



HAL
open science

Représentation et simulation de projets de construction entachés d'incertitudes en utilisant des modèles relationnels probabilistes

Thi Thuy Phuong Tran

► **To cite this version:**

Thi Thuy Phuong Tran. Représentation et simulation de projets de construction entachés d'incertitudes en utilisant des modèles relationnels probabilistes. Mécanique [physics]. Université de Bordeaux, 2018. Français. NNT : 2018BORD0014 . tel-01782409

HAL Id: tel-01782409

<https://theses.hal.science/tel-01782409>

Submitted on 2 May 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Thèse de Doctorat

Présentée à

L'UNIVERSITÉ DE BORDEAUX

ÉCOLE DOCTORALE DES SCIENCES PHYSIQUES ET DE L'INGENIEUR

Par

TRAN Thi Thuy Phuong

Pour obtenir le grade de docteur

Spécialité : Génie civil, gestion des risques

**REPRESENTATION AND SIMULATION OF CONSTRUCTION PROJECTS
TAINTED WITH UNCERTAINTIES BY USING PROBABILISTIC RELATIONAL
MODELS**

Soutenu le 14 février 2018

Devant le jury composé de :

Christophe GONZALES	Professor – Sorbonne Universités, UPMC Univ Paris 6, CNRS, UMR, 7606 LIP6, Paris-France	Rapporteur/ Président du jury
Laurent PEYRAS	Ing. de Recherche, IRSTEA, Aix en Provence	Rapporteur
Olivier DECK	Professor - U. Lorraine, Ecole des Mines of Nancy, UMR 7359	Examineur
Denys BREYSSE	Professor - U. Bordeaux I, I2M-GCE CNRS UMR 5295	Directeur de thèse
Franck TAILLANDIER	Associate Prof. - U. Bordeaux I, I2M-GCE CNRS UMR 5295	Co-directeur de thèse
Cédric BAUDRIT	Chargé de recherche - U. Bordeaux I, INRA, U. Bordeaux-I2M, USC 1368.	Co-directeur de thèse

Abstract

The difficulty to manage risks in construction projects comes from their complexity. They are composed of many entities (activities, actors, contracts, resources, etc.) among which interactions exist at many levels and influence the system response. In turn, this response can influence the behaviour of some entities. In order to capture the complexity of the system, it is necessary to structure, model and share cross-disciplinary and interdisciplinary knowledge flows in a common and unifying framework. Because of this high complexity, the system response may appear as unpredictable. Uncertainties at all scales are source of risk for the construction project itself. Tackling this complexity could improve our grasp of the whole system, in order to provide more robust and efficient decision alternatives in risk management. It is then essential to propose conceptual approaches able to represent the behaviour and the interactions of system entities over the time.

Different approaches and tools have been proposed to model and simulate risk of construction project as Risk Breakdown Structure, Bayesian networks, Network Theory, Monte Carlo Simulation, Analytical Network Process, etc. These tools and methods can be used to simulate the behaviour of the system, but they are inadequate for representing large and complex dynamical system because they are based on case-dependant model (i.e. a specific model has to be built for each studied construction project), the fragmented representation of knowledge, the lack of common vocabulary, the lack of generic character. Hence, an ontology paradigm is developed in order (a) to provide a common vocabulary able to represent the knowledge about construction projects and its risks, (b) to shape the structure (interrelations) between those identified database and (c) to represent construction project integrating as well technical, human, sustainability dimensions at different detailed levels of uncertainty.

In this context, by coupling the advantages of ontology and Bayesian network, the framework of probabilistic relational model (PRM) will provide a practical mathematical formalism allowing to **represent** and **simulate** complex stochastic dynamical systems. PRMs extend the formalism of Bayesian networks by adding the notion of object paradigm where uncertainty attached to the system is then taken into account by quantifying probabilistic dependence between the properties of objects and other properties of related objects. To the best of our knowledge, this thesis report will be the first application in which PRM have been proposed to model and simulate construction project while accounting uncertainties.

Therefore PRM is used to simulate the propagation of uncertainties existing in this complex dynamic and multi-scale system, which lead to construction project risk. A prototypal software framework has been developed to check the consistency and the viability of the concept. It will be shown how it can be used in order to predict the uncertain response of the system as well as to study how the overall response of the system is sensitive to local values or assumptions. Lastly, PRM will be applied for two case-studies (a road and bridge construction in Hue-Vietnam and another building project in France). Results show that the formalism of PRMs allows to (1) implement any kind of construction project, (2) to take uncertainty into account, (3) to simulate and predict the behaviour of system and (4) to derive information from partial knowledge.

Key words: *Complex system, Construction project, Probabilistic relational model (PRM), Uncertainty modelling, Knowledge base.*

Résumé

La gestion des risques est un enjeu majeur, mais difficile pour les projets de construction. La difficulté à gérer les risques dans les projets de construction vient de leur complexité. Ils sont composés de nombreuses entités (activités, acteurs, contrats, ressources, *etc.*) dont le comportement collectif influence les comportements individuels. Afin de mieux appréhender et comprendre la complexité du système dans son ensemble, il est nécessaire de capitaliser et structurer la connaissance dans le but de proposer un modèle capable de décrire et simuler le comportement du système étudié. Cependant, la formalisation de tels modèles se confronte à de nombreuses difficultés : présence de facteurs humains, rareté de modèles, connaissances souvent expertes et qualitatives difficiles à formaliser, méconnaissance des mécanismes régissant certains processus, données parcellaires, hétérogènes et souvent imparfaites, échelles multiples, *etc.* L'objectif est de proposer des approches conceptuelles permettant d'assembler des morceaux de connaissances hétérogènes multi-sources et multi-échelles dans le but de proposer un modèle capable de réduire les incertitudes liées au fonctionnement, au devenir, à la conception et au pilotage des projets de construction.

Différentes approches et outils ont été proposés pour modéliser et simuler les projets de construction : structure de répartition des risques, réseaux bayésiens, théorie des réseaux, simulation de Monte Carlo, réseau analytique, *etc.* Ces outils et méthodes sont utilisés pour simuler le comportement de systèmes, mais inadéquats pour représenter des systèmes complexes dynamiques à grandes échelles. Ils sont pour la plupart parcellaires et ne présentent pas ou peu de généralités. Dans ce contexte, les modèles relationnels probabilistes (MRPs) fourniront un formalisme mathématique pratique permettant de représenter et de simuler des systèmes dynamiques complexes entachés d'incertitudes. Les MRPs étendent le formalisme des réseaux bayésiens en ajoutant la notion de paradigme objet où l'incertitude attachée au système est alors prise en compte en quantifiant la dépendance probabiliste entre les propriétés des objets.

Pour ce faire, une ontologie du domaine a été développée pour (a) fournir un vocabulaire commun capable de représenter les connaissances sur les projets de construction, (b) identifier les interconnexions entre les différentes entités techniques, humaines, économiques à différents niveaux de description. Guidé par cette ontologie un

MRP a été élaboré et utilisé pour simuler le comportement des projets de construction tout en prenant en compte les incertitudes. On montrera comment il peut être utilisé pour prédire la réponse incertaine du système ainsi que pour étudier comment la réponse globale du système est sensible aux valeurs ou hypothèses locales. Enfin, le MRP sera utilisé pour deux études de cas (la construction de routes et de ponts à Hue-Vietnam et d'un bâtiment en France). Les résultats montrent que le formalisme des MRPs permet (1) d'instancier tout type de projets de construction, (2) de prendre en compte l'incertitude, (3) de simuler et prédire le comportement du système et (4) d'extraire de la connaissance à partir d'informations partielles.

Mots clés : *Système complexe, Projet de construction, Modèle relationnel probabiliste, Modélisation d'incertitude, Base de connaissances*

Acknowledgment

With the support of financement of Vietnamese government, I had a great chance to research under the guidance of Prof. Denys Breyse, Dr. Franck Taillandier, and Dr. Cédric Baudrit. Their guidance, patience, and motivation helped me in all the time of researching and writing of this thesis. I could not have imagined having better advisors and mentors for my Ph.D study.

First of all, my sincere thanks goes to my professor Denys Breyse for his kindness, and clear advices on scientific research orientation during my thesis. He also gave me a strong motivation in learning French.

Besides, I would like to thank Dr. Franck Taillandier and Dr. Cédric Baudrit for their insightful comments and encouragement. During three years of thesis, they help me from the first step of writing a basic scientific paragraph to code a program that I've never known before. Working with them, I learnt scientific work style and work organization.

I thank my fellow labmates at I2M laboratory with whom I have pleasure to work and for all the fun we have had in the last three years.

The most important is my family. My mother sacrificed all of her life for me and gave the best thing to make me comfortable during three years. I believe that my father in paradise will be happy about all the things I've done. I would like to thank my husband, LE Xuan Sang, and to my daughter, Uyen Nhi, for supporting me spiritually throughout writing this thesis and my life in general.

I respect and love you all with all my hearts.

TRAN Thi Thuy Phuong.

TABLE OF CONTENTS

Introduction	9
Chapter 1.....	17
State-of-the-art about risk management in construction project and formalism to model complex system tainted with uncertainty	17
1.1. State-of-the-art of risk management in construction project.....	19
1.1.1. Construction project	19
1.1.1.1. Definition and characteristic	19
1.1.1.2. Components.....	20
1.1.1.3. Performance of construction project	21
1.1.2. Risk management	22
1.1.2.1. Risk definition.....	22
1.1.2.2. Risk management principles	23
1.1.2.3. Application of risk management	28
1.1.3. Tools and model for risk management.....	28
1.1.3.1. Operational risk management tools.....	28
1.1.3.2. Risk management model for construction project	31
1.1.4. Other current models	35
1.2. Conceptual framework for uncertainty analysis.....	36
1.2.1. Semantic knowledge model	36
1.2.1.1. Concepts, attributes, and relations	37
1.2.1.2. Instantiating ontology.....	38
1.2.2. Bayesian networks	42
1.2.3. Probabilistic relational model (PRM)	43
1.2.4. Hierarchy and specialization extension.....	48
1.3. Conclusion.....	51
Chapter 2.....	53
Development of a holistic generic model to formalize construction project.....	53
2.1. Introduction	55
2.2. Concepts	56
2.3. Relations between concepts	60
2.4. Attributes.....	66
2.5. Relation between attributes	74
2.6. Conclusion.....	78
Chapter 3.....	79
From Ontological model to PRM for construction project	79
3.1. Introduction	81
3.2. Calculation method in PRM of construction project.....	81
3.2.1. Defining the scales of attributes' value	81
3.2.2. A priori probability.....	82
3.2.3. Conditional probability tables (CPTs)	82
3.2.4. Aggregation operator	87
3.2.5. V-structure transformation	88
3.3. Implementation.....	89
3.3.1. Implementation of the Construction Project PRM via O3PRM.....	90
3.3.2. Optimization strategies.....	91
3.3.2.1. Calculation time	91
3.3.2.2. Optimization strategy to solve time calculation problem	92
3.3.3. Accelerating model inference using Clustering computing	92
3.4. Conclusion.....	92

Appendix	143
Appendix 1. Developed ontology in construction project	143
Appendix 2. Entities, attributes, and their significations in level 1	160
Appendix 3. Entities, attributes, and their significations in level 2.....	170
Appendix 4. Concepts' relations in level 1	208
Appendix 5. Concepts' relations in level 2.....	211
Appendix 6. Attributes' relations in level 0 and their signification.....	221
Appendix 7. Attributes' relations in level 1.....	223
Appendix 8. Attributes' relations in level 2.....	240
Appendix 9. Signification of attributes' states in level 2.....	315
Appendix 10. List of instances in level 1 of project 2BS.....	343
Appendix 11. List of instances in level 2 of project 2BS.....	344
Appendix 12. List of instances in level 1 of project NTI.....	349
Appendix 13. List of instances in level 2 of project NTI.....	350
Appendix 14. Specific instances' relations in level 0 project 2BS.....	353
Appendix 15. Specific instances' relations in level 1 project 2BS.....	355
Appendix 16. Total relation of instance in Level 1	369
Appendix 17. Specific instances' relations in level 2 project 2BS.....	370
Appendix 18. Specific instances' relations in level 0 project NTI.....	413
Appendix 19. Specific instances' relations in level 1 project NTI.....	416
Appendix 20. Total relation of instance in Level 1	425
Appendix 21. Specific instances' relations in level 2 project NTI.....	426

LIST OF TABLES

Table 1-1: Advantage and disadvantage of each method of risk identification (Project Management Institute 2008).....	29
Table 1-2: Correspondent works in each phase risk management of construction project of recent works in laboratory I2M.	33
Table 1-3: Advantages and disadvantages of recent works in laboratory I2M.	33
Table 1-4: Our direction based on existing problem of precedent research.....	34
Table 2-1: Main concepts in the model.....	56
Table 2-2: <i>Finer concepts of level 1 and 2</i>	59
Table 2-3: Correspondent concepts' relations in level 2 of relations <i>Climate-Contractor</i> in level 1.	63
Table 2-4: 16 descriptive attributes of concepts in level 0.....	67
Table 2-5 : Definitions of some of attributes in level 1 and 2.....	72
Table 2-6: Signification negative and positive states of some attributes of <i>Environment</i> and <i>Actor</i> in level 2.	73
Table 2-7: Relations between attributes and their example in level 0.	76
Table 2-8 : Inheritance relations between <i>Actor.Cost</i> and <i>Activity.Cost</i> from level 0 to level 2	78
Table 3-1: Examples of a CPT which model the relation between <i>Activity.Cost</i> and <i>Product.Cost</i>	83
Table 3-2: Consistent pre-designed CPT	84
Table 3-3 : Antagonist pre-designed CPT.....	84
Table 3-4 : Characteristics of eight default matrices.....	85
Table 4-1: Sources of instance's information and chosen instances.....	98
Table 4-2 : Instances of Activity and Actor involved in feasibility phase.....	102
Table 4-3 : Instances of Activity and Actor involved in implementation phase.....	102
Table 4-4 : Instances of Activity and Actor involved in operation phase.....	103
Table 4-5 : Instances of human in project 2BS.....	103
Table 4-6: Instances of machine in project 2BS.....	104
Table 4-7 : Instances of Product of project 2BS.....	104
Table 4-8: Instances of entities in level 0.....	105
Table 4-9 : Scenario _{project} and Scenario _{project+} of project 2BS.....	113
Table 4-10 : Instances of Activity and Actor in feasibility phase.....	118
Table 4-11: Instances of Activity and Actor in implementation phase.....	118
Table 4-12: List of human of project NTI.....	119
Table 4-13 : Instances of machine in project NTI.....	119
Table 4-14: Instances of products of project NTI (generic and instantiated).....	120
Table 4-15: Instances of entities in level 0.....	120
Table 4-16 : Scenario _{project} and Scenario _{project+} of project NTI.....	124

LIST OF FIGURES

Figure 0-1 : Outline of thesis.....	15
Figure 1-1: (a), (b) Example of an ontology structure level 0 and 1 by using a graphic representation, (c), (d) Example of instantiations level 0, 1 of ontology model.....	41
Figure 1-2: A basic BN.....	42
Figure 1-3: Example of a Bayesian network.....	42
Figure 1-4: Example of a PRM structure based on knowledge model.....	46
Figure 1-5: An example of a skeleton associated with the PRM structure.....	47
Figure 1-6: Equivalent ground Bayesian network stemming from the skeleton and the PRM structure.....	47
Figure 1-7: Example of a PRMs structure based on knowledge model describing two levels of knowledge.....	50
Figure 2-1 : Order of works in chapter 2.....	56
Figure 2-2 : List of concepts relate to <i>Environment</i> which create uncertainties in construction project.....	59
Figure 2-3: List of words relate to sub-concepts of <i>Climate</i>	59
Figure 2-4: Ontological structure describing a generic representation of project construction at a meta-level.....	62
Figure 2-5: (a) Relations between Environment and Actor in level 0, (b) Inherited concepts' relations from level 0 to level 1.....	64
Figure 2-6 : Hierarchical ontology model describing relation between <i>Environment</i> and <i>Actor</i> of construction project at level 2 which stem from figure 3-5.....	65
Figure 2-7: Examples of inherited attributes in taxonomy (a) and partonomy relations (b)....	66
Figure 2-8 : Relation network between the descriptive attributes in level macro-level.....	75
Figure 3-1: Simple example of attribute without parent A1.....	82
Figure 3-2 : An example of priori probability $P(A1)$, $P(A2)$	82
Figure 3-3: A sample of n <i>Actor</i> realizing the <i>Activity</i> Act_1 of Act_i	88
Figure 3-4 : Convergent connexion of node Y.....	89
Figure 3-5 : V-structure.....	89
Figure 3-6 : V-structure versus Transformed V-structure where A (resp. R) correspond to Actor (resp. Resource).....	89
Figure 3-7 : Four main parts of code.....	90
Figure 4-1: Viewpoint of project through satellite.....	99
Figure 4-2 : Relations between owner, designer, contractors and suppliers in project 2BS..	101
Figure 4-3 : The relational skeleton using elements from Table 5 and the PRM model	107
Figure 4-4 : Marginal probability distribution of (a) the quality (b) the cost, (c) the duration of <i>building</i> of project 2BS, (d) the complexity of contract linking owner and designer, (e) the capacity of designer and (f) the quantity of human resource during the implementation phase given three scenarios: $\{EE.Agg=E\}$ in grey, $\{EE.Agg=SSN\}$ in black, $\{EE.Agg=SSP\}$ in white where $EE=environment$	110
Figure 4-5: Marginal probability distribution of $PIP2BS_Building_Duration$ given correspondent five scenarios (a) $Economy2BS.Inflation =SSN$, (b) $Administration2BS.Inertia =SSN$, (c) $Climate2BS.Intensity =SSN$	112
Figure 4-6: Marginal probability distribution of (a) the quality, (b) the cost and (c) the duration of <i>building of project 2BS</i> given scenario _{project} and scenario _{project+}	114
Figure 4-7: Marginal probability distribution of <i>Building.Duration</i> given correspondent two scenarios (a) $Economy2BS.Inflation =SSN$, (b) $Economy2BS.Inflation =SSN$, $Climate2BS.Intensity =SSN$	115

Figure 4-8: Marginal probability distribution of <i>BridgeLD.Duration_Of_Building</i> given correspondent two scenarios (a) <i>NationalEconomy2BS. IncreasingNationalTax =SSN</i> , (b) <i>NationalEconomy2BS. IncreasingNationalTax =SSN, Temperature2BS. LevelOfDegree =SSN</i>	116
Figure 4-9 : Architecture perspective of Nursing training institute.	117
Figure 4-10 : Relations and contracts between owner, designer, contractors and suppliers in project NIT.	118
Figure 4-11: The relational skeleton using elements from Table 5-16 and the PRM model level 0.....	121
Figure 4-12 : The relational skeleton level 1 of project NTI.....	122
Figure 4-13 : Instances of product in level 0 and 1.....	125
Figure 4-14 : Marginal probability distribution in level 1 of (a) the duration, (b) the cost and (c) the quality of three instances (<i>Detailed_DesignNTI, Regulation_DocumentNTI, BuildingNTI</i>) in level 1 of <i>Product of project NTI</i> when all attributes of instances of <i>Environment</i> are prior centred distribution (in black), all centred excepted climate SN (in grey), and scenario _{project} (in white).	126
Figure 4-15 : Marginal probability distribution through model covering level 1 and 0 of (a) the duration, (b) the quality and (c) the cost of <i>product of project NTI</i> in level 0 given when all attributes of instances of <i>Environment</i> are prior centred distribution (in black), all centred excepted climate SN (in grey), and scenario _{project+} (in white).	127
Figure 4-16 :Comparing $P(\text{BuildingNTI. DurationOfBuilding} \text{scenario})$ taken from level micro-meso (grey column), meso level (white column).....	130
Figure 4-17 : Comparing $P(\text{PIP. Duration} \text{scenario})$ taken from meso-macro (grey column) and macro level (white column).....	130
Figure 4-18 : Input variables (light orange) and output variables (bright orange) attached with instances in 3 levels.....	131
Figure 5-1: An example of simple model and CPTs in each level.....	137
Figure 5-2 : ADP and ADCP.....	138

Introduction

- Context

Each project is a unique and temporary process that consists of many activities which are performed and controlled by actors to achieve requirements under the conditions of time, cost, quality (ISO 10006 2003). A construction project can be a process of alteration (adjustment), conversion, commissioning, renovation, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure (safe work australia 2013).

Most construction projects do not reach their expected results regarding time, cost and quality, due to the internal and external environment variations (Love et al. 2002), as the impacts of human factors (Andrew R. Atkinson 1999), natural hazards (Middelmann 2007), technological hazards etc. Fails in construction project remain current like today's:

- the 'Philharmonie de Paris' project that was delayed about 24 months and whose final cost exceeded the prior estimate by 276 M€,
- the budget of 'Musée des Confluences' in Lyons which changed from 61 M€ (initial cost) to 253 M€ (final cost),
- the 'EPR de Flamanville' project which was delayed in six years and current budget is more twice than initial one,
- the collapse of Can Tho Bridge (Vietnam) was a severe construction accident in September 2007, with 52 fatalities and the final cost is upper than 2 M€.

Construction projects are complex systems. They are composed of many heterogeneous entities (activities, actors, contracts, resources, etc.) among which interactions exist at many levels and influence the system response. In turn, this response can influence the behaviour of some entities. In order to capture the complexity of system, it is necessary to structure, model and share cross-disciplinary and interdisciplinary knowledge flows in a common and unifying framework. Tackle this complexity could improve our grasp of the whole system, in order to provide more robust and efficient decision alternatives in risk management. It is then essential to propose conceptual approaches able to represent the behaviour of system entities over the time.

Nevertheless, it is not an easy task given the heterogeneous character of the sources of knowledge and manipulated scales. Briefly, idea of suitable model should be able to deal with:

- heterogeneous sources of knowledge expressed by definition of vocabulary (based on perspective of technical experts, administrative, etc.),
- different formalisms used by different disciplines (equations, ontology, probabilistic models, relational graphs, cognitive maps, etc.),
- various manipulated scales (resource, human, worker, etc.),
- different forms of uncertainty (natural randomness, imprecision in expert opinions, data scarcity, etc.).

- Problematic

Different approaches and tools have been proposed to model and simulate risk of construction project as Risk Breakdown Structure (Mehdizadeh Rasool 2012), Bayesian network ((Rita L. Sousa and Einstein 2012), (Spackova, Sejnoha, and Straub 2013), (Wu et al. 2015)), Network Theory (Fang et al. 2012), Monte Carlo Simulation (Patterson and Neailey 2002), Analytical Network Process (Boateng, Chen, and Ogunlana 2015), Fuzzy logic ((Case and Chrysostomos D. Stylios 2016), (Nieto-Morote and Ruz-Vila 2011)), etc. Depend on characteristics of the project (i.e. number of uncertainties that can influence to project), organization's policy (i.e. community resistance, decentralization in management organization), project management strategy, risk attitude of the project team members, availability of the resources, etc., suitable tool(s) will be applied (Boateng, Chen, and Ogunlana 2015). These tools and methods can be used to simulate the behavior of the system, but they are inadequate for representing large and complex dynamical system because they are based on case-dependant model; i.e. a specific model has to be built for each studied construction project. Furthermore, Fidan and Dikmen (Fidan and Dikmen 2011) have pointed that developed models about risks suffer from (1) the fragmented representation of knowledge, (2) the lack of common vocabulary, and (3) the lack of generic character, i.e none approach presents a global view with an unified vocabulary in managing uncertainty; they suggested to rather use ontology paradigm to provide common vocabularies which form database about risk of construction project and to shape the structure (interrelations) between those identified database. Different ontologies were developed in the sector of construction project:

+ Diraby et al. (El-Diraby, Lima, and Feis 2005) developed an ontology into many levels for the construction domain allowing to share a common vocabulary (notions) and retrieval of information. There is an important point which was not mentioned in this paper is the lack of

describing the interrelations between those notions in each detailed level.

+ Sun et al. (Sun and Meng 2009) presented how taxonomies (about change causes and change effects) may be used by professionals to manage changes during the construction projects.

+ Tserng et al. (Tserng et al. 2009) developed an ontology-based risk management framework allowing the contractor to reduce risk threats during risk management procedures.

+ Jiang et al. (Jiang, Zhang, and Zhang 2013) provided an ontology-based semantic retrieval method to use projects' experience for risk management of construction project but their analysis was restricted to risks of cost overrun.

+ Issa et al. (Jia Niu and Issa 2015) developed a first version of a taxonomy (a part of ontology) to address actual construction contractual claim issues.

+ Zhong et al. (Zhong and Li 2015) developed an ontological and semantic model for construction risk knowledge formalization.

However, none holistic approach is proposed to represent construction project integrating as well technical, human, sustainability dimensions at different detailed levels of uncertainty. Although ontology allows to describe domain and to retrieval information, it is not capable of simulating the behaviour of the system while taking into account uncertainty.

By coupling the advantages of two previous approaches (ontology, Bayesian network), the framework of probabilistic relational model (PRM) (Getoor et al. 2007) provides a practical mathematical formalism that allows to represent and simulate complex stochastic dynamical systems. The network structure provides an intuitively appealing interface for human experts to model highly-interacting sets of variables, resulting in a qualitative representation of knowledge. Stochastic uncertainty attached to the system is then taken into account by quantifying dependence between variables by means of conditional probability distributions. Although there exists a substantial literature about risk management in civil engineering, and if a wide variety of tools and methods have been proposed to improve the risk management, we are not aware of any works where PRM have been proposed to model and simulate construction project while accounting uncertainties.

In the model building process, different challenges must be overcome. First, construction project is a wide sector, it will exist many confusing and contradictory terminologies (i.e. definitions). The first challenge consists in synthesizing vocabulary and proposing clear and,

if possible shared definition, of the different notions related to construction project. Second, complex interaction between real things in a construction project. Hence, the next challenge is to propose interactions which are installed sufficiently and are suitable for any type of construction project.

- Objectives of thesis

The objective of this thesis is to propose an innovative and generic approach which is able to :

- represent and simulate the behavior of system of construction project,
- take uncertainty into account,
- be reusable for any kind of construction project,
- applicate the proposed model in two case-studies to show the useful in simulating the behavior of construction project system.

This approach is based on the development of mathematical model relying on the formalism of PRM. The aim is to use this model to analyse and quantify risks deriving from all uncertainties existing in this complex, dynamic, and multi-scale system.

- Thesis outline

This thesis is organized as follows (figure 0-1):

- **Part 2** will introduce the state of art regarding two topics: risk management for construction project and formalism to model complex system tainted with uncertainty. The first part presents and analyses main points about construction project, classification of risks, process of risk management, and tools which have been applied in risk management. The second part gives an overview about the conceptual framework for uncertainty analysis.
- **Part 3** proposes a holistic generic model to formalize construction project. In this part, all of concepts, attributes and their relations in different detailed levels will be explained.
- **Part 4** proposes a PRM for construction project based on the knowledge model exposed in part 3. In this part, PRM will be illustrated by specific examples. In order to support the PRM inference computations, the program O3PRM (**O**pen **O**bject-**O**riented **P**robabilistic **R**elational **M**odel) will be introduced.
- **Part 5** shows implementations of examples based on two real case-studies: a road and bridge construction in Hue (Vietnam) and a nursing training institute (France). This part shows how this approach can deliver quantified results and how they can be analysed.
- Finally, **part 6** provides conclusion and perspective for the future researches.

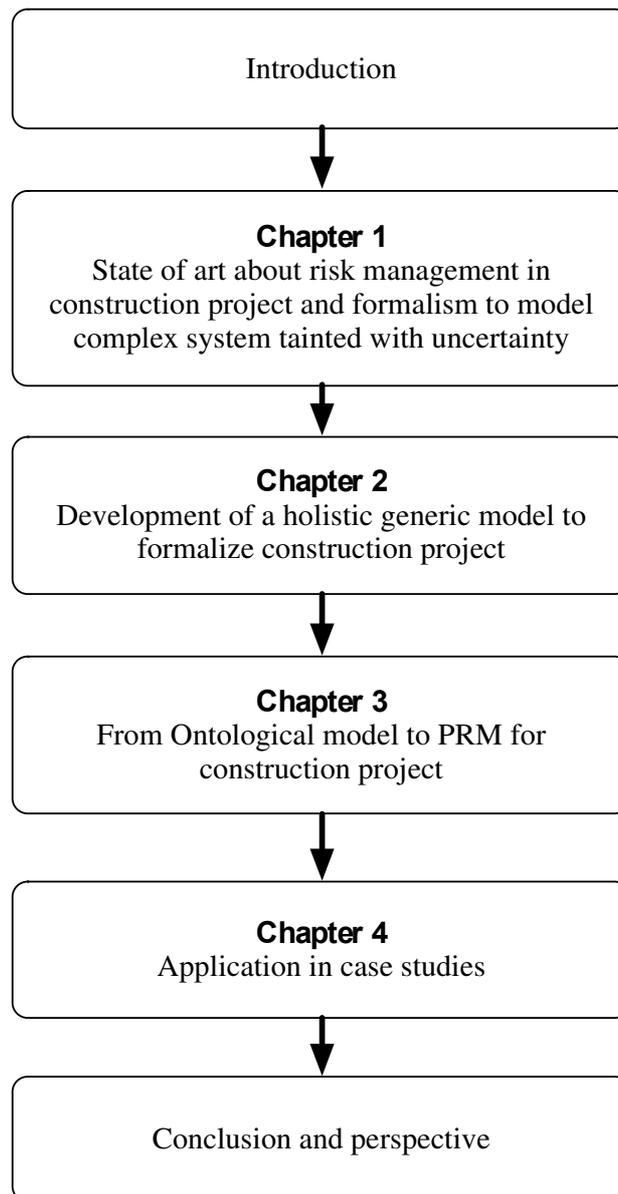


Figure 0-1 : Outline of thesis

Chapter 1

State-of-the-art about risk management in construction project and formalism to model complex system tainted with uncertainty

Contents

- 1.1. State-of-the-art of risk management in construction project
 - 1.1.1. Construction Project
 - 1.1.1.1 Definition and characteristic
 - 1.1.1.2 Components
 - 1.1.1.3 Performance of construction project
 - 1.1.2. Risk management
 - 1.1.2.1 Risk definition
 - 1.1.2.2 Risk management principles
 - 1.1.2.3 Application of risk management
 - 1.1.3. Tools and model for risk management
 - 1.1.3.1 Operationnal risk management tools
 - 1.1.3.2 Risk management model for construction project
 - 1.1.4. Other current models
 - 1.2 Conceptual framework for uncertainty analysis
 - 1.2.1 Semantic knowledge model
 - 1.2.1.1 Concepts, attributes, and relations
 - 1.2.1.2 Instantiating ontology
 - 1.2.2 Bayesian network
 - 1.2.3 Probabilistic relational model (PRM)
 - 1.2.4 Hierarchy and specialization extension
 - 1.3. Conclusion
-

1.1. State-of-the-art of risk management in construction project

The dynamic and instability of internal (actors, resources, etc.) and external environment (climate, economic, etc.) during the process of construction project are the reasons for unpredictable effects regarding time, cost, and quality of the project. Thus, in order to :

- understand clearly the behaviour of a construction project under the negative and positive influences of those impacts,
- manage objectives (time, cost, and quality) of construction project effectively,

risk management will be our concerned.

