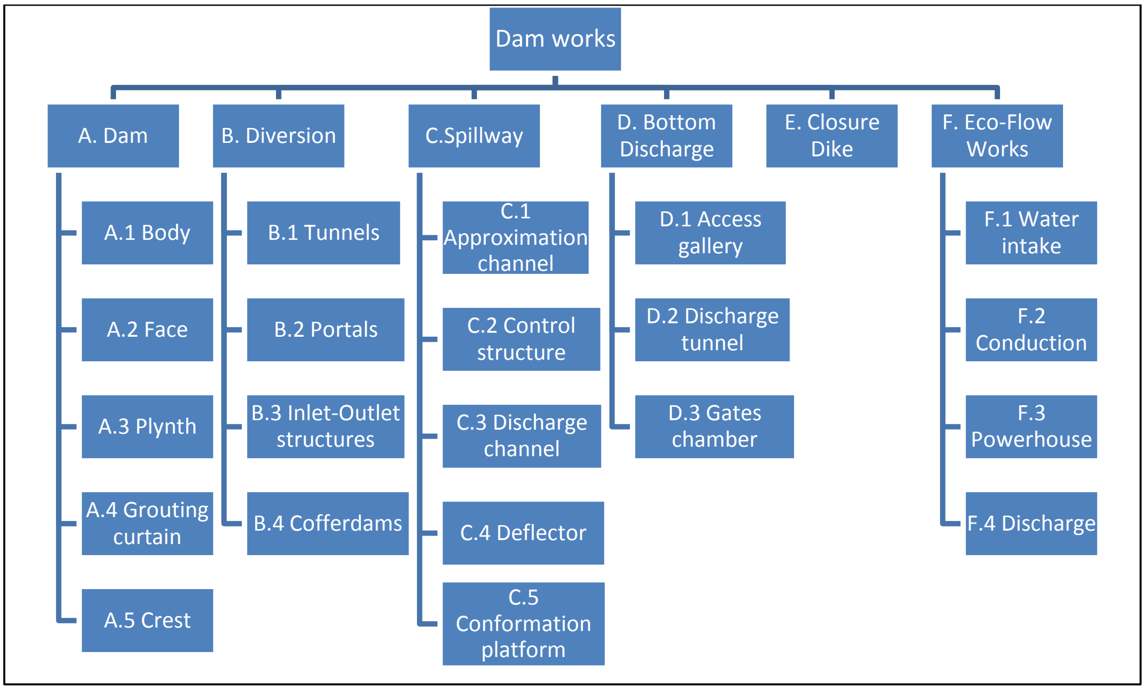

Figure B.1: dam works´ system breakdown structure

The type of dam designed for this project is a Concrete Face Rockfill Dam (CFDR). Its main body [A.1] has 173m height and a total volume of 11 600 000m^3 . It is divided in nine different zones in function of the granulometry and mechanical qualities of the filling material, which is extracted mostly from the river bed and the works´excavations (e.g. spillway). Approximately 90% of this material can be placed wihtout any prior processing . In its upstream slope a concrete face [A.2] is constructed as a barrier to prevent the passage of water. Its total area is of 110 000m^2 and is supported on a concrete plynth [A.3] anchored to the rock and with a total length of almost 1400m. To assure there will be no infiltration affecting the dam´s body a grouting curtain [A.4] is constructed throughout the plynth line. For this purpose holes are drilled and afterwards grout is injected at high pressure to fill any crack in the rock mass. In the upper part or crest [A.5] of the dam a 8m wide road is constructed to connect both margins of the river, confined at each side by a concrete parapet wall. Before the dam´s body is constructed approximately 2 300 000m^3 of material should be excavated and removed from the place.

In order to provide a dry area of work for the dam´s construction the river must first be deviated from its natural course. The diversion system is composed by two tunnels **[B.1]** with a excavation diamater of 14m, a length of 650m and 770m respectively and a concrete linning with an internal diameter of 12.6m. At both ends of the tunnels portals **[B.2]** are excavated (aproximately 530 000m^3) and stabilized to provide safe access during the construccion process, as well as to ensure the slopes will stand firm during the operation phase. To regulate the water inlet and outlet concrete structures **[B.3]** are constructed at the mouths of the tunnel. The inlet structure includes the installation of four sliding gates of 11.8m height, 6.6m wide and a total weight between 145Ton and 315Ton. The river diversion is finally achieved by constructing a set of three cofferdams **[B.4]:** two constructed upstream of the dam to obstruct the flow of water and the third one downstream to prevent the water returning to the construction site once evacuated by the tunnels. The main cofferdam, upstream and closest to the dam, is made of rolled and compacted concrete (RCC) with a total volume of 105 000m^3 and a height of 30m. The other two are minor structures mainly composed by rocks found on the riverbed.

The spillway **[C]** is constructed in the dam´s right margin and its main function is to evacuate the water of the reservoir once it exceeds the allowable limits. Its maximun discharge flow is of 14 477m^3/s. It is divided in five main sections: approximation channel **[C.1]**, control structure **[C.2]**, discharge channel **[C.3]**, deflector **[C.4]** and conformation platform **[C.5]**. The approximation channel **[C.1]** has the objective of direct the water to the control structure. I has a length of 460m and is coated with rocks in order to prevent erosion. The control structure **[C.2]** is of reinforced concrete and consist of three pillars of 4m wide and 38m heigh, as well as two perimetral walls of similar dimensions. In between these elements four radial gates of approximately 460Ton each are installed to control the flow of water, each of them with a set of stoplogs (**see figure B.4**). A 8m wide bridge is also constructed in the upper part of the structure to allow the transit of vehicles from one side of the dam to the other. Next to the control structure a 70m wide and 450m long reinforced concrete discharge channel **[C.3]** conducts the water to a sky jump deflector **[C.4]** which dissipates its energy before its incorporation to the river. A total excavation required for these works is of 7 000 000m^3.

To allow a controlled filling of the reservoir as well as its emptying in case of any eventuallity an underground bottom discharge **[D]** with the capacity to evacuate 380m^3/s of water is constructed. In comprises of three parts: an access gallery **[D.1]** of 203m long , a discharge tunnel **[D.2]** (bypass on internal diversion tunnel) with an excavation diameter of 8.7m and a length of 232m and a gate chamber **[D.3]** of 11m height, 18.5m long an 14m wide, in which a a 5.5m height radial gate is installed, allong with a stoplog (**see figure B.5**).

The closure dyke **[E]** is a small clay core rockfill dam of 15m heigh, 300m long and a peak widht of 8m. Its total volume is of approximately 250 000m^3 and is constructed adjacent to the spillway´s control structure in order to close a natural topographical depression.

Finally the eco-flow works **[F]** are located in the dam´s right margin and are designed to constantly let pass approximately 20m^3/s downstream of the dam to support the wildlife and human uses, and at the same time to produce electricity. It has mainly four components: water intake **[F.1]**, conduction **[F.2]**, powerhouse **[F.3]** and discharge **[F.4]**. The water intake **[F.1]** is a box-culvert type reinforced concrete structure, founded in a slope to the left of the spillway´s approximation channel **[C.1]**. The structure is constructed between the levels 241 m.a.s.l and 310 m.a.s.l and has inlets at five different leves in order to ensure an adequate mixture of oxigen and temperature in the water: 250, 270, 277.5, 285 and 292.5 meters above sea level. The width of the box section varies from 10.5m in the base to 5m in the upper part. The lower inlet can be closed independently from the others by means of 4 individual sliding gates. In addition a main sliding gate is also installed to close the entire intake at the mouth of the tunnel.

The eco-flow conduction **[F.2]** has a general diameter of 3.2m and is composed of a 77m long upper tunnel, a 113m height shaft and a 168m long lower tunnel. Every segment of the conduction is lined with cast in place reinforced concrete, except the last 133m of the lower tunnel which has a steel lining with internal diameters between 2.5m and 2.2m. Connecting directly to the lower tunnel, the powerhouse **[F.3]** is located in a cavern of 41.7m long, 19.7m width and 29m height with a total volume of 24 600m^3. It consist of a reinforced concrete structure with multiple levels. In the first floor (or sub structure) a 27Mw vertical axis Francis generation unit is installed, including a by-pass intake valve as well as a sliding gate in the discharge chamber. In an upper level the assembly room (or superstructure) is constructed, including the installation in the principal beams of a an overhead crane with a lifting capacity of 80 Ton and used during the assembly of the main electromechanical components (turbines, generators, intake valves, etc), as well as during the operation phase to assist in the maintenance works. Adjacent to the superstructure a 3 floor control room is constructed. As part of the powerhouse works, several galleries are constructed in order to provide access, ventilation and to get out the power cables to an exterior platform in which a set of transformers are installed. The final component of this system is a discharge tunnel **[F.4]** of approximately 88m long and a diameter of 4m that connects with an angle of 50° one of the diversion tunnels **[B.1],** which is used to finally discharge the water back to the river.

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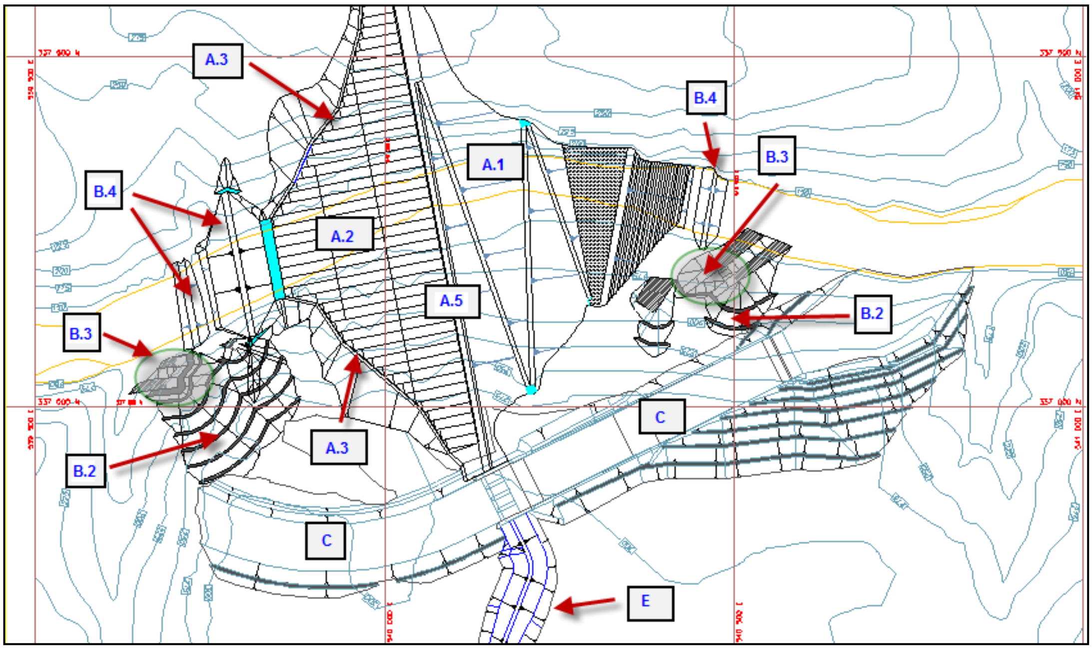


Figure B.2: general layout dam works

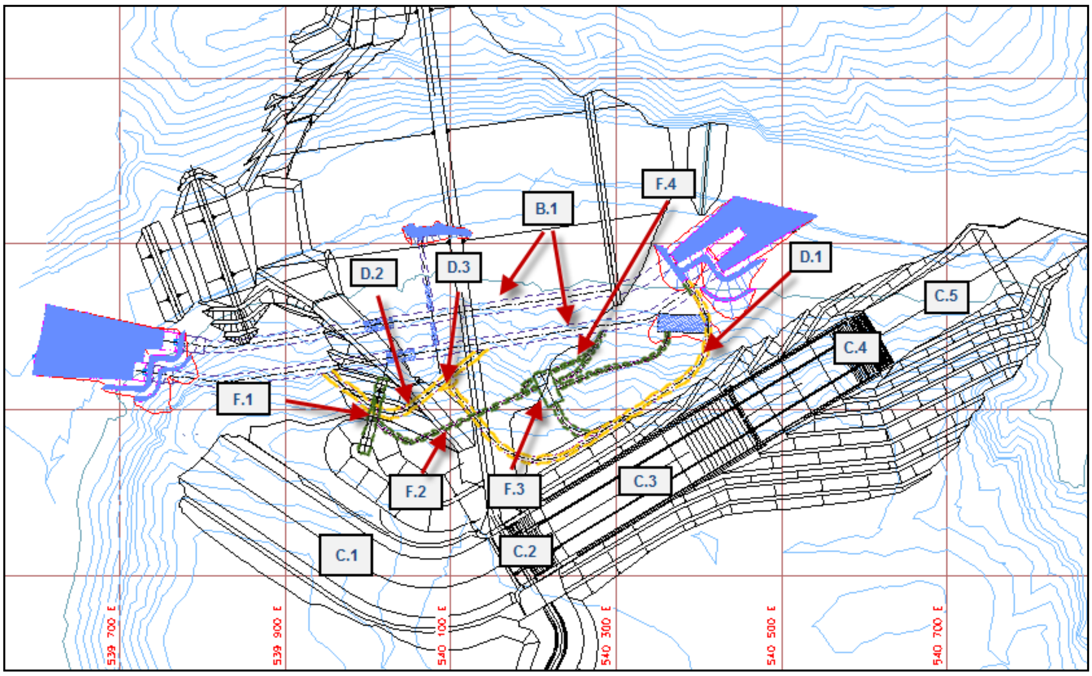
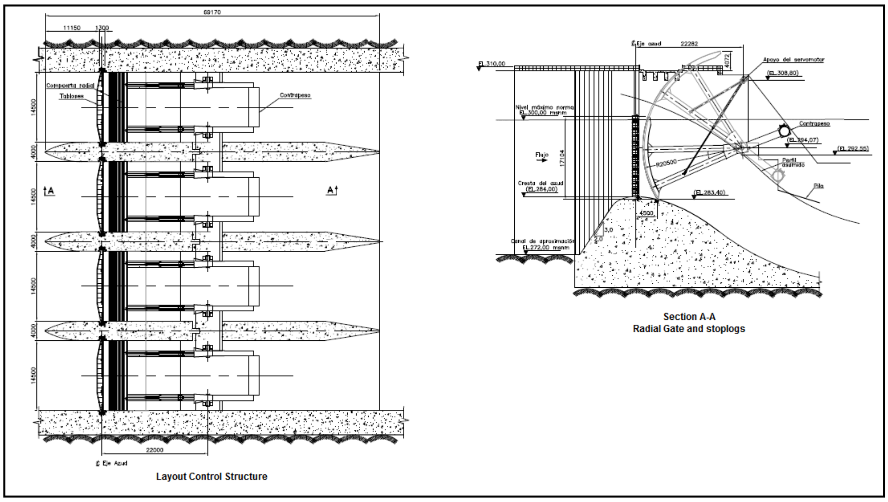