Risk management is the topic of many researches (Baccarini and Archer 2001), (Zou, Zhang, and Wang 2007), (Rezakhani 2011), etc. with different tendencies. In order to find innovation direction about the propagation of risks in a construction project and its behaviour when uncertainties happen, we will analyse and synthesize recent research results about risk management of construction project. In a first step, we will analyse literatures and common practices regarding the concepts arising in construction project. Based on this analysis, we will propose a definition for each main concept.

1.1.1. Construction project

1.1.1.1. Definition and characteristic

Construction project consists of organized activities (*Construction Work* 2012) which perform construction works (construction, alteration, conversion, fitting-out, commissioning, renovation, repair, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure). Construction work does not include: the manufacture of plant, the prefabrication of elements (ex. making precast concrete panels or roof), testing, maintenance or repair work of a minor nature carried out in connection with a structure (ex. testing or repairing a smoke detector, pressure piping, etc.).

In order to execute a construction project in a cost-efficient manner, effective time and quality under the fluctuation of environment, it requires the stringent planning and efforts of all stakeholders which participate in a construction project.

Definition: Construction project is a project which gathers many actors who use resources to carry out activities with the agreement with contracts to achieve requirements about time, cost and quality below the fluctuation of environment.

Main characteristics of construction project are listed in the table below:

- Each construction project (PMBOK 2013):
 - + is unique in nature: Every construction project is different from others, whereas operational activities often involve undertaking repetitive (identical) processes,
 - + has a defined timescale: it has a clearly specified starting and end date within which the deliverables must be produced to meet a specified customer requirement,
 - + has an approved budget: it is allocated a level of financial expenditure within which the deliverables must be produced to meet a specified customer requirement,
 - + has limited resources: at the starting time of a project, an agreed amount of resources (labour, machines, materials) is allocated to a construction project,
 - + involves uncertainties,
- Construction works are conducted after orders through contracts.
- Construction activities are impacted by external environment (law, economic, ...)
- There are potential impacts (internal or external) which can affect positively or negatively the objectives of construction project.

A construction project consists of many components. These components will be analysed in the next part.

1.1.1.2. Components

In order to build a generic model which can represent any type of construction project, many possible components has be taken into account to model the project. Based on literature review ((Mehdizadeh Rasool 2012),(Khartabil, Breysse, and Taillandier 2013),(Fidan and Dikmen 2011),(El-Diraby, Lima, and Feis 2005),(Tserng et al. 2009),(Sun and Meng 2009),(Jia Niu and Issa 2015),(Yildiz, Dikmen, and Birgonul 2014),(Franck Taillandier et al. 2016)) and our experience on construction project, six main components were defined : environment, actor, resource, contract, activity, and product.

- Environment: entities outside of project but which are susceptible to affect project.
- Actor: individuals or organizations who perform activities and are linked by contracts.
- Resource: assets that are used by actors to carry out activities of construction.

- Contract: legal documents which combine obligations and responsibilities of actors in performing activities.
- Activity: actions which are performed by actors using resources.
- Product: the results of activities which should satisfy predefined needs.

Under the impact of those components, the performance (success) of a construction project will be affected. Hence, the next part, the performance of construction project is our concern.

1.1.1.3. Performance of construction project

Project performance reflects the success of a construction project ((Meng 2012), (Cho, Hong, and Hyun 2009)). Several criteria were studied to state the issue of project success. Three criteria commonly form “the iron triangle” (time, cost and scope) of Atkinson (Atkinson 1999) and are considered crucial for project success. Chan et al. (Chan, Scott, and Lam 2002) and Robert et al. (Chinowsky, P.S. Meredith 2001) addressed that the time, cost and quality criteria were used to assess the success of construction projects. Moreover, “if a project is completed on time, within the agreed budget and set quality, then the project is deemed successful” (Garbharran and Govender 2012). In the paper of Kylandri et al. (Kylandri et al. 2012), time, cost and quality were also used to evaluate the success of a construction project.

Each objective (time, cost, and quality) has its own importance. About time, schedule delay is the time which overruns the date specified in a contract or agreement between parties in a construction project (Hossen, Kang, and Kim 2015). Schedule delay can lead to lawsuits between owner and contractors, increased costs (because of longer time working, extra labour cost, etc.), loss of revenue and contract termination (Hossen, Kang, and Kim 2015). About quality, it is regarded as the expectation of project participants and required standards. Because of failures of product (poor quality), more cost must be spent to repair. Hence, quality is an important object and needs to be considered along the whole life of project (Mallawaarachchi and Senaratne 2015). About cost, it is a primary concern for the vast majority of construction clients. The total cost cannot exceed the budget which is regulated in contract.

DEFINITION: The performance of the project is evaluated according to multi-dimensional criteria for each actor. This criteria covers at least three dimensions: quality of the product, time to delivery, and cost.

Performance or success of a construction project is not uncertainty because of risks which are created by its components. Hence, in order to control the performance of a project, we find out the way to manage risk in the next part.

1.1.2. Risk management

1.1.2.1. Risk definition

There are two sources which create risks: randomness of nature and lack of knowledge. Risk plays an important role in the success of construction project, i.e. it impacts project performance. As stated by Raz et al. (Raz, Shenhar, and Dvir 2002), risks can cause construction project delays, excessive cost, unsatisfactory quality of project's product. In two main sources of risks, lack of knowledge of human being is more crucial than the other. Under the impact of nature, human being's belief, attitudes, judgement, and feelings will decide the reaction to solve problems effectively in order to achieve time, cost, and quality as planned.

Depending on the viewpoint, experience, there are different significations of risk (Baloi and Price 2003). While risk measures both the uncertainty of a chance (positive) and a loss (negative) of a situation ((ISO 10006 2003), (Dziadosz, Tomczyk, and Kapliński 2015)). Ward (Ward 2003) argued that the term "risk" is often associated with adversity and focuses on threats, not opportunities. Barber (Barber 2005) defined risk as "a threat to project success, where the final impact upon project success is not certain".

Risks are also attached with construction project processes and the product of project (ISO 10006 2003). Under impact of uncertainties, sometimes we get positive results, sometimes we get negative results. Risk is manageable, diminishable, transferable or acceptable but not ignorable (Bakr, El Hagla, and Abo Rawash 2012). When uncertainties happen, risk will propagate and cumulate through complex and multiple interactions in a construction project.

Definition: Risk in construction project is the uncertain consequence (negative or positive) of an event on project objectives. It lastly concerns the deviation between expectation and real value of time, cost, quality of the construction project.

Main characteristics about risk in construction project are listed in the table below:

- Risks are created by randomness of nature and lack of knowledge.
- Risks can be positive or negative.

- Uncertainties appear at anytime of a construction project
- Important risks which affect to the performance of construction project must be reviewed and assessed.

1.1.2.2. Risk management principles

The purpose of systematic and practical risk management practices is to handle and manage risks so that the success of projects can be ensured. Thus, risk management process is a systematic application of management policies, procedures, and practices to the activities of communicating, consulting, context establishment, and identifying, analysing, evaluating, treating, monitoring, and reviewing risk (*ISO 31000:2009*). Risk management must maximize the probability and consequences of positive events, while minimizing the probability and consequences of adverse events regarding project objectives.

Risk management is a process based on decisions and/or actions of stakeholders which influence directly or indirectly the project performance. The construction project management involves numerous participants: owner, contractor, end users, promoters, construction companies, project designers, government/public bodies as well as a large number of sub-contractors, suppliers, etc. (Pérez, Gonzalez-Cruz, and Pastor-Ferrando 2010) whose interests and demands need to be considered in the managerial decision-making process ((Aaltonen 2011), (Akintoye and MacLeod 1997)). Moreover, each of those participants has a role in investigating, solving and/or cooperating with the others to manage risk effectively.

Many actors divided risk management into different phases (Berkeley, Humphreys, and Thomas 1991), (Elkington and Smallman 2001), (C. Chapman 1997), (Mehdizadeh Rasool 2012). Based on PMBOK Guide (PMBOK 2013) and ISO 10006-2003 (ISO 10006 2003), risk management process of construction project can be subdivided into four main phases:

- risk identification,
- risk analysis (qualitative, semi-quantitative, quantitative analysis),
- risk response,
- control risk.

a/ Risk identification

Risk identification is the process of finding, recognizing, and describing risks (Hossen, Kang, and Kim 2015). It determines which risks might affect the project and documents their

characteristics (PMBOK 2013). In this phase, potential risks associated with a construction projects are identified (Zou, Zhang, and Wang 2007) through available scientific documents by using a consistent and structured method.

Two important aspects need to be taken into account during the identification of risks:

- the way to identify risks. Identification of risks is a great challenge for researchers, managers and practitioners (Guilan Shen, Fang, and Chen 2009). Experience and historical researches from previous papers or projects should be used for this purpose.
- the way to determine relations between risks. The interactions between risks of construction project always exist. Process of identifying relations between risk based on experiences.

Many stakeholders can participate in identifying risks of construction project: project manager, project team members, risk management team (if assigned), experts that are not members of the project, customers, end users, other project managers, stakeholders, and risk management experts (Mojtahedi, Mousavi, and Makui 2010). Chapman (R. J. Chapman 2001) pointed out that quality of risk identification affects directly the later phases of risk management. Risk identification has to be employed effectively to identify opportunities as well as threats.

b/ Risk analysis

Risk analysis analyses how often those events may occur and the magnitude of their consequences by using a wide variety of techniques (D. Cooper et al. 2015). Hence, the main inputs of risk analysis process are the identified risks from risk identification process. The probability and impact of identified risks are two main keys in assessing risk.

There exist many tools to analyse risk in construction project. The reasons to choose suitable tools are the familiarity with the techniques, lack of information and knowledge, suitability to applicate on construction project, the magnitude of construction project (Akintoye and MacLeod 1997).

In order to analyse risk efficiently, it is necessary to: model the dependencies between events, demonstrate the correlation between source events of an accident, consider all feasible accidents or failure scenarios and their related consequences, describe behaviour of the whole system, model the relationship between the context (environment and operational conditions)

and the probability of human and technical failures, characterize, represent and propagate uncertainties (Medina Oliva et al. 2009).

Risk analysis can be qualitative, semi-quantitative or quantitative ((Kollarits et al. 2009), (Taroun 2014a), (Serpella et al. 2014)).

- Qualitative analysis

The qualitative risk analysis is the “process of prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact” (PMBOK 2013). In qualitative analysis, probability is the degree of belief that be hold in the occurrence and level of impact of an event.

A typical qualitative risk assessment usually includes (Kallman 2005): a brief description of the risk, the stages of the project when risk may occur, the elements of the project that could be affected, the factors that influence risk to occur, the relationship with other risks, the likelihood of risk occurring, and how risk could affect the project.

Methods are used in qualitative analysis are probability-impact matrix (PMBOK 2013), FMEA (Failure Modes and Effects Analysis) (Sai X. Zeng, Tam, and Tam 2010), etc. Probability-impact matrix is mainly used in an initial evaluation of risks or for a rapid assessment. This matrix can be used for assessing threats and opportunities using two grids of negative impacts (threats) and positive impacts (opportunities) ((Hillson 2002), (Liu et al. 2016)). Purpose of FMEA is to identify the potential failure modes and their consequences. This analysis is performed at the early stage of a project to take actions to reduce or eliminate failures.

- Semi-quantitative analysis

Semi-quantitative analysis contains a mixture of quantitative and qualitative data. It assigns numerical values to the description of risk from the qualitative analysis (Hossen, Kang, and Kim 2015). Some methods are suggested which involve both quantitative and qualitative data. For example, analytic hierarchy process method (AHP).

- Quantitative analysis

The quantitative risk analysis is the “process of numerically analysing the effect of identified risks on overall project objectives” (PMBOK 2013). Advantage of quantitative risk analysis is that it provides a measurement of the magnitude of impacts, which can be used for

further analysis and which produces quantitative risk information to support decision making in order to reduce project uncertainty ((PMBOK 2013), (Hossen, Kang, and Kim 2015)).

c/ Risk response

Outputs of risk analysis will be inputs for the risk response analysis. Risk response is a “process of developing options and actions to enhance opportunities and to reduce threats to project objectives” (PMBOK 2013). Strategy of risk response depends on stakeholders' risk attitudes and the specified constraints (budget, plan of stakeholders, etc.). There are two groups of risk response strategies: strategies for negative risks and strategies for positive risks (PMBOK 2013).

Strategies for negative risks consist of: avoid, mitigate, transfer, and accept.

- Avoid: changing project plans in a way that an identified risk is no longer relevant. It enables stakeholders to eliminate the threats that impact negatively on the construction project. Example of activities that can help to avoid potential risk (D. Cooper et al. 2015): more detailed planning, alternative approaches, protection and safety systems, operation reviews, training and skills enhancement, permits to work, procedural change, and preventive maintenance.

- Mitigate: finding ways to reduce the probability and/or impact of risk. Reducing the probability and/or impact before a risk occurs, will be more effective than trying to repair the damage after the risk has occurred (Ward 2003). Some projects invest in hiring experts to manage high-risk activities (Darnall and Preston 2007). Mitigation strategies can include (D. Cooper et al. 2015): contingency planning, quality assurance, separation activities and resources, contract terms and conditions, crisis management and disaster recovery plans.

- Transfer: transferring risks to other parties (Schieg 2006). Transfer of risk nearly always involves payment of a risk premium to the party taking on the risk (Ward 2003). “Transferring liability for risk is most effective in dealing with financial risk exposure” (PMBOK 2013). A risk can be transferred to another actor or organization who has a greater capacity.

As mentioned in Potts (Potts 2008), there are four common ways for the transfer of risk:

+ client to contractor,

+ contractor to subcontractor,

+ client, contractor, subcontractor or designer to insurer,

+ contractor or subcontractor to surety.

- Acceptance: making an informed decision to accept the likelihood and impact of a particular risk (Maley 2008).. For example: Project manager accepts particular risk like force majeure (flood, earthquake, etc...) or changes of state policy on finance or procedure.

In brief, avoidance and mitigation strategies mainly apply for critical risks with high impact, while transfer and acceptance are used for threats that are less critical and with low overall impact (PMBOK 2013). Akintoye et al. (Akintoye and MacLeod 1997) had a different viewpoint. They mentioned that risk acceptance becomes the only choice where other ones are impossible; i.e. when avoidance is undesirable, possible financial loss is small, probability of occurrence is negligible and transfer is uneconomic. So, depending on attitudes, experience, available conditions etc. of stakeholders, suitable strategies regarding negative risks will be used.

Strategies for positive risks consist of: exploit, enhance, share and accept.

- Exploit: increase the chance of a positive risk which the benefit is clear. For example: Before the project ends, there is a bid of another project (clear information). So, contractor tries to end the first project earlier than initially planned.

- Enhance: increase the chance of a positive risk which the benefit is not clear. For example: Before this project ends, there is an unclear information (rumor) that there can have a bid of another project. So, contractor tries to end this project earlier than planned if possible.

- Share: use when there are not capable of realizing opportunity on our own. In this case, an individual/organization may team up with another individual/organization to realize the opportunity.

- Accept: take no action to realize the opportunity, just accept. For example: when the supply service is exclusive, so if there is requirement, supplier will accept it.

d/ Control risks

Purpose of this phase is to ensure all achieving results (time, cost, quality) according to plan. Risk control keeps track of the identified risks and new risks (PMBOK 2013). It also covers the execution of planned strategies on the identified risks and the evaluation of their effectiveness.

Those four main phases (risk identification, risk analysis, risk response, and control risk) always be concerned in any application of risk management. In the next part, we will analyse some applications of risk management.

1.1.2.3. Application of risk management

Risk management has two main applications in : (1) studying and treating the risk of specific activities, (2) performing generic risk research by developing concepts, theories, frameworks, approaches, principles, methods and models to understand, assess, characterise, communicate and manage/govern risk (Aven and Zio 2014), (Aven 2016). The boundary between these main applications is clear. With the first one, degree of general is limited. For example: application only in tunnel project, or in solar energy project, etc. The second task is relevant for all types project of a domain. For example: developed model can applied for any types for project in domain of construction.

Our thesis will combine two those tasks of risk management. It means that a generic model in domain of construction project (the second task) will be developed, after that, this developed model will be applied in real specific projects (the first task).

Literature of risk management were introduced. But in order to manage risks effectively, there must have the support of tools in defining, analysing, controlling and models in risks which help us in applying those tools in managing risks. Next part will introduce some tools with their advantages and disadvantages, moreover, some models will be also analysed about their different orientations in researching risks in construction project in order to find new approach about risks.

1.1.3. Tools and model for risk management

1.1.3.1. Operational risk management tools

For risk identification, many tools have been used to identify risks in construction project. Common approaches are: literature review (Taroun 2014b), brainstorming, check-list, interview (face-to-face) (D. Cooper et al. 2015), Delphi technique (Yildiz, Dikmen, and Birgonul 2014), etc. Each method has its own advantages and disadvantages (table 1-1).

Table 1-1: Advantage and disadvantage of each method of risk identification (Project Management Institute 2008).

Method	Advantage	Disadvantage
Literature review	<ul style="list-style-type: none"> - Review of existing knowledge on areas : theories, methodologies, researching finding, etc. 	<ul style="list-style-type: none"> - cannot be exhaustive - limits to know risks
Brainstorming	<ul style="list-style-type: none"> - Suitable with academic researchers, business team. - Many ideas of many people are gathered in the short time. 	<ul style="list-style-type: none"> - Quality of method depends on quality of work of each people in a group. - Require many people take part in. - Processing and ordering ideas become a complex procedure.
Check-list	<ul style="list-style-type: none"> - Apply for the similar project - Delivery to many units (employees, companies, etc.) - Vast knowledge is consolidated in a concise way. - Improve memory recall 	<ul style="list-style-type: none"> - Depend on personality in drafting check-list. - Limit the questions which are just mentioned in the checklist.
Interview (face-to-face)	<ul style="list-style-type: none"> - Misunderstanding and mistake will be rectified directly. - Collect more suitable information than initial idea of interviewer. 	<ul style="list-style-type: none"> - Time consuming. - Divagating the subject of interview. - Unsuitable candidate of interview.
Delphi technique	<ul style="list-style-type: none"> - Useful tool for interactive decision-making - Help users to focus on the main issues - Collect ideas form many people 	<ul style="list-style-type: none"> - It takes time to organize a structure of Delphi (organize the complexity of data, conflict between participants,
Fault tree analysis	<ul style="list-style-type: none"> - Identifying ways in which hazards 	<ul style="list-style-type: none"> - Require considerable amount of

	can lead to accident (various scenarios that can cause accident)	time to complete - Depend on expertise of experts - Cannot be used for all risks when the system size increases
FMEA	- Great help in finding root of risks - Visual presentation of the causes.	- Unsuitable for a complex situation (a large number of causes)

There exist many tools which have been used for analysing risks in construction project. Chosen tools of risk analysis depends on specify purpose of users (Perret et al. 2012):

- Impact of possible deviations from expected objectives, i.e. investigate how the real results deviate from the planned (expected) ones: Hazard and Operability Analysis (HAZOP), Hazard Analysis and Critical Control Points (HACCP), SWIFT (Weber et al. 2012), (Jeynes 2002).

- Impact on objectives of various types of operating variances. These methods are used to evaluate potential problems for a plan of action according to different scenarios or hypothesis which spread from negative to positive.

- Failure modes and their likelihoods: root cause analysis, analysis of failure modes and their effects, fault tree analysis. In fact, these methods are process for identifying the root causes of a problem or event, and finding solutions to prevent future incidents.

- Dynamics of accident sequences or malfunction: Markov analysis, Monte-Carlo simulation, Bayesian analysis / Bayes networks. They are used to forecast the value of a variable when it exists relation between events.

- Choice of preventive actions /risk mitigation: Event Tree Analysis, Causes and Consequences Analysis, Analysis of the causes and their effects, Analysis of Protection Levels (LOPA), "Butterfly Knot" Analysis, Analysis of insidious conditions (transient analysis), Consequence / probability matrix.

- Optimization of resource allocation, efficiency: Decision tree (single criterion), Cost-benefit analysis, Analysis of multi-criteria decisions.

Based on scope of each research, suitable tools and methods will be applied for each phase of risk management. In the next part, we will introduce some researches which applied tools and methods in developing new model in risk management in construction project.

1.1.3.2. Risk management model for construction project

By inheriting the research works about managing risk in construction project in the I2M laboratory (Institut de mécanique et d'ingénierie), my thesis will continue to improve the drawbacks and to find the innovation approach in risk of construction project. Risk management of construction project was the concern of three recent PhD works in I2M laboratory ((Mehdizadeh Rasool 2012),(Esra Tepeli 2014),(Rodney 2016)). Regarding the four main phases of risk management in construction project (risk identification, risk analysis, risk response and control risk), each of these works had its own interest.

Based on the analysis of available Risk Breakdown Structure (RBS), Mehdizadeh (Mehdizadeh Rasool 2012) developed tailor-made RBS which could be fitted to the stage and degree of development of the project, able to offer different views for the different partners (multi-perspective approach). In phase of risk identification, literature review was applied to identify risks. Mehdizadeh et al. (Mehdizadeh Rasool 2012) structured all the information in a systematic way (grouped the identified risk events into different levels following a bottom-up approach based on RBS) to aid understanding and managing. He **pointed many difficulties regarding the definition of terms**, since there was often a confusion between risk events, their sources, and their consequences. Thus the **need for a more rigorous approach of concept definition was clearly identified**.

Faced with the complexity: uncertainty of external environment (extreme competition of the economic, industrial, social environment) and internal environment (the growing number of stakeholder with different roles and other difficulties encountered in the process of managing construction project), a success of a project is conditioned by the way of project managers know how to identify, investigate, analyse and overcome potential risks. Based on these issues, with the view of improving management of major building and infrastructure, there are three original contributions in Tepeli's work (Esra Tepeli 2014): developing a specific method for identifying risk factors for complex and strategic projects, analysing these factors qualitatively and quantitatively and proposing action plans. Four main analysed dimensions which were mentioned in research of Tepeli: **life cycle of the project, the structural organization (i.e. actor), the resources and the contractual framework** (this last dimension impacts the structural organization). The backbone of knowledge base (risk identification) was formed by documentary resources from the international literature (literature review), feedback from complex and strategic projects of the partner company Vinci Construction France. However, some specific issues need to be completed:

- relations among external environment, life cycle of project, the actors, the resources and their attributes were mentioned in different detailed levels but interactions between them were not analysed ,
- it was not mentioned whether some relations exist between elements in different level or not,
- each attribute has its own value, and its own scale of measurement, without any consistency on units (can be a simple note, a duration, a quantity, etc.). This is adapted to a comparative analysis: the risk analysis process suggested by Tepeli is such that at few key stages, several options are compared and that the best alternative regarding risk can be privileged. It is however difficult to offer a consistent view of the project performances, and to finally assess risk, or even to assess which risk is positive or negative,
- results of research depend on so many subjective ideas through notes. For example: The complexity and priority of an activity, quantity and quality of resources are assessed by notes.

The risks affecting a solar energy plant project and generated by the project were the concern of Rodney (Rodney 2016). She developed a model which is based on GERAM framework and project risk management methods adapted to the specificities of renewable energies. This model provides a multi-scale representation (from macroscopic vision, i.e. general project, projects of renewable energies, to a fine vision, i.e. projects of thermodynamic solar power) and is multi-faceted (project life cycle analysis, genericity, and modelling views). Probabilistic formalism was used to represent and manipulate the many uncertainties in the project and its environment. Thus, outputs were also delivered in a probabilistic form for each variable of interest. This formalism allows a sensitivity analysis. Although its interest, this work has some limitations and drawbacks in order to answer this thesis problematic:

- attributes' relations were not modeled,
- all entities are characterized by a set of attributes taking different values at different stages of the project process and at different levels of genericity.

List of characteristics of works, advantages, and disadvantages in research of Mehdizadeh, Tepeli, and Rodney are analyzed in table 1-2 and table 1-3.

Table 1-2: Correspondent works in each phase risk management of construction project of recent works in laboratory I2M.

	Mehdizadeh (Mehdizadeh Rasool 2012)	Tepeli (Esra Tepeli 2014)	Rodney (Rodney 2016)
Basic roots and tools for the development of research	RBS	Expert practice	GERAM framework, complex processes modelling
Type of model	Tree	Graph	Multi-scale and structured model
Research zone	Construction project	Construction project	General project, business
Risk identification	Literature review, discussion with experts	Literature review, discussion with experts (feedback)	Literature review, discussion with experts (feedback)
Risk analysis	Semi-quantitative	Semi-quantitative (risk matrix)	Quantitative (probabilistic evaluation of different options)
Risk response	Do not analyse	Based on engineering practice, defined at key stages of the project	Not developed
Control Risk	Do not analyse	Definition of best options at some key stages. Focus on the contract and its implication (risk sharing)	Do not analyse

Table 1-3: Advantages and disadvantages of recent works in laboratory I2M.

	Mehdizadeh (Mehdizadeh Rasool 2012)	Tepeli (Esra Tepeli 2014)	Rodney (Rodney 2016)
Advantage	- A reference about holistic risks for who is concerned in construction project - multi-perspective approach in multi-level	Developing data base (entities, attributes, values, some basic relations between concepts) of construction project.	- Based on ISO 31000 - 2010, two others phases were analysed : set the context, address risks. - Developed a data base adapted to different levels of genericity.
Disadvantage	- Has not been applied to all types of construction project	- adapted to the construction project of Vinci group about	- developed a project risk management method

	<ul style="list-style-type: none"> - suitable with tunnel project. - Do not model the project itself, but only risk entities 	<ul style="list-style-type: none"> organization between stakeholder, activity, contract, etc., not all construction project - Weakness of evaluation 	<ul style="list-style-type: none"> adapted to the specificities of renewable energies, not all construction project.
--	--	--	---

Based on existing problem of risk management like we listed above, we have our own direction which will be listed like table 1-4 below :

Table 1-4: Our direction based on existing problem of precedent research.

Based on thesis of	Problem	Our direction
Mehdizadeh	Difficulties regarding the definition of terms	efforts devoted to concept definition
Tepeli	Relation between attributes were not analysed	Developing all relations between attributes
	Did not mention about whether it exist relations between elements in different level or not.	Defining all relations between concepts in the same and different levels
	Risk is seen as an independent element which has its own existence and relates with the other elements.	risk is not a independent element. It exists implicitly in each attribute of all concepts, i.e. if values of attributes change, risk will appear.
	Each of attribute's value almost has its own scale	all attributes must be defined on a consistent scale , where deviation from neutral view is clear.
	The consequences of source event are not described in a consistent way.	A unique type of relation (by conditional probability table) will relate cause and consequence.
	Architecture of the approach is adapted to a specific type of a project and a client.	Apply for all type of construction project
Rodney	Attributes' relations were not explained	Developing and explaining all relations between attributes
	The consistency between various scales of description has not been fully addressed	consistent results must be delivered if the level of analysis is modified

By refining knowledge from the observations of recent works of Mehdizadeh, Tepeli, and Rodney, we give some research orientations:

+ developing a semantic knowledge base which consists of concept, attributes, value, relation, definition, detailed level which is related to the risk of construction project,

+ developing a mathematical model which can reproduce the propagation of risks in the developed model. Moreover, it consists of conditional probability table which shows the dependence relation between attributes.

Besides model about risk management which were researched in laboratory I2M (University of Bordeaux 1), there were other models which were also applied in risk of construction project but with different orientations. Those approaches will be analysed in the next part.

1.1.4. Other current models

Some other models have been developed for risk management of construction project. We will analyse: ICRAM-1 and SMACC.

- ICRAM-1 framework (International Construction Risk Assessment Model) (Hastak and Shaked 2000) provides a structure to **evaluate the risk indicators** involved in an international construction operation and to examine in a specific project in a foreign country. Three different levels were considered in the application: macro level (i.e. country level), market, and project. In each level (macro, market, and project), there were other specific risks which attached in sub-levels (risk hierarchy).

The results of this model highlight: High-risk indicators, impact of country environment on a specific project, impact of market environment on a specific project, overall project risk.

Disadvantages of this model are:

+ There is just only one impact direction: from macro level to project level, while inverse relations (from project to macro) are not considered.

+ Not all risks in macro level have relation with market level and not all risks in market level have relation with project level.

+ Do not analyse the sensitivity of construction project when the state of risk fluctuates.

- SMACC (Stochastic Multi-Agent simulation for Construction projeCt) (Franck Taillandier et al. 2015), (Franck Taillandier et al. 2016) is multi-agent model enabling to **simulate the progress of a project** while integrating possible risks in order to evaluate their impact on the project on different objectives (delay, quality and cost) for each stakeholder.

This model proposes a neutral perspective on risks, considering the whole project and all stakeholders, estimates the project cost, duration, and quality of project activities. It focuses on the stakeholders and the way they act and react facing risks. It enables to test different risk mitigation strategies by measuring their impact on the project.

However, the model has some disadvantages:

- + it does not include the project environment and its interactions with the project.
- + the model does not enable to make reverse inference (e.g. to answer question as “How many worker must I plan in order to ensure the respect of the delay”).
- + it does not propose a generic model allowing the user to implement rapidly a specific case study
- + it requires to define a priori the risk events; the method has then to be completed by a more classical risk analysis (e.g. Tailored RBS (Mehdizadeh Rasool 2012)).

Those models have a problem to represent knowledge in a generic way, so we will introduce a better structured and generic knowledge model in the next part.

1.2. Conceptual framework for uncertainty analysis

1.2.1. Semantic knowledge model

Semantic knowledge consists of meaningful words which are used to describe the real world (Fallis 2013). Ontology is a knowledge model. There are many definitions about ontology. For Gruber (Gruber 1993), ontology is an explicit specification of a conceptualization. A conceptualization simplifies the real world that we want to represent for our purposes. « An ontology is a formal, explicit specification of a shared conceptualization » (Studer, Benjamins, and Fensel 1998). A conceptualization shows the abstract model of real world by identifying the relevant concepts. Chandrasekaran et al. (Chandrasekaran and Josephson 1999) define ontology as a representation vocabulary. It is specialized for a domain or matter. According to Hendler (Hendler 2002), ontology is the specification of a conceptualization. It defines terms and relationships between them in formal and preferably machine-readable manner. Common points of all definitions above are the specification of conceptualization and representation vocabulary. Based on those points, with us, ontology is the specification of conceptualization in a specific domain. It defines concepts, properties (attributes) and their relations.

In this research, knowledge model will be based on the formalism of ontology and will provide a structured representation of domain knowledge. It is defined by a hierarchic organization of concepts and relations that exist between them with rules and axioms which constrain them.

1.2.1.1. Concepts, attributes, and relations

Knowledge model describes a set of concepts (other synonymous are entities, categories, or classes), denoted C , where each concept $C \in C$ is associated with a set of descriptive attributes/properties, denoted $\mathcal{A}(C)$, and a set of relations denoted $\mathcal{R}(C)$. For instance, figure 1-1.a displays, at macro level (level 0), a graphic structure with two concepts *Environment* and *Actor*, i.e. $C = \{Environment, Actor\}$. Each concept (C) is associated with:

- A set of concept's relations \mathcal{R} such that for $R \in \mathcal{R}(C)$, $C.R$ references another concept C' by adopting the object paradigm notation. For instance, Fig. 1-1.a displays the relation *Impacts* linking the concepts *Environment* and *Actor* (i.e. $\mathcal{R}(Environment)=Impacts$). Each relation R is typed with its domain¹ $Dom[R]=C$ (e.g. $Dom[Impacts]=Environment$) and its range² $Range[R]=C'$ (e.g. $Range[Impacts]=Actor$) meaning that R is a function from C to C' and its inverse R^{-1} is a function from C' to C . Relations $R \in \mathcal{R}(C)$ may be clustered into:

- + Taxonomy (is-a, is-a-kind-of) defines a partial order over the set of concepts characterized by sub-super-concept tree structures and known as specification relation. For example, figure 1-1.b shows that *Owner* and *Contractor* are sub-concepts of *Actor*.

- + Partonomy (mereology) (is-a-part-of) defines concepts that are parts of other concepts. It expresses composition relations. For example, figure 1-1.b shows that *Climate*, *Economy* and *Administration* are part of *Environment*.

- + Associative relationships that describe the relation of one concept with respect to another as for instance *Impacts* in figure 1-1.

- A set of attributes relation \mathcal{A} (properties, functions) such that for $A \in \mathcal{A}(C)$, $C.A$ denotes an attribute of C characterizing the concept C . For instance, the attribute *Aggressiveness* (resp. *Cost*) characterizes property about the concept *Environment* (resp. *Actor*). That is $\mathcal{A}(Environment)=\{Aggressiveness\}$ and $\mathcal{A}(Actor)=\{Cost\}$ (see Fig. 1-1.a).

¹ Domain of a relation points to a source concept

² Range of a relation points to a target concept

Note that C.R.A references an attribute to concept C, for instance, attribute *Environment.Impacts.Cost* characterizes the *Cost* of *Actor* (or of a set of actors) impacted by one party of *Environment* (or a set of environment).

+ The relation *Is-a* allows to inherit attributes and associative relations down from super-concept to sub-concept. For instance, sub-concept *Contractor* inherits of attribute *Cost* and associative relation from its concept *Actor* (see fig 1-1.b).

+ The relation *Is-a-part-of* whether allows to inherit or not associative relations down from super-concept to its concept which named composed-concept. For instance, composed-concepts *Economy* and *Administration* inherit associative relation *Impacts*. Moreover, attribute *Inflation* (resp. *Corruption*) (see fig 1-1.b) allows to refine the characteristics of composed-concepts *Economy* (resp. *Administration*). Composition characteristics of all composed-concepts (*Economy.Inflation*, *Administration.Corruption*) make the total characteristic of its sub-concept (*Environment.Aggressive*). Another composed-concept *Climate* does not inherit associative relation because it does not impact on *Cost* of *Actor*.

1.2.1.2. Instantiating ontology

Given the structure (see figure 1-1.a, 1-1.b) of hierarchical ontology, the instantiating of ontology consists in specifying: (1) the set of objects c^3 , denoted $I(C)$, in each concept C, (2) the values for object's attributes c.A, denoted $\mathcal{V}(C.A)$, and (3) relations R between each object. Each relation $R \in \mathcal{R}$ is defined by:

$$R := \{(c, c'), c \in I(C), c' \in I(C')\} \quad (1)$$

where $I(C)$ (resp. $I(C')$) denotes the set of instances/elements of concept C (resp. C'). By adopting the oriented-object paradigm, we use C.R to denote the reference slot of C (e.g. *Environment.Impacts=Actor*) meaning that

$$\forall c \in I(C), c.R = \{ c' \in I(C') / (c, c') \in R \} \subseteq I(C') \quad (2)$$

Relations $R \in \mathcal{R}(C)$ may be clustered into:

- Taxonomy: For example, in figure 1-1.b, *Contractor* is a sub-concept of *Actor*. Hence, *Building Contractor_projectX* (an object of concept *Contractor* in level 1) (figure 1-

³ Objects are set of instances of a concepts in a real project. For example : A project names X, concept *Actor* has objects : *Owner_of_project_X*, *contractor_of_project_X*, etc.

1.d) is also a sub-concept of *Contractor_projectX* (an object of concept *Actor* in level 0) (figure 1-1.c).

- Partonomy: For example, figure 1-1.b shows that *Economy* is a part of *Environment*. Hence, an object of *Economy* (*Economy_projectX*) (figure 1-1.d) is also a part of object of *Environment* (*Environment_projectX*) (figure 1-1.c).

- Associative relationships: Each attribute $A \in \mathcal{A}(C)$ associated with the concept C is defined by

$$A := \{(c, v), c \in I(C), v \in \mathcal{V}(C.A)\} \quad (3)$$

where $C.A$ (resp. $c.A$) denotes an attribute of concept C (resp. the value assigned to the attribute A of object c) and $\mathcal{V}(C.A)$ denotes its domain of values.

For example, figure 1-1.c displays an instantiation of level 0 ontology model where $I(\text{Environment}) = \{\text{Environment_projectX}\}$, $I(\text{Actor}) = \{\text{Owner_projectX}, \text{Contractor_projectX}\}$, $\mathcal{R} = \text{Impacts} = \{(\text{Environment_projectX}, \text{Owner_projectX}), (\text{Environment_projectX}, \text{Contractor_projectX})\}$.

Figure 1-1.d displays an instantiation of level 1 ontology model where $I(\text{Economy}) = \{\text{Economy_projectX}\}$, $I(\text{Administration}) = \{\text{Administration_projectX}\}$, $I(\text{Owner}) = \{\text{Owner_projectX}\}$, $I(\text{Contractor}) = \{\text{Building Contractor_projectX}, \text{Installing Contractor_projectX}\}$, $\mathcal{R} = \text{Impacts} = \{(\text{Economy_projectX}, \text{Owner_projectX}), (\text{Economy_projectX}, \text{Building Contractor_projectX}), (\text{Economy}, \text{Installing Contractor_projectX}), (\text{Administration_projectX}, \text{Owner_projectX})\}$.

In instance of level 0, the *Cost* of *Owner_projectX* could be “high”, “medium”, and low” meaning that $\mathcal{V}(\text{Owner_projectX.Cost}) = \{\text{high}, \text{medium}, \text{low}\}$. *Environment_projectX* impacts on two objects of *Actor* (*Owner_projectX*, *Contractor_projectX*) and *Environment.Impacts.Cost* corresponds to the set $\{\text{Owner_projectX.Cost}, \text{Contractor_projectX.Cost}\}$.

The ontology structure (figure 1-1.a and 1-1.b) remains valid for all construction projects while the instantiated model (figure 1-1.c and 1-1.d) corresponds to a specific project, in its specific context, and it will be characterized by defining the specific instances (i.e. specific actors and activities) and the values of their attributes.

This clear distinction between the model and its instantiation enables the versatility of description. However, the concepts and their properties are defined in the model and are unchanged whatever the project.

Although ontology allows to describe domain and to retrieve information, it is not capable of simulating the behaviour of the system while taking into account uncertainty. Hence, it must be combined with another model which can simulate the propagation and the behavior of a construction project when uncertainties happen.

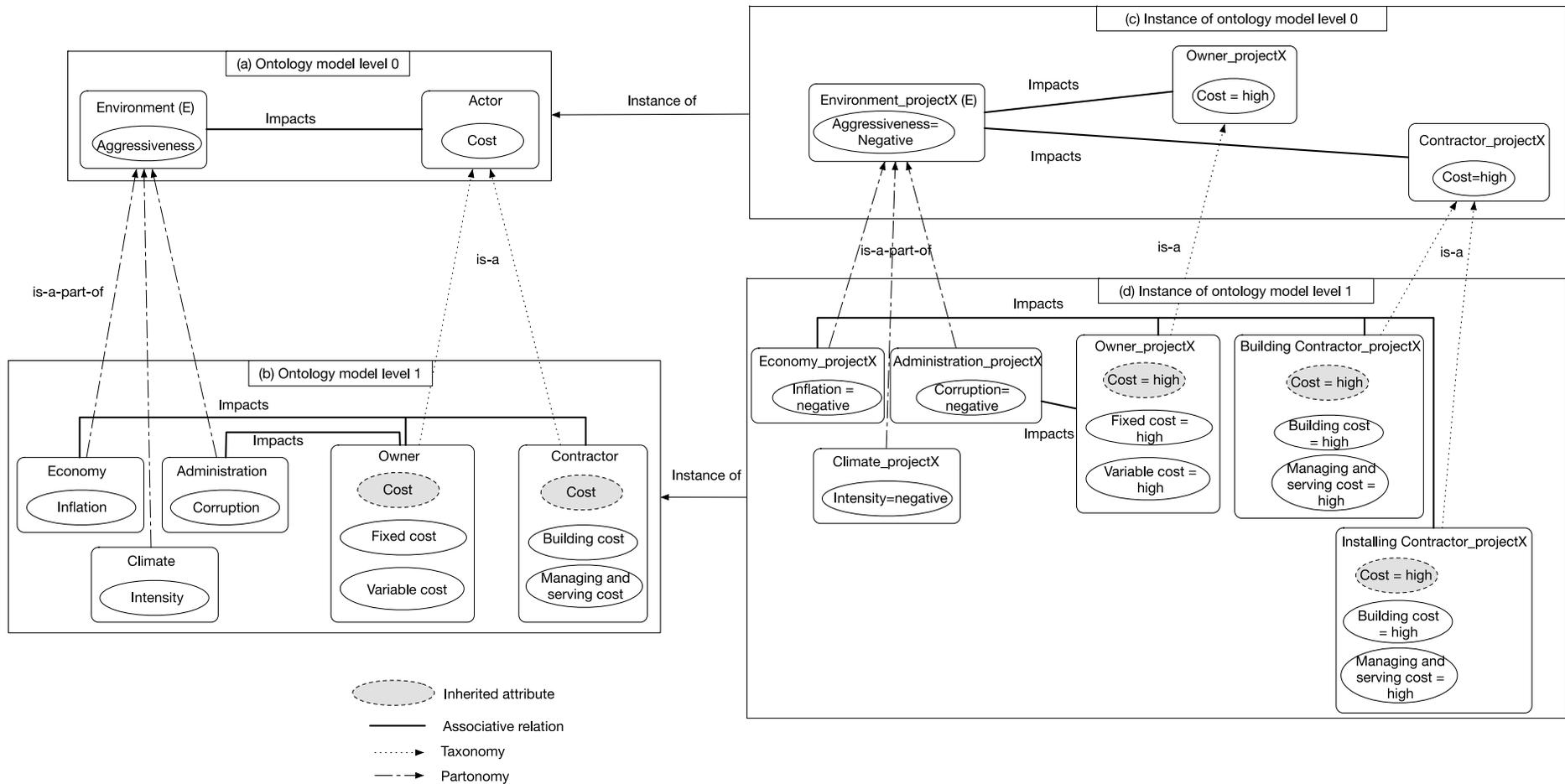


Figure 1-1: (a), (b) Example of an ontology structure level 0 and 1 by using a graphic representation, (c), (d) Example of instantiations level 0, 1 of ontology model.

1.2.2. Bayesian networks

A Bayesian Network (BN) (Jensen, Toftum, and Friis-Hansen 2009) is a graph-based model of a joint multivariate probability distribution that captures properties of conditional independence between variables. On one hand, it is a graphical representation of the joint probability distribution and on the other hand, it encodes independence between variables. BN provides a practical mathematical formalism and an intuitively appealing interface for human experts to model highly-interacting sets of random variables allowing to describe stochastic complex systems. Formally a Bayesian network is a directed acyclic graph (DAG) whose nodes X_i represent random variables, and whose missing arcs encode conditional independence between the variables (figure 1-2).

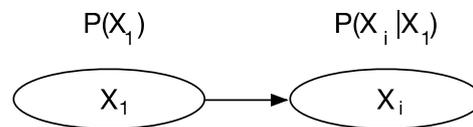


Figure 1-2: A basic BN

In a Bayesian network, the joint probability distribution of the node values can be written as the product of the local probability distribution of each node and its parents. If the set of parent nodes of a node X_i is denoted by $Pa(X_i)$, we have:

$$P(X_1, \dots, X_n) = \prod_{i=1}^n P(X_i | Pa(X_i))$$

where $P(X_i | Pa(X_i))$ denotes the conditional probability function associated with the random variable X_i knowing $Pa(X_i)$.

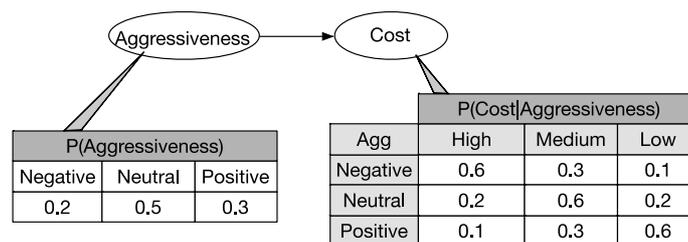


Figure 1-3: Example of a Bayesian network

So, in a probabilistic graphical model, the graphic network shows dependencies (or independence) between variables and provides a visual support for knowledge representation. For example, figure 1-3 displays a simple Bayesian network in which the *Cost* (of an *Actor*) depends on the *Aggressiveness* (of involved *Environment*). The use of probabilistic formalism allows to take into account uncertainty in quantifying the dependencies between variables by means of conditional probabilities. For example, conditional probability

$P(\text{Cost}|\text{Aggressiveness})$ in figure 1-3 encodes in what the extent the *Cost* of an actor may be *High*, *Medium*, or *Low* given the *Aggressiveness* level of environment of project. The probability $P(\text{Cost}=\text{High}|\text{Aggressiveness}=\text{Negative})=60\%$ means there is a strong belief that the *Cost* of Actor is high if the *Aggressiveness* of *Environment* is negative.

Different methods exist to learn about the structure or the parameters (i.e. conditional probabilities) from substantial and/or incomplete data combined with expert elicitation (Heckerman 1999)(Krause 1999)(Faria and Smith 1997)(O'Hagan et al. 2002)(Feelders and van der Gaag 2006)(Buntine 1996). Such use of BNs, known as inference, consists in query expressed as conditional probabilities (Darwiche 2010)(Jensen, Toftum, and Friis-Hansen 2009). The most common task we wish to solve is to estimate the marginal probabilities $P(X_Q|X_E = x_E)$ where X_Q is a set of query variables, and X_E is a set of evidence variables. From the example in figure 1-3, we may estimate which has been the *Aggressiveness* of *Environment* given the fact that *Cost* of Actor has been *Medium*, i.e. $P(\text{Cost}|\text{Aggressiveness}=\text{Medium})$.

The computing of marginal probability distributions for all nodes in the network is NP-Hard (G. Cooper 1990) meaning that the worst-case time complexity of estimating $P(X_Q|X_E = x_E)$ is exponential in the size of the network. This can be a strong limitation of such models for practical application to real-life problems. It can be seen, from figure 1-3 that the size of the network may quickly increase as soon as we will consider lower levels of detail, and this can prevent the practical use of such models. Hence, according to the complexity and the size of the network, different kinds of algorithms are available (Lauritzen and Spiegelhalter 1988) (Cano et al. 2007)(Murphy, Weiss, and Jordan 1999).

BN is inadequate for representing large and complex dynamical system because it fixes in advance its variables and its dependencies network specifically to the studied system. That means that a specific model has to be built for each studied system. Hence, they cannot represent general principles, about multiple similar objects, which can then be applied in multiple contexts. The model in the next part will help us in solving all that problems.

1.2.3. Probabilistic relational model (PRM)

Probabilistic relational models (PRMs) (Getoor et al. 2007)(Pierre-Henri Wuillemin and Torti 2012) extend the formalism of Bayesian networks (see Section 1.2.2) by relying on a hierarchical ontology scheme (see Section 1.2.1) where the attributes of concept C.A represent random variables. Formally, PRMs may be formalized by:

- A set of nodes $C.A$ for all $C \in C$ associated with their descriptive attributes $A \in \mathcal{A}(C)$.
- A set of parents $\text{Pa}(C.A) = \{U_1, \dots, U_n\}$ where U_i may have the form $C.B$ or $\gamma(C.R.B)$ for all $i \in \{1, \dots, n\}$ where \mathbf{R} is a reference slot chain (combination of relations R), B is another attribute of C or related to concept C , \mathbf{R} and γ is an aggregate of $C.R.B$.
- The conditional probability distributions $P(C.A | \text{Pa}(C.A))$.

For example, figure 1-4 displays an example of PRM structure extending the ontology structure in figure 1-3 with probabilistic dependencies between attributes *Aggressiveness*, and *Cost* of concepts *Environment*, *Actor* respectively. This PRM is composed of two concepts *Environment* and *Actor* (i.e. $C = \{\text{Environment}, \text{Actor}\}$) characterized by node attributes *Aggressiveness* and *Cost* respectively (i.e. $\mathcal{A} = \{\text{Aggressiveness}, \text{Cost}\}$) where *Cost* of *Actor* (i.e. $\mathcal{A}(\text{Actor}) = \{\text{Cost}\}$) depend on the *Aggressiveness* of *Environment*. Dashed arrow encodes the reference slot⁴ *Environment.Impacts* and dashed node encodes the reference node⁵ *Actor.Impacts⁻¹.Aggressiveness* or the reference aggregate node $\gamma(\text{Actor.Impacts}^{-1}.\text{Aggressiveness})$ corresponding to the aggregation of all environment aggressiveness involved in actors.

There are several aggregation (γ) methods like mode (most frequently occurring value), mean, median, maximum, minimum value etc. Moreover, figure 1-4 shows the conditional probability table associated with the node *Actor.Cost* where $\text{Pa}(\text{Actor.Cost}) = \gamma(\text{Actor.Impacts}^{-1}.\text{Aggressiveness})$ and $\mathcal{V}(\text{Actor.Cost}) = \{\text{High}, \text{Medium}, \text{Low}\}$.

An instantiated model (denoted σ_R) in the PRMs formalism (also named skeleton), specifies the set of objects $\sigma_R(C)$ for each concept C and the relations R between the objects, i.e. $\sigma_R(C) = \langle I(C), \mathcal{R}(C) \rangle$. Figure 1-5 displays the relational skeleton associated with the PRM model in figure 1-4 meaning that *Environment_of_projectX* impacts on both *Owner_of_projectX* and *Contractor_of_projectX*.

A PRM model associated with a skeleton σ_R defines the following ground Bayesian network:

- There is a set of nodes $c.A$ for all $c \in \sigma_R(C)$ and $C \in C$.
- There is set of parents $\text{Pa}(c.A) = \{U_1, \dots, U_n\}$ where U_i may have the form $c.B$

⁴ A reference slot of concept C (i.e. *Actor*) denoted by $C.p$ (i.e. *Actor.Realizes*). For each reference slot p , a reversed slot p^{-1} can be defined.

⁵ A reference node is a node (attribute) which points to a node in another concept.

or $\gamma(c.R.B)$ for all $i \in (1, \dots, n)$ where γ is an aggregation given a summary of a multi-set of random variables $\{c'.B/(c, c') \in \mathbf{R}\}$ where $(c, c') \in \sigma_{\mathbf{R}}(C) \times \sigma_{\mathbf{R}}(C')$. For example, if two actors namely $actor_1, actor_2$ realize an activity $activity_1$ then $activity_1.Realize^{-1} = \{actor_1, actor_2\}$ and $activity_1.Cost$ depends on

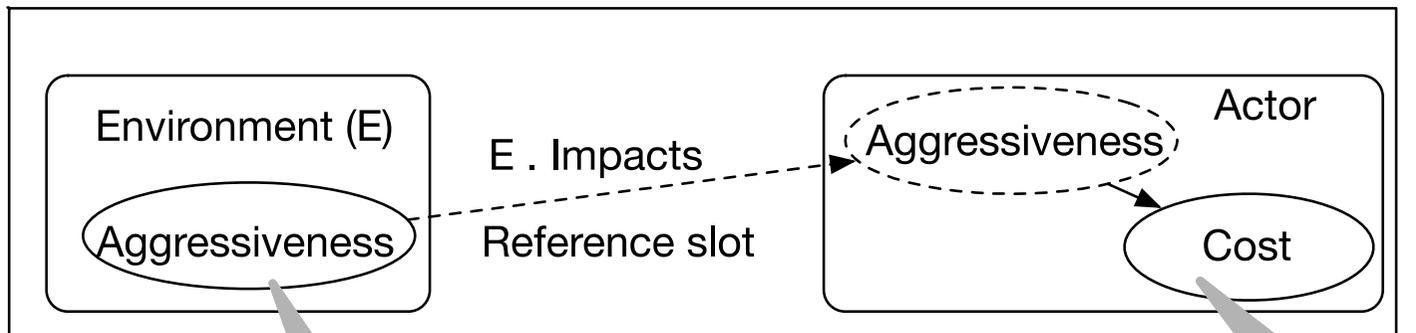
$$\gamma(activity_1.Realize^{-1}.Cost) = \gamma(\{actor_1.Cost, actor_2.Cost\})$$

- The conditional probability distributions $P(c.A|Pa(c.A))$, by assuming that $P(c.A|Pa(c.A)) = P(c'.A|Pa(c'.A))$ for all $(c, c') \in \sigma_{\mathbf{R}}(C)^2$. For $u \in \mathcal{V}(Pa(C.A))$, $P(c.A|u) : \mathcal{V}(C.A) \rightarrow [0,1]$ defines a probability mass distribution over $\mathcal{V}(C.A)$ where $\mathcal{V}(C.A)$ denotes the domain of attribute values for all elements $c \in \sigma_{\mathbf{R}}(C)$. For example: As illustrated in figure 1-6, $P(Owner_of_projectX.Cost|Environment_of_projectX.Aggressiveness) = P(Contractor_of_projectX.Cost|Environment_of_projectX.Aggressiveness)$ for $Owner_of_projectX(c)$ and $Contractor_of_projectX(c')$ are objects of concept *Actor*.

For a given skeleton $\sigma_{\mathbf{R}}$, the PRM structure then induces a ground Bayesian network and specifies a probability distribution over a set of instantiation \mathcal{I} consistent with $\sigma_{\mathbf{R}}$:

$$P(\mathcal{I}) = \prod_{C \in \mathcal{C}} \prod_{A \in \mathcal{A}(C)} \prod_{c \in \sigma_{\mathbf{R}}(C)} P(c.A|Pa(c.A))$$

Figure 1-6 depicts the ground Bayesian networks stemming from the PRM model in figure 1-4 associated with the skeleton in figure 1-5. Unlike Bayesian networks, PRMs specify independence networks in a generic way that can be applied to any relational structure. Like in Bayesian networks, inference in PRMs (Getoor et al. 2007)(Torti, Gonzales, and Willemin 2010) consists in propagating influence between the interrelated objects and reducing the number of computations. When the skeleton is small, exact inference may be used (Medina Oliva et al. 2010) whereas when it is very large, approximate inferences are preferable (Schmidt and Murphy 2009). The well-known method of parameter learning from Bayesian network may be used in PRMs by referring to the skeleton where parameters for different nodes are forced to be identical (Pfeffer and Koller 2000).



P(Aggressiveness)		
Negative	Neutral	Positive
0.2	0.5	0.3

	P(Cost Aggressiveness)		
	Negative	Neutral	Positive
Negative	0.6	0.3	0.1
Neutral	0.2	0.6	0.2
Positive	0.1	0.3	0.6

-----> Reference slot

----- Reference node

Figure 1-4: Example of a PRM structure based on knowledge model

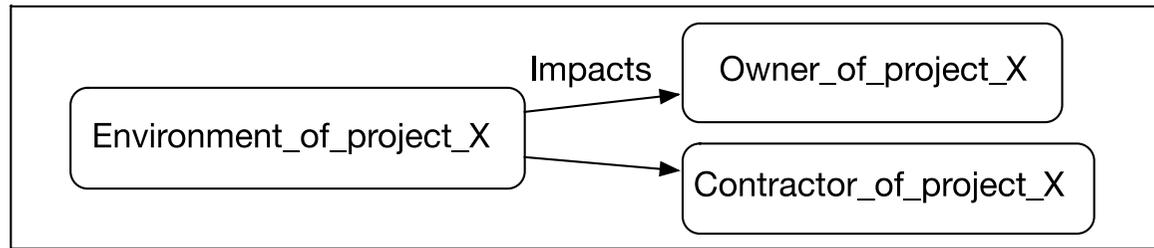
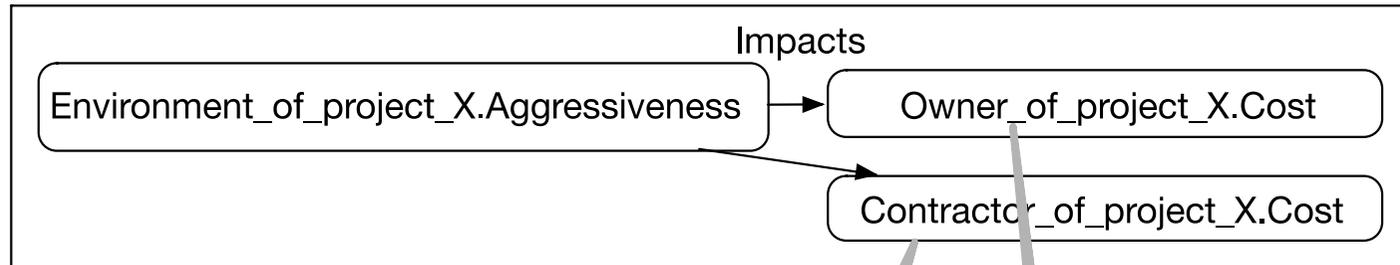


Figure 1-5: An example of a skeleton associated with the PRM structure.



P(Cost Aggressiveness)			
	Negative	Neutral	Positive
Negative	0.6	0.3	0.1
Neutral	0.2	0.6	0.2
Positive	0.1	0.3	0.6

Figure 1-6: Equivalent ground Bayesian network stemming from the skeleton and the PRM structure.

1.2.4. Hierarchy and specialization extension

Model describing two detailed levels (level 0 and 1) by means of PRMs in figure 1-7 thus proposes a finer representation where dotted grey nodes (resp. dotted arrows) encodes inherited node (resp. inherited reference slot). For example, dotted nodes *Cost of Owner* and *Cost of Contractor* in level 1 are inherited from *Cost of Actor* in level 0. Dotted arrow between *Economy.Inflation* and *Contractor.BuildingCost* in level 1 is inherited from relation of *Environment.Agressiveness* and *Actor.Cost*.

Let $\mathcal{H}(C)$ be a set of sub-concepts (\bar{C}) to concept C (taxonomy). Each sub-concept has characteristics which are listed below :

- Each sub-concept $\bar{C} \in \mathcal{H}(C)$ always inherits the attributes $A \in \mathcal{A}(C)$ and reference slots $R \in \mathcal{R}(C)$ of its super concept C. For example: Sub-concept *Contractor* inherits the attributes *Cost* and reference slots *Realizes* of its super concept *Actor* (figure 1-7.b).

- Each sub-concept $\bar{C} \in \mathcal{H}(C)$ may become more specialized

- + by adding specific attributes $\bar{A} \in \mathcal{A}(\bar{C})$ (e.g. *Building Cost*, *Managing and serving cost* for *Contractor*),

- + by refining the range of reference slots (e.g. *BuildingContractor.Realizes*, *InstallingContractor.Realizes*).

- There does not exist relation between inherited attributes $\bar{C}.A$ in level 1. At this level, the relation between concepts will be specialized into relations between its sub-attributes. For instance, the relation between *Contractor.BuildingCost* and *Implementation.CostToBuild* specializes relation between *Contractor.Cost* and *Implementation.Cost*.

- Parents of sub-attributes $\text{Pa}(\bar{C}. \bar{A})$ and conditional probability distributions $P(\bar{C}. \bar{A} | \text{Pa}(\bar{C}. \bar{A}))$ may

- + either remain equal, that is $P(\bar{C}. \bar{A})=P(C.A)$ and $P(\bar{C}. \bar{A} | \text{Pa}(\bar{C}. \bar{A}))= P(C.A | \text{Pa}(C.A))$.

For example $P(\text{Contractor.BuildingCost} | \text{Economy.Inflation}) = P(\text{Actor.Cost} | \text{Environment.Agressiveness})$ (see figure 1-7).

- + or be specialized by

- * using a different conditional probability distribution: $P(\bar{C}. \bar{A}) \neq P(C.A)$ and $P(\bar{C}. \bar{A} | \text{Pa}(\bar{C}. \bar{A})) \neq P(C.A | \text{Pa}(C.A))$. For example:

$P(\text{Owner.VariableCost}|\text{Economy.Inflation}) \neq$

$P(\text{Actor.Cost}|\text{Environment.Aggressiveness})$ (see figure 1-7),

* or removing parents in $\text{Pa}(\bar{C}. \bar{A})$ leading to without exist CPTs. For example: In level 1, not all $\bar{C}. \bar{A}$ of *Environment.Aggressiveness* have relations with that one of *Actor.Cost*, i.e *Administration.Corruption* is parent of *Owner.FixedCost*, but with *Contractor.BuildingCost* or *Contractor.ManagingAndServingCost*, this parent is removed.

- Each C.A in level 0 synthesizes all of its inherited attributes $\bar{C}. \bar{A}$, where $\bar{C}. \bar{A}$ synthesizes all of its sub-attributes $\bar{C}. \bar{A}$.

Let $H^*(C)$ be a set of composed-concepts to concept C (partonomy). Each composed-concept has characteristics which are listed below :

- Each composed-concept $\bar{C} \in H^*(C)$ whether inherits or not the reference slots $R \in \mathcal{R}(C)$ of its super concept C. For example: Composed-concept *Economy* inherits the reference slots *Impacts* of its super-concept *Environment*. *Economy* impacts on both *Owner* and *Contractor*. Another composed-concept *Climate* does not inherit reference slots *Impacts* because it does not impact on *Cost* of *Owner* and *Contractor*.

- Attributes' relations in level 1 will specialize into other relations between its composed-attributes.

- Parents of composed-attributes $\text{Pa}(\bar{C}. \bar{A})$ and conditional probability distributions $P(\bar{C}. \bar{A} | \text{Pa}(\bar{C}. \bar{A}))$ use a different conditional probability distribution: $P(\bar{C}. \bar{A}) \neq P(C.A)$ and $P(\bar{C}. \bar{A} | \text{Pa}(\bar{C}. \bar{A})) \neq P(C.A | \text{Pa}(C.A))$ or remove parents in $\text{Pa}(\bar{C}. \bar{A})$ leading to without exist CPTs.

- Each C.A in level 0 synthesizes all of its composed-attributes $\bar{C}. \bar{A}$.