Figure B.3: general layout dam works



Layout Control Structure

Section A-A
Radial Gate and stoplogs

Figure B.4: spillway´s control structure

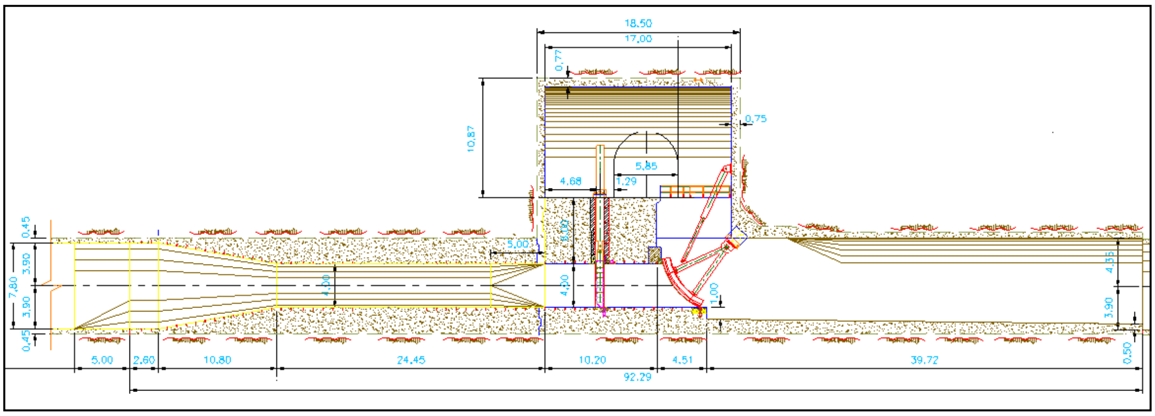


Figure B.5: profile botton discharge tunnel and gates chamber.

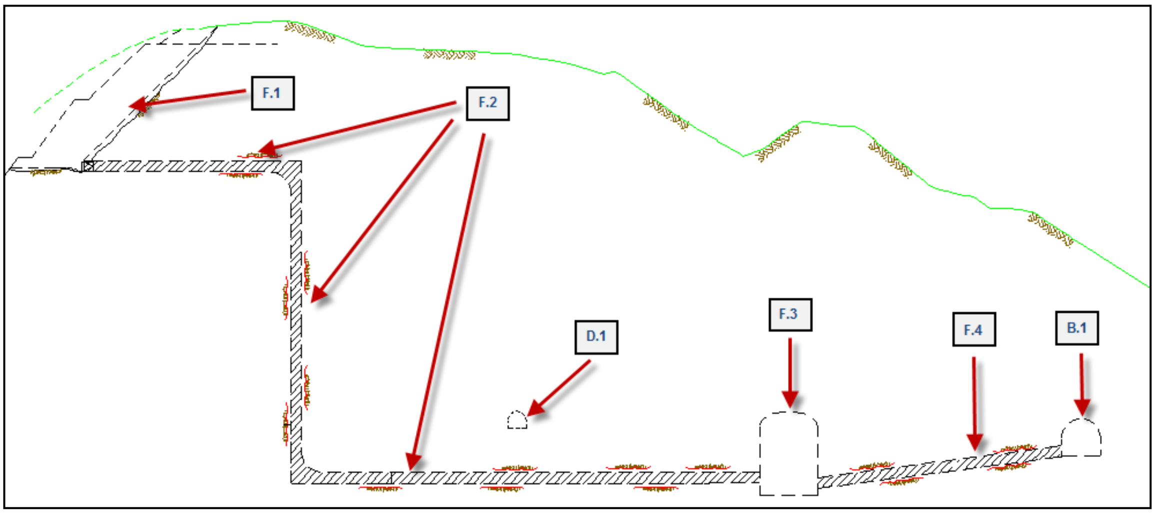


Figure B.6: profile Eco-flow works.

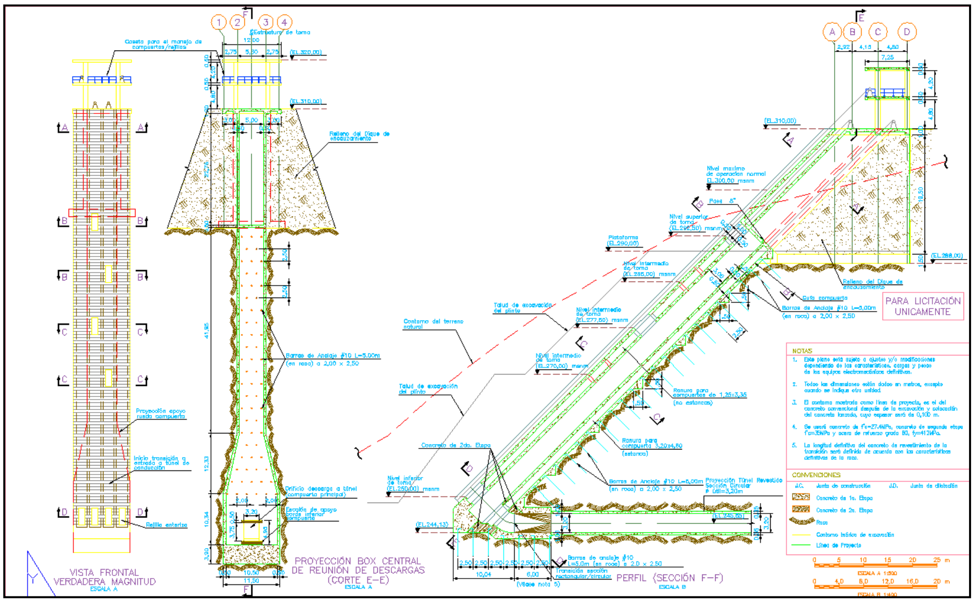


Figure B.7: detail water intake [F.1], eco-flow works.

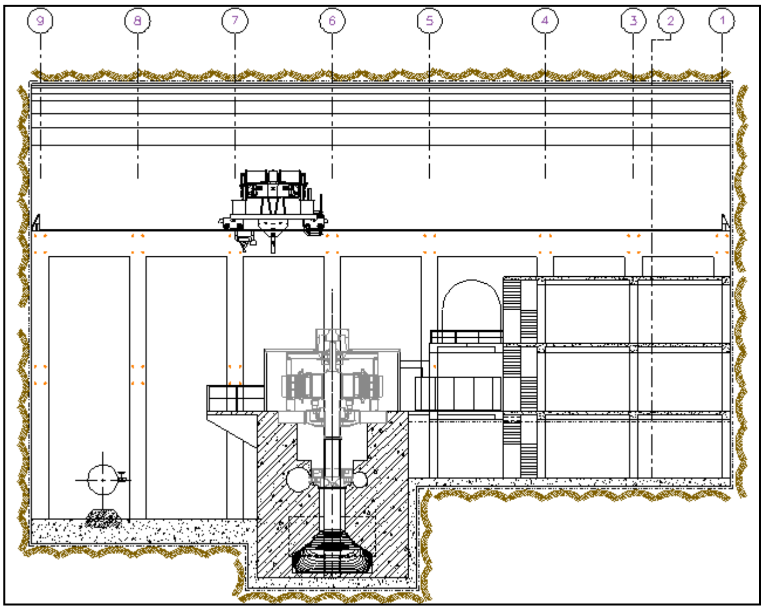


Figure B.8: tranversal section powerhoue [F.3], eco-flow works.

B.2 Intake works

The main function of the intake works is to catch the water from the reservoir so that it can be carried by the conduction system. It is composed mainly of two components: intake tower [A] and bridge [B].

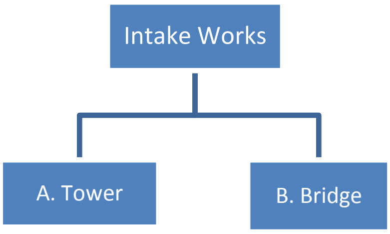


Figure B.6: Intake works´ system breakdown structure.

The tower [A] is a reinforced concrete structure that catches water from different levels of the reservoir to assure an adequate mixture of oxigen and temperatures, two important factors for the river´s wildlife once the water is discharged after electricity is produced. Its heigh is of 75m and it has an hexagonal section with a total area of 760m^2. Metal grades have been arranged in each inlet orifice to prevent the passage of objects that could damage the turbines. Additionally it supports the lifting mechanism of a sliding gate located at the entrance of the main conduction tunnel. To provide access to the upper part of the tower a reinforced concrete bridge [B] of approximately 214m long and with a maximun pillar height of 30m is constructed. In total 17 000m^3 of concrete will be used in this works, which additionally demand the excavation of approximately 225 000m^3 of material. Figures B.7 and B.8 show general details of these works.

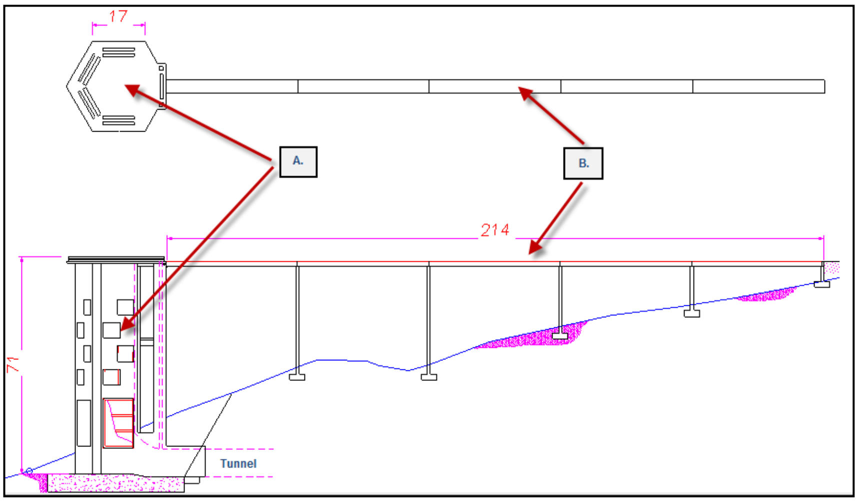


Figure B.7: general layout and profile intake works.

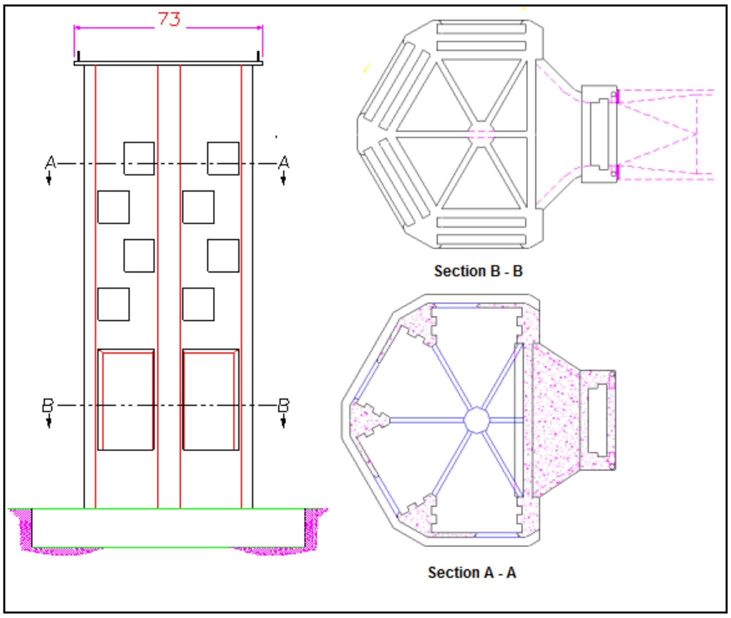


Figure B.8: details intake tower.