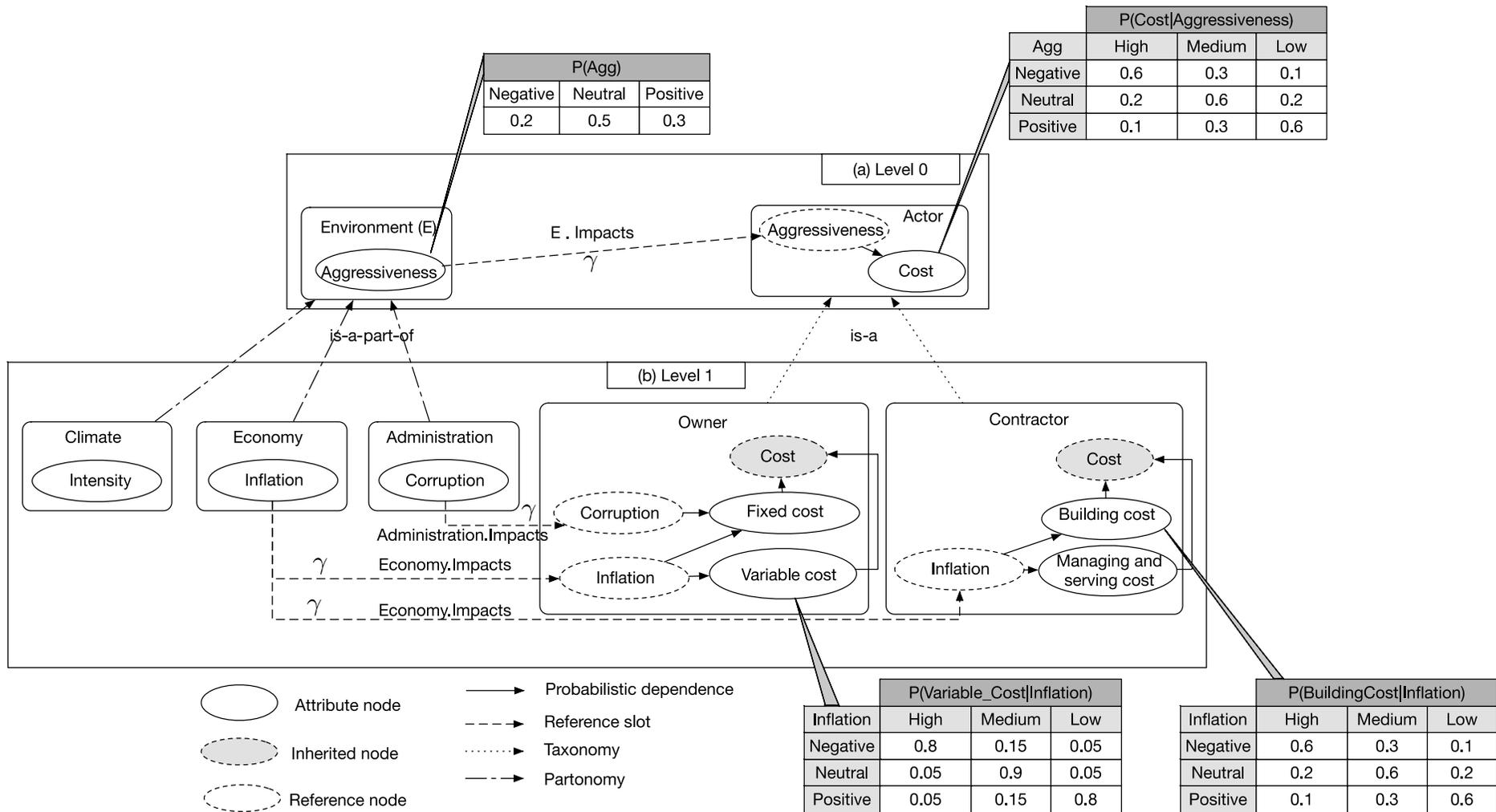


Figure 1-7: Example of a PRMs structure based on knowledge model describing two levels of knowledge

1.3. Conclusion

In this chapter, we analyse the literature foundation and our perspective about construction project and risk management. Based on advantages and disadvantages of recent researches on risk management for construction project, we propose a new approach based on PRM formalism to model construction project and to simulate project processing considering risks.

In the next chapter, we will develop the holistic generic model to formalize construction project. It means that, all relations between concepts, attributes will be built which are suitable with any types of construction project. Context of next chapter is the foundation part in order to develop PRM.

Chapter 2

Development of a holistic generic model to formalize construction project

Contents

2.1. Introduction

2.2. Concepts

2.3. Relations between concepts

2.4. Attributes

2.5. Relation between attributes

2.6. Conclusion

2.1. Introduction

We will develop in this chapter a holistic model for construction project risk management considering different levels of detail. The model is developed according to three levels of detail named macro (level 0), meso (level 1), and micro (level 2). In the macro level (level 0), concepts and attributes are described in the most general way. In the meso level (level 1), concepts and attributes from the level 0 are specialized. In the micro level (level 2), concepts and their attributes are even more specified; it is the level with the highest sharpness of description.

The 3-level model allows to ensure a consistency between information and simulation accuracy of project from general (level 0) to specific (level 2). The macro level can also be used to have rapidly results with limited instantiation effort. As the project goes on from macro to micro level, the project manager could want to have more accurate results.

Based on the literature and expert knowledge, we develop an ontology according to the three defined levels, following figure 2-1 process. In the section 2.2, list of concepts in macro level will be clearly analysed by defining definitions (giving our own perspective), sub-concepts in meso and micro levels will be listed but their definitions will be mentioned in appendix. Next section will explain all relations between concepts in level 0, relations from levels 1 and 2 are explained in appendix. Section 2.4 and 2.5 will analyse for concepts' attributes, list of all attributes' relations will be listed in appendix.

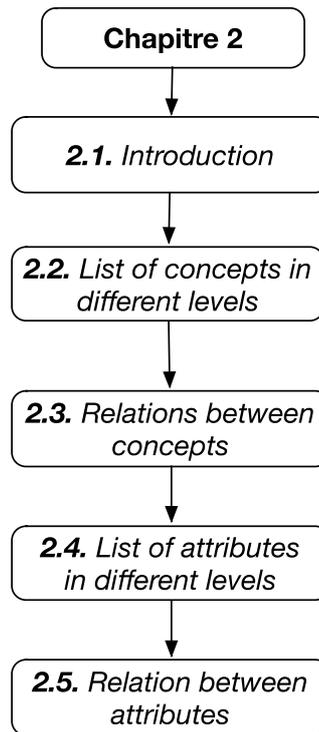


Figure 2-1 : Order of works in chapter 2

2.2. Concepts

Based on a literature review (see Table 2-1), six main concepts in level 0 were defined: *Activity, Actor, Contract, Environment, Product, and Resource.*

Table 2-1: Main concepts in the model

Name	Definition	Reference
<i>Activity</i>	Actions which performed by actors and resources	(Mehdizadeh Rasool 2012)(Khartabil, Breyse, and Taillandier 2013)(El-Diraby, Lima, and Feis 2005)(Tserng et al. 2009)(Sun and Meng 2009)(Jia Niu and Issa 2015)(Franck Taillandier et al. 2016)

<i>Actor</i>	Individuals or organizations who/which perform activities and are linked by a contract	(Mehdizadeh Rasool 2012)(Khartabil, Breysse, and Taillandier 2013)(Fidan and Dikmen 2011)(El-Diraby, Lima, and Feis 2005)(Tserng et al. 2009) (Sun and Meng 2009)(Jia Niu and Issa 2015)(Yildiz, Dikmen, and Birgonul 2014)(Franck Taillandier et al. 2016)
<i>Contract</i>	Legal documents which combine obligations and responsibilities of actors in performing activities	(Tserng et al. 2009)(Sun and Meng 2009)(Jia Niu and Issa 2015)(Yildiz, Dikmen, and Birgonul 2014)(Franck Taillandier et al. 2016)
<i>Environment</i>	Entities outside of project but which are able to either affect project or be affected by the project	(Mehdizadeh Rasool 2012)(Khartabil, Breysse, and Taillandier 2013)(Fidan and Dikmen 2011)(Tserng et al. 2009)(Sun and Meng 2009) (Jia Niu and Issa 2015)(Yildiz, Dikmen, and Birgonul 2014)(Franck Taillandier et al. 2016)
<i>Product</i>	The results of activities which satisfy predefined needs	(Khartabil, Breysse, and Taillandier 2013)(El-Diraby, Lima, and Feis 2005)(Jia Niu and Issa 2015)(Franck Taillandier et

		al. 2016)
<i>Resource</i>	Assets that are used by actors to carry out activities of construction	(Khartabil, Breysse, and Taillandier 2013)(Fidan and Dikmen 2011)(El-Diraby, Lima, and Feis 2005)(Jia Niu and Issa 2015)(Franck Taillandier et al. 2016)

The models in meso (level 1) and micro (level 2) levels refine the previous model (level 0) by adding respectively 19 and 40 sub-concepts, composed-concepts. Table 2-2 displays all concepts regarding the three levels. The breakdown of concept to sub-concepts, composed-concepts belong to two kinds of relation: taxonomy and partonomy (see chapter 1). The whole set of concept definitions in level 1 and 2 are given in appendix 2, 3.

In order to find the sub-concepts or composed-concepts of a concept, we use literature review to summarize and filter the most concerned concepts in a construction project. For example, we find the composed-concepts in meso level (level 1) which correspondent with concept *Environment* (a concept in level 0) by referencing 12 scientific papers ((Dawood 1998), (Tah and Carr 2001),(Y. B. Zhang, Chen, and Zhu 2012), (Bing et al. 2005), (Middelmann 2007), (Yildiz, Dikmen, and Birgonul 2014), (Nasir, McCabe, and Hartono 2003), (Sanvido et al. 1992), (Franck Taillandier et al. 2015), (Mehdizadeh Rasool 2012), (Zou, Zhang, and Wang 2007), (Zou, Zhang, and Wang 2012)); number of words relate to *normative context, economy, extreme event, administration, climate, third party, ecosystem* are 2, 7, 2, 4, 4, 2, 2 respectively (figure 2-2). For example, four words which relate to *administration* are: “Bureaucracy of government”, “Excessive procedures of government approvals”, “Unstable government”, “Poor public decision-making process”. Among of composed-concepts in level 1 of *Environment*, based on number related words, *Climate, Economy, and Administration* are the most concerned ones which can impact on construction project. In micro level (level 2), the *Temperature* and *Precipitation* as the two composed-concepts of *Climate* which have the higher ability in creating risks for construction project (figure 2-3).

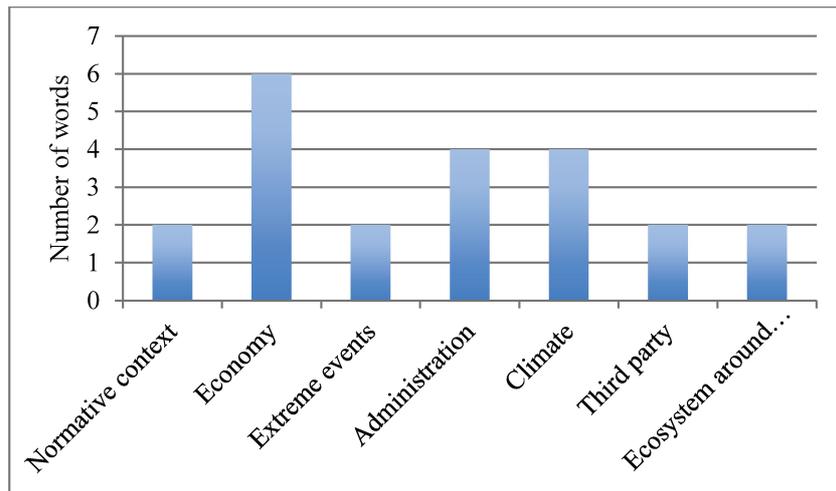


Figure 2-2 : List of concepts relate to *Environment* which create uncertainties in construction project

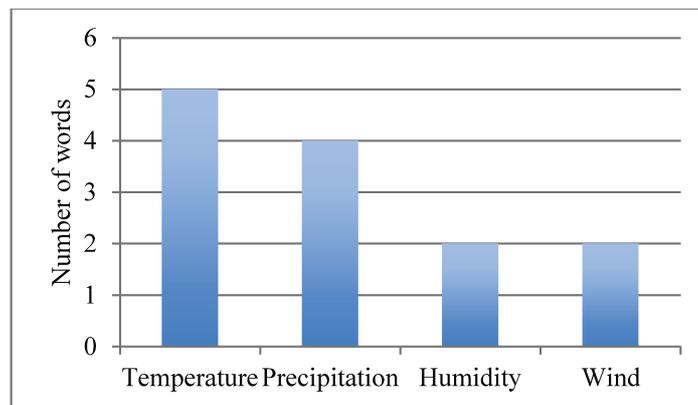


Figure 2-3: List of words relate to sub-concepts of *Climate*.

Table 2-2 presents all concepts at level 1 and 2.

Table 2-2: *Finer concepts of level 1 and 2.*

Level 0 6 Concepts	Type of relation	Level 1 19 Concepts	Level 2 40 Concepts
<i>Environment</i>	<i>Partonymy</i>	<i>climate</i>	<i>temperature, precipitation</i>
		<i>economy</i>	<i>national economic, international economic</i>
		<i>administration</i>	<i>ministry, department</i>
		<i>etc.</i>	
<i>Resource</i>	<i>Partonymy</i>	<i>human resource</i>	<i>worker, engineer, office staff</i>
		<i>machine</i>	<i>construction machine, office machine</i>
		<i>material</i>	<i>reusable material, consumable material</i>
<i>Actor</i>	<i>Taxonomy</i>	<i>contractor</i>	<i>building contractor, installing contractor</i>
		<i>designer</i>	<i>structural designer, architectural designer</i>

		<i>owner</i>	<i>owner</i>
		<i>supplier</i>	<i>material supplier</i>
		<i>etc.</i>	
<i>Contract</i>	<i>Taxonomy</i>	<i>building contract</i>	<i>main building contract, installing contract</i>
		<i>design contract</i>	<i>structural design contract, architectural design contract</i>
		<i>supply contract</i>	<i>material supply contract</i>
		<i>etc.</i>	
<i>Activity</i>	<i>Taxonomy</i>	<i>activity in feasibility phase</i>	<i>field work, preliminary design, economic research</i>
		<i>activity in implementation phase</i>	<i>detailed design, preparing procedure before construction, construction</i>
		<i>activity in operation phase</i>	<i>operation monitoring, performance of maintain work</i>
<i>Product</i>	<i>Taxonomy</i>	<i>document of procedure,</i>	<i>document of site survey, preliminary design, document of economic efficiency</i>
		<i>building</i>	<i>detailed design, procedure document, building</i>
		<i>list of repaired maintenance works</i>	<i>document of operation monitoring, document of performing maintain work</i>

In table 2-2, *Environment* and *Resource* have partonomy relations with their sub-concepts. For example, *Economy* is a part of *Environment*, *Human* is a part of *Resource*. The others macro-concepts have taxonomy relations with their sub-concepts. For example, *Contractor* is an *Actor*. The different between taxonomy and partonomy is:

+ Taxonomy : expresses the unnecessary of existance of a concept in a construction project. For example : A construction project does not need a *Contractor* if *Owner* has ability in constructing. Moreover, all concepts in taxonomy have the same nature (homogeneous).

+ Partonomy : expresses the necessary of existance of a concept in a construction project. For example, property of *Climate* is always expressed by synthesizing properties of *Temperature*, *Precipitation*, etc. With *Resource* in construction project, it always exists *Human*, *Machine* and *Material* in order to ensure the efficiency of construction activity. Moreover, all concepts in partonomy have the different nature (heterogeneous).

2.3. Relations between concepts

Beyond the partonomy and taxonomy relations describing the link between a concept

and its composed-concepts, sub-concepts (concepts' relation between different levels), the model also contains relations between concepts in the same level, based on the formalism of the light ontology (Cimiano 2006). The model contains respectively 13 relations between concepts at macro-level, 61 at meso-level, and 213 at micro-level (appendix 4, 5). Figure 2-4 displays the relation (realize, impact, and reflexive) between concepts at macro-level. These relations are:

- *Actor* **realizes** the *Activity* on which it works, leading to create a relation from *Actor* to *Activity* denoted *Realizes*.

- *Environment* **impacts** on *Resource*, *Actor*, and *Contract*. For instance, a change in economy as inflation (*Environment*) could impact on resource cost (*Resource*) (e.g. unit cost of material), actor cost (*Actor*) (e.g. salary of actors will be changed), contracts magnitude (*Contract*).

- *Resource* **impacts** on *Actor* and *Activity* are impacted by. For example, workers (*Resource*) impact on the skill of the contractor that they belong to (*Actor*) and the activity quality (*Activity*) depends on used material quality (*Resource*).

- *Contract* **impacts** on *Actor*. For example, the more ambiguous claims of construction contract (*Contract*), the more difficult work organization of contractor (*Actor*).

- *Activity* **impacts** on *Product*. For instance, outcome of installing steel wrong way (*Activity*) will make low quality of foundation structure (*Product*).

- *Actor* **impacts** on *Resource*. For instance, consumable quantity of materials (*Resource*) is bought based on productivity of building contractor (*Actor*).

- *Actor* **impacts** on *Contract*. For instance, contractor (*Actor*) decides requirements about quantity, quality of supplying contract (*Contract*).

- *Product* **impacts** on *Activity*. For example, if quality of site surveying process (*Product*) is not enough, *Activity* of building foundation will be affected.

- Finally, *Activity* and *Actor* are **self-related**. For example, duration of exploration activity (*Activity*) impacts on duration of the next activity and productivity of contractor (*Actor*) is affected by productivity of supplier (*Actor*).

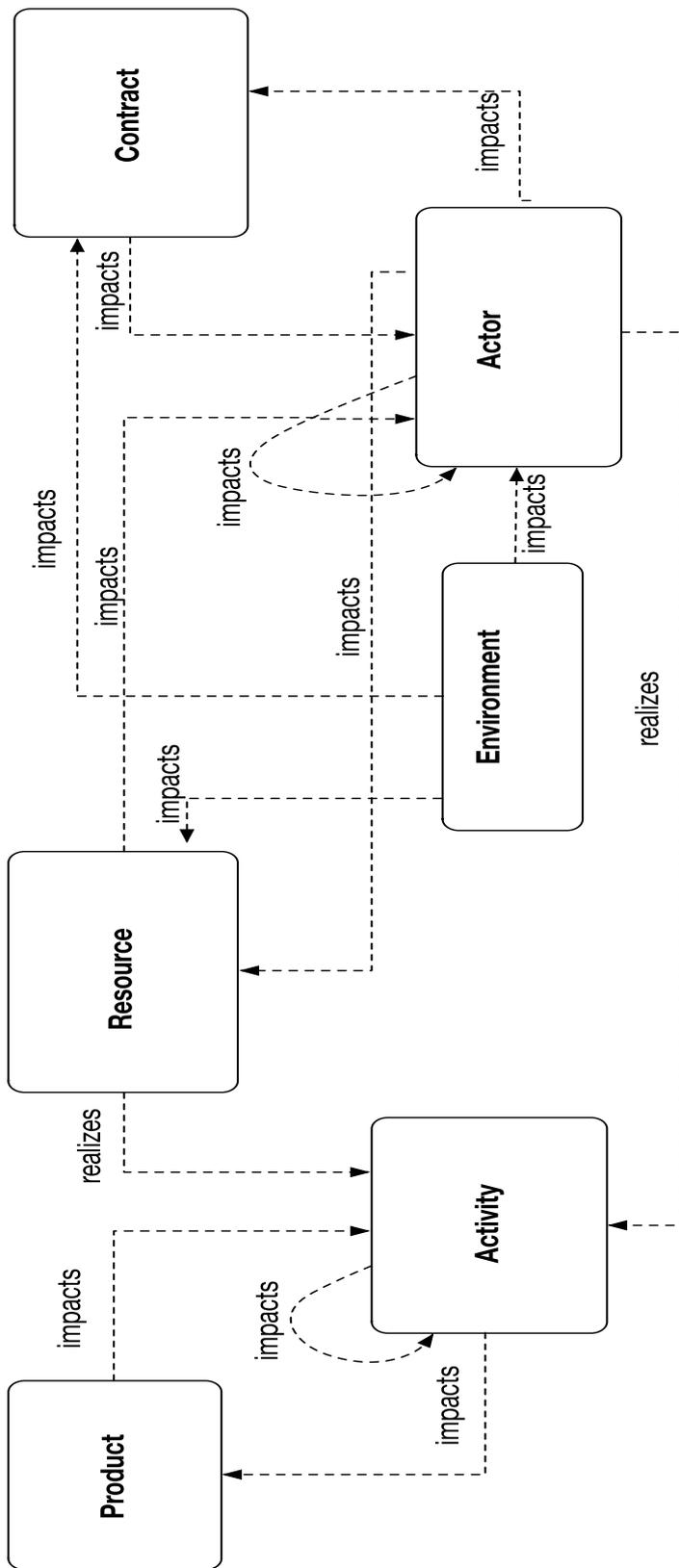


Figure 2-4: Ontological structure describing a generic representation of project construction at a meta-level.

The relations of concepts at sub-levels is inherited from the relations of the related concept at upper level. In order to illustrate clearly how relations are inherited between level 0 and 1, level 1 and level 2, we take here the example of relation between concepts *Environment* and *Actor* (level 0) which is refined at level 1 (figure 2-5) and level 2 (figure 2-6). The relations between *Environment* and *Actor* are detailed at lower levels (level 1 and 2), illustrating how some attributes of composed-concepts may influence some attributes of other sub-concepts.

Figure 2-5 illustrates the relations between *Environment* and *Actor* at level 1 by relations between:

- + *Climate* and *Contractor*. For example: Intensity of *Climate* impacts on productivity in building project of *Contractor*.
- + *Administration* does not impact on productivity of *Contractor*.

Figure 2-6 continues to illustrate the relations between *Climate-Contractor* at level 2 by relations in table 2-3.

Table 2-3: Correspondent concepts’ relations in level 2 of relations *Climate-Contractor* in level 1.

Level 1	Level 2	For example
<i>Climate-Contractor</i>	<i>Temperature-Building contractor</i>	High <i>Temperature</i> impacts on productivity in arranging reasonable priority construction work of <i>Building Contractor</i>
	<i>Temperature-Installing contractor</i>	Heavy rain (<i>precipitation</i>) impacts on productivity in applying technology in building of <i>Building Contractor</i>
	<i>Precipitation - Building contractor</i>	Heavy rain (<i>precipitation</i>) impacts on productivity in process of building of <i>Building Contractor</i>

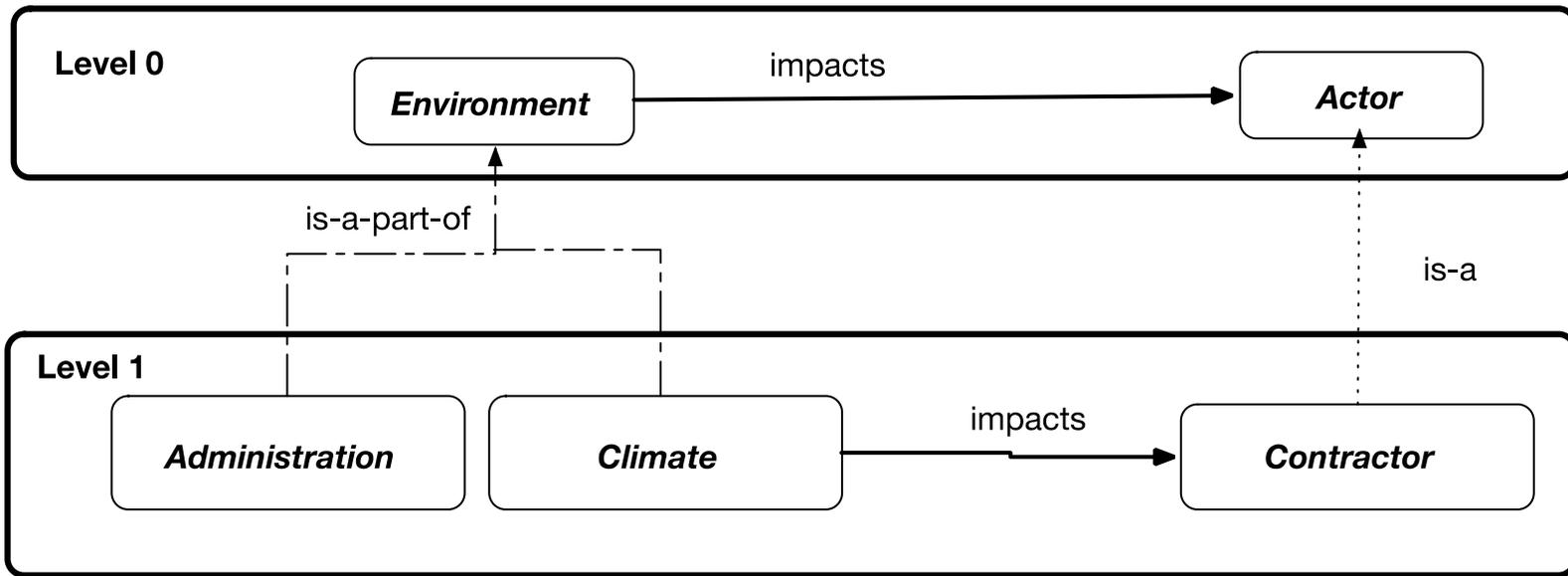


Figure 2-5: (a) Relations between Environment and Actor in level 0, (b) Inherited concepts' relations from level 0 to level 1

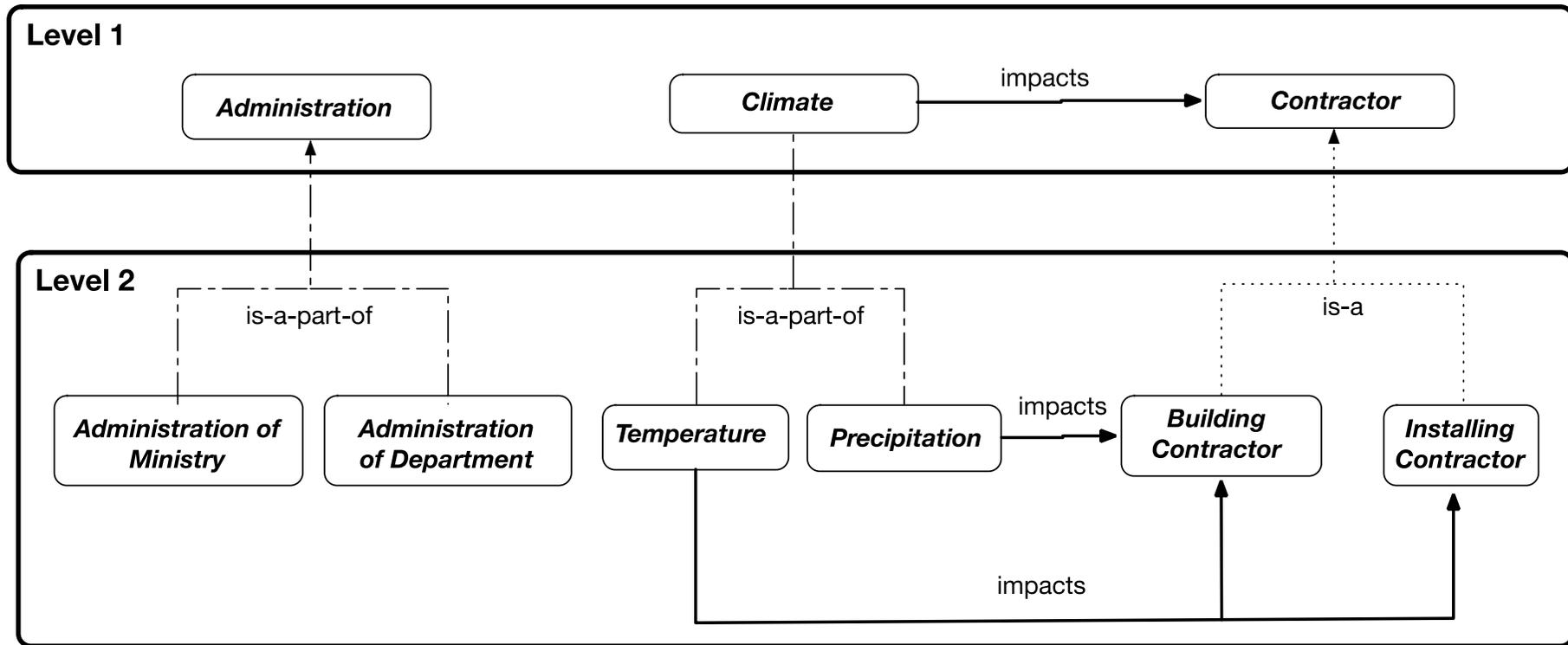


Figure 2-6 : Hierarchical ontology model describing relation between *Environment* and *Actor* of construction project at level 2 which stem from figure 2-5

2.4. Attributes

Each concept is characterized by a set of attributes (e.g. attribute *Productivity* of concept *Actor*). Attributes of concepts are sufficiently general to be suitable for all kinds of construction project (table 2-4). As concepts which are refined into meso and micro levels, attributes are also refined regarding levels.

In taxonomy relations, an attribute of the precedent level will be kept (or inherited) and be refined on all the next level. For example: attribute *Productivity* of *Actor* in level 0 will be kept and refined to *Productivity_in_building_project* of *Contractor* in level 1. In level 2, both attribute *Productivity* and *Productivity_in_building_project* of *Contractor* continues to be kept and refined into *Productivity_in_arranging_reasonable_priority_building_work* of *Building_contractor* (figure 2-7.a).

In partonomy relations, an attribute in this level will not be kept (or inherited) but still refined on the next level. For example, attribute *Aggressiveness* of *Environment* in level 0 will be refined to *Instability* of *Economy* in level 1. In level 2, attribute *Instability* continues to be refined into *Fluctuation* in *National economy* (figure 2-7.b).

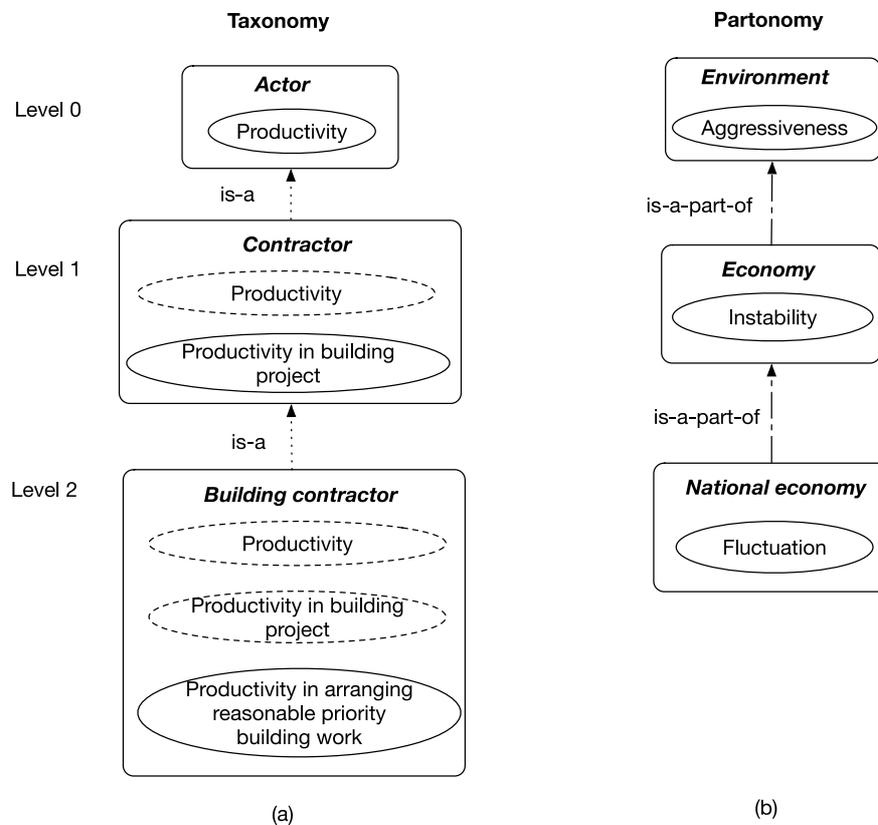


Figure 2-7: Examples of inherited attributes in taxonomy (a) and partonomy relations

(b)

Characteristics of concept's attribute are:

- Each concept has at least one attribute.
- In taxonomy relation, attribute in this level will be inherited and refined in the next level (figure 2-7.a).
- In partonomy relation, attribute in this level will not be inherited but refined in the next level (figure 2-7.b).

Table 2-4 summarizes the descriptive attributes associated with each concept described in level 0.

Table 2-4: 16 descriptive attributes of concepts in level 0.

Entity	Attribute	Definition	Reference
<i>Activity</i>	<i>Duration</i> <i>Quality</i> <i>Cost</i>	<i>Duration</i> is the time to create products. <i>Quality</i> of <i>Activity</i> can be qualitative (based on assessment of actors), or a quantitative factor (based on regulation or standards). <i>Cost</i> of <i>Activity</i> is sum of cost of resources, actors to perform activities under constraint of contracts.	(Dukić, Dukić, and Babić 2007)(Burt and Kemp 1994)(Dawood 1998)(Leu, Chen, and Yang 2001) (Khang and Myint 1999)(Chassiakos and Sakellaropoulos 2005)(H. Zhang and Xing 2010)
<i>Actor</i>	<i>Capacity</i> <i>Cost</i> <i>Productivity</i> <i>Experience</i>	<i>Capacity</i> is the ability of <i>Actor</i> in doing some activities (taking decisions, performing works, managing works, planning a project, etc.). <i>Cost</i> of <i>Actor</i> is the money to pay for their involvement. <i>Productivity</i> of an <i>Actor</i> is velocity to perform the activity. <i>Experience</i> is the cumulated knowledge and skill acquired over time.	(Lu et al. 2015)(Yang et al. 2011)(Mallawaarachchi and Senaratne 2015)(Moselhi, Gong, and El-rayes 1997)(Akinci and Fischer 1998)

<i>Contract</i>	<i>Magnitude</i> <i>Complexity</i>	<i>Magnitude</i> defines the size of the project (from a small private house to a huge civil engineering project). It can be related with the project budget. <i>Complexity</i> expresses the criticality of schedule, claims, etc. to achieve the expected outcomes of a <i>Contract</i>	(Dziadosz, Tomczyk, and Kapliński 2015)(Eggleston 2000)(Odeh and Battaineh 2001)(Babaioff 2014)(Antoniou et al. 2013)
<i>Environment</i>	<i>Aggressiveness</i>	<i>Aggressiveness</i> expresses how the <i>Environment</i> can impact other entities.	(Ofori 1992)(Marzouk and Azab 2014)(Nasir, McCabe, and Hartono 2003)
<i>Product</i>	<i>Duration</i> <i>Quality</i> <i>Cost</i>	<i>Quality of Product</i> is the synthesis of quality of activities which lead to this product. <i>Duration of Product</i> is the synthesis of duration of activities to manufacture a product. <i>Cost of Product</i> is sum of cost of activities to manufacture a product.	(Ayachit, Attarde, and Kulkarni 2014)(Tang et al. 2015)
<i>Resource</i>	<i>Quantity</i> <i>Quality</i> <i>Cost</i>	<i>Quantity</i> is the number of units of <i>Resources</i> that are required by construction activities. <i>Quality of Resource</i> is its aptitude to be used in a good way. <i>Cost of Resource</i> is the price that must be paid when the resource is used.	(Björk 1992)(Odeh and Battaineh 2001)(Sambasivan and Soon 2007)

Attributes and their definitions in level 1, 2 of *Environment* and *Actor* will be presented in table 2-5. Attributes of all concepts in level 0 and their definitions will be refined in other two levels (148 attributes in level 1 and 625 attributes in level 2) are given in Appendix 2, 3.

Negative and positive states of each attribute have different significations. For example in table 2-6, *Productivity_in_arranging_work* of *Building contractor* is negative

when it is **slower** than expectation, but *Period_duration* of *Precipitation* is negative when it is **longer** than expectation.

There are many attributes correspondent three detailed levels. In fact, in table 2-6, we just give the signification the attribute's state of some composed-concepts, sub-concepts of *Environment* and *Actor* in level 2 (*temperature, precipitation, building contractor*). All of significations of all attributes in level 2 will be showed in Appendix 9.

Level 0		Level 1			Level 2		
Concept	Attribute	Concept	Attribute	Definition	Concept	Attribute	Definition
<i>Environment</i>	<i>Aggressiveness</i>	<i>Climate</i>	Frequency	Frequency is the number of occurrences of a repeating natural event per unit time	<i>Temperature</i>	Frequency of degree	is the repetitive time of a level of degree (days, weeks, years)
					<i>Precipitation</i>	Frequency of precipitation	is the repetitive time of a level of precipitation (days, weeks, years)
			Intensity	Intensity is a property which is used to reflect level impact of natural event on entities of construction project	<i>Temperature</i>	Level of degree	is the degree of temperature (°C)
						Period duration of degree	is the duration of a level of degree
					<i>Precipitation</i>	Level of precipitation	is the level of precipitation (mm)
						Period duration of precipitation	is the duration of a level of precipitation
<i>Actor</i>	<i>Productivity</i>	<i>Contractor</i>	Productivity		<i>Building contractor</i>	Productivity	
			Productivity in arranging work	is the velocity of contractor in arranging construction work		Productivity in arranging work	
						Effective teamwork	is the effective in co-operation work of a team
						Applicating suitable software in building	is the velocity of building contractor in applicating suitable software in building
						Productivity in building project	
						Productivity in using new technology in building	is the velocity of building contractor in using new techonology in building construction project
						Productivity in	is the velocity of building contractor in

	Capacity				arranging reasonable priority building work	arranging construction work reasonably
		Capacity			Capacity	
		Capacity in arranging work	is the ability in arranging construction work		Capacity in arranging work	
		Capacity of teamwork			Capacity of teamwork	is the ability in co-operating in a team to arrange work
		Capacity in using software			Capacity in using software	is the ability in using software in arranging work
		Capacity in building project	is the ability in building construction project		Capacity in building project	
		Capacity in using new technology			Capacity in using new technology	is the ability in using technology of building project
	Cost	Flexibility in building work			Flexibility in building work	is the flexibility in solving all problem happening in process of building construction project
		Cost			Cost	
		Building cost	is the necessary cost of contractor to perform construction project		Building cost	
		Main building cost			Main building cost	is the necessary cost of building contractor to build construction project
		Cost of managing for building work			Cost of managing for building work	is the necessary cost of building contractor to manage construction work
		Serving cost for constructing	is the cost which is used to serve for constructing work of contractor		Serving cost for constructing	
		Cleaning building			Cleaning building	is the cost which is used to clean

					construction site	construction site
	Experience				Health service of building	is the cost which is used to serve health for human during the process of building construction project
		Experience			Experience	
		Experience in building project	is the cumulative addition skill of building project acquired over time		Experience in building project	
					Experience in arranging construction work	is the cumulative addition skill of arranging construction work acquired over time
					Experience in building project	is the cumulative addition skill of building main part of project acquired over time
		Past qualification assessment about building	is the statistic on the effectiveness of building projects in the past		Past qualification assessment about building	
					Qualification in arranging construction work	is the statistic on the effectiveness of arranging construction works in the past
					Qualification in building project	is the statistic on the effectiveness of building projects in the past

Table 2-5 : Definitions of some of attributes in level 1 and 2

Table 2-6: Signification negative and positive states of some attributes of *Environment* and *Actor* in level 2.

Level 2			
Concept	Attribute	Negative	Positive
<i>Temperature</i>	Frequency of degree	Likely	Unlikely
<i>Precipitation</i>	Frequency of precipitation	Likely	Unlikely
<i>Temperature</i>	Level of degree	High	Low
	Period duration of degree	Long	Short
<i>Precipitation</i>	Level of precipitation	So much	Little
	Period duration of precipitation	Long	Short
<i>Building contractor</i>	Productivity in arranging work	Slow	Fast
	Effective teamwork	Inefficient	Efficient

2.5. Relation between attributes

The model defines also relations between attributes which have to be consistent with relations between concepts. According to the notation adopted in section 1.2.3 in Chapter 1, figure 2-8 displays the relation network between the descriptive attributes in macro-level. For instance, while at this level *Resource* impacts *Activity*, this relation corresponds to the fact that *Quantity of Resource* impacts on *Duration of Activity*.

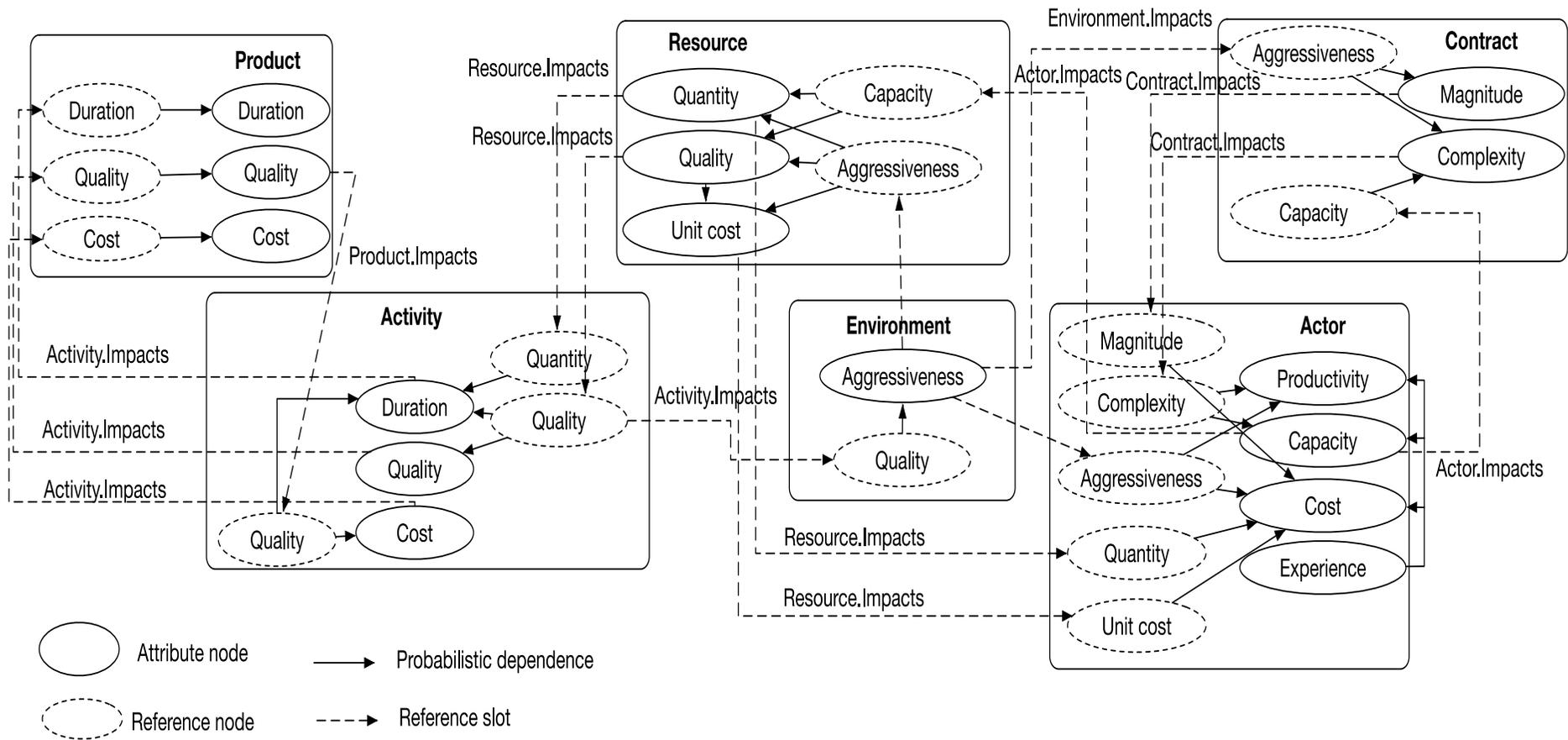


Figure 2-8 : Relation network between the descriptive attributes in macro-level

Explanation of all attributes' relations in level 0 are given in table 2-7.

Table 2-7: Relations between attributes and their example in level 0.

Order	Source attribute	Target attribute	For example
1	<i>Environment.Aggressive</i>	<i>Contract.Magnitude</i>	Dimension of the project can be reduced if inflation of economy increases
2		<i>Contract.Complexity</i>	Complex condition of climate will make the schedule be more critical
3		<i>Actor.Productivity</i>	High temperature reduces the productivity of actor
4		<i>Actor.Cost</i>	Cost of Actor increases because of inflation of economy
5		<i>Resource.Quantity</i>	High inflation of economy can reduce the requirement about quantity of resource
6		<i>Resource.Quality</i>	High humidity makes the quality of cement lower than expectation
7		<i>Resource.Cost</i>	Inflation makes cost of resource change
8	<i>Contract.Complexity</i>	<i>Actor.Productivity</i>	Criticality of schedule in the contract decides the productivity of actor
9		<i>Actor.Capacity</i>	Capacity of actor is chosen based on claims of contract
10	<i>Contract.Magnitude</i>	<i>Actor.Cost</i>	Cost of actor is decided by magnitude of contract
11	<i>Resource.Quantity</i>	<i>Actor.Cost</i>	Cost of contractor composes if quantity of resource
12		<i>Activity.Duration</i>	Lack of quantity of resource will make the duration of activity longer than expectation
13	<i>Resource.Quality</i>	<i>Activity.Duration</i>	Low quality of resource will make the duration of activity longer because of repairing failures
14		<i>Activity.Quality</i>	Quality of activity is decided by quality of resource
15		<i>Resource.UnitCost</i>	The better quality, the higher unit cost of resource
16	<i>Resource.UnitCost</i>	<i>Actor.Cost</i>	Cost of Contractor is composed of unit cost of resource
17	<i>Actor.Productivity</i>	<i>Activity.Duration</i>	Productivity of actor decides duration of activity
18	<i>Actor.Capacity</i>	<i>Activity.Duration</i>	Capacity of contractor decides duration of

			activity
19		<i>Resource.Quantity</i>	Capacity in calculating of contractor decides the quantity of resource
20		<i>Resource.Quality</i>	Capacity in managing of contractor decides the quality of resource
21		<i>Contract.Complexity</i>	Capacity in drafting contract of contractor decides the complexity of contract
22	<i>Actor.Cost</i>	<i>Activity.Cost</i>	Cost of activity is composed of cost of actor
23	<i>Actor.Experience</i>	<i>Actor.Productivity</i>	Experience decides the productivity of contractor
24		<i>Actor.Capacity</i>	Experience decides the capacity of contractor
25	<i>Activity.Duration</i>	<i>Product.Duration</i>	Duration of activity decides the duration of product
26	<i>Activity.Quality</i>	<i>Product.Quality</i>	Quality of activity decides the quality of product
27	<i>Activity.Cost</i>	<i>Product.Cost</i>	Cost of activity decides the cost of product
28	<i>Product.Quality</i>	<i>Activity.Duration</i>	If quality of precedent product is bad, duration of next activity will be longer because of repairing failures
29		<i>Activity.Cost</i>	If quality of precedent product is bad, cost of next activity will be higher because of repairing failures

These 29 relations between attributes at macro-level are refined in the sub-levels; it results in 283 attributes' relations in meso-level and 1489 attributes' relations in micro-level. These relations are provided in Appendix 7 and 8. They constitute the model which is assumed to be valid for all types of construction projects.

In order to illustrate the inheritance of attributes' relations from level 0 to level 2, table 2-8 exposes the examples of relations between *Actor.Cost* and *Activity.Cost*.

Table 2-8 : Inheritance relations between *Actor.Cost* and *Activity.Cost* from level 0 to level 2

Level 0		Level 1		Level 2	
Source attribute	Target attribute	Source attribute	Target attribute	Source attribute	Target attribute
Actor.Cost	Activity.Cost	Owner.Variable_Cost	Activity_of_feasibility_phase.Cost_to_perform_work	Owner.Variable_cost_in_building	Field_work.Cost_of_survey
			Activity_of_feasibility_phase.Cost_to_adjust_work		Field_work.Cost_of_experimenting
					Field_work.Cost_of_re-survey
					Field_work.Cost_of_re-experimenting
		Contractor.Building_Cost	Activity_of_implementation_phase.Cost_to_build	Building_Contractor.Main_Building_Cost	Construction.Cost_To_Arrange_Construction_Work
				Building_Contractor.Cost_Of_Managing_Building_Work	Construction.Cost_To_Arrange_Construction_Work
			Activity_of_operation_phase.Cost_to_repair_errors	Building_Contractor.Main_Building_Cost	Performance_Of_Maintain_Work.Cost_Of_Repairing_Errors
		Contractor.Serving_Cost	Activity_of_operation_phase.Cost_to_maintain	Building_Contractor.Cleaning_Construction_Site	Performance_Of_Maintain_Work.Cost_of_Preparing_To_Repair_Errors
			Activity_of_operation_phase.Cost_to_repair_errors	Building_Contractor.Cleaning_Construction_Site	Performance_Of_Maintain_Work.Cost_Of_Repairing_Failures

2.6. Conclusion

In this chapter, we developed a holistic generic model in three detailed levels which can model any type of construction project. This model consists of concepts, concepts' relations, attributes, attributes's relations and their signification.

These concepts are sufficient to cover most construction projects. However, the model structure allows the project manager to add new concepts for a specific kind of project (for instance, tunnel project, dam project, etc.).

In the next chapter, based on this model, we will apply mathematical methods to simulate the propagation of risks and behaviour of construction project when attributes' states change.

Chapter 3

From Ontological model to PRM for construction project

Contents

- 3.1. Introduction
 - 3.2. Calculation method in PRM of construction project
 - 3.2.1. Defining the scales of attributes' value
 - 3.2.2. A priori probability
 - 3.2.3. Conditional probability tables (CPTs)
 - 3.2.4. Aggregation operator
 - 3.2.5. V-structure transformation
 - 3.3. Implementation
 - 3.3.1. Implementation of the PRM via O3PRM
 - 3.3.2. Optimization strategies
 - 3.3.2.1 Calculation time
 - 3.3.2.2 Optimization strategy to solve time calculation problem
 - 3.3.3. Accelerating model inference using Clustering computing
 - 3.4. Conclusion
-

3.1. Introduction

In the previous chapter, we developed a holistic model for construction project risk management in three levels of detail (model entities with their attributes and the semantic relations between them). Ontology describes how concepts are defined and related but is not capable alone of simulating the behaviour of the system. In this chapter, we introduce a dedicated framework of probabilistic relational model (PRM) to address this problem. PRM allows to model relations between attributes as probabilistic dependencies and to propagate uncertainty over this network. More particularly, by using PRM, we will be able of:

- taking into account uncertainty,
- and simulating the construction problem by propagating the uncertainties.

In order to apply mathematical formalism in an ontological model which was developed in Chapter 2, in this chapter, we will define how to evaluate attributes, define probabilistic dependency relationships between attributes via CPTs, aggregation rules and implement the developed generic model.

Once the PRM defined, the O3PRM language will be used as a supporting tool for programming developments. This software will be run on the university cluster computing infrastructure, so we can get the results automatically after having specified all relations mathematical coefficients and data values.

3.2. Calculation method in PRM of construction project

3.2.1. Defining the scales of attributes' value

The PRM model is based on the ontological model exposed in Chapter 2. It adds assessment of attributes and attributes' relations. In our model, all attributes are assessed according to a common discrete qualitative 7-level Likert scale:

$$V(C.A) = \{SSN, SN, N, E, P, SP, SSP\}$$

where each of the seven possible values correspond to a comparison with expectation. The "E" value corresponds to the expected (central or neutral) behaviour of system. For instance, a value of "E" on the attribute *Product.Cost* means that this product was delivered with the expected cost. The scale is ordered from "Strong Strong Negative" (SSN), which means that the attribute is very strongly worse than expected, to "Strong Strong Positive" (SSP), which means that the attribute is very strongly better than expected. The notion of negative and

positive has to be understood in the point of view of the project manager; for instance, a delay or an over cost are modelled as negative whereas a resource less expensive than expected or an unusual nice weather are modelled as positive.

3.2.2. A priori probability

In PRM, we assume that most of the attribute values of the system is not perfectly known. The lack of knowledge, i.e. the uncertainties, is modelled by a probability distribution. The probability distribution of any attribute depends on the relation network and more precisely on the distributions of all its parent attributes; parent attributes of an attribute X correspond to all attributes which have an impact on X. Some attributes may have no parent (e.g. attributes A1, A2 in figure 3-1). In this case, we have to define a priori probability distribution which expresses our beliefs about these attributes before getting any data or evidence to estimate them.

A reasonable approach to define a priori probability distribution is to assume symmetric distribution centered on the expected (central) behaviour of system without excluding the possibility of extreme favourable or unfavourable values like SSN and SSP, i.e. $P(.) = \{0.05, 0.1, 0.15, 0.4, 0.15, 0.1, 0.05\}$ (figure 3-2).

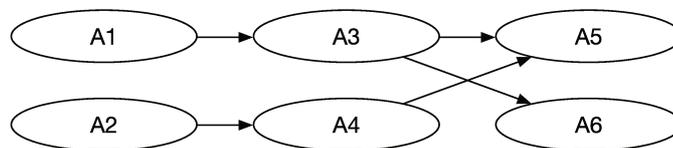


Figure 3-1: Simple example of attribute without parent A1, A2.

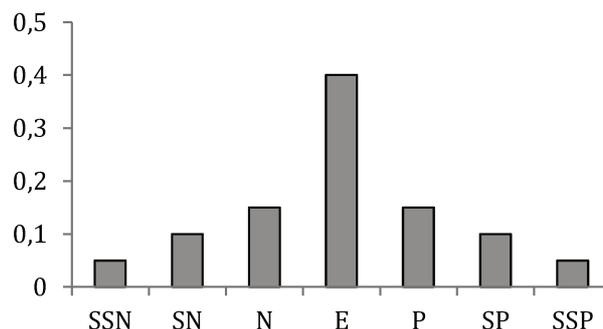


Figure 3-2 : An example of priori probability P(A1), P(A2).

3.2.3. Conditional probability tables (CPTs)

In a PRM, all the relations between attributes are considered as probabilistic dependencies formalized by conditional probability tables (CPTs). Each CPT indicates the

influence of one or several attributes on another one, formalized in a probabilistic framework. For instance, Table 3-1 provides the CPT which models the relation from *Activity.Cost* to *Product.Cost*.

Table 3-1: Examples of a CPT which model the relation between *Activity.Cost* and *Product.Cost*

		<i>Product.Cost</i> (output)							
		Value	SSN	SN	N	E	P	SP	SSP
<i>Activity.Cost</i> (input)	SSN	0.500	0.417	0.069	0.012	0.002	0.000	0.000	
	SN	0.400	0.500	0.083	0.014	0.02	0.000	0.000	
	N	0.057	0.343	0.500	0.083	0.014	0.002	0.000	
	E	0.009	0.056	0.335	0.500	0.084	0.014	0.002	
	P	0.002	0.009	0.056	0.334	0.500	0.086	0.014	
	SP	0.000	0.002	0.009	0.056	0.333	0.500	0.100	
	SSP	0.000	0.000	0.002	0.012	0.069	0.417	0.500	

The information contained conditional probability tables (CPTs) expresses the experts' judgement or their beliefs about the relation between attributes. In PRMs, the conditional probability tables (CPTs) are generic in the process of analysing a real project.

In order to make the knowledge elicitation easier, we define two kinds of CPT respectively named **consistent** and **antagonist** CPTs. Consistent CPT means that the input and output values are positively correlated, while they are negatively correlated for antagonist CPT. Generic CPT can be built with a very limited number of "shape parameters", as illustrated respectively in table 3-2 (resp. table 3-3) for Consistent (resp. Antagonist) CPT, where the CPT are fully determined with only three parameters, where:

- a is the amplitude of the term on the diagonal ($0.5 \leq a \leq 1$),
- r corresponds to the off-diagonal decrease rate ($r > 1$),
- β corresponds to the balance between optimistic and pessimist statement ($0 \leq \beta \leq 1$).

where $P = \frac{(1-a) \cdot (1-r)^n}{(1-r^n)}$ with ($n \in \mathbb{Z}^+$, $n = [1, 5]$).

Thus, by simply changing the values of the three shape parameters (a, β , r), the values in all cells of consistent and antagonist tables are modified accordingly, enabling to describe a variety of dependencies.

Table 3-2: Consistent pre-designed CPT

		Output variable							
		SSN	SN	N	E	P	SP	SSP	Sum
Input variable	SSN	a	$r^5.P$	$r^4.P$	$r^3.P$	$r^2.P$	r.P	P	1
	SN	$P.(1-\beta)$	a	$r^4.P.\beta$	$r^3.P.\beta$	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	N	$P.(1-\beta)$	$r.P (1-\beta)$	a	$r^3.P.\beta$	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	E	$P.(1-\beta)$	$r.P (1-\beta)$	$r^2.P (1-\beta)$	a	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	P	$P.(1-\beta)$	$r.P (1-\beta)$	$r^2.P (1-\beta)$	$r^3.P (1-\beta)$	a	$r.P.\beta$	$P.\beta$	1
	SP	$P.(1-\beta)$	$r.P (1-\beta)$	$r^2.P (1-\beta)$	$r^3.P (1-\beta)$	$r^4.P (1-\beta)$	a	$P.\beta$	1
	SSP	P	r.P	$r^2.P$	$r^3.P$	$r^4.P$	$r^5.P$	a	1

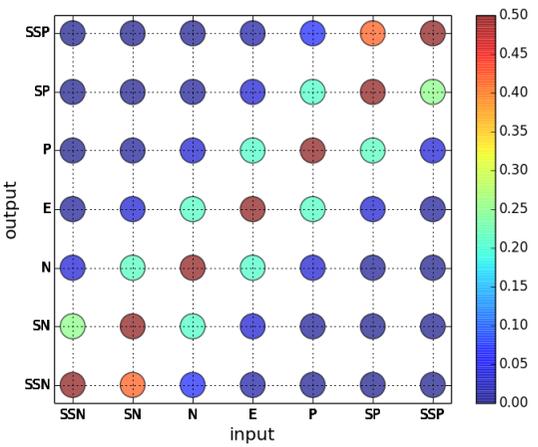
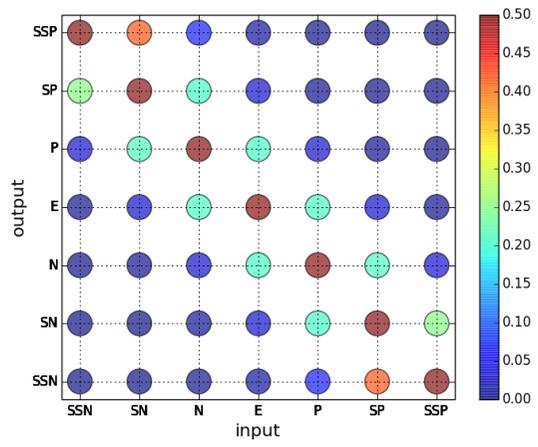
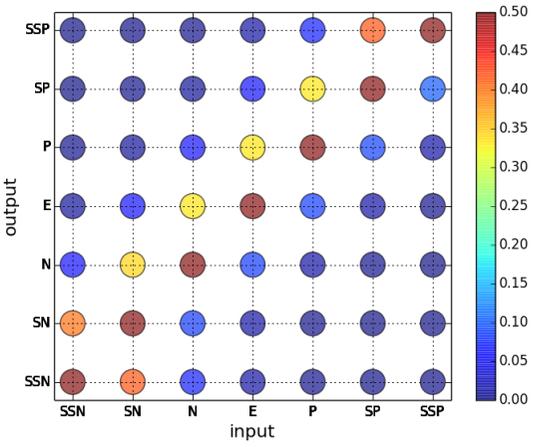
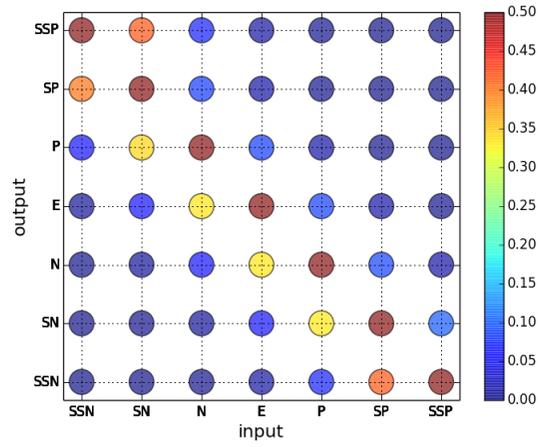
Table 3-3 : Antagonist pre-designed CPT

		Output variable							
		SSN	SN	N	E	P	SP	SSP	Sum
Input variable	SSN	P	r.P	$r^2.P$	$r^3.P$	$r^4.P$	$r^5.P$	a	1
	SN	$P.(1-\beta)$	$r.P.(1-\beta)$	$r^2.P.(1-\beta)$	$r^3.P.(1-\beta)$	$r^4.P.(1-\beta)$	a	$P.\beta$	1
	N	$P.(1-\beta)$	$r.P.(1-\beta)$	$r^2.P.(1-\beta)$	$r^3.P.(1-\beta)$	a	$r.P.\beta$	$P.\beta$	1
	E	$P.(1-\beta)$	$r.P.(1-\beta)$	$r^2.P.(1-\beta)$	a	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	P	$P.(1-\beta)$	$r.P.(1-\beta)$	a	$r^3.P.\beta$	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	SP	$P.(1-\beta)$	a	$r^4.P.\beta$	$r^3.P.\beta$	$r^2.P.\beta$	$r.P.\beta$	$P.\beta$	1
	SSP	a	$r^5.P$	$r^4.P$	$r^3.P$	$r^2.P$	r.P	P	1

Based on this parameter approach and in order to facilitate the elicitation work, we build a set of pre-defined tables. For both consistent and antagonistic CPT, we have chosen to consider four specific sets of (a, β , r) values which correspond to four main tendencies, respectively named neutral, pessimistic, optimistic, and identity. The characteristics of these eight (2 x 4) default matrices are illustrated on Table 3-4 and the respective values of (a, β , r) sets are summarized in the following:

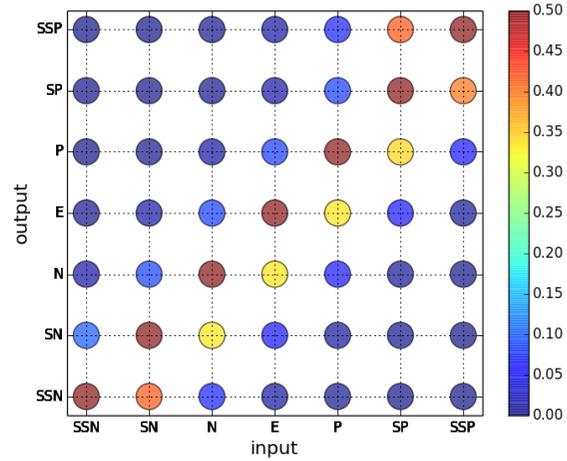
- Type 1 (Type 5): Neutral ($0.5 \leq a < 1$; $\beta = 0.5$; $r > 1$).
- Type 2 (Type 6): Pessimistic ($0.5 \leq a < 1$; $0 \leq \beta < 0.5$; $r > 1$).
- Type 3 (Type 7): Optimistic ($0.5 \leq a < 1$; $0.5 < \beta \leq 1$; $r > 1$).
- Type 4 (Type 8): Identity ($a=1$; $0 \leq \beta \leq 1$; $r > 1$).