B.3 Conduction works

The conduction system has the function of transporting the water from the reservoir to the power generation facilities. It consist of three main components: tunnel [A], surge tank [B] and penstock [C].

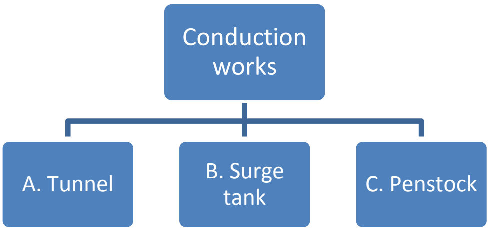


Figure B.9: Intake works´ system breakdown structure.

The tunnel [A] is approximately 11.3km long. A cast in place reinforced concrete lining is provided to its full length with an internal diameter of 9.8m. The only exception to the latter is the tunnel´s last 206m, for which a steel lining has been designed in order to connect the surge tank with the penstock. The tunnel has a slope of 0.3% and maximum ground coverage of 600m.

The final segment of the conduction between the tunnel´s exit and the powerhouse is undertaken by means of a steel penstock [B] of approximately 1 175m. It has a variable diameter, beginning with 9.8m in the connection with the tunnel and reduced to 6.9m after the first bifurcation (0+030). From this point on the penstock is divided in two parallel lines in which the diameter is progressively reduced until it reaches 5.9m in the second bifurcation, immediately before entering the powerhouse. Its thickness also varies between 24mm and 38mm. The total weight of the penstock is of approximately 12 200Ton and it is supported along its length in several concrete mounts and pedestals, which transmit the loads to the ground. At certain points and to counteract the loads to which it is subjected the penstock is embedded in massive concrete blocks. The total concrete required for these works is of approximately 50 000m3. In addition to these, two butterfly valves will be installed at the station 0+110 in order to cut the pass of water if required during the operation stage. The construction of the penstock also includes the excavation of a trench, involving the removal of 1 400 000m^3 of material from the site to a dump waste.

The final component of the conduction system is the surge tank **[C]**. This 110m height steel structure is connected to the steel lining approximately 140m before the tunnel´s exit and has the function of dissipating energy in case of an abrupt emergency closure of the inlet valves in the powerhouse. Its internal diameter is of 28m and its thickness varies between 15mm in its upper part to 35mm at the tank´s base. From its total height 57m are below the surface, and therefore a shaft with a diameter of 31m should be excavated before the tanks assembly begins. The tank weights 2 050ton and approximately 9 155m3 of concrete are needed to fill the space between the tank and the shaft excavation line.

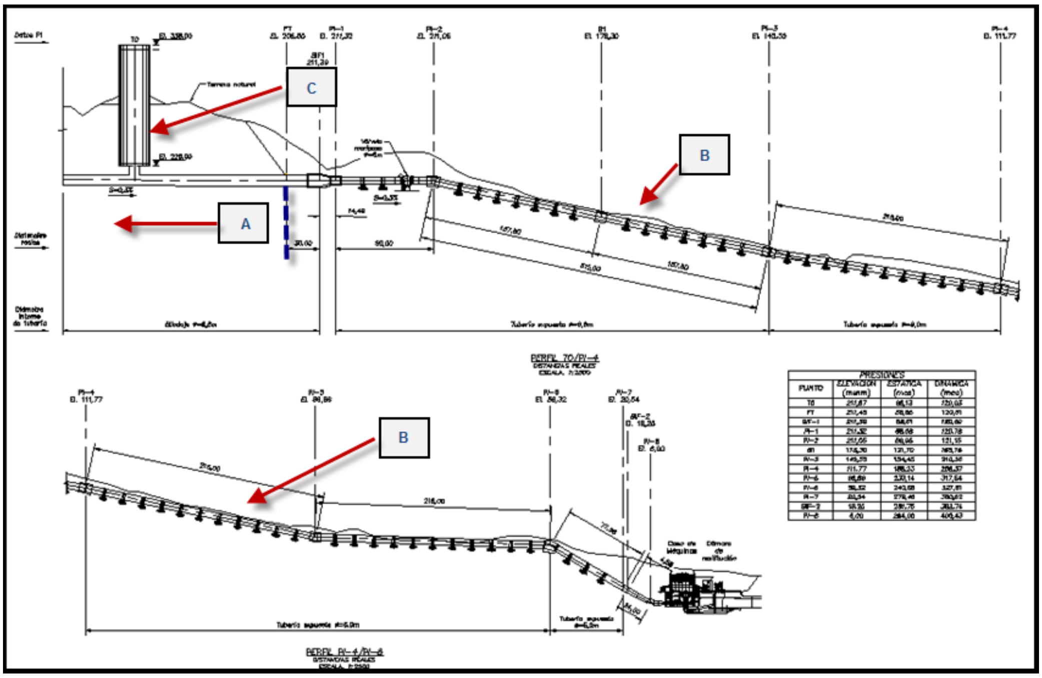


Figure B.10: general profile conduction system.

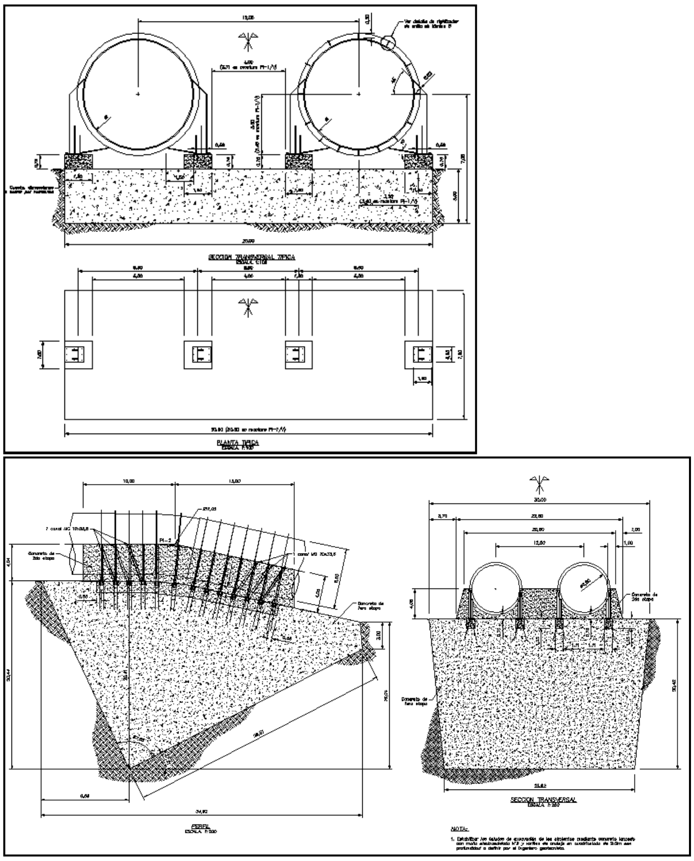


Figure B.11: detail of penstock´s mounts and anchor blocks.

B.4 Generation works

The generation works are responsible of transforming the kinetic energy of the water into electricity. In this project two main components can be distinguished: powerhouse **[A]** and restitution channel **[B]**.

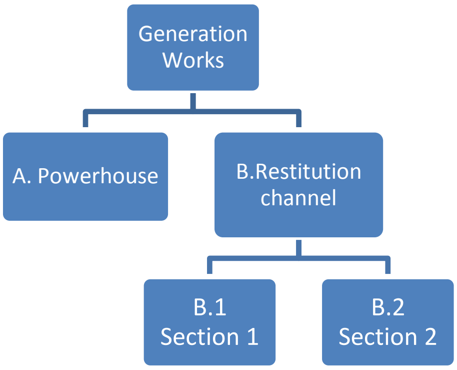


Figure B.12: Generation works´ system breakdown structure.

The powerhouse **[A]** is a four-level semi-buried reinforced concrete structure. It contains four Francis units of 156MW each, located in the first three levels of the structure (also known as sub-structure). The fourth level is known as assembly room or superstructure. Two overhead cranes with a lifting capacity of 230Ton each are installed in the principal beams of this section and are used during the assembly of the main electromechanical components (turbines, generators, intake valves, etc), as well as during the operation phase to assist in the maintenance works. Outside of the assembly room five three-phase transformers (one per unit and a fifth as reserve) are installed to elevate the output voltage from 13.4KV to 230KV. Adjacent to the superstructure a control room is constructed. The total volume of concrete required for these works is of approximately 30 000m^3. In addition an excavation of 1 500 000m3 is required to prepare the area for construction.

After it is used for the production of electricity, the water is returned to the river by means of a 2.4Km long restitution channel **[B]**, which is divided in two sections. The first **[B.1]** has a total length of 1km, a slope of 0.1% and a base width of 25m. It is lined with reinforced concrete and its walls have a slope of 50%. Meanwhile, the second section **[B.2]** has the same slope of 0.1%, but the width of the base is increased to 100m. Its walls have a slope of 17% and its section is coated with selected rocks in order to prevent erosion. The construction of the channel requires an excavation of near 2 000 000m^3.

The main components of this subsystem are shown in figure B.13, B.14 and B.15.

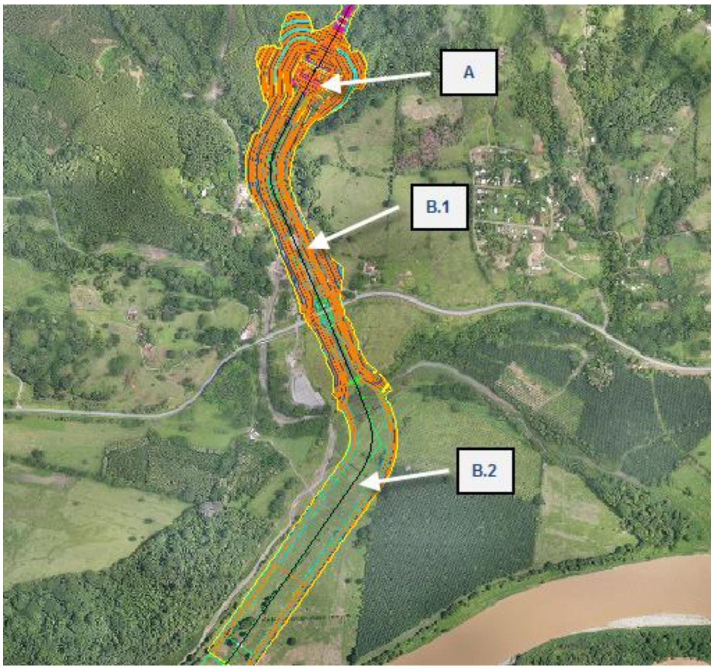


Figure B.13: general layout generation works

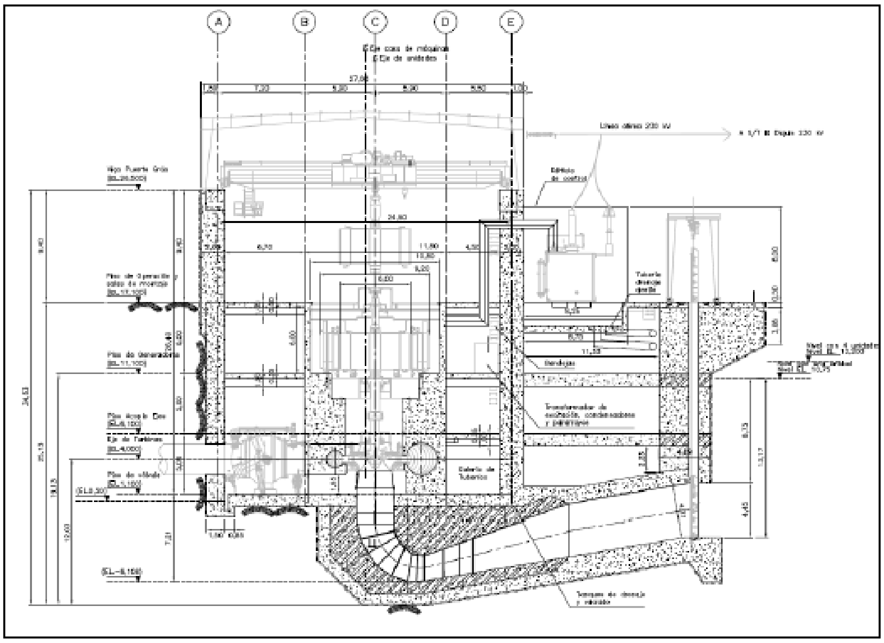


Figure B.13: cross section powerhouse.