Table 3-4 : Characteristics of eight default matrices.

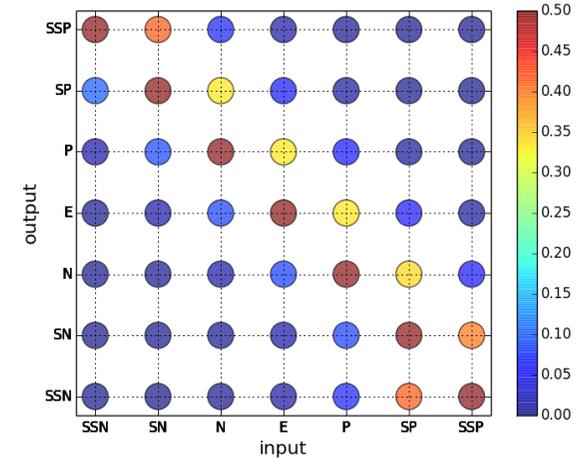
	Consistent pre-designed CPT	Antagonist pre-designed CPT
<p>Neutral</p> <p>Probabilities of output when it is more negative (N) and more positive (P) than parameter “a” are equal.</p>	 <p>Type 1 ($a=0.5 ; \beta = 0.5 ; r=6$)</p>	 <p>Type 5 ($a=0.5 ; \beta = 0.5 ; r=6$)</p>
<p>Pessimistic</p> <p>Symmetry through parametre “a”, probabilities of output when it is negative (N) is always larger than positive (P).</p>	 <p>Type 2 ($a=0.5 ; \beta = 0.2 ; r=6$)</p>	 <p>Type 6 ($a=0.5 ; \beta = 0.2 ; r=6$)</p>

Optimistic

Symmetry through parametre “a”, probabilities of output when it is negative (N) is always less than positive (P).



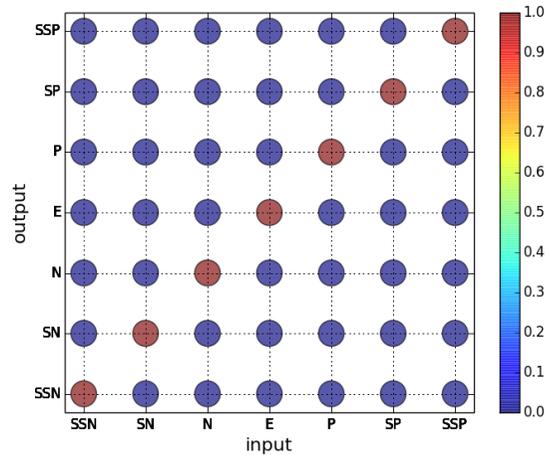
Type 3 ($a=0.5$; $\beta = 0.8$; $r=6$)



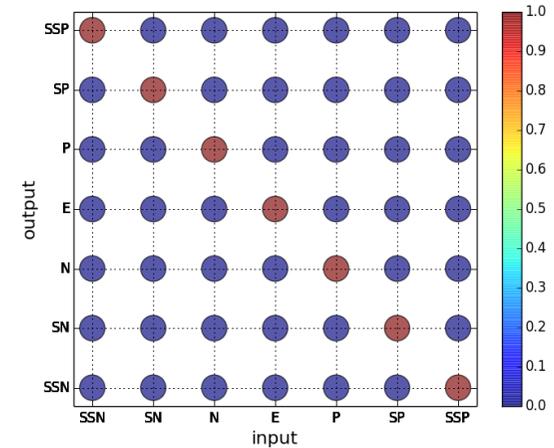
Type 7 ($a=0.5$; $\beta = 0.8$; $r=6$)

Identity

Probabilities of output when it is equal parametre “a” are always 1.



Type 4 ($a=1$, $\beta=1$; $r=1$)



Type 8 ($a=1$, $\beta=1$; $r=1$)

A major issue of the model consists in modelling probabilities dependencies between attributes by defining the corresponding CPT. In the simplify approach we choose, one CPT among the eight pre-built on the basis of expert knowledge, for each attribute relation. According to the PRM paradigm, this CPT is independent on the project considered and depends only on the relations between attributes. However, this approach allows the project manager to redefine relation for a specific project, but the model (including CPT) must be as generic as possible and the redefinition of CPT must stay an exception; modify too often the CPT can indicates a default in the model structure.

Based on literature and on our own expertise, we choose for each level and each attribute the CPT which appeared to us as the more relevant. This choice should be consolidated by other experts and/or by feedback on real projects, but we assume that the current CPT choice is sufficient, in a first step, to highlight the interest of the approach.

3.2.4. Aggregation operator

Aggregation operator is a function that enables to derive the distribution probability of an attribute from those of a set of identical attributes. For example, figure 3-3 shows how the *Duration of Activity* Act_i depends on the *Capacity* of a number n of *Actor(s)*; the *Capacity* of the n *Actor(s)* will be aggregated in order to assess its impact on the *Duration* of the *Activity* that they perform together. According to section 1.2.3 in the first chapter, the reference aggregate node (represented by dashed nodes on the figure 3-3) appears when the attribute of an instance $c'.A$ (i.e. $Act_i.Duration$), $c' \in I(C')$ with $I(C')=\{Act_i\}$ depends on a set of instances $c.R.B=\{c_1.B, \dots, c_n.B\}$ (i.e. $Actor.Realizes.Capacity=\{A_1.Capacity, \dots, A_n.Capacity\}$), $c_i \in I(C)$ with $I(C)=\{A_i\}$, $(c', c_i) \in R$, leading to estimate firstly the reference aggregate dashed node $\gamma(c_1.B, \dots, c_n.B)$ for the probability distribution $P(c'.A | \gamma(c_1.B, \dots, c_n.B))$. For instance, in figure 3-3, the probability distribution to be estimated is $P(Act_i.Duration | \gamma(A_1.Capacity, \dots, A_n.Capacity))$ with the aggregate node $\gamma(A_1.Capacity, \dots, A_n.Capacity)$ represented by the dashed node *Capacity*. In the following of this section, we have decided to associate the aggregator node $\gamma(c_1.B, \dots, c_n.B)$ with a normal probability distribution⁶ with mean m and standard deviation σ :

$$(m, \sigma) = (1/n \sum_i c_i.B, (1/(n-1) \sum_i (c_i.B - \overline{c.B})^2))$$

⁶ For example : normal probability distribution $P(Act.Duration | A_1.Capacity, A_2.Capacity, A_3.Capacity) = [0.02, 0.08, 0.18, 0.26, 0.25, 0.15, 0.06]$ when *Act.Duration* is impacted by $A_1.Capacity, A_2.Capacity, A_3.Capacity$ with their values are -1, 0, 2 respectively.

where $\bar{c} \cdot \bar{B} = 1/n \sum_i c_i \cdot B$.

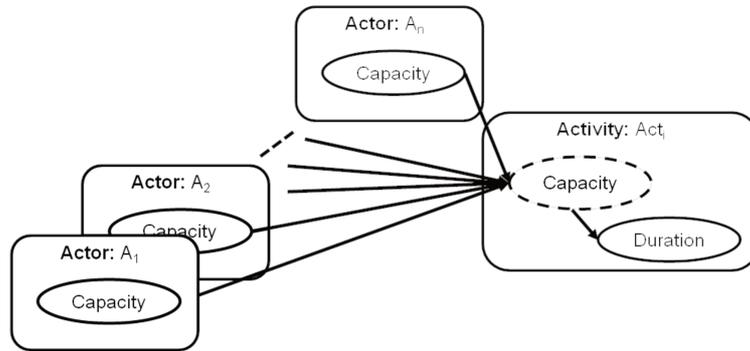


Figure 3-3: A sample of n Actor realizing the Activity Act_1 of Act_i

3.2.5. V-structure transformation

V-structure transformation is a function enabling to compute the probability distribution of an attribute from a set of heterogeneous (i.e. non identical) attributes. For example : *Actor.Cost* depends on *Actor.Capacity*, *Actor.Productivity*, and *Resource.Cost*.

Normally, in the PRM (or Bayesian network) theory, it would imply to build a CPT considering all the parent attributes. For example, in figure 3-4, node Y has n parents, so, thus the dimension of CPTs of Y is 7×7^n . The dimension of a CPT corresponding to convergent connexions exponentially increases with the number of parents which leads to a real practical difficulty to estimate the probability or to elicit the beliefs of experts. To avoid combinatorial explosion, intermediate nodes $(Y_i)_i$ are introduced between X_i and Y in all convergent connexions $\{X_1, \dots, X_n\} \rightarrow Y$ (known as V-structure) such that the aggregation is decomposed into two steps (figure 3-5):

(a) at the first step, $\{X_1 \rightarrow Y_1\}, \dots, \{X_n \rightarrow Y_n\}$

(b) at the second step, Y is associated with a normal probability distribution with parameters $(1/n \sum_i Y_i, (1/n - 1) \sum_i (Y_i - \bar{Y})^2)$ where $\bar{Y} = 1/n \sum_i Y_i$.

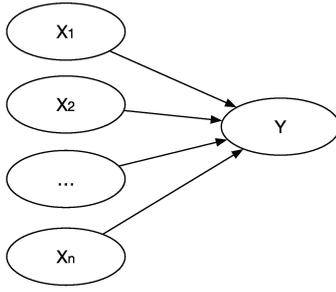


Figure 3-4 : Convergent connexion of node

Y

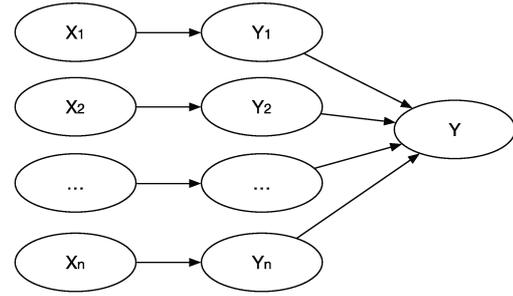


Figure 3-5 : V-structure

This transformation assumes that there is no mutual effect of X_i on Y . Thus, these intermediate nodes do not appear in figure 3-4 for the sake of clarity. For example, figure 3-6.a displays the convergent connexion $\{Actor.Capacity, Actor.Productivity, Resource.Cost\} \rightarrow Actor.Cost$ and figure 3-6.b, the modified V-structure where $Actor.Cost$ is associated with the normal probability distribution with parameters $(\overline{A.Cost}, \text{std}(A.Cost))$ where $\overline{A.Cost}$ (resp. $\text{std}(A.Cost)$) corresponds to the mean (resp. the standard deviation) of the random variables $(Actor.Cost_i)_i$.

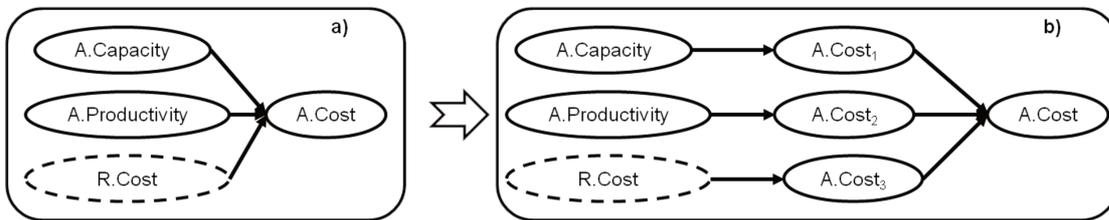


Figure 3-6 : V-structure versus Transformed V-structure where A (resp. R) correspond to Actor (resp. Resource)

3.3. Implementation

In order to implement the model in a tool able to integrate the knowledge base and to perform the probability calculation, we used O3PRM (**O**pen **O**bject-**O**riented **P**robabilistic **R**elational **M**odel), a domain language dedicated to the modelling of PRM (Torti et al. 2013). O3PRM is interfaced with the aGrUM (C++) (Gonzales, Torti, and Wullemmin 2017) and pyaGrUM libraries, which provides a set of functions enabling to perform the Bayesian inferences (Benferhat, Eds, and Goebel 2017).

In the next section (3.3.1), we will introduce how to use this program to calculate the results. Time calculation and strategy to solve some problems in the process of calculating

will be discussed in section 3.3.2. While the complexity of relations increases and exceeds the ability of a PC, using the computing cluster of Bordeaux University helped us to solve all the problems that we have studied.

3.3.1. Implementation of the Construction Project PRM via O3PRM

O3PRM distinguishes the generic model from the instance; it enables to apply the same generic model to different instances (i.e. case study). The O3PRM code contains four parts (figure 3-7).

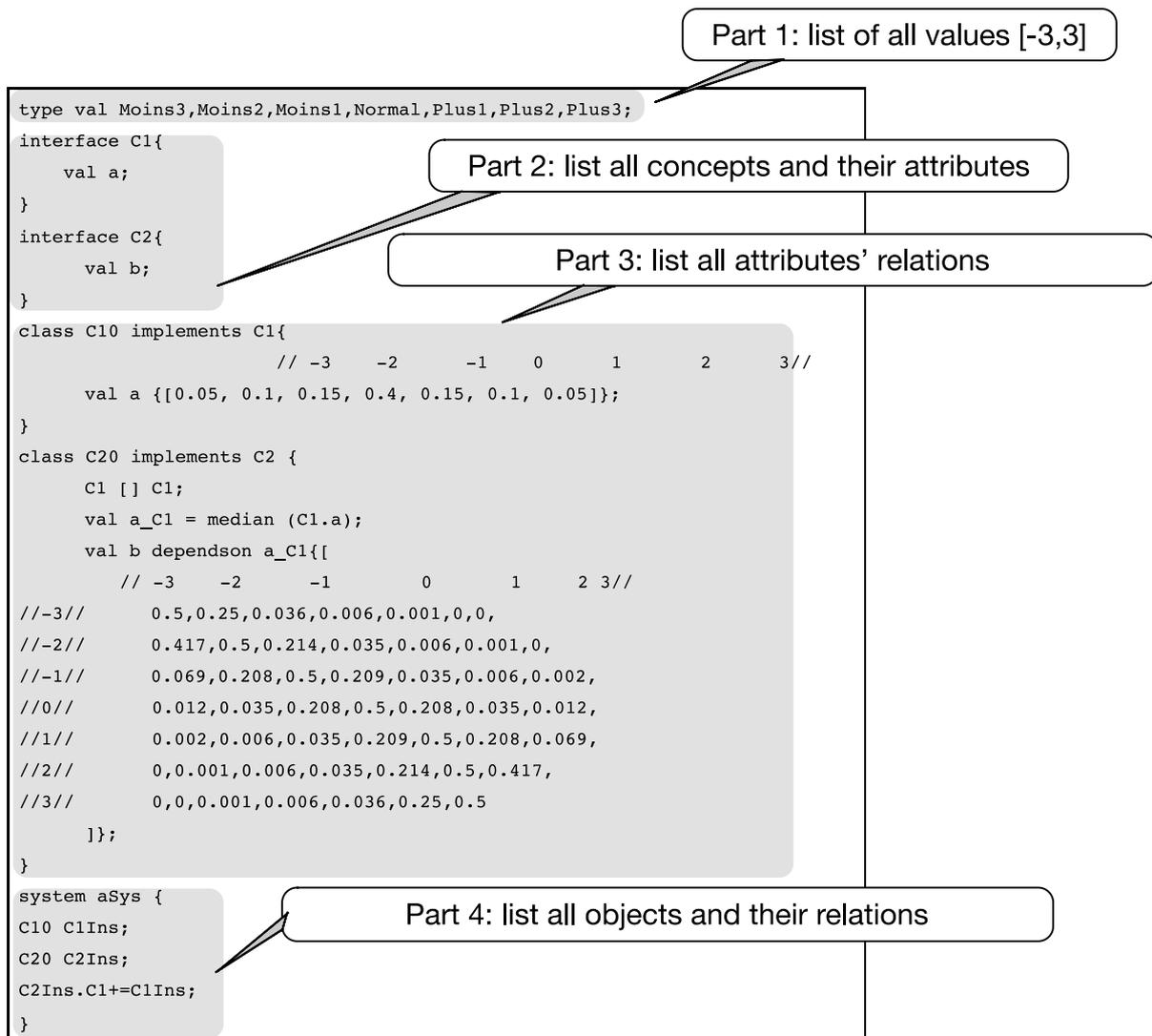


Figure 3-7 : Four main parts of code

Generally, codes are divided into 4 main parts:

- **Part 1:** the user declares the different possible values of attributes (here, SSN, SN, N...).
- **Part 2:** the user declares entities and their attributes; O3PRM being an oriented-object

language, it integrates the notion of inheritance.

- **Part 3:** the user declares the entities and attributes' relations. The CPT are declared in this part, so as prior probabilities.
- **Part 4:** the user declares the instances and their relations.

The parts 1 to 3 correspond to the definition of the generic model; these parts do not vary according to the case study. At the opposite, the part 4 corresponds to the instantiation of the model; this part formalizes the case study.

In addition, the user can specify input and output data. Input data are those which are known by the user; for instance, it may be the skill of a stakeholder. These input data are given in a probability distribution format; obviously, the distribution can be reduced to only one value with a probability of 100% if the uncertainty on it is null. Output data correspond to data that the user wants to observe; for instance, it could be for instance the cost of an activity. A strong interest of the PRM is the possibility to set any value as input and output; for instance, if we want to analyse a project from its result, the final project delay and cost can be defined as inputs and for example the skill of an actor the output. The Bayesian inference does not require to follow chronological order or cause/consequence chain; the inference propagates uncertainties in every direction.

Finally, the user must specify the calculation mode (exact or approximate), method and ending condition in case of approximate calculation (approximate inference). This choice will impact the accuracy of the results and the delay to perform the calculation. The next part will develop this point.

3.3.2. Optimization strategies

3.3.2.1. Calculation time

The generic model contains three levels of description (macro, meso and micro). Its implementation is divided into 3 models: model of just level 0 (macro), model covering level 1 and level 0 (macro-meso), model covering level 2, level 1 and level 0 (meso-micro-macro). Of course, calculation time of macro model is the shortest and meso-micro-macro model is the longest. Most of all, calculation time depends on the complexity of attributes' relations, the number of instances and their relations and the number of scenarios which are given by user. Calculation time vary from some minutes to many days, weeks, etc. So, if one wants to keep the calculation time into reasonable limits, we must have a strategy to reduce the calculation time of the model.

3.3.2.2. Optimization strategy to solve time calculation problem

As mentioned in the previous part, the calculation time depends on: (a) the number of instance, (b) the number of scenario and (c) the number of relation. The two first points (a & b) are given by user, and are basic requirements derived from project; they cannot be reduced or simplified. The last point (c) is the more critical; indeed, the calculation time increase exponentially according to the maximum number of parent attributes of the different attributes.

Hence, in order to reduce calculation time, we simplify attributes' relations structure, i.e. changing them so that an attribute does no longer depend on many other attributes. When one attribute has many parent attributes, we keep only relations have the strongest influences. For example, if an attribute depends on about 10 other attributes (dimension of CPT is 7×7^{10}), the computational time is much longer than when it depends on about 4 or 5 other attributes.

3.3.3. Accelerating model inference using Clustering computing

Although the implementation strategies exposed in the previous part, the calculation time may remain important for complex project (i.e. project with many entities and relations). A solution to obtain calculation results in a reasonable time is the use of a calculation cluster. A clustering calculation system consists of a set of connected computers (independent servers) that work together in a parallel and distributed manner.

At University of Bordeaux (France), a clustering calculation system named Avakas exists. It is freely available to all researchers and students of this university. In our work, we used Avakas to distribute our experiments between several nodes.

With 3 types of model: model level 0, model covering levels 0 and 1, model covering levels 0 and 1 and 2, we can run them independently on the cluster. All the calculation for the case studies, which will be presented in the next chapter, were performed with Avakas.

3.4. Conclusion

In this chapter, from the generic model of construction project described in chapter 2, we built a PRM in order to simulate the uncertainties propagation in construction project. In this model, each relation between attribute is formalized as probability dependencies. To complete the model, we proposed a priori probability, set of CPTs, aggregation operator and V-structure transformer.

The model was implemented with the O3PRM language making the simulation tool operational. It allow the user to describe its construction project, to assess the impact of

uncertainties on the project objectives (delay, cost and quality) and to test different scenario or alternative strategy in order to establish her/his risk management strategy.

In order to illustrate the functioning of the proposed approach and to highlight our interest, in the next chapter, we will instantiate the model according to two real construction projects and simulate the uncertainty propagation in order to analyse their risks.

Chapter 4

Application in case studies

Contents

- 4.1. Introduction
 - 4.2. Case study 1 application (Road and bridge project 2BS)
 - 4.2.1. Project presentation
 - 4.2.1.1. Environment of project 2BS (instances of Environment in level 2)
 - 4.2.1.2. Actor of project 2BS
 - 4.2.1.3. Contracts in project 2BS
 - 4.2.1.4. Activities in project 2BS
 - 4.2.1.5. Resources in project 2BS
 - 4.2.1.6. Products of project 2BS
 - 4.2.2. Instantiated model (skeleton)
 - 4.2.3. Results and discussion
 - 4.2.3.1. Sensitivity analysis of the *Building_project2BS* in some governing factors
 - 4.2.3.2. Sensitivity analysis of the *PIP2BS_Building.Duration* regarding different scenarios correspondent with priori attributes in level 1
 - 4.2.3.3. Simulation of the influence of some real-time decision during the project in macro level (level 0)
 - 4.2.3.4. Analysing of the *Building.Duration2BS* regarding different scenarios correspondent with level 1 and 2.
 - 4.3. Case study 2 application (nursing training institute)
 - 4.3.1. Project presentation
 - 4.3.2. Instances of project NTI (instances of project NTI in level 2)
 - 4.3.3. Instantiated model (skeleton)
 - 4.3.4. Results and discussion
 - 4.3.4.1. Simulation of the influence of some real-time decision in the macro-meso model
 - 4.3.4.2. Analysing the consistency of product of project NTI between the three levels
 - 4.4. Results and discussion
-

4.1. Introduction

In this chapter, we will illustrate the interest of our approach, and in particular of the proposed PRM, to analyse the propagation of uncertainties in real construction project. We propose two different case studies in order to demonstrate the capacity of the model to deal with real projects and to simulate their behaviour facing uncertainty, at different detailed levels of description. The first project is a bridge project in Hue city (Vietnam). The second project consists in the construction of a nursing training institute located in the South-West of France. On both projects, we will illustrate the sensibility of model when scenario changes and show how, when the specific model is implemented in O3PRM language that allows us to code PRMs and then by using the pyAgrum libraries to make approximate inferences, the simulation results can inform the project risk manager about the project development and help him/her for a better risk control.

For each of these two projects, we will instantiate the generic model in order to formalize them. Thus, we will analyse the project results which are based on different scenarios; scenario followed by the real project and different what-if scenarios.

4.2. Case study 1 application (Road and bridge project 2BS)

4.2.1. Project presentation

The 2BS project is located near Huong river. Before the starting of the project, it existed an old road and bridge (named Lich Doi) (figure 4-1) which was built 17 years ago. Because of its degradation and the increasing demands in transportation, the construction and renovation project 2BS was performed in 2013.

Based on preliminary studies, the cost of project was estimated to more than 6 billion Vietnam dongs (VND) ($\approx \text{€ } 242\,000$). Project 2BS was planned to be performed in 10 months, but because of a series of negative events (negative from the point of view of the project) which happened during its development (minimum salary of worker increased, a flood occurred, etc.), project 2BS last two months (*i.e.* 20%) more than planned and the cost was increased by more than 0,5 billion VND ($\approx \text{€ } 19\,700$, *i.e.* 8%).

Despite its limited size, this project appears to be a good case-study for a first practical application of the modelling approach. The considerations developed in the next section are a matter of expertise. To apply the model, for each real project, the characteristics of the project and of its environment must be checked and analyzed by experts (engineers, project manage, etc.) having enough experience in order to know how the model can be specified in the

particular context of this project. This work has been carefully carried out by reviewing all information we could get about the project and, since this project was closed, how it had developed. Instances of a project can be taken from many sources: detailed level (macro, miso, and micro level), type of relation (taxonomy, partonomy), and source of data (table 4-1).

Table 4-1: Sources of instance’s information and chosen instances.

Sources of instances’ information			Chosen instances
Detailed level	Type of entity’s relation between detailed levels	Source of data	
Macro, miso, micro level	Taxonomy, partonomy	Information of real project (survey data, contract, etc.)	by people who analyse project directly (i.e. user, project manager, experts, etc)

From sources of instance’s information to the desired outputs, we go through four main steps:

- Step 1: Depending on the level of information available and the desired fineness of analysis, the user (i.e. project manager, experts, etc.) chooses the level of detail.
- Step 2: From the entities of the generic model, it creates the instances that correspond to its real project.
- Step 3: Specifying the relations between instances
- Step 4: Indicating the observations of scenario
- Step 5: Giving the desired outputs.



Figure 4-1: Viewpoint of project through satellite.

4.2.1.1. Environment of project 2BS (instances of Environment in level 2)

In the process of building process (2013), there are some negative impacts which effect to construction project 2BS: salary of workers and cost of resources increased, inflation of economy. Moreover, waiting time to do administrative procedure (e.g. obtain a building permit) impacts the duration of project. Lastly, climate (i.e. temperature, storm, etc.) can decrease the productivity of workers and then increase the duration of construction project.

Although Environment is composed of many instances, for the model instantiation regarding the project 2BS, three instances of Environment, which mainly impact the project, were defined: economy, administration and climate.

In fact, this project is already finished, and we know precisely all the events that occurred during the project and its result. The choice of the entity was partly guide by this knowledge, but in a new project without a priori knowledge, more instances of Environment should be chosen.

4.2.1.2. Actor of project 2BS

The project 2BS has involved 9 actors:

- The Owner is Unit of Investment and Transport Construction Thua Thien Hue (UITC) (a

state agency) which gave funds for the project.

- The Designer is Joint stock company Consultant about Design Transport Thua Thien Hue (CDT). In 2BS, it worked as designers from feasibility phase to implementation phase.

- There are three Contractors in this project:

- Joint stock company Road Management and Construction Thua Thien Hue (RMC) which had a 24-year experience in road, bridge, and civil construction. In project 2BS, it participated in phase of implementation (road Ton That Tung and bridge Lich Doi construction) with its resources (machines, human, some materials).

- Joint stock company Roaild 1 TT Hue (R1) which was established in 2009. Its role in project 2BS is a contractor of road Bui Thi Xuan construction. Machines, human and some materials were available in this company.

- Limited liability company Thanh Ngan (TN) which was established in 2003. Its main activities are construction, supply and installing electric lighting systems. This company participates to more than 12 projects in different cities of Vietnam (Quang Tri, Thua Thien Hue, Phan Thiet, Long An, Nghe An, Hoa Binh). It had supplied and installed electric systems in project 2BS (road Bui Thi Xuan, Ton That Tung, and bridge Lich Doi). Some materials, served for process of installing electric systems, like cements, sand, rock, etc. were supplied by other suppliers.

- Four Suppliers were involved in the project for the delivery of materials:

- Long Tho (LT) which is the largest cement company in Thua Thien Hue. It has supplied cement for project 2BS.
- Limited liability company UN (UN) which supplied sand for project 2BS.
- Limited liability company AA (AA) which supplied macadam.
- Limited liability company TV (TV) which supplied steel.

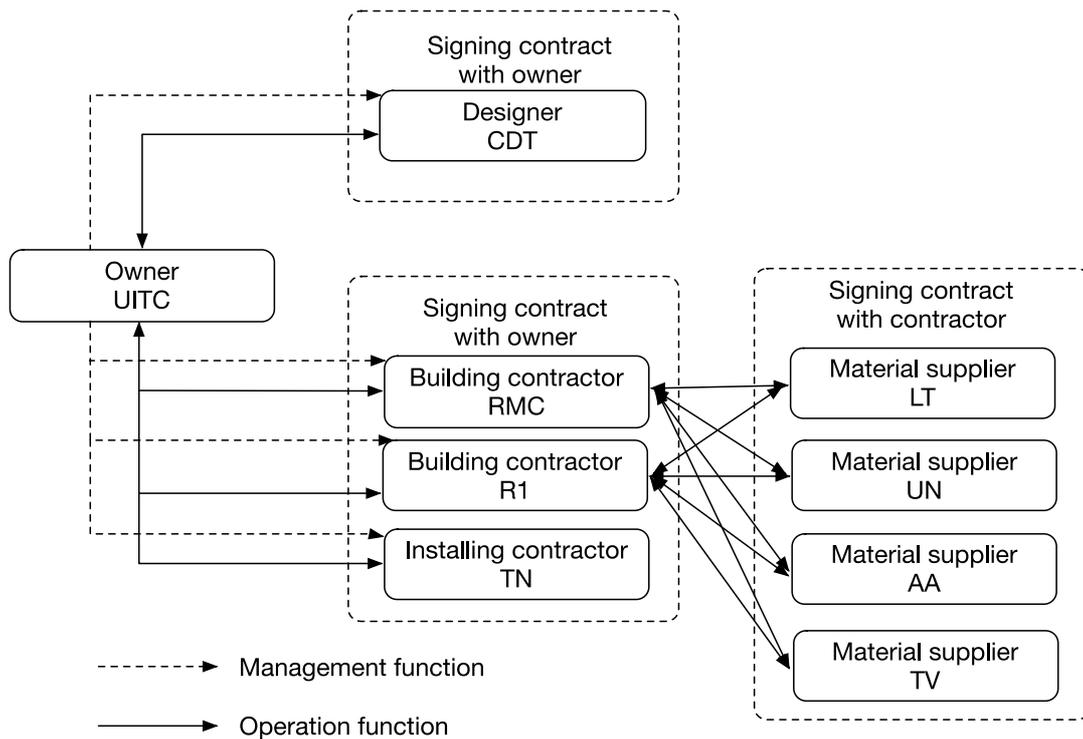


Figure 4-2 : Relations between owner, designer, contractors and suppliers in project 2BS.

These 9 actors interact each other during the constructing project. Based on operation function, the owner is always in contact with designer and contractors to guide and give his/her requirements. Besides, during process of implementing, management is a required process of the owner to control works that he/she handled. LT, UN, AA, TV supply materials to contractors RMC and R1. Hence, productivity of suppliers has direct effect on the productivity of contractors. Otherwise, requirement of contractors impacts on effective working of suppliers. Relations between actors are illustrated in figure 4-2.