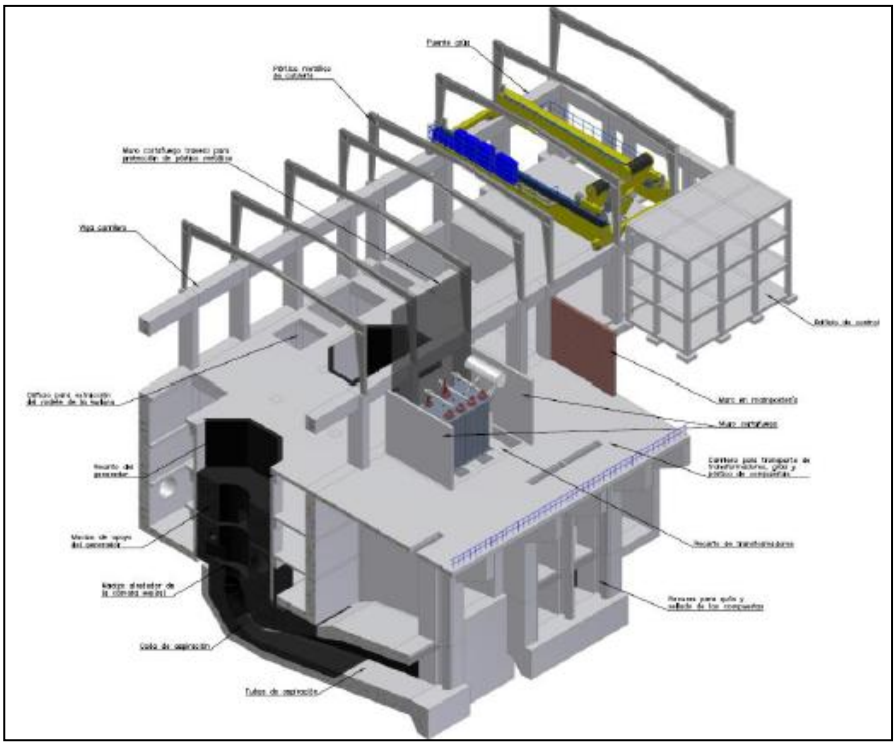


Figure B.14: powerhouse 3D model.

B.5 Reservoir

The area of the reservoir corresponding to the dam´s peak level (310 m.a.s.l) is of 6800 Ha. Its total storage volume up to the maximum operating level (300 m.a.s.l) is of 2858 hm^3, of which 1 646 hm^3 are usable considering that the minimum operating level is at 260 m.a.s.l. The main works required to conform the reservoir[69] is to remove the vegetation of certain percentage of its area in order to avoid the excesive decomposition of organic material, as well as discrete stabilization of slopes to prevent the degradation of the basin´s margins. These works are still to be dimensioned.

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[69] Other important works related to the flooding of the reservoir´s area, such as the resettlement of populations and the rescue of wildlife are part of the sub system of mitigation and compensation works, excluded from the scope of this study.

ANNEX C: Characterization of transactions

EARTHMOVING
Excavation-Load-Haul-Spread-Compaction & Soil Treatment

Dimension		**Criteria**	**Analysis**				**Conclusions**	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	*In all the works*			The physical assets for this trade consist mainly on fully standardized equipments, such as excavators (from 20Ton to 50Ton), tractors (from D6 to D8), compactors (mainly of 10 ton with vibratory roller), Loaders (CAT 936 to 950 or similar) trucks (from tandem of $12m^3$ to articulated of 32Ton for the extractions of material in the river bed), general purpose track drills (Mustang 4-F4, Sandick 550, etc.), micropiling drills (Solimec SM-21 or similar), concrete spraying machines (Aliva 263 or similar), grouting equipments and other of general use such as compressors and small cranes.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and design the construction process involved in big earthmoving operations, as well as to operate the equipment. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project	MED	Even thought the knowledge at the level of coordination is difficult to transfer, the fact that it can be applied to any other project of the same type justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Full standardization of the work is not possible and some degree of judgment is necessary to adjust the process to the ever changing geological conditions. Even though the skills required to operate the physical assets can be transferred within the time span of a single projects, those required to coordinate the production process require extensive experience only possible to obtain by having participated in more than one project [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. Once on the site they can move by their own means. Some fixed facilities such as mechanical workshops to repair the equipment and diesel dispensers may be required, but their Installation cost is negligible in comparison with the production costs.		
	Temporal	Time criticality	Spillway ,Intake works Penstock, Powerhouse, Restitution channel, Reservoir		Diversion, Dam, Main Tunnel	The projects have two critical paths affecting earthmoving operations: the construction of the dam, beginning with the diversion of the river, and the conduction works dependable of the main tunnel. The remaining works have the following slack in months: Spillway (5), Intake Works (8), Penstock (6), Main Powerhouse (7), Restitution Channel (9), and Reservoir (9).	HIGH (Diversion, Dam, Main Tunnel) --------------- MED (Spillway, Penstock, Main Power house) ------------- LOW (Remaining works)	The replacement time has been estimated in 3 months. The assigned levels are justified as follows: **High** = total stack<replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining cases
		Difficulty to arrange replacement		*In all the works*		ICE is subject to public procurement law. The process to procure an entire construction work exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by direct administration. For this purpose ICE is subscribed to a special contracting procedure for the rental of machinery and equipment. If available in the local market most of the physical assets could be operational in a period no longer than 2 months [1]. There may still be a problem if the materials required for these operations (e.g. explosives and perforation steels, anchor bolts, cement, etc) could not be taken directly from ICE´s stocks. In this case the procurement time of the latter should be taken into consideration. Nevertheless it will be considered for the purpose of this analysis that materials are in general a minor component of the production process in this sub trade, in which machinery is clearly the dominant factor. Therefore it is assumed that in such a case a direct purchase procedure (with a limit of approximately USD 115 000 and a normal duration of 3 months) could be used to procure the missing materials and resume the operations.		
	Dedicative	Market capacity		*In all the works*		It may be possible that the current local capacity is insufficient to provide all the equipment required for these operations at the same time [1]. For instance, just to transport the Dam´s filler material over 30 articulated trucks of 32 Ton will be needed in unison. Nevertheless the works are big enough to count with international providers. If the local capacity is expanded, the use of highly standardized equipments makes it possible to use them in additional transaction or to recover the salvage value.	MED	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions			*In all the works*	Even with a good level of base line studies it is not possible to predict the real geological conditions of the excavation site. In addition earthmoving operations are highly susceptible to weather conditions, which by definition are highly unpredictable, especially in tropical countries as Costa Rica. The possibility of a not anticipated change in the original conditions cannot be assumed as negligible and is usually a cause of concern for the contract managers [2].	HIGH	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. All the earthmoving sub trades can be characterized as having plenty of capable suppliers. Therefore the possibilities of prospective interactions with the same provider are in general low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central.
		Type of transaction			*In all the works*	In general basis every hydropower project requires this kind of operations		

CONCRETES
Aggregate production

Dimension		Criteria	Analysis				Conclusion	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	*In all the works*			The production plant is composed by specific configurations of pieces of equipment such as feeders, crushers, screens, conveyors and grinders, among others. Wheel loaders no bigger than a CAT 950 are also used to load the raw material into the feeders and accommodate the material stocks. Despite the fact that the configuration of each plant is customized to fit the specific requirements of the project as well as the characteristics of the input material, the components of the system separately are fully standardized.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Particular knowledge and experience is required to efficiently manage the production process and to successfully meet the aggregates quality requirements, even though the level of technology involved in the production process is rather low. The knowledge required is specific for this kind of trade, which is of general demand in any heavy construction project.	MED	Implicit in the analysis
		Difficulty of knowledge transfer		*In all the works*		Work cannot be fully standardized, in particular the plant coordinator should make quick adjustments to the production process (as for example adjust the outlet opening of the crusher and configuration of the screening system in function of the characteristics of the input material) that are learned only by doing [1,2]. A good coordinator should nevertheless be able to acquire this type of knowledge within the time span of a single project [1].		
	Site	Importance of proximity			*In all the works*	In average the cost of concrete aggregates for this project has been estimated in USD$ 10/m^3 (including extracting and processing costs). The aggregates will be transported partly by public roads in which legal restrictions for the mobilization of heavy goods apply. This in conjunction with difficult topographical conditions in some segments of the route makes necessary to transport the material in tandem trucks not exceeding 7 m^3. Under this condition the transportation cost can be estimated in USD$ 0.45/km-m^3. Therefore the transportation cost exceeds the production cost after approximately 22Km. Aggregates should therefore be produced within the region.	LOW	Assuming that the property rights of the exploitation sites remain on ICE, this conclusion is the result of having negligible relocation costs of the production system.
		Relocation cost	*In all the works*			Based on past experience (Pirris Hydropower Project) the cost required to install and uninstall each aggregate production plant can be estimated in $240 000, considering a flat location with direct access to water and to a distribution line. To be used in concrete production more than 2 000 000m^3 of aggregates with a total production cost exceeding USD$ 20 million will be produced in three main sites, making the relocation costs of the production facilities not a relevant factor.		
	Temporal	Time criticality	*In all the works*			All the construction works that are on the critical path of the project require as input material aggregates produced by some of the three main production facilities. Nevertheless, there are two elements that significantly reduce the time criticality of this activity. First in general there is enough space to stock material for the future consumption of several months. For instance it is a normal strategy to produce more material during the dry season in order to have a reserve for the rainy season, in which direct extraction from the river bed is more complicated. Secondly the existence of three plants creates redundancy in the production system, and if one plant fails to produce another one can provisionally provide the required material (at the expenses of an increase in the transportation costs).	LOW	Replacement time is shorter than storage potential. In addition there is redundancy in the production system.
		Difficulty to arrange replacement		*In all the works*		ICE is subject to the public procurement law. The procurement process of a not standardized good or service with a value over USD$ 115 000 should follow a tender procedure and can be expected to last more than 12 months from the moment the bidding rules are ready to the endorsement of the Comptroller General of The Republic. In case a replacement must be arranged the fastest option would be to resume the works by direct administration. For this purpose ICE is subscribed to a special contracting procedure for the rental of machinery and equipment. If available in the local market most of the physical assets could be operational in a period no longer than 4 or 5 months, taking into consideration the time required to install the production system [1].		
	Dedicative	Market capacity	*In all the works*			There is currently enough local capacity to support these transactions [1].	LOW	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions		*In all the works*		The final product of this transaction is aggregate that should met clear quality requirements. In general it should be possible to establish all the relevant provisions from the outset of the agreement. Nevertheless, there is always the possibility that the raw material found is very different from what was originally supposed. Under these conditions in may be necessary to adjust the production process in not anticipated ways. The possibilities of appearance of important changes are nevertheless quite low.	MED	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. There are plenty suppliers available that have the capabilities of producing aggregates. Therefore the possibilities of prospective interactions with the same provider are in general low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis every hydropower project requires this kind of operations		

CONCRETES
Concrete production

Dimension		Criteria	Analysis				Conclusions	
			Low	***Medium***	***High***	***Comments***	***Level***	***Justification***
Asset specificity	Physical	Customization of physical assets	*In all the works*			A concrete plant is a standardized production system that is purchased in its entirety to one of many equipment manufactures. It usually consist of a set of dispensers able to dose by weight the cement, water, and aggregates, as well as a mixer, cement silos, compressors, cement screws and a control system. In function of the requirements a cooling system can be incorporated. Wheel loaders no bigger than a CAT 950 are also used for the manipulation of aggregates.	**LOW**	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		The knowledge required to coordinate and operate the production system is specific to this type of operation, which in general basis is required in any heavy construction project.	**LOW**	Even though the required knowledge for these transactions is trade specific, the fact that it can be transferred fairly easy justifies a low level of specificity.
		Difficulty of knowledge transfer	*In all the works*			The modern concrete production plants have highly automated production systems and standardized production procedures that ease the knowledge transfer. With the appropriate support of the equipment provider, the knowledge required to operate the system is easily transferred [1].		
	Site	Importance of proximity			*In all the works*	Normally the concrete is transported from the concrete plant to the site in 6m^3 automixer. The transportation cost is dependable of the conditions of the road. With an average slope of 10% the transportation cost can reach $6.5/m3-km. Taking into consideration a total production cost of $130/m3, the transportation cost becomes more important after 20Km. In addition, to assure the quality of the material and assuming the weather conditions in the project´s location (humidity > 90%, average temperature over 27°C) the concrete should not be kept in the automixer for more than 60min – 90min in the case of conventional concrete and 45min for RCC (in this case, transported by truck). Concrete should be produced therefore within the region for the sake of both cost and quality.	**LOW**	It is reasonable to assume that ICE will have the ownership rights of at least a couple of sites nearby the works with the potential to install a concrete plant. Relocation of the facilities is easy and therefore site specificity is low.
		Relocation cost	*In all the works*			Based on past experience (Pirris Hydropower Project) the cost of install and uninstall a medium size (50hr-100m3/hr) concrete plant in a flat location with direct access to water and to a distribution line should not exceed USD$ 100 000. In total near 1 500 000m^3 of concrete will be produced in the project in four different location with a total production cost of near $USD 200 million. The relocation costs of the production system are therefore negligible.		
	Temporal	Time criticality	Spillway ,Intake works Penstock, Power House, Restitution channel, B.D.	Eco Flow Works	Diversion, Dam, Tunnel	The projects have two critical paths affecting concrete operations: the construction of the dam, beginning with the diversion of the river, and the conduction works dependable of the main tunnel. The remaining works have the following slack in months: Spillway (5), Intake Works (8), Penstock (6), Main Powerhouse (7), and Restitution Channel (9), Eco Flow Works (4), Bottom Discharge (18).	**HIGH** (Diversion, Dam, Tunnel, Spillway, Penstock, Eco Flow Works, Main Power house, R.C.) --------------- **MED** (Intake works) -------------- **LOW** (Bottom Discharge)	The replacement time has been estimated between 6 and 12 months. The assigned levels are justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The procurement process of a not standardized good or service with a value over USD$ 115 000 million should follow a tender procedure and may last more than 12 months from the moment the bidding rules are ready to the endorsement of the Comptroller General of The Republic. In case a replacement most be arranged the fastest option would be to resume the works by direct administration. For this purpose ICE is subscribed to a special contracting procedure for the rental of machinery and equipment. Nevertheless two conditions may make this difficult: first the regular procurement process for the acquisition of materials (e.g. cement and additive) cannot be avoided and second the offer of concrete production plants in the local market is limited [1]. In general the rate in which cement is demanded by all the project´s concrete plants makes a full tender procedure the only feasible procurement option. The only exception is the production facilities for the intake works, which requires cement at a significant lower rate and therefore an abbreviate procurement process can be used to start up the production process. For this reason a replacement time of six month for the latter and 12 months for the remaining concrete plants is considered as adequate for this analysis.		
	Dedicative	Market capacity		*In all the works*		For this project it has been estimated that the peak of cement demand will not surpass the required for the construction of the RCC Dam of the Pirris Hydropower Project, which was provided with local capacity (Holcim Production Plant, in *Aguas Calientes* of *Cartago*). Nevertheless according to ICE estimations it may be necessary to partially increase the local supply of concrete production facilities or to resort to external providers if these transactions are contracted to a third party [1].	**MED**	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions	*In all the works*			The final product of the transaction is concrete that should met clear quality requirements. Even though the design of the concrete mixture depends on the characteristics of the aggregates, which are to certain extend subject to change, the payment items can be established to take this into consideration (e.g. by paying the production process separately from the cement and additives). In normal conditions, changes in the original agreement are not expected.	**LOW**	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. Even though in Costa Rica the provision of cement is controlled manly by two big providers (Holcim and Cemex), which also have the capabilities and assets to produce concrete, at the end there are other providers with the capacity to produce concrete as well. Therefore the possibilities of prospective interactions with the same provider are in general low.	**LOW**	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis every hydropower project requires this kind of operations		

CONCRETES

Placement

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	All other works	Dam Face and Plinth, Spillway		The physical assets for this sub trade consist mainly on fully standardized equipments, such as wheeled and tower cranes, concrete pumps, compressors, welders, etc. Nevertheless there are some specific exceptions. For instance for the construction of the dam´s concrete face and the spillway slab it is necessary to customize a sliding formwork and a wheeled frame to place the reinforcement mesh, which should fit the characteristics defined in the designs regarding the distance between concrete joints. In the same manner a sliding formwork should also be customized for the construction of the plinth, adjusted to the specific geometry of this structure. Other partial customized equipments are the benders for fabricating the copper joints to be placed between adjacent segments of the concrete face of the dam. Despite this the customized assets can be described as involving low technology and their value is negligible in comparison with the cost of the works they are associated.	MED (Dam face and plinth, spillway) ---------- LOW (Remaining works)	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and design the construction process involved in large scale concrete placements. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project	MED	Even thought the knowledge at the coordination level is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Full standardization of the work is not possible because there is always the need to adjust the production process to the real conditions of the construction site. Large scale concrete placement operations are labor intensive, requiring the coordination of big groups of personnel in conditions in which safety is a relevant factor (e.g. high rise structures). Even though the skills required to operate the assets and to execute the manual work associated to the lower ranks can be transferred within the time span of a single projects, those required to coordinate the production process demand extensive experience only possible to obtain by having participated in more than one project [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. Once in the site, most of them can move by their own means. The most important fixed physical assets are tower cranes and workshops for the fabrication formwork, reinforced steel and others. Nevertheless the relocation costs of these facilities are negligible in comparison with the total production costs.		
	Temporal	Time criticality	Spillway, Intake works Penstock, Power House, Restitution channel, Bottom discharge	Eco Flow Works	Diversion, Dam	The projects have two critical paths affecting concrete operations: the construction of the dam, beginning with the diversion of the river, and the conduction works dependable of the main tunnel. The remaining works have the following slack in months: Spillway (5), Intake Works (8), Penstock (6), Main Powerhouse (7), Restitution Channel (9) and Eco Flow Works (4) and Bottom Discharge (18).	HIGH (Diversion, Dam, Spillway, Penstock, Eco Flow Works) --------------- MED (Remaining works) -------------- LOW (Bottom Discharge)	The replacement time has been estimated in 6 months. The assigned levels are justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The process to procure an entire construction work exceeding USD$ 115 000 million should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by ICE´s direct administration. In this case not only equipment but also materials and labor are important production factors. Because the real replacement time depends on elements such as ICE´s stocks at the moment of the eventuality, which are difficult to accurately predict, a general assumption of 6 months [3] to resume the works by direct administration will be taken for this and other works in which material and labor are as relevant as equipment.		
	Dedicative	Market capacity	*In all the works*			In general terms the physical assets and labor specialties required for this trade are not different from those employed in other concrete works, including some building construction projects which are more frequent within the local construction market. No additional capacity is expected from the latter to support these transactions.	LOW	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions		*In all the works*		Even though the designs for this project have a high level of detail there is always the possibility for not anticipated changes to occur during the construction process. Concrete operations are especially susceptible to rain, which in a tropical country such as Costa Rica is usually a factor difficult to predict accurately. The original specifications can also be affected by changes in the design required to cope with substantially different geological conditions. Nevertheless considering the high level of information available for this project the possibility for a relevant not anticipated change to occur is consider to be rather low [3].	MED	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. There are enough suppliers with the capacity to build concrete structures such as the ones included in this project so as to conclude that the possibility of prospective interactions with the same provider is in general low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis every hydropower project requires this kind of operations		

TUNNELING
Excavation

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	*In all the works*			In this project all the tunnels will be excavated using drill and blast. The physical assets required for this methodology consist on fully standardized equipments, such as Jumbo Drills, submergible water pumps, fans, combustion generators, compressors, welders, etc. It also imply the use of standard earthmoving machinery (loaders, backhoe, tandem trucks), as well as track based extraction equipment. In the case of shaft and caverns (e.g. eco-flow works and surge tank shaft) it is also possible to use raise boring, but with no special customized characteristics.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and design the construction process involved in the excavation of tunnels, shafts and caverns. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project in which tunneling is involved	MED	Even thought the knowledge at the coordination level is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Full standardization of the work is not possible and considerable experience and skills are required to adjust the excavation strategy to the ever changing geological conditions. Using drill and blast methodology the activity can be characterized as labor intensive and one of the most dangerous undertakings in construction projects. Even though the skills required to operate the assets and to execute the manual work associated to the lower ranks can be transferred within the time span of a single projects, those required to coordinate the production process safely and efficiently demand extensive experience only possible to obtain by having participated in more than one project [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. Once in the site, most of them can move by their own means. The most important fixed physical assets are fans, combustion generators and miscellaneous workshops. Nevertheless, the relocation costs of these facilities are negligible in terms of the total production costs.		
	Temporal	Time criticality	*Bottom Discharge, Surge Tank*	*Eco Flow Works*	*Diversion, Main Tunnel*	The projects have two critical paths affecting underground excavations: the diversion of the river and the main conduction tunnel. The remaining works in which tunneling is required have the following slack in months: Bottom Discharge (18), Eco Flow Works (4), Surge tank (12).	HIGH (Diversion, Main Tunnel) --------------- MED (Eco Flow Works) -------------- LOW (Bottom Discharge, Surge Tank)	The replacement time has been estimated in 6 months. The assigned levels are justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to the Administrative Procurement Law. The process to procure an entire construction work exceeding USD$ 115 000 million should follow a tender procedure and may take as much as two years. In case a replacement most be arranged the fastest option would be to resume the works by ICE´s direct administration. Not being machinery and equipment the only relevant production factors (materials and labor are equally important) the assumption of 6 months to resume the work by direct administration introduced in the analysis of concrete placement is also applicable to this case.		
	Dedicative	Market capacity		*In all the works*		Besides ICE no other local contractor has the capacity to construct tunnels. Work would need to be undertaken by international contractor, partly using local resources. Therefore, some expansion of the local capacity may be required. In theory this could be used in any other tunneling project.	MED	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions			*In all the works*	The extension and coverage of the tunnels in mountainous topographies makes normally impossible to have from the outset a precise idea of the geological conditions that will be found during the construction. Basic studies rely strongly on geophysics that by definition have limited predictive qualities. The possibilities of not anticipated changes during construction are relevant enough to be a major source of concern [2,3]. For instance, in the construction of the Pirris Hydropower Project main tunnel several not detected geological faults caused an infiltration flow more than ten times bigger than it was predicted. The water pumping and electricity generation systems collapsed, flooding the tunnel for several months.	HIGH	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. The possibilities for an international provider to interact again with the organization are perceived as very low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis almost every hydropower project requires this kind of operations.		

TUNNELING
Lining

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets		*In all the works*		For the lining of tunnels and shafts several standardized equipment and tools, such as compressors and concrete pumps, are required. Nevertheless the formwork is usually customized in length and diameter to fit the specific geometric characteristic and level of performance demanded by the work. The use thereof in other lining operations is restricted to those works with very similar characteristics because the possibilities to adapt this equipment are very limited.	MED	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and design the construction process involved in the lining of tunnels and shafts. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project in which tunneling is involved	MED	Even thought the knowledge at the coordination level is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Being a lineal and cyclic work under normal conditions with an adequate support of the formwork´s manufacturer the knowledge required to start up and operate the production system can be transferred from the outset of the lining operation and progressively improved during the course of the activity. The problem arises with the appearance of unexpected conditions (see comment on complexity for an example), that even though may not be too frequent in terms of the total duration of the activity they demand extensive learning-by-doing experience from the coordinators of the production process to introduce the necessary adjustments [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. Once in the site, most of them can move by their own means. The most fixed physical assets are fans, combustion generators and miscellaneous workshops. Nevertheless, the relocation costs of these facilities are negligible in terms of the total production costs.		
	Temporal	Time criticality	*Bottom Discharge, Surge Tank*	*Eco Power Works*	*Diversion, Tunnel*	The projects have two critical paths affecting lining operations: The projects have two critical paths affecting underground excavations: the diversion of the river and the main conduction tunnel. The remaining works in which tunneling is required have the following slack in months: Bottom Discharge (18), Eco Power House (4), Surge Tank (12).	HIGH (Diversion, Main Tunnel) --------------- MED (Eco Flow Works) -------------- LOW (Bottom Discharge, Surge Tank)	The replacement time has been estimated in 6 months. The assigned levels are justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The process to procure an entire construction work exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by ICE´s direct administration. Not being machinery and equipment the only relevant production factors (materials and labor are equally important) the assumption of 6 months to resume the work by direct administration introduced in the analysis of concrete placement is also applicable to this case.		
	Dedicative	Market capacity		*In all the works*		Besides ICE no other local contractor has the capacity to conduct underground works. Work would need to be undertaken by international contractor using partly local resources. Therefore, some expansion of the local capacity may be required. In theory this could be used in any other tunneling project.	MED	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions			*In all the works*	Much of the uncertainty surrounding the construction of underground works dissipates once the excavation ends and therefore the geological conditions are clear. Nevertheless if these conditions are too different from the originally anticipated, changes in the design and construction process are to be expected. For instance the construction process for the lining of the Pirris Hydropower Project main tunnel was changed substantially from the original plans in order to cope with extremely high and not foreseeable infiltration rates. The design itself of the lining may require variations to adjust it to different external pressures. In general, not anticipated changes are a major concern in this type of operations.	HIGH	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. The possibilities for an international provider to interact again with the organization are perceived as very low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis almost every hydropower project requires this kind of operations.		

Electro mechanic works
Fabrication

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	In all the works			The same physical assets are used to fabricate the electro mechanic equipments of any large hydropower project. No specific customization is expected for this project.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		From all the elements included in the construction of a large hydropower project, the electro mechanic equipments are the ones in which a higher level of technology is implicit in the production process. Despite the fact that very specialized skills and knowledge are required to produce these components, these are in general applicable to any project of this type.	MED	Even though very specialized know how is required, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Some parts of the work may be standardized, but extensive know how is required to fabricate these components.		
	Site	Importance of proximity	*In all the works*			Electro mechanic equipment has in general very high production cost. For instance, the turbines, generators and associated systems for the main power house of this project cost approximately USD$ 200 million. In this context transportation cost is not a relevant factor.	LOW	Because transportation cost is not a relevant factor, site specificity is low regardless of the relocation costs.
		Relocation cost			*In all the works*	The fabrication of these kinds of components is undertaken in centralized production facilities that benefit from economies of scale. Relocation cost cannot be justified in terms of one project only.		
	Temporal	Time criticality	*Power house , Spillway, Bottom Discharge, Intake works.*	*Eco flow works*	*Diversion*	The fabrication of the gates for the inlet structures of the diversion tunnels is part of the project´s critical path. The remaining works in which fabrication of electro mechanic equipments is required have the following slacks in months: Eco Flow Works (4), Main Power House (8), Spillway gates (6), Bottom Discharge gates (18), and main intake gates (9)	HIGH	The replacement time has been estimated in 24 months. The assigned levels are justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The process to procure the fabrication of electro mechanical equipments exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In this case, ICE does not have the technology to resume the production process by direct administration and therefore there is no alternative available in this case other than to restart the procurement process.		
	Dedicative	Market capacity	*In all the works*			Current market capacity is unaffected by just one single project. In this specific case the boundaries of the market are irrelevant.	LOW	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions	*In all the works*			In general electro mechanic equipments are fabricated using functional specifications, such as flow and water head, for which no relevant changes are expected. This can be confirmed from ICE´s procurement history [4].	LOW	Implicit in the analysis
Frequency		Transacting party		*In all the works*		Very few suppliers in the world are capable of fabricating the electromechanical equipment of a large hydropower projects. The same provider can be expected in future projects, even though exclusivity cannot be assured.	MED	Even though the same transaction applies to every project of this kind and that few suppliers are available, at the end future collaborations between the parties cannot be assured.
		Type of transaction			*In all the works*	Every hydropower project requires electro mechanic equipment.		