4.2.1.3. Contracts in project 2BS

Based on operation function in figure 4-2, three types of contract have to be considered in project 2BS:

- 3 building contracts: UITC – RMC, UITC – R1, UITC – TN. With these contracts, owner will give requirements to contractors.
- 1 design contract: UITC-CDT. Owner gives the requirements to CDT about design drawing.
- 8 supply contracts: LT, UN, AA, TV supply material to two contractors RMC and R1. Requirements about materials of contractors impact directly the efficiency of suppliers and vice versa (when supplier delays in supplying material, productivity of contractor

will be impacted).

In building contracts, design contract, a section regulates the periodic inspection period or management function of owner.

4.2.1.4. Activities in project 2BS

There are three main phases in project 2BS: feasibility, implementation and operation phase. The first phase consists of exploration, site survey, preliminary design and economic research (table 4-2).

Table 4-2 : Instances of Activity and Actor involved in feasibility phase.

Activity	Actors involved
Exploration	UITC, CDT
Site survey	UITC, CDT
Preliminary design	UITC, CDT
Economic research	UITC

Implementation phase consists of activities that prepare for construction. There are three main activities: detailed design, preparing procedure before construction, road and bridge construction (table 4-3).

Table 4-3 : Instances of Activity and Actor involved in implementation phase.

	Activity	Actors involved
Detailed design	Detailed design	UITC, CDT
	Licence of investment	UITC
Preparing procedure before construction	Licence of constructing	UITC
	Compensation	UITC
	Bidding	UITC
	Signing contract	UITC
	Preparing for constructing	UITC
Road and bridge construction	Building roadbed	R1, RMC
	Building road surface	R1, RMC
	Building traffic safety equipments	R1, RMC
	Building roadside	R1, RMC
	Building and installing culverts	R1
	Building and installing water sumps (pit water collection)	R1, RMC
	Building and installing vertical drains	R1, RMC
	Destroying old bridge Lich Doi	RMC

Building bridge Lich Doi	RMC
Installing lighting system	TN

Operation phase is the last phase of project. This phase consists of: operation monitoring and maintenance work (table 4-4).

Table 4-4 : Instances of Activity and Actor involved in operation phase.

	Activity	Actors involved
operation monitoring	Monitoring operation of road and bridge	UITC, RMC, R1, TN
maintenance work	Repairing errors of road and bridge	UITC, RMC, R1, TN
	Completion of maintenance	RMC, R1, TN

4.2.1.5. Resources in project 2BS

There are three types of resources that are used in project 2BS: human, machine, materials. Human resources contain worker, engineer, and office staffs. Workers perform the construction works directly. Engineers design all step of works before transferring to worker. Office staff helps actors for all works that relates to paper documents (table 4-5).

Table 4-5 : Instances of human in project 2BS.

Human resources	Instances
Worker	Worker team of UITC
	Worker team of RMC
	Worker team of R1
	Worker team of TN
Engineer	Engineer of UITC
	Engineer of RMC
	Engineer of R1
	Engineer of TN
	Engineer of CDT
Office staff	Office staff of UITC
	Office staff of RMC
	Office staff of R1
	Office staff of TN
	Office staff of CDT

In table 4-5, designer CDT did not hire workers because CDT did not perform construction work. For suppliers (LT, UN, AA, TV), worker, engineer, and office staff are not formalized because they do not implement project directly.

Machines can be classified into two types: construction machine and office machine (table 4-6).

Table 4-6: Instances of machine in project 2BS.

Machine	Instances
Construction machine	Construction machine of RMC
	Construction machine of R1
	Construction machine of TN
Office machine	Office machine of UITC
	Office machine of RMC
	Office machine of R1
	Office machine of TN

Intances of material resources can be divided into: reusable and consumable resources. Reusable resource consists of: Scaffolding, formwork, gratings, etc. Consumable resources consist of: sand, rock, water, steel, cement, etc.

4.2.1.6. Products of project 2BS

Corresponding to all activities and all phases of construction project, we have listed the products delivered at the end of the activities. These products can consist in physical/technical objects (most are parts of the final construction), in documents and in decision. They are summarized in table 4-7.

Table 4-7 : Instances of Product of project 2BS.

Activity in feasibility phase	Product
Exploration	Report of exploration project 2BS
Site survey	Report of survey project 2BS
Preliminary design	Preliminary design project 2BS
Economic research	Document of economic efficiency project 2BS
Activity in implementation phase	
Detailed design	Detailed design of project 2BS
Licence of investment	Licence of investment of project 2BS
Licence of constructing	Licence of constructing of project 2BS

Compensation	Empty site of project 2BS
Bidding	Choosing contractor
Signing contract	Agreement of contract
Preparing for constructing	Site of construction project 2BS
Building roadbed	Roadbed
Building road surface	Road surface
Building traffic safety equipment	Traffic safety equipment
Building roadside	Roadside
Building and installing culverts	System of culvert
Building and installing water sumps	Water sumps
Building and installing vertical drains	Vertical drains
Destroying old bridge Lich Doi	Clear site of bridge Lich Doi
Building bridge Lich Doi	Bridge Lich Doi
Installing lighting system	Lighting system
Activity in operation phase	
Monitoring operation of road and bridge	Document of monitoring operation
Repairing errors of road and bridge	Document of errors

4.2.2. Instantiated model (skeleton)

As exposed in the previous chapters, the generic model can be instantiated models according to 3 levels (micro, meso and macro). In the first approach, the project 2BS is modelled according to the macro-level (level 0).

In project 2BS, 1 (*resp.* 4, 4, 3, 3, 3) instances associated with *Environment* (*resp.* *Actor*, *Resource*, *Contract*, *Activity*, *Product*) have been identified. Table 4-8 summarizes the different instances involved in the project in level 0. Instances of all concepts in level 1 (39 instances) and 2 (122 instances which are listed in section 4.2.1) are shown in appendix 10 and 11.

Table 4-8: Instances of entities in level 0

Entity	Instances
<i>Environment</i>	<i>environment of project 2BS</i>
<i>Actor</i>	<i>owner of project 2BS,</i> <i>contractor of project 2BS,</i>

	<i>supplier of project 2BS, designer of project 2BS</i>
<i>Resource</i>	<i>resource of owner, resource of contractor, resource of supplier, resource of designer</i>
<i>Contract</i>	<i>owner-contractor, owner-designer, contractor-supplier</i>
<i>Activity</i>	<i>activities in feasibility phase, activities in implementation phase, activities in operation phase</i>
<i>Product</i>	<i>survey document, building, report of maintenance process</i>

Figure 4-3 displays the developed relational skeleton between instances (see Table 4-8) of this project which is instantiated from the generic model. Some examples (dotted lines) will describe some instances' relations in level 0. Specific description of all instances' relations in level 0, 1, and 2 are respectively mentioned in appendix 14, 15, 16, and 17.

- *Resource of owner of project 2BS and resource of designer of project 2BS depend on external environment of project 2BS.*
- *Activity of feasibility phase of project 2BS depends on resource of owner of project 2BS and resource of designer of project 2BS.*

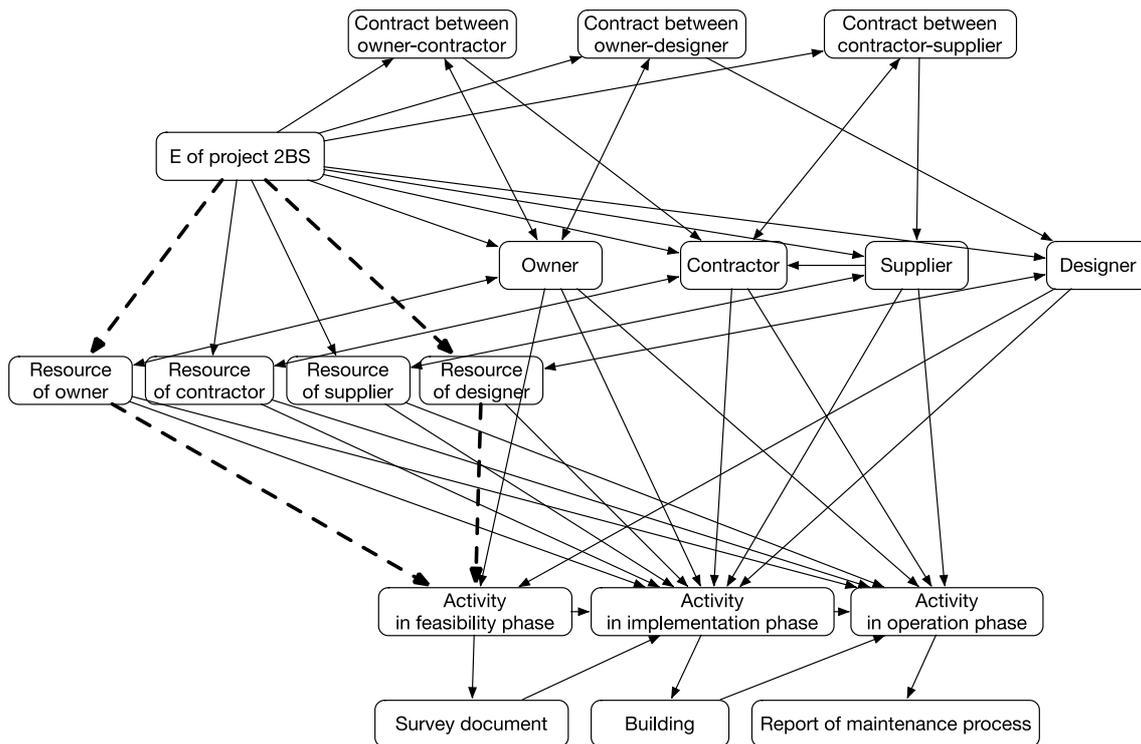


Figure 4-3 : The relational skeleton using elements from Table 4-8 and the PRM model

The relational skeleton of figure 4-3, specified from generic model in level 0 according to the particularities of 2BS project will be used for the project simulations and analysed, according to a set of scenarios.

4.2.3. Results and discussion

Using the PRM structure and the skeleton, a joint probability over the set of instances is then defined and different inferences may be calculated according to different observation scenarios in order to test the behaviour of the project at different detailed levels of description. For the given skeleton in figure 4-3, the PRM model specifies a probability distribution over descriptive attributes in level 0 defined on a 7-level Likert scale. The model be analysed following these different steps:

- Firstly, by analysing how some changes in specific inputs can influence the distribution of specific outputs at level 0,
- Secondly, by analysing sensitivity of the *Building.Duration2BS* regarding different scenarios at level 1,
- Thirdly, by simulating in the real-time management of the project described at level 0,
- Lastly, by analysing outputs correspondent with scenarios in level 1 (*Economy2BS.Inflation*, *Climate2BS.Intensity*) and 2

(NationalEconomy2BS.IncreasingNationalTax, Temperature2BS.LevelOfDegree).

4.2.3.1. Sensitivity analysis of the *Building_project2BS* in some governing factors

Under the variation of input variables, we will analyse the sensitivity about quality, duration, and cost of *Builidng_project2BS*. *Builidng_project2BS* is the product which reflects the performance (success) of a construction project. Hence, quality, duration, and cost of *Builidng_project2BS* are our concern. Besides, sensitivity of other variables will be concerned in order to compare the level of variation.

We choose the descriptive attribute *Aggressiveness* associated with the instance *Environment* is an input variable of the model in level 0. Hence, it seems to be interesting to focus on variable *Environment* on which some observations may be available and tested in order to estimate the sensitivity of the model regarding this parameter. According to the value of *Environment.Aggressiveness*, all of other variables will change and we can observe the different level of sensitivity of *Builidng_project2BS.Duration*, *Builidng_project2BS.Cost*, *Builidng_project2BS.Quality*.

We propose different scenarios (*i.e.* a set of observations like *Environment.Aggressiveness=SSP*) and analyse their impact on six interest variables: *Building_project2BS* quality, duration and cost, and three other variables corresponding to the complexity of contract linking owner and designer, the capacity of designer and the quantity of contractor's resource during the implementation phase. All of those six attributes are in a chain of relation as showed in figure 2-8 chapter 2. Three scenarios are considered, corresponding to three different values of *Environment.Aggressiveness* (figure 4-4): expected, negative and positive values. Figure 4-4 presents the marginal probability $P(\text{interest variable}|\text{scenarios})$ of interest variables given three scenarios such that:

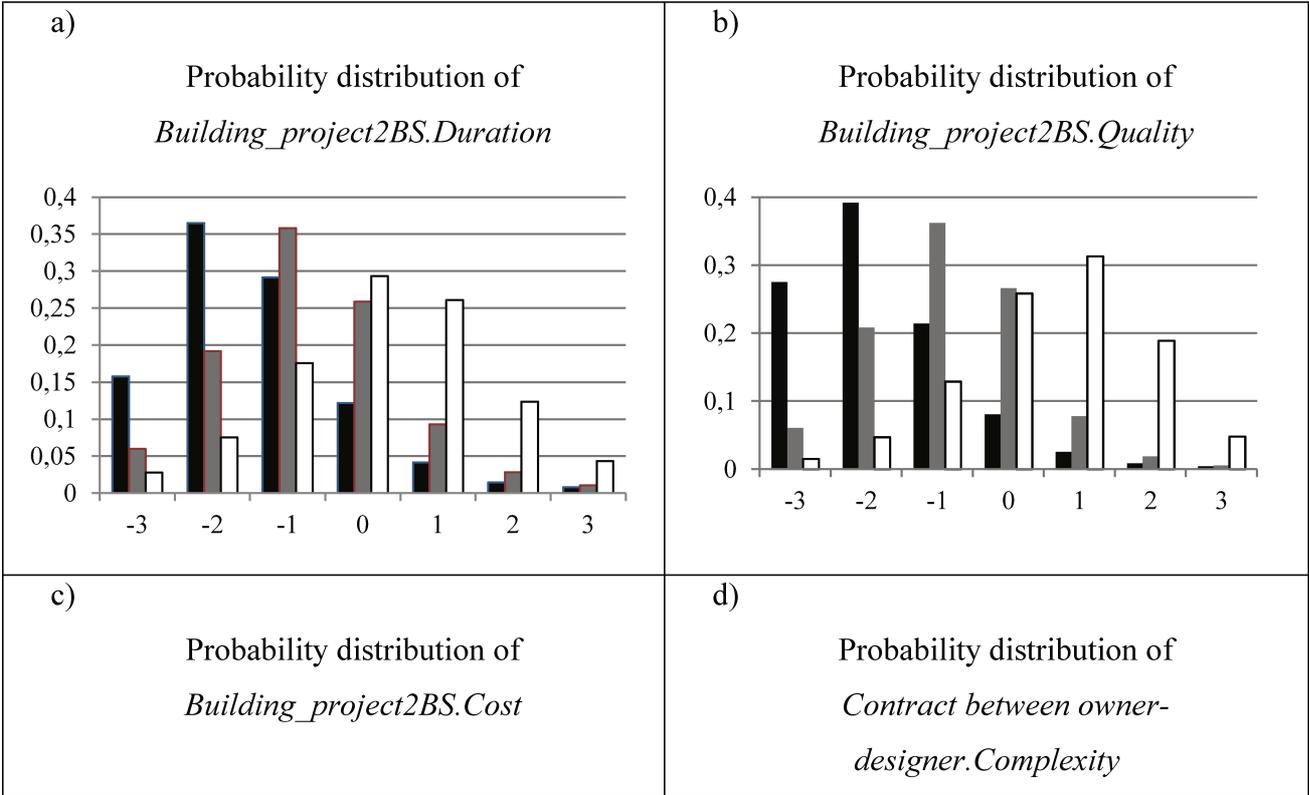
- scenario₁={ *environment.Aggressiveness =E*} in grey colour,
- scenario₂={*environment.Aggressiveness =SSN*} in black colour,
- scenario₃={ *environment.Aggressiveness =SSP*} in white colour.

Figures 4-4.a to 4-4.f plot the marginal probability distribution of the six interest variables regarding the three scenarios. They show similar features with centred and symmetric distributions in black colour, skewed distributions towards the left (*resp.* right) in grey (*resp.* white) colour for scenario₂ (*resp.* scenario₃). The skewness is more accentuated for the *Complexity of contract* (see figure 4-4.d). This is due to the fact that there only exists one

intermediate variable between the *Complexity* and the value namely *Aggressiveness* (see figure 2-8 chapter 2), thus making the dependency relation more effective. The *Complexity* of contract variable is impacted by both of *Aggressiveness* and *Capacity* (see figure 2-8 chapter 2). It explains the strong negative or positive impact of *Aggressiveness* and *Capacity* over *Complexity* of *Contract*. For others variables, the flattering of skewness (see figure 4-4.a,b,c,e,f) is due to the propagation of uncertainty through a substantial network of variables between *Aggressiveness* and *Duration*, *Cost*, *Quality* (see figure 2-8 chapter 2). These results highlight that:

(a) some variables of the model are more or less sensitive according to observation and the model allow to assess this sensibility through observation, and

(b) the behaviour of system regarding marginal probabilities seems to be relevant and consistent (*i.e.* the results are consistent with predicable values according to the three scenarios: correspondent with values *SSP*, *E*, *SSN* of variable *Environment.Aggressiveness*, probability of *Building.Duration* finishes in time (*E*) increase with probability 12%, 26%, and 29% respectively).



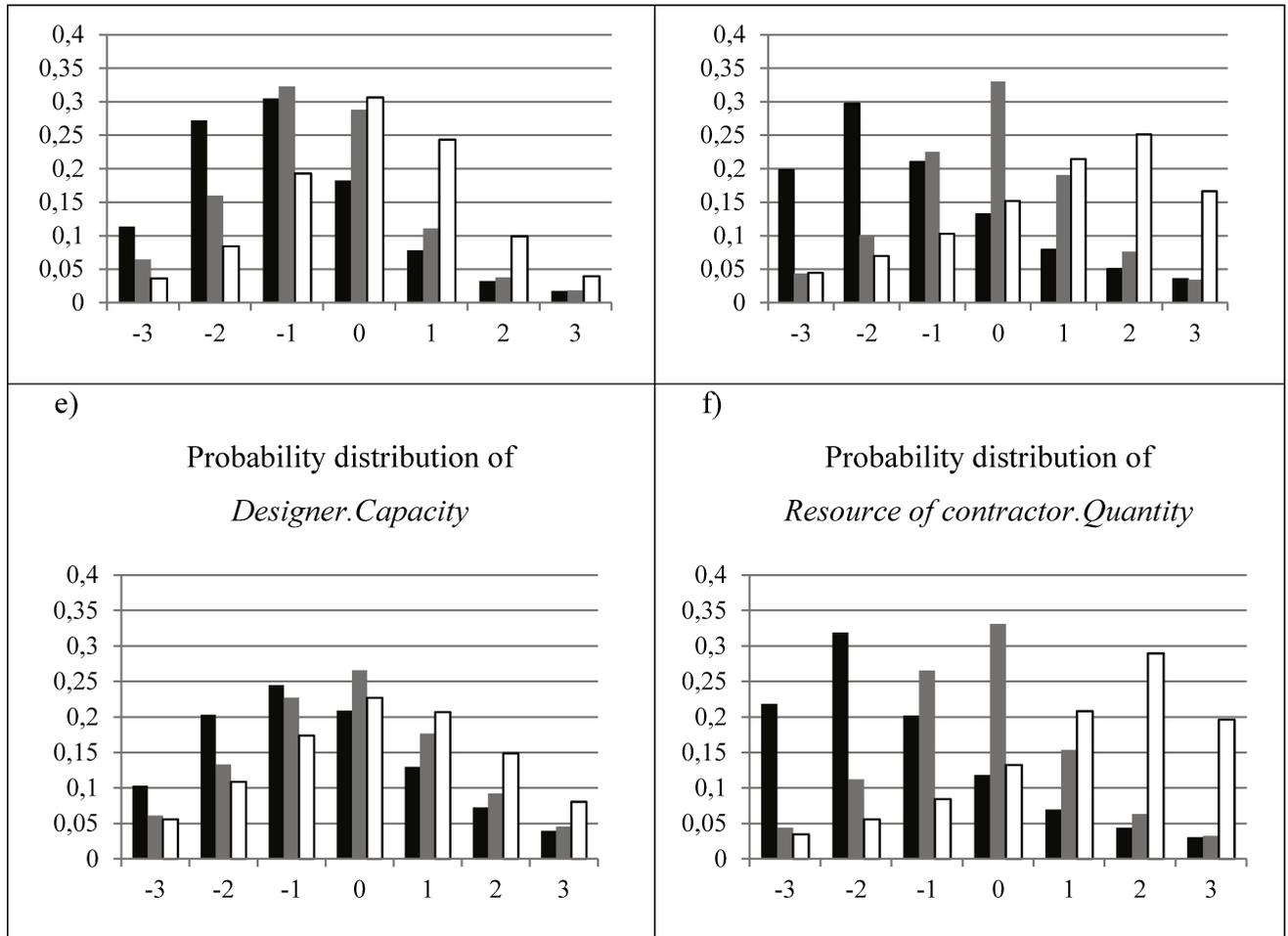


Figure 4-4 : Marginal probability distribution of (a) the quality (b) the cost, (c) the duration of *building* of project 2BS, (d) the complexity of contract linking owner and designer, (e) the capacity of designer and (f) the quantity of human resource during the implementation phase given three scenarios: $\{EE.Agg=E\}$ in grey, $\{EE.Agg=SSN\}$ in black, $\{EE.Agg=SSP\}$ in white where $EE=environment$.

4.2.3.2. Sensitivity analysis of the *PIP2BS_Building.Duration* regarding different scenarios correspondent with priori attributes in level 1

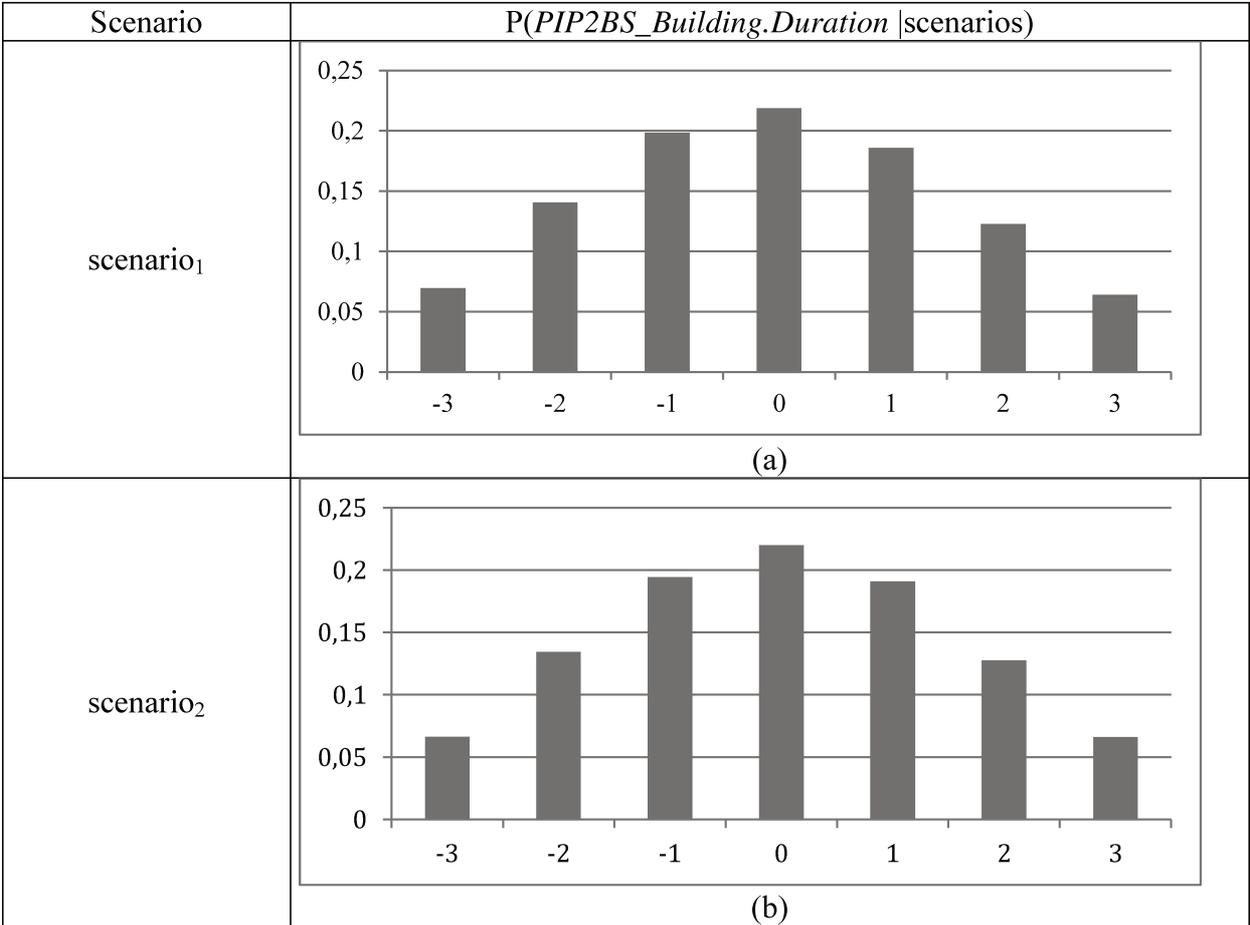
In the previous part, we analysed *Building_project2BS* which is an instance of concept *Product* in level 0. In level 1, *Building_project2BS* consists of other three instances which are *PIP2BS_DetailedDesign.Duration*, *PIP2BS_RegulationDocument.Duration*, *PIP2BS_Building.Duration*. In this part, we will analyse the sensitivity of *PIP2BS_Building.Duration* regarding different scenarios correspondent with priori attributes in level 1 (*Economy2BS.Inflation*, *Administration2BS.Inertia*, and *Climate2BS.Intensity*). Purpose of this work is to know which chosen input variable has the most impact on *PIP2BS_Building.Duration*.

Figure 4-5 presents the marginal probability $P(PIP2BS_Building.Duration | scenarios)$ of interest variables given three scenarios such that:

- scenario₁ = { *Economy2BS.Inflation* =SSN},
- scenario₂ = { *Administration2BS.Inertia* =SSN},
- scenario₃ = { *Climate2BS.Intensity* =SSN},

Figures 4-5.a to 4-5.c plot the marginal probability distribution of *PIP2BS_Building.Duration* regarding the three scenarios respectively. Figure 4-5 shows similar features with skewed distributions towards the left when all scenarios are SSN. The skewness of *PIP2BS_Building.Duration* is the most accentuated when *Climate2BS.Intensity* is SSN, after that are *Economy2BS.Inflation*, *Administration2BS.Inertia* when they are also SSN.

These results highlight that *PIP2BS_Building.Duration* is the most impacted by *Climate2BS.Intensity*. Hence, one of ways to control duration of *PIP2BS_Building.Duration* is to handle information about climate in order to control all bad event can impact to the duration of project.



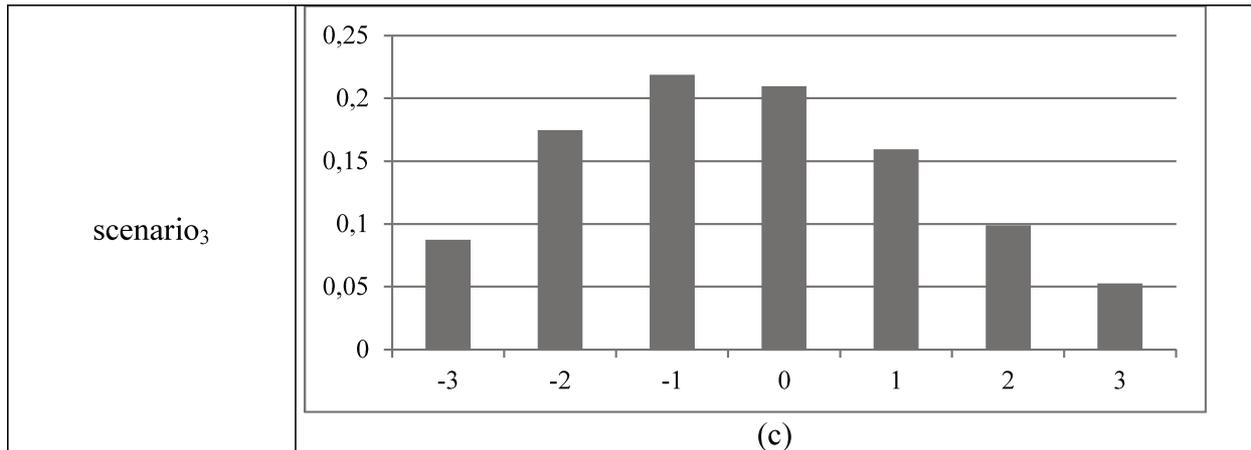


Figure 4-5: Marginal probability distribution of PIP2BS_Building.Duration given correspondent five scenarios (a) Economy2BS.Inflation =SSN, (b) Administration2BS.Inertia =SSN, (c) Climate2BS.Intensity =SSN.

Although, in the most general detailed level (level 0), skewed distributions of *Building_project2BS.Duration* strongly towards the left (figure 4-4.a, black column) when *EE.Agg=SSN*, but that does not mean that instance of *Building_project2BS.Duration* in level 1 (*PIP2BS_Building.Duration*) have the same tendency (strongly towards the left) when it is impacted by instances of *EE.Agg* (*Economy2BS.Inflation=SSN*, *Administration2BS.Inertia=SSN*, *Climate2BS.Intensity=SSN*) (figure 4-5.a, b, c). More particular, results in level 1 supply us the more exact information about the impact level of each instance of environment to an instance of product.

4.2.3.3. Simulation of the influence of some real-time decision during the project in macro level (level 0)

In fact, project 2BS finished in 2013. We will use the simulation to check and compare the calculated results with real ones. Hence, the model is now tested according to two scenarios:

- the real scenario of project, as it happened (see Scenario_{project} in table 4-9). In this project, some attributes receive a value which correspondents to what has been observed during the project, and no longer the prior distribution.
- an alternative scenario in which it is assumed that the supplier and designer, faced with the risk of missing the project objectives have adapted their capacity and their productivity in the next phase of project to face with (attributes in bold in Scenario_{project+} table 4-9). It means that in the beginning, this project faced with many negative impacts, so in the next phase, we give strategy (increasing capacity and productivity of designer and supplier) to improve the project results. In the second scenario, all others variables are kept unchanged.