Electro mechanic works
Assembly

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	In all the works			Fully standardized equipments and tools, such as tower and wheel cranes, welders and compressors are required to undertake the assembly operations of electro mechanical components.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and conduct the operations required to install electro mechanic equipment. In general this knowledge is specific for this kind of trade, although it is generally applicable to any other hydropower project.	MED	Even thought the knowledge required both at the coordination and operative levels is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Even though the assembly process can be standardized to a high degree and installation manuals are usually prepared by the equipment manufacturer, it is still a very precise operation in which highly skilled operators are required. The equipment may have specific traits related to the technology used by a particular manufacturer and therefore the constant presence and support of a representative of the latter during the assembly process is necessary. Because of its dimensions and interfaces with the concrete works, the equipment is usually shipped in a large number of pieces and local adaptations are often needed during the integration process. The knowledge required to coordinate and conduct these operations involves extensive learning by doing experience derived from having participated before in several projects of this kind [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. The relocation costs of any fixed facility are negligible compared with the assembly costs.		
	Temporal	Time criticality	*Spillway, Bottom Discharge, Intake works*	*Eco flow works, Power house*	*Diversion*	The installation of the gates for the inlet structures of the diversion tunnels is part of the project´s critical path. The remaining works in which the assembly of electro mechanic equipments is required have the following slacks in months: Eco Flow Works (4), Main Power House (4), Spillway gates (6), Bottom Discharge gates (18), and main intake gates (9).	HIGH (Diversion, Spillway gates) --------------- MED (Main Power house Eco Flow Works) -------------- LOW (Bottom Discharge, Intake Works)	The replacement time has been estimated between 3 and 6 months. The classification is justified as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement		*Remaining works*	*Spillway*	ICE is subject to public procurement law. The process to procure an entire construction work exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by ICE´s direct administration. Because the physical assets required for the assemblies are either already in place (e.g. overhead traveling cranes) or relatively easy to arrange (standard wheel cranes and minor equipment) and materials other than those provided by the equipment´s manufacturer are a minor component of the process, labor is the dominant production factor. In this case ICE has vast in house experience to resume the assemblies and the replacement time is defined for how long it takes to put the human resources on the site. A period of 3 months will be assumed for this purpose [4]. An exception should be introduced with regards to the spillway´s gates that require a tower crane of large dimensions for which a replacement may be not so easy to arrange. In this case a replacement period of 6 months has been considered appropriate.		
	Dedicative	Market capacity		*In all the works*		There are local contractors other than ICE that have undertaken the electro mechanic assemblies of small or medium hydropower projects (e.g. Vargas Matamorros). Nevertheless because of the scale of this project they would probably need to expand its capacity [2]. In theory this additional capacity could be used in other projects as well.	MED	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions			*In all the works*	The assembly of electro mechanic equipments in a hydropower facility implies the integration of systems with a large number of elements and with interfaces with concrete structures. The configuration of the coupling between these two different trades are usually not feasible to specify completely from the outset of the work, and therefore local adaptation in the assembly works are common to adjust the work to the real conditions of already built structures [4].	HIGH	Implicit in the analysis
Frequency		Transacting party	*In all the works*			The support of the equipment manufacturer during the assembly is a normal condition regardless of who actually performs the assembly process. Under this condition the offer for the assembly services is higher than for the fabrication of the equipments, and the possibilities for the same provider to participle again in a future project are perceived as low.	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	Every hydropower project requires the assembly of electro mechanic equipment.		

Metal works Fabrication								
Dimension		**Criteria**	**Analysis**				**Conclusions**	
			Low	***Medium***	***High***	***Comments***	***Level***	***Justification***
Asset specificity	Physical	Customization of physical assets	*In all the works*			The physical assets required to manufacture the steel segments of the penstock, surge tank and lining are fully standardized equipment and tools such as plasma cutting machines, lifting systems, bending machines, arc welders, welding ovens, oxy acetylene cutters, sandblasters, wheel cranes and others.	**LOW**	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate the fabrication process of steel elements such as the ones demanded in this project. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project in which this kind of metal works are required [2].	**MED**	Even thought the knowledge required both at the coordination and operative levels is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Even though the production process can be standardized to a high degree, it is a very precise operation in which highly skilled operators are required. Usually this knowledge involves having participated in the same operations before in at least a couple of projects.		
	Site	Importance of proximity	*In all the works*			According to ICE estimations [1] the most economical option is to set up the manufacturing facilities on the construction site. The main reason is that if the steel elements are fabricated elsewhere, the land transportation cost would be twice in comparison to transporting the steel plates without alterations. In other works, twice the weight of virgin steel plates can be transported in the same freight in comparison with already fabricated tube segments. The savings in transportation are sufficient to justify the installation of the manufacturing facilities on the site. Nevertheless the total transportation cost would never exceed the production costs regardless of where the tubes are fabricated.	**LOW**	It may be convenient to place the fabrication facilities near the assembly site in order to economize in transportation costs, but the activity would still be feasible if manufacturing occurs in a different place.
		Relocation cost		*In all the works*		According to ICE estimations the costs of setting up the manufacturing facilities required to fabricate the steel segments of the penstock, surge tank and lining is of approximately USD$ 6 million (2013c). Even though this accounts for only 5% of the total production cost (including assembly), this cost cannot be considered negligible.		
	Temporal	Time criticality	*Surge tank, Bottom Discharge*	*Penstock, Eco Flow Works*	*Tunnel*	The steel lining of the main conduction tunnel is in the critical path of the project. For the remaining works the following stack apply: surge tank (5), penstock (4), Eco Flow Works (4) and Bottom Discharge (18).	**HIGH** (Remaining works) --------------- **LOW** (Bottom Discharge)	The replacement time has been estimated in 12 months. The classification is justify as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The process to procure the fabrication of metallic components exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by ICE´s direct administration. ICE has a central metal mechanic workshop with the technology to undertake these fabrication processes. Assuming it has enough capacity at the moment of the replacement the bottleneck is the acquisition of the steel. Taking into account the quantities and rate of requirement of the material, the expected time to have enough steel plates on the manufacturing facilities to resume the production process is estimated in 1 year. Even though this estimation is taken as a basis for the current analysis it should be noted that in case the capacity is not available at the moment of the replacement new facilities would need to be installed from scratch, increasing the replacement time to at least 1.5 years [1].		
	Dedicative	Market capacity	*In all the works*			There are local providers which currently have the capacity to undertake this kind of work [1].	**LOW**	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions	*In all the works*			The metal mechanic works of a hydropower project are designed based on assumptions that are not expected to change, such as flow and water hammer pressure. In a contract that can last for several years the prices of the basic inputs such as the steel are subject to change, but adjustment formulas can be incorporated for this purpose from the outset of the agreement [5].	**LOW**	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. There are enough suppliers with the capacity to fabricate metal mechanic elements such as the ones included in this project. The possibilities of future interactions between the parties are low.	**LOW**	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis almost every hydropower project requires this kind of operations.		

Metal works
Assembly

Dimension		Criteria	Analysis				Conclusions	
			Low	*Medium*	*High*	*Comments*	*Level*	*Justification*
Asset specificity	Physical	Customization of physical assets	*In all the works*			The physical assets required to install the steel segments of the penstock, surge tank and lining are fully standardized equipment and tools such as multitrac SAW tractor welders, arc Welders, infrared thermometers, welding ovens, heaters for thermal treatments, painting machines, wheel cranes, and others.	LOW	Implicit in the analysis
	Human	Idiosyncratic skills, knowledge and experience		*In all the works*		Specialized knowledge is required to coordinate and to perform the metal works´ assembly operations. In general this knowledge is specific for this kind of trade, although it is generally applicable in any heavy construction project in which metal works are required.	MED	Even thought the knowledge required both at the coordination and operative levels is difficult to transfer, the fact that it can be applied to any other similar projects justifies a medium level of specificity.
		Difficulty of knowledge transfer			*In all the works*	Even though the assembly process can be standardized to a high degree and installation manuals are usually elaborated beforehand, it is still a very precise operation in which highly skilled operators are required. For instance the tolerance for error in the installation of each segment of the penstock (aprox. 25 Ton each) is of just a few millimeters. Additionally due to the high pressures at which the works will be exposed during the operation stage, any quality deficiency in the welding process can potentially have disastrous consequences. Usually this knowledge involves having participated in the same operations before in at least a couple of projects [2].		
	Site	Importance of proximity	*In all the works*			Not a relevant factor, once fabricated the steel segments production system needs to be mobilized to the site.	LOW	Implicit in the analysis
		Relocation cost	*In all the works*			Highly mobile production assets. The relocation costs of any fixed facility are negligible compared with the assembly costs.		
	Temporal	Time criticality	*Surge tank, Bottom Discharge*	*Penstock, Eco Flow Work*	*Tunnel*	The steel lining of the main conduction tunnel is in the critical path of the project. For the remaining works the following stack apply: surge tank (5), penstock (4), Eco Flow Works (4) and Bottom Discharge (18).	HIGH (Tunnel, surge tank) -------------- MED (Penstock, Eco Flow Works) -------------- LOW (Bottom Discharge)	The replacement time has been estimated between 3 and 6 months. The classification is justify as follows: **High** = total stack< replacement time **Medium** = Total slack < replacement time + 4 months (5% project duration) **Low**= all the remaining works
		Difficulty to arrange replacement			*In all the works*	ICE is subject to public procurement law. The process to procure an entire construction work exceeding USD$ 115 000 should follow a tender procedure and may take as much as two years. In case a replacement must be arranged the fastest option would be to resume the works by ICE´s direct administration. In general the physical assets required for these operations are relatively easy to arrange, with the possible exception of some large capacity cranes. ICE has the know how to coordinate the work and assuming there would be no difficulties in getting the equipment, the replacement time is conditioned to the time required to hire any missing personnel (qualified welders being the most critical). Taking into consideration the nature of this type of operations, in normal conditions this time can be estimated in 3 months [1]. An exception should be made regarding the assembly of the surge tank, because a high capacity tower crane is required (therefore if ICE does not have one available both rental and installation time should be taken into account). In the latter a replacement period of 6 months is assumed.		
	Dedicative	Market capacity	*In all the works*			There are local providers which currently have the capacity to undertake this kind of work [1].	LOW	Implicit in the analysis
Complexity		Likelihood of non-anticipated changes in conditions	*In all the works*			The assembly of steel elements is undertaken once all the others associated works, such as excavations, mounts and stands are finished and the fabricated segments on the site. In regular basis it should be possible to anticipate adequately any possible change from the outset of the contractual relationship [5].	LOW	Implicit in the analysis
Frequency		Transacting party	*In all the works*			Future works are subject to competitive tendering. There are enough suppliers with the capacity to assembly metal mechanic elements such as the ones included in this project. The possibilities of future interactions between the parties are low	LOW	In this case the fact that there is a clear limitation for future collaborations between the parties is taken as a dominant factor for a TCE analysis, in which opportunistic behavior is central
		Type of transaction			*In all the works*	In general basis almost every hydropower project requires this kind of operations.		

NOTE:

This analysis was developed based to a large extent on the author´s own experience working for ICE in the planning and construction of hydropower projects and documental analysis of EDHP´s basic information. It was enriched with semi structured interviews held with several specialists regarding specific points in which reaffirmation or additional knowledge was considered to be relevant. When it was deemed appropriate reference numbers were included to mark a particular piece of information that was included as a direct outcome of these discussions. The table below presents general information and the reference numbers of these sources as mentioned in the analysis. All the interviews were conducted in March 2013.

N°	Name	Position of interest / Specialty	Contact
[1]	Ronald Alpizar	Chief Engineer Technical Services El Diquis Hydropower Project/ Specialist in construction machinery, equipment and metal works. Over 20 years of experience.	RAlpizarCa@ice.go.cr
[2]	Roberto L. Prado	Independent Consultant/Specialist in planning of power generation facilities. Over 35 years of experience working in the region and internationally.	013rlp@gmail.com
[3]	Irene Zuñiga	Chief Engineer ICE´s Contract Management Department of Construction Works/ Specialist in contractual topics. Over 20 years of experience.	LZuniga@ice.go.cr
[4]	Jorge Mario Castro	Chief Engineer Electro Mechanical Assemblies Pirris Hydropower Project/ Specialist in Electro Mechanical Works. Over 20 years of experience.	jocastr@ice.go.cr
[5]	Jesus Bertozzi	Contract Manager Metal Works Pirris Hydropower Project / Specialist in Electro mechanical works with over 20 years of experience.	JBertozzi@ice.go.cr
[6]	Diego Campos	Chief Engineer Construction Department El Diquis Hydropower Project/ Specialist in Underground works with more than 15 years of experience	dicampos@ice.go.cr
[7]	Mauricio Varela	Chief Engineer Engineering Department El Diquis Hydropower Project/ Specialist in structural design and coordination of design processes with more than 20 years of expirience	MVarela@ice.go.cr

ANNEX D: Adaptation and enforcement provisions in foreseen agreements

Work	Relevant clauses[70]	
	Adaptation	Enforcement
Integrated contract dam site ***Foreseen agreement:*** *“General and particular contract conditions Pirris Hydropower Project Dam Site construction works (ICE, 2005) ”*	**Clause 7.1: Supplementary drawings and instructions.** The engineer is authorized to periodically provide the contractor supplementary drawings and instructions, or corrections to the tender drawings. The latter should be considered as originally included in the contract. The costs of these changes should be acknowledged by the employer, according to the procedure established in the contract. **Clause 11.1 Site inspection.** The employer should provide the contractor information regarding the site conditions that have been obtained on behalf of the employer. The contractor is nevertheless responsible for its interpretation. It should be considered that the contractor has inspected and examined the site and the available information (***so far as is practicable, having regard to considerations of cost and time***) before submitting the tender. **Clause 12.2: Unforeseen obstacles or physical conditions.** In the contractor finds ***unforeseen physical obstructions or conditions*** that could not be ***reasonably anticipated by an experienced contractor***, he should communicate this to the engineer, who is empowered to grant an extension of time and cost. This does not apply to weather conditions. **Clauses 20.3 and 20.4: Employer´s risks.** The employer assumes the risk of changing circumstances such as political conditions and forces of nature that the contractor ***could not reasonably anticipated***, or that could foresee but against which it ***could not reasonably have taken adequate measures***. In such cases the contractor should fix losses or damages, the cost of which will be acknowledged by the employer according to the procedure established in the contract. **Clause 27. Fossils**. If archeological remains are found the contractor should take ***reasonable precautions*** to prevent their extraction and damage. The contractor should inform immediately the engineer and follow his instructions. Additional cost and time will be acknowledged by employer if necessary. **Clause 48.3.Substantial completion of parts**. When a part of the permanent works has been ***substantially completed*** and it has successfully passed the acceptance tests described in the contract, the engineer may issue a certificate for that part of the work. **Clause 51 and 52. Modifications**. The engineer shall have the authority to make any modification that ***considers necessary or convenient for any reason*** in the form, quantity and quality of the Works in case of unforeseen circumstances and for no more than 50% of the contract object. Such modification in any way vitiates or nullifies the contract. A written instruction is required, except in those cases in which the modification consists of a variation in quantity of a work already included in the payment lines. If the latter cannot be used to estimate the price of the change, this price will be agreed between the parties. If no agreement is reached, the engineer will preliminary set the price that considers adequate and used it to make the payments until the final prices are finally agreed or fixed. No additional procedure is required if the total variation in the contract prices is not greater than 10%. Revisions in the time or construction are also possible when the total quantity of work executed under a payment line exceeds 15% of the original quantity. The engineer if is considers it necessary can undertake by direct administration the modifications, for which the contractor has to facilitate the resources. **Clause 65**. **Force Majeure**. Force majeure means and event or exceptional circumstance that: a) Is out of control of the party b) For which the party could not take ***reasonable precautions*** before entering in the agreement. c) That if arisen the party could not ***reasonable avoid or overcome.*** d) That cannot be ***substantially attributable*** to the other party. The contractor is entitled to extension in time and the recognition of additional costs incurred because of such events. **Clause 70. Variations of costs and legislative changes**. The payments to the contractor will be adjusted for changes in the costs of the production inputs, according to the adjustment formulas established in the contract. In addition, in case of legislative changes after 28 before the submitting the offer, the risk is assumed by the employer.	**Clause 10. Performance guarantee.** The performance guarantee is of 10% of the contract price and should be delivered no later than 21 days after the letter of acceptance. **Clause 16.1. Right of the employer to object.** The engineer has the right to object and to demand the contractor the immediate removal of any person that not meets the contract requirement. **Clause 47.1**. **Damages for delay.** The contractor should pay USD$ 75 000 per day of delay. This will be applied by simple verification of the engineer. The total fine for delay shall not be greater than 20% of the contract price. These deductions are made from any money paid or accrued. **Clause 47.4: Fines for contract´ breach**. If the contractor fails to comply with any provision in the contract, the engineer gives a notice and a reasonable time to amend. If after this period no correction is undertaken, a fine of USD$ 2 000 is charged for the first 10 days, and USD$ 4 000 for the following 10. After this period of 20 days, if the problems persist the engineer is authorized to suspend the payments to the contractor. **Clause 47.5. Bonus for early termination**. Subject to the discretion of the employer and depending of the status of the project planning a bonus of USD$ 35 000 can be granted to the contractor for each day of early termination, up to a total of 10% of the contract price. **Clauses 60.5 and 60.6. Retention of payments.** The engineer shall make a deduction of 5% of each partial payment, as additional contractual guarantee, from which the employer can pay fines, damages, repairs, etc not covered by the contractor. Half of the retentions are given back to the contractor once the works are accepted and the other half once the work´s guarantee period expires. **Clause 63. Failure of the contractor.** In accordance to the conditions established for this purpose in the agreement, the employer has the authority to terminate the contract. After this the employer may complete the works or hire other contractor to do it so. If the employer considers appropriate to use the equipment and materials the contractor has on the site, he will be entitled to do it so paying the contractor a reasonable amount in accordance with the offer. Except where legally prohibited, if the employer consider it necessary the contractor must pass the employer any agreement held for the supply of goods, materials, services or any work related to the contract. **Clause 67. Dispute settlement.** If the contractor disagrees with a decision of the engineer, he can take the claim to the project director exhausting hereby the administrative remedy. The possibility of a arbitration is open, subject to the approval of the executive board and in accordance with the law 7727 “Alternative resolution of conflicts”. The arbitration should be held in an institutionalized conciliation and arbitration center. The final decision is binding on both parties. .
Metal work contract ***Foreseen agreement:*** *“General and particular contract*	**Clause 7.1: Supplementary drawings and instructions.** IDEM integrated contract dam site. **Clause 8.3: General design obligations**. After receiving notification of commencement of works, the contractor must thoroughly examine the specifications and references points included in the contract. Within 55 days the contractor should notify the engineer about any error, omission or other found defect. If it is determined that this condition ***could not have been detected by an experienced contractor exercising due care*** during the period of tender preparation, the contractor is entitle to compensation for the require modification.	**Clause 10. Performance guarantee.** IDEM integrated contract of Dam Site. **Clause 16.1. Right of the employer to object.** IDEM integrated contract of Dam Site. **Clause 47.1**. **Damages for delay.** The contractor should pay USD$ 75 000 per day of delay if this directly affect the start of the project´s operation and USD$ 4 000 if not. This will be applied by simple verification of the employer. The total fine for delay shall not be greater than 20% of the contract price. These deductions are made from any money paid or accrued.

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[70] The original clauses included in the contracts are in Spanish. For the purpose of this work the clauses presented in table 5.2 were summarized and translated to English by the author. Therefore they should not be considered as being precise from a legal point of view, even though care was taken to make an accurate translation of those parts of the text important for the governance structure´s classification.

conditions Pirris Hydropower Project-Design, fabrication and installation of the penstock and steel lining of the final segment of the conduction tunnel (ICE, 2006a) ”	**Clause 12.2: Obstacles or unforeseen site conditions.** IDEM integrated contract dam site. **Clauses 20.3 and 20.4: Employer´s risks.** IDEM integrated contract dam site. **Clause 27. Fossils**. IDEM integrated contract dam site. **Clause 51 and 52. Modifications**. The engineer shall have the authority at any time before the works are received to order the contractor to change, fix, omit or include any part of the works for no more than 50% of the contract´s object. Such modification in any way vitiates or nullifies the contract. The contractor shall not make effective any modification without a written order from the engineer. If the contract prices are applicable, they should be used as a basis to estimate the price of the modification. If the contract prices are not applicable, this price will be agreed between the parties. If no agreement is reached, the engineer will preliminary set the price that considers adequate and use it to make the payments until the final prices are finally agreed. If a change order is received, the contractor shall execute the modification as if this was originally in the contract, without waiting for an agreement regarding the recognition of extra time and cost. The engineer if is considers it necessary can undertake by direct administration the modifications, for which the contractor has to facilitate the resources. **Clause 65**. **Force Majeure**. IDEM integrated contract dam site.. **Clause 70. Variations of costs and legislative changes**. IDEM integrated contract dam site..	**Clause 47.4: Fines for contract´ breach**. IDEM integrated contract of Dam Site. **Clause 47.5. Bonus for early termination**. IDEM integrated contract of Dam Site. **Clauses 60.5 and 60.6. Retention of payments.** IDEM integrated contract of Dam Site. **Clause 63. Failure of the contractor.** IDEM integrated contract of Dam Site. **Clause 67. Dispute settlement.** IDEM integrated contract of Dam Site. .
Electro mechanic contract ***Foreseen agreement:*** *“Contract conditions Fabrication of Electro mechanic Equipments and associated services for Pirris Hydropower Project Powerhouse (ICE, 2006b)”*	**Clause 5.12. Obstacles or unforeseen site conditions.** IDEM clause 12.2 integrated contract dam site. **Clause 14. Modifications, additions and omissions.** IDEM clauses 51 and 52 Metal Work contract. **Clause 23.2 Employer´s risk.** IDEM clause 20.3 integrated contract dam site. **Clause 24. Force Majeure.** IDEM clause 65 integrated contract dam site.	**Clause 5.4.3 Right of the engineer to object public disorder**. If the engineer considers that the assembly supervisors are incapable or not appropriate for the job, he has the right to ask for their removal. The contractor has to proceed at his cost and without delay. **Clause 5.9 Performance guarantee.** IDEM Clause 10 Integrated contract dam site. **Clause 20. Failure of the contractor.** IDEM clause 63 integrated contract of Dam Site. **Clause 28. Dispute settlement.** IDEM clause 67 integrated contract of Dam Site. **Clause 31. Paying damages.** If the contractor fails to meet the equipment´s delivery dates he should pay the employer all the damages caused by this delay. This charge will be applied by simple verification of the engineer. **Clause 32.1. Penalty for late delivery of documents.** If the contractor fails to deliver on time the documents listed in the specifications, a fine of USD$ 1 000 should be paid to the employer. **Clause 32.2. Penalty for delay in the initiation and completion of the works.** If the contractor fails to start or to end the supervisions services or acceptance tests within the time limits, the engineer should send the contractor a written warning establishing a reasonable time to amend. After this period the contractor must pay a fine of USD$ 2 000 per day, that increases to USD$ 4 000 after 10 days. Beyond this point the engineer is entitle to suspend the payments to the contractor. **Clause 33.1. Warranty of efficiency.** If the actual efficiency resulting from the onsite testing is lower than the guaranteed by the contractor, the latter should pay the employer USD $ 200 000 for every 0.1% of deficit. If the deficit exceeds 1% the employer has the right to ask the contractor to rectify such equipment or to negotiate a reduction in the contract´s price. This clause will be applied by simple verification of the engineer. **Clause 33.2. Warranty capacity.** If the actual net capacity resulting from the onsite testing is lower than the guaranteed by the contractor, the latter should pay the employer USD $ 1 000 for KW of deficit. If the deficit exceeds 150KW the employer has the right to reject the equipments or to negotiate a reduction in the contract´s price. This clause will be applied by simple verification of the engineer. **Clause 33.3. Level of noise.** If the level of noise resulting from the onsite testing is higher than legally established, the employer has the right to reject the installations and to apply the performance guarantee. **Clause 34. Recovery of damages or fines.** The employer has the right to recover the amounts established in clauses 31,32 and 33 from any amount not yet payable to the contractor, or from the performance guarantee (clause 5.9). The total charge for damages and fines should not be greater than 20% the contract´s price.

ANNEX E: Summary of sub cases and main decision factors

Project	Characteristics	Selected organizational arrangement	Main decision factors
Angostura (AHP)	**Capacity :** 177 MW **Average production:** 970 GWh/year **Scheme:** Reservoir (daily regulation) **Main works:** ***Dam and intake works*** Rock fill with impervious central core (H=36 m, V= 450 000m^3), frontal spillway with 4 radial gates (Cap = 5 500 m^3/s), bottom discharge (169m long channel, Cap= 300m^3/s), water intake (attached to the spillway). Spillway and bottom discharged used to divert the river. ***Conduction and generation works*** Main tunnel (L= 6 750m), semi buried surge tank (D= 20m, H=79m), penstock (single line, L= 327m, D= 6.4m-2.8m),main power house (superficial, 3 Francis units, 177 MW). No eco flow powerhouse. **Total cost:** USD$ 366 million **Construction period:** 1993-2000 **Status:** commercial operation.	**Mix development scheme:** ***Buy:*** **Package 1**: dam site works **Package 2:** fabrication and assembly of metal works (tunnel´s last segment steel lining, surge tank, penstock) **Package 3:** fabrication of electro mechanic equipments ***Make:*** Remaining works	1. Historical Inertia. 2. Restriction financial entities. 3. Time criticality imposed by national expansion plan. 4. Rigidity in procurement processes to deal with interfaces between suppliers. 5. Foreseen contractual hazards in underground works. 6. Economies of scale (electro mechanical equipments).
Pirris (PHP)	**Capacity :** 138 MW **Average production:** 600 GWh/year **Scheme:** Reservoir (monthly regulation) **Main works:**	**Mix development scheme:** ***Buy:*** **Package 1**: dam site works (general excavation not included)	1. Historical Inertia. 2. Restrictions of financial entities.

	Dam and intake works RCC dam (H=113 m, V= 730 000m3). Spillway, bottom discharge and water intake integrated to dam´s main body. ***Conduction and generation works*** Main tunnel (L= 10 508m), penstock (single line, L= 748m, D= 2.0m-2.2m), main power house (superficial, 2 Pelton units, 138 MW). No surge tank and eco flow powerhouse. **Total cost:** USD$ 627 million **Construction period:** 2000-2011 **Status:** commercial operation	**Package 2:** metal works (tunnel´s last segment steel lining and penstock) **Package 3:** fabrication electro mechanic equipment ***Make:*** Remaining works	3. Time criticality imposed by national expansion plan. 4. Rigidity in procurement processes to deal with interfaces between suppliers. 5. Lack of experience (RCC Dam) 6. Foreseen contractual hazards in underground works. 7. Economies of scale (electro mechanical equipments).
Reventazón (RHP)	**Capacity :** 305.5 MW **Average production:** 1 573GWh/year **Scheme:** Reservoir (bimonthly regulation) **Main works:** ***Dam and intake works*** CFRD dam (H=132m, V= 8 400 000m3), two diversion tunnels (D= 793m & 667m), frontal spillway with 4 radial gates (Cap = 11 380m^3/s), bottom discharge, 638m long tunnel (Cap= 500m^3/s), water intake (H=44m, steel grids supported in side walls) ***Conduction and generation works*** Main tunnel (L= 1 685m, 0.8%), superficial surge tank (D= 27m, H=51m), penstock (single line, L= 894m, D= 8.6m-	**Direct administration scheme:** Only fabrication of electro mechanic equipments and some minor works[71] commissioned to third parties.	1. Time constraints imposed by national expansion plans. 2. Delay in financial closure due to legal limitation of available schemes. 3. Leverage limitations 4. Delay in designs. 5. Rigidity in procurement processes to deal with interfaces between suppliers. 6. Recommendation of consultants

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[71] The formwork system for the construction of the dam´s concrete face, the placement of the cofferdam´s membrane and the cleaning of the reservoir area are planned as subcontracts.

	8.2m),main power house (superficial, 4 Francis units, 290MW),eco flow power house (Superficial, 1 Francis unit, 13.5MW). **Total cost:** USD$ 1 440 million **Construction period:** 2009-2016 **Status:** Under construction		(subcontracts of minor works). 7. Economies of scale (electro mechanical equipments).
El Diquís (EDHP)	**Capacity :** 650 MW **Average production:** 3 050GWh/year **Scheme:** Reservoir (annual regulation) **Main works:** ***Dam and intake works*** CFRD dam (H=173m, V= 11 600 000m3), two diversion tunnels (D= 618m & 688m), frontal spillway with 4 radial gates (Cap = 22 300m^3/s), bottom discharge (tunnel, Cap= 527m^3/s), water intake (H=75m, tower with multi level inlets) ***Conduction and generation works*** Main tunnel (L= 11 300m), semi buried surge tank (D= 28m, H=110m), penstock (double line, L= 1 175m, D= 6.9m-2.5m),main power house (superficial, 4 Francis units, 623MW),eco flow power house (underground, 1 Francis unit, 27 MW). **Total cost:** USD$2 072 million **Construction period:** 2014-2021 **Status:** environmental license in process	**Mix development scheme:** ***Buy:*** **Package 1**: dam site works (general excavation not included) **Package 2:** metal works (tunnel´s last segment steel lining and penstock) **Package 3:** fabrication electro mechanic equipment ***Make:*** Remaining works	1. Historical Inertia. 2. Anticipated restrictions of financial entities. 3. Time constraints imposed by national expansion plans. 4. Rigidity in procurement processes to deal with interfaces between suppliers. 5. Foreseen contractual hazards in underground works. 6. Economies of scale (electro mechanical equipments).

NOTE: the examination of these sub cases was based on triangulation of sources:

- **Participatory observation**: PHP & EDHP
- **Documental analysis:**
    - *AHP:* Electrical Development Program N°3 (ICE, 1993), Final Report Angostura Hydropower Project (ICE, 2000)
    - *PHP:* Final report Pirris Hydropower Project (ICE, 2012a)
    - *RHP:* Project Management Plan Reventazón Hydropower Project (ICE, 2010), PHR Financial scheme (ICE, 2013a)
    - *EDHP:* Project Management Plan El Diquís Hydropower Project (ICE, 2013b),
- **Semi structured interviews:** several participants in the decision making process or with historical knowledge of the institutions where contacted. The name of these sources and their contact information are provided in the table below.

Source	Position of interest	Contact
Ignacio Arguedas	Director AHP	iarguedas@ice.go.cr
Luis Diego Baltodano	Chief Engineer Planning and Control Department, RHP	LBaltodano@ice.go.cr
Franklin Avila	Director EDHP	FavilaP@ice.go.cr
Alexander Solis	ICE´s General Coordinator of Construction Projects (2005-to present)	ASolisBa@ice.go.cr
Gravin Mayorga	Former ICE´s CEO Electricity Sector (2009-2013) Former general director ICE´s UEN PySA (2004 – 2009)	gravinmayorga@gmail.com
Irene Zuñiga	Chief Engineer ICE´s Contract Management Department of Construction Works	LZuñiga@ice.go.cr
Roberto Labarca	Former Chief Engineer ICE´s planning and control department (1980-1985)	013rlp@gmail.com

ANNEX F: Characterization of Costa Rican culture

Costa Rica constitutes in some cultural aspects an exception among the Latin American countries. According to Hofstede et al. (2010) in terms of power distance Costa Rica has the lowest index in all America, comparable with many North European countries. Costa Rica is the oldest democracy in Latin America, and remains without an army since it was abolished in 1948. Democracy is deeply registered in the mind set of Costa Ricans. Even now a days, when the public´s support and confidence in the government is substantially low as a product of several corruption scandals during the last decade, a recent study (Vargas-Cullell et al., 2006) indicates that the public perception toward the need of a stronger leader has not changed at all. Despite the disappointment with the political system, Costa Ricans remain intolerant to any intent in breaking the democratic regime, nor accept the figure of a strong and authoritarian leader, as is common in other countries of the region. Even thought corruption exists, as it was stated before, Costa Rica ranks third in Latin America regarding corruption perception index (Transparency International, 2012) and the legal system is recognized as transparent and independent from other republic powers.

The country´s small power distance is also noticeable in its comparative high middle class composition, which has been identified as a determinant factor that separates the country from the Latin American standards in terms of social inequalities (Monge, 2012). The social interchanges of people of different strata is not unusual in Costa Rica, and a person of a lower social class will in general not feel restrained about directly addressing in any social ambit to one of higher class, nor the latter will consider it inappropriate. So, even though construction companies for example usually hold very hierarchical structures, specially the temporal organizations build up to undertake a specific project, this represents more inequalities of roles than of societal levels. Even thought status symbols are given to higher hierarchical level, these are usually taken discretely.

Another cultural characteristic in which Costa Rica is different from other Latin American countries is in the masculinity-femininity dimension. Costa Rica has been a pioneer in Latin America in the enactment of laws aimed towards equality between women and men (PNUD, 2012). The salary gap between genders is the lowest in the region, even though women still perceive in average a salary 13.7% lower than men in an equivalent position (IDB, 2009). The participation of women in politics is also comparative higher, as can be stated by the fact that the current President of The Republic and one third of the congress members are women. Even though there are still inequalities, especially regarding labor rights (PNUD, 2012), gender discrimination is not (at least publicly) tolerated and is common for companies to adopt internal policies to promote an egalitarian condition between women and men.

Femininity can also be distinguished in the fact that consensus in Costa Rica has a decisive role in the preservation of social order (Soto, 2011). Without the existence of an army, and with it an effective mean of repression, the Costa Rican authorities heavily rely on the open dialogue to solve conflicts within the society. In practice this cultural trait has been translated to the work relationships, in which the resolution of conflicts is often achieved by means of compromise and negotiation.

In terms of individualism or collectivism, the Costa Rican society is characterized by Hofstede et al. (2010) as one in which a strong collectivistic behavior persist, following in this aspect the typical trend described by other Latin American countries. Interestingly this perception contradicts the opinion of many Costa Rican scholars (Beirute, 2008, Molina, 2010), who describe Costa Rican society as individualistic. This is often attributable to the spread rural development that characterized Costa Rica in the first half of the twentieth century and to the structural adjustment programs propitiated by the International Monetary Fund and the World Bank after the economic crisis of the earlier 1980´s, which have help to propitiate in the Costa Ricans an increasing feeling of isolation from the society, individualism and indifference to anything exceeding their family ambit (Molina, 2010).

Despite de above, there are a number of relevant collectivistic elements recognized by Hofstede that can be easily appreciated in the Costa Rican culture. It is fair to say that the sense of belonging to a larger social group still remains in general as an important need for Costa Ricans (although, as noticed by Molina, this feeling is declining). Many companies are family owned enterprises, in which it is common to find family members in different positions of the company and where the leading member has substantially large decision power. Knowing someone in a company´s key position is usually the easiest way to get onboard. Even though this practice may raise some negative comments, the use of influences is a general accepted practice. It is not unusual neither to see that employer-employee relations transcend the contractual. Loyalty is highly appreciated in employees and in return there is a tacit moral responsibility of the employer to protect their subordinates. In case of personnel cuts for example, it is expected of the employer to help the employee in getting a new job.

Costa Rica can also be described as a high context communication society, in which there is a great amount of information either in the physical and socio-relational context or internalized in the people. The most extreme example of this is the way addresses are given in Costa Rica. San José, the Costa Rican capital city, is the only place in the country in which streets have names. There are about sixteen streets formally named, even though the actual signs are hard to find. To get around Costa Rican cities and towns sometimes a deep historical knowledge of the place is needed, because people rely mostly on landmarks that are implicitly known. In some cases this landmarks have been demolished many years ago.

Another cultural characteristic of Latin American countries, which according to Hofstede et al. (2010) is shared by Costa Rican society, is its remarkably high uncertainty avoidance. This can be easily perceived in the very typical Costa Rican characteristic of having laws for everything, even though they are often not respected. The Costa Rican legal system can be described as an intricate cobweb that usually results overwhelming to foreign investors. This was recognized by the recent “Doing Business 2012” report of the World Bank, in which the regulations to establish companies in 183 economies were compared in terms of how conductive they were to efficient business activity. Costa Rica was ranked in the 121 position, which in this case means that excessive business regulations hamper economic productivity and foreign investments (WB and IFC, 2012).

It should be noted that regarding tolerance to other cultures, xenophobia has been present in Latin America since the colonial era. Some racist ideas introduced by Europeans during this period are still present in a segment of the Latin American society (Solis, 2009) and it is often focused on ethnic minorities. Because of its comparable better living conditions in the regional context, Costa Rica is a country with a high immigration rate. Most of this migration comes from the neighbor Nicaragua, which population in the country according to the official estimates (INEC, 2012) represents around 7% of its total population. Discrimination and xenophobia against this national group is visible. Nevertheless this discrimination is mostly focused on the northern neighbors and Costa Ricans in general are open-minded about accepting people from other nationalities. Even though Catholicism is the country´s official religion, the separation between government and religious authorities is market, having the latter little influence in the decisions made by the government or private companies.

Costa Rica has not been included in the results of the last two cultural dimensions mentioned by Hofstede et al. (2010), Long-Term Orientation and Indulgence and Restrain. Nevertheless, there is no reason to believe that the country is different in these two aspects from other Latin American countries. Costa Rica can be described as a short term orientation country, in which the government lacks of vision to focus in problems further than those within its own period (Vega, 2011). This can be exemplify by the country´s precarious conditions of the transport infrastructure, ranking 121st among 142 countries analyzed in The Global Competitiveness Report 2011-2012 (World Economic Forum, 2011). The consumption habits of Costa Ricans also exhibit shortsighted tendencies. The debt associated with credit cards reached a 2.7% of the total GDP in 2011 (Arce, 2012) and the practice of saving has been historically low in the country.

Costa Rica can also be described as a cultural indulgent country. In 2012 for the second time in a row it ranked first worldwide in the Happy Planet Index, an index of human well being and environmental impact that was introduced by the New Economics Foundation in 2006 (NEF, 2012). Costa Ricans in general can be described as extroverted people, for whom friendship is not only important but also it is relatively easy to develop. Freedom of speech is paramount for Costa Ricans and it is taken as a fundamental right of every citizen. The country ranked 2nd in America after Canada and 19th in the world in terms of the Press Freedom Index 2011/2012 (Reporters without Borders, 2012). This cultural indulgence can be recognized in a very typical Costa Rican social behavior known as *"choteo",* which literally means derision or joke. Costa Ricans tend to address others in a very informal way in which mockery is abundant, even with recently met people. This of course can affect susceptibilities of those not use to this very common social practice.

NOTE: this characterization was prepared by the author for the course EPA 1433 Cross Cultural Management and included in the research paper ***"Nicaraguan Inter-oceanic Canal: dealing with cultural differences of an Iranian-Costa Rican Joint Venture".***