Table 4-9 : Scenario_{project} and Scenario_{project+} of project 2BS

Scenario _{project}	Corresponding situation	Scenario _{project+}	Corresponding situation
<i>environment.Agg=SN</i>	Inflation of environment	<i>environment.Agg=SN</i>	Inflation of environment
<i>resource_of_contractor.Cost=SN</i>	Pay increased	<i>resource_of_contractor.Cost=SN</i>	Pay increased
<i>resource_of_contractor.Quantity=SN</i>	Personal accident	<i>resource_of_contractor.Quantity=SN</i>	Personal accident
<i>resource_of_contractor.Quality=SN</i>	Breakdown machines	<i>resource_of_contractor.Quality=SN</i>	Breakdown machines
		<i>designer.Capacity=SSP</i>	<i>Experienced designer</i>
		<i>designer.Productivity=SSP</i>	<i>Plentiful team</i>
		<i>supplier.Capacity=SSP</i>	<i>Reliable supplier</i>
		<i>supplier.Productivity=SSP</i>	<i>Large supplier</i>

Figures 4-6.a to 4-6.c synthesize the marginal probability distributions of the three attributes of the *building of project 2BS* (resp. *Quality* on figure 4-6.a, *Cost* on figure 4-6.b, and *Duration* on figure 4-6.c), given scenario_{project} in gray colour and scenario_{project+} in white colour. According to figures 4-6.a to 4-6.c, scenario_{project} has a strong negative impact for the project with highly left-skewed distributions, whose values are N or SN, in good agreement with what was reached by the real (and unique) project. The real project (2BS) was two months (*Building.Duration*) longer than planned and the cost (*Building.Cost*) was increased by more than 0,5 billion VND ($\approx \text{€}19\,700$).

On the other hand, scenario_{project+} highlights that a very strong positive capacity and productivity of designer and supplier would have a positive effect over the response of the system and enable to counterbalance negative events regarding duration. However, the impact is lower on cost and quality:

- the distribution of quality is moved towards the right, while the probability of SN or SSN values is strongly reduced.

- the cost distribution is quite identical for the two alternatives, which implies that the model tells that changing the productivity and capacity of the supplier and designer has only a small impact on the building cost itself.

These results show that the model, despite the simplicity of required information, is able to reproduce complex results, where the relative sensitivity of attributes depends on multiple interactions between project variables.

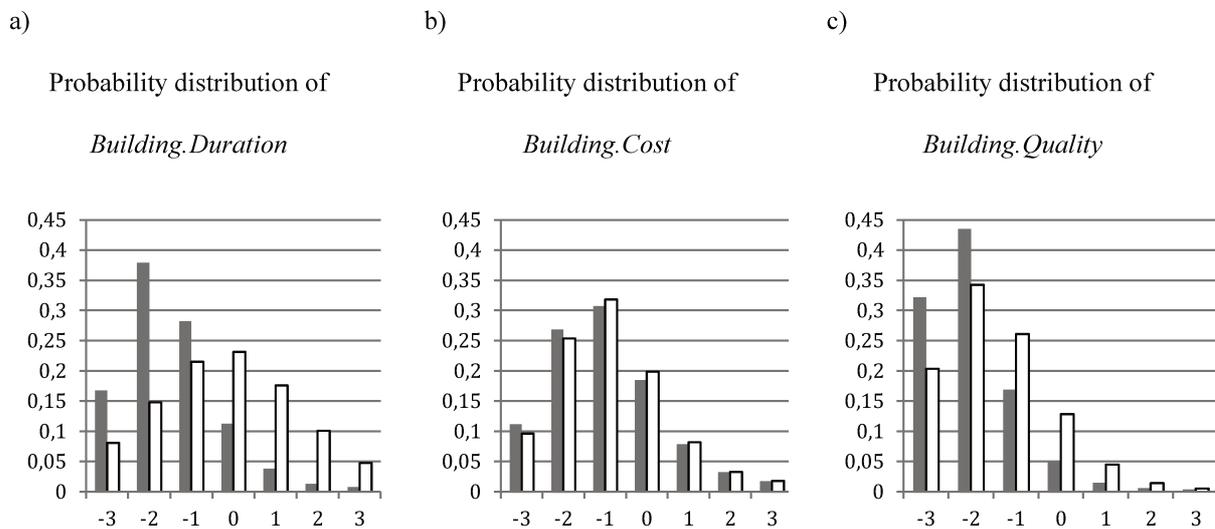


Figure 4-6: Marginal probability distribution of (a) the quality, (b) the cost and (c) the duration of *building of project 2BS* given scenario_{project} and scenario_{project+}.

4.2.3.4. Analysing of the *Building.Duration2BS* regarding different scenarios correspondent with level 1 and 2.

When the model is instantiated at a finer level, scenario can be defined more precisely. In this case, instead of scenario which consists of *Environment2BS.Aggressiveness* in level 0, the scenario become *Economy2BS.Inflation* and *Climate2BS.Intensity* in level 1. These new scenarios better reflect the real condition that impact on project 2BS.

- scenario₁ = { *Economy2BS. Inflation* =SSN},

- scenario₂ = { *Economy2BS. Inflation* =SSN, *Climate2BS. Intensity* =SSN},

Figures 4-7.a and 4-7.b plot the marginal probability distribution of *Building.Duration* regarding the two scenarios respectively. Figure 4-7 shows similar features with skewed distributions towards the left. When scenario is more negative (scenario 2), the skewness is more negative (figure 4-7.b) than the first scenario.

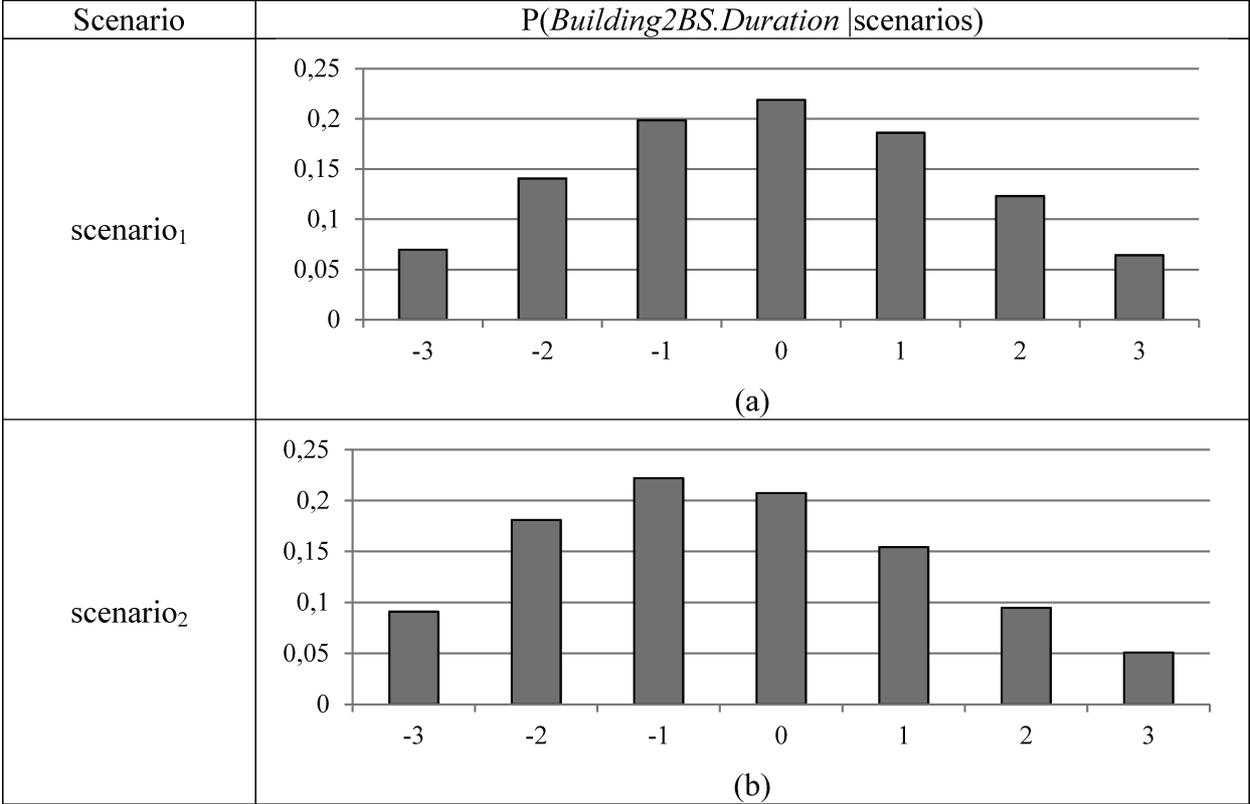


Figure 4-7: Marginal probability distribution of *Building.Duration* given correspondent two scenarios (a) *Economy2BS.Inflation =SSN*, (b) *Economy2BS.Inflation =SSN*, *Climate2BS.Intensity =SSN*.

In the micro level (level 2), the scenario can be more specified. Instead of *Economy.Inflation* and *Climate.Intensity*, we consider *National_Economy2BS.Inflation* and *Temperature2BS.Level_Of_Degree*.

- scenario₁={*NationalEconomy2BS.IncreasingNationalTax =SSN*},

-scenario₂={*NationalEconomy2BS.IncreasingNationalTax =SSN*, *Temperature2BS.LevelOfDegree =SSN*},

Figures 4-8.a and 4-8.b plot the marginal probability distribution of *BridgeLD.Duration_Of_Building* regarding the two scenarios respectively. Figure 4.8 shows similar features with skewed distributions towards the left. When scenario is more negative (scenario 2), the skewness is more negative (figure 4-8.b) than the first scenario. So, under the changes of negative scenario, we can persuade and control the sensitivity of *BridgeLD.Duration_Of_Building*.

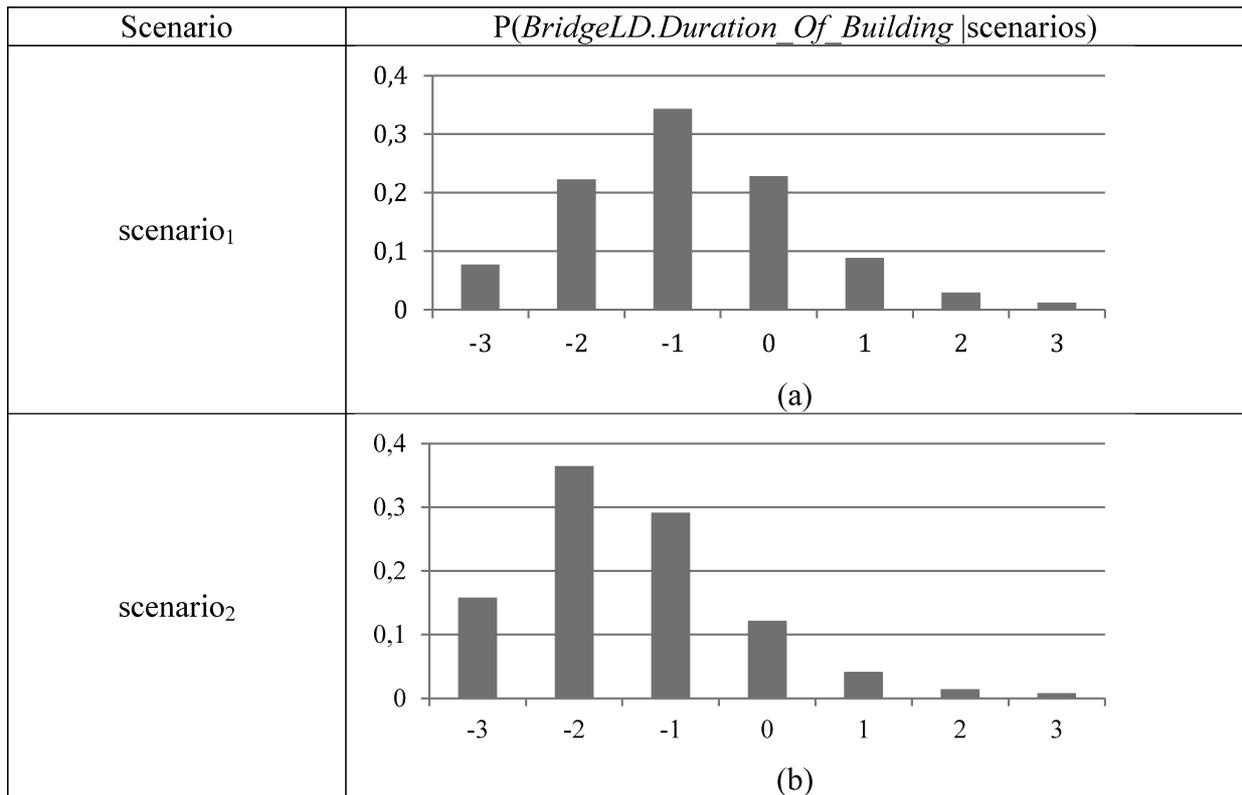


Figure 4-8: Marginal probability distribution of *BridgeLD.Duration_Of_Building* given correspondent two scenarios (a) *NationalEconomy2BS. IncreasingNationalTax =SSN*, (b) *NationalEconomy2BS. IncreasingNationalTax =SSN, Temperature2BS. LevelOfDegree =SSN*

Through the results which are taken from level 1 and 2, we can see that the more specific detailed level, the more exact results of output that we can get.

4.3. Case study 2 application (nursing training institute)

4.3.1. Project presentation

The nursing training institute (NTI) is a building project which is located in the Southwest of France (figure 4-9).

The planned budget of project is 3.9M€ and the total time to execute project is 18 months (352 working days). During the construction phase, different negative events happened, e.g. the temperature was higher than normal condition and an unusual rain event happened, but by increasing quantity of resource (worker), the time and budget of the project finished as planned.



Figure 4-9 : Architecture perspective of Nursing training institute.

4.3.2. Instances of project NTI (instances of project NTI in level 2)

As for 2BS project, considering that the project already ended and that we have the knowledge of what really happened during the project, we define just one instance of Environment which mainly impacted this project: Climate. Six main types of actors were involved in this project, namely:

- Owner: CHR
- Structural designer: BT
- Architectural designer: DC
- Building contractor: CP
- Installing contractor: CS
- Material supplier: MS1, MS2, MS3.

Like in project 2BS, the owner is always in contact with designer and contractor, to guide and control construction works. Only MS1 and MS2 supply material to building contractor CP, while material of installing contractor is supplied by MS3 (figure 4-10).

As described on figure 4-10, there are three types of contract in project 2BS:

- 2 building contracts: CHR – CP and CHR – CS
- 2 design contracts: CHR – DC and CHR – BT
- 3 supply contracts: MS1-CP, MS2-CP and MS3-CS.

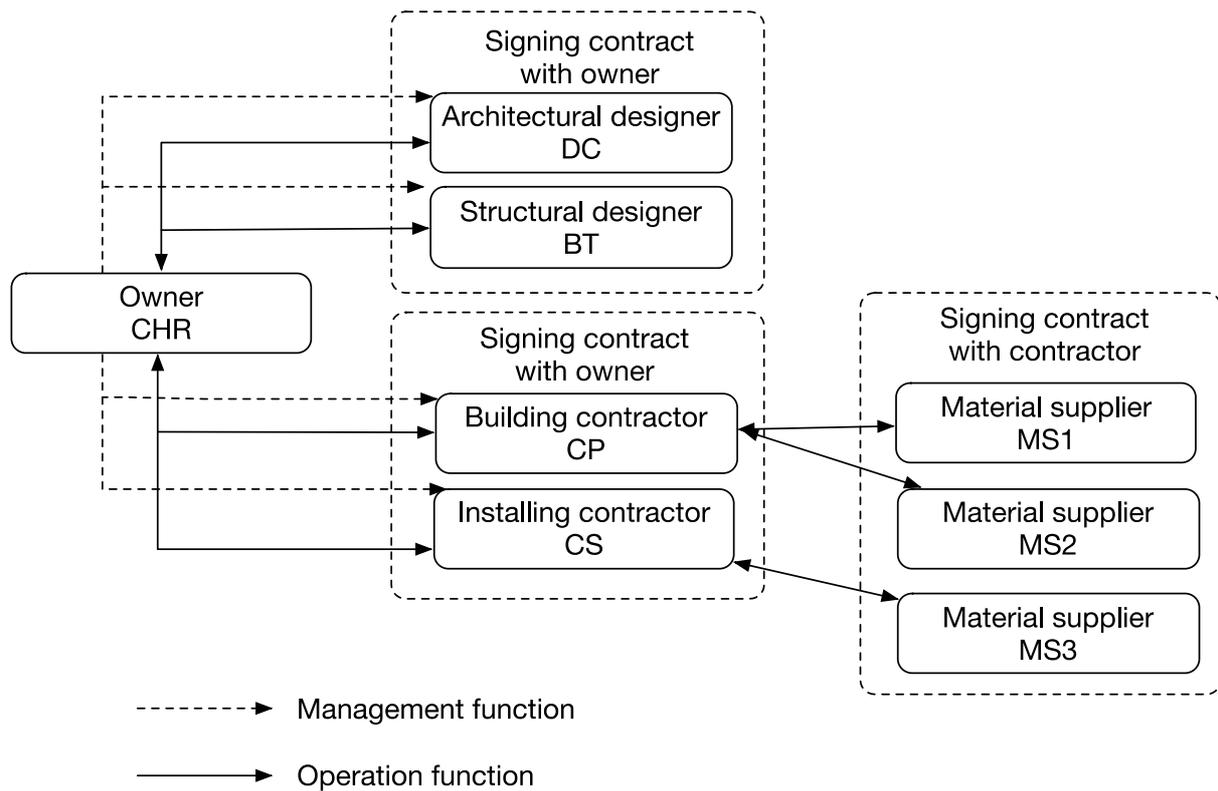


Figure 4-10 : Relations and contracts between owner, designer, contractors and suppliers in project NIT.

The project is divided in two main phases: feasibility and implementation phase. The feasibility phase consists of pre-studies, pre-design and economic study and it involves 3 actors (table 4-10).

Table 4-10 : Instances of Activity and Actor in feasibility phase.

Activity	Actors involved
Pre-studies	CHR
Pre-design	CHR, DC, BT
Economic study	CHR

Implementation phase consists of activities that implement construction: detailed design, procedure before works, building construction (table 4-11). Building construction consists of: prepare works, soil and foundation works, structural works, equipment works, and finalizing construction.

Table 4-11: Instances of Activity and Actor in implementation phase.

Activity	Actors involved
Detailed design	CHR, DC, BT
Procedure before works	CHR
Prepare works	CHR

Soil and foundation works	CP
Structural works	CP, CS
Equipment works	CP, CS
Finalizing construction	CHR, CP, CS

Like the project 2BS, the project NTI has three types of resources: human, machine and material. Human resources are worker, engineer and office staffs. Worker performs construction works directly. Engineer designs all steps of works that worker has to implement. Office staff helps actors for all works that relate to paper documents (Table 4-12).

Table 4-12: List of human of project NTI.

Human	Instances
Worker	Worker team of CP
	Worker team of CS
Engineer	Engineer of BT
	Engineer of DC
	Engineer of CP
	Engineer of CS
Office staff	Office staff of CHR
	Office staff of BT
	Office staff of DC
	Office staff of CP
	Office staff of CS
	Office staff of MS1
	Office staff of MS2
Office staff of MS3	

Machine resources are divided in two types: construction machine and office machine. Instances of machines are mentioned in table 4-13.

Table 4-13 : Instances of machine in project NTI

Machine	Instances of machine
Construction machine	Machine of CP
	Machine of CS
Office machine	Office machine of CHR

	Office machine of BT
	Office machine of DC

Material resources are divided into reusable and consumable resource. Reusable and consumable resource are used for work site installation, foundation work, structure work, equipment work.

According to the different activities of construction project, we have listed the products delivered at the end of these activities (table 4-14).

Table 4-14: Instances of products of project NTI (generic and instantiated).

Products	Instances
Document of site survey	Document of site survey
Preliminary design	Preliminary design
Research of economic	Document of economic
Detailed design	Detailed design
Procedure document	Procedure document
Building	Site prepared
	Foundation
	Structure
	Equipment
	Finished building

4.3.3. Instantiated model (skeleton)

In project NTI, 1 (*resp.* 4, 4, 3, 2, 2) instances associated with *Environment* (*resp.* *Actor*, *Resource*, *Contract*, *Activity*, *Product*) have been identified. Table 4-15 summarizes the different instances involved in the project in level 0. Instances of all concepts in level 1 and 2 (listed in the section 4.3.2) are shown in appendix 12, 13.

Table 4-15: Instances of entities in level 0

Entity	Instance
<i>Environment</i>	<i>Environment of project NTI</i>
<i>Actor</i>	<i>owner,</i> <i>contractor,</i> <i>supplier,</i> <i>designer</i>
<i>Resource</i>	<i>resource of owner,</i>

	<i>resource of contractor, resource of supplier, resource of designer</i>
<i>Contract</i>	<i>owner-contractor, owner-designer, contractor-supplier</i>
<i>Activity</i>	<i>activities in feasibility phase, activities in implementation phase</i>
<i>Product</i>	<i>survey document, building</i>

Figure 4-11 and 4-12 displays the relational skeleton between instances in level 0 and level 1 of project NTI which is instantiated from the generic model.

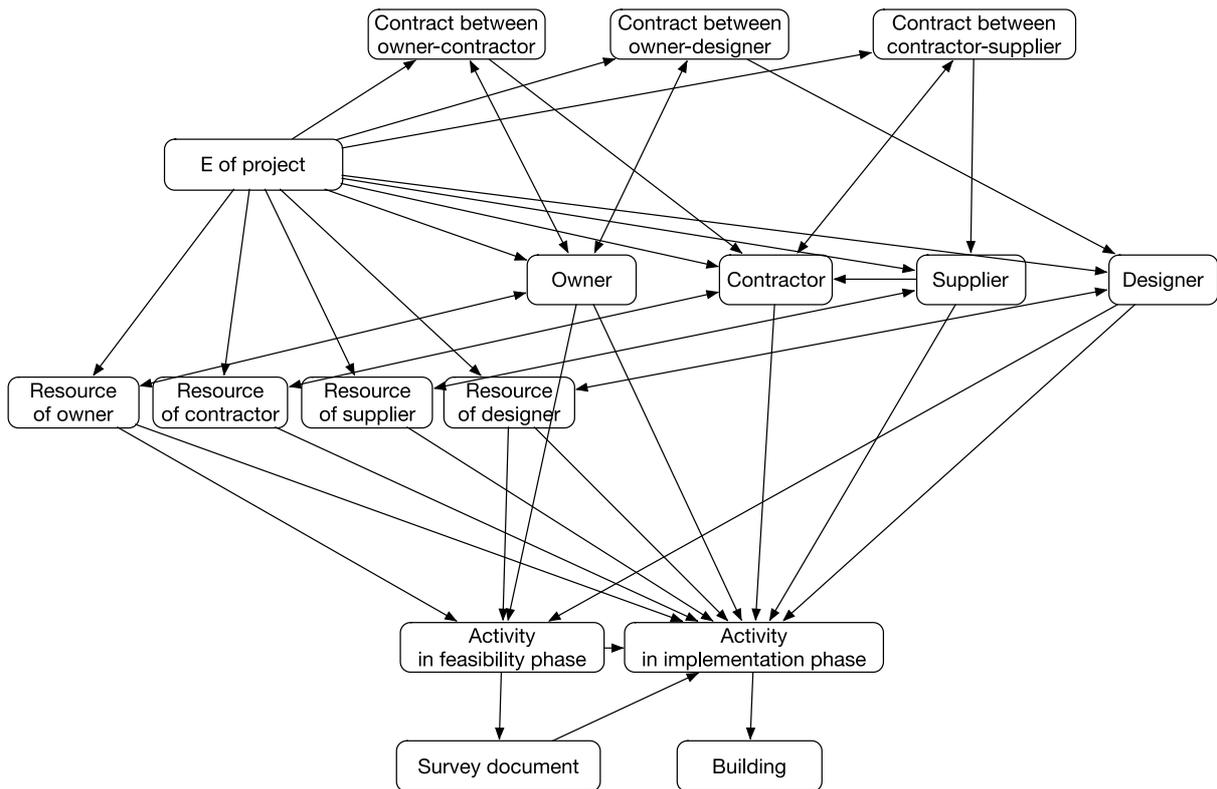


Figure 4-11: The relational skeleton project NTI using elements from table 4-15 in level 0

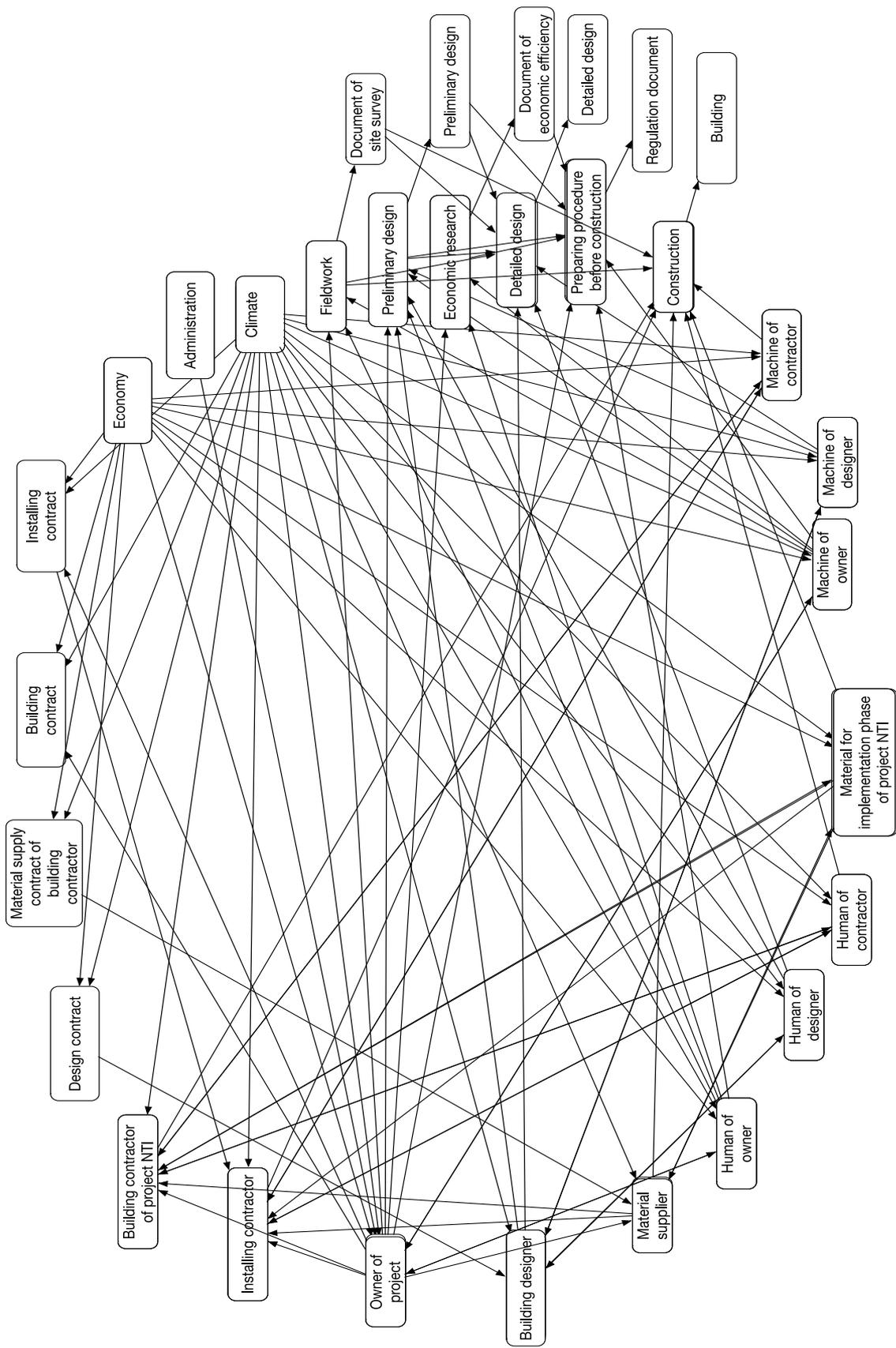


Figure 4-12 : The relational skeleton level 1 of project NTI.

4.3.4. Results and discussion

In the project 2BS, we analysed independently the behaviour of the project at the separated three levels according to different scenarios. With this project (NTI), we will analyse the results coupling macro and meso levels (macro-meso), meso and micro levels (meso-micro) in order to discuss the consistency between level issue.

Due to the number of variables and the complexity of relationship networks, the model will be tested and used in two steps:

- In the first time, we will simulate different scenarios and comparing the efficiency of some additional observations in the real-time management of the project in the macro-meso model.
- then by analysing the consistency of the model described at the couple of different levels: macro-meso and meso-micro.

4.3.4.1. Simulation of the influence of some real-time decision in the macro-meso model

Couplage model in macro-meso level (generic model in Appendix 7 and relational skeleton in figure 4-12) is now tested according to two scenarios:

- the real scenario of project in level 1, as it happened, for which climate is unfavourable and the contractor has increased the quantity of its resources (SN for *Intensity* of *Climate* and SP of *Total_work_of_performing* of *Human* of Contractor) (see Scenario_{project} in table 4-16). The results of this scenario will be compared to those obtained with: (a) all attributes of instances of *Environment* are prior centred distribution, (b) all centred excepted climate SN. We compare results corresponding with these three scenarios in a figure to observe the tendency of duration, cost, and quality of products when the scenarios are more negative than real conditions (without increasing quantity of resource).
- the scenario of project in level 0 (see Scenario_{project+} in table 4-16) was inferred from the real scenario in level 1 in the model covering level 0 and 1, we will observe time, cost, and quality of product in level 0. Results of this step will be compare with two other scenario which are also inferred from (a) and (b) in the first case.

Table 4-16 : Scenario_{project} and Scenario_{project+} of project NTI

Scenario _{project} (Level 1)	Corresponding situation	Scenario _{project+} (Level 0)	Corresponding situation
<i>climate.Intensity=SN</i>	Changing intensity of climate	<i>Environment_NTI.Aggressiveness = [0.053,0.141,0.249,0.266,0.174,0.083,0.034]</i>	Changing aggressiveness of environment
<i>human_of_contractor.Total_work_of_performing=SP</i>	More human resources for contractor	<i>Resource_Contractor.Quantity = [0.052,0.108,0.189,0.246,0.214,0.129,0.062]</i>	More resources for contractor

In the model covering level 0 and 1, the probability distributions of the attributes in level 0 are inferred from the level 1. It means that, correspondent with instance *Environment_NTI.Aggressiveness* in level 0, we have six instances in level 1 (*EconomyNTI.Instability*, *EconomyNTI.Inflation*, *AministrationNTI.Inertia*, *AministrationNTI.Corruption*, and *ClimateNTI.Frequency*, *ClimateNTI.Intensity*). In real condition, except *ClimateNTI.Intensity=SN*, the others are prior centred distribution. Based on section 3.2.5 in chapter 3, we can calculate the probability distributions of *Environment_NTI.Aggressiveness* in level 0 ([0.053,0.141,0.249,0.266,0.174,0.083,0.034]).

The same with *Resource_Contractor.Quantity* in level 0, it has 9 instances in level 1 (table 4-17). In real condition, except *human_of_contractorNTI.Total_work_of_performing=SP*, the others will become the variables which will be calculated like the other variables in the project NTI (they are not prior centred distribution). After synthesizing results of the 9 instances in level 1, we will have probability distributions of *Resource_Contractor.Quantity* in level 0 is [0.052,0.108,0.189,0.246,0.214,0.129,0.062].

Table 4-17 : Intances of *Resource_Contractor.Quantity* in level 1

Order	Instances of <i>Resource_Contractor.Quantity</i> in level 1
1	<i>Machine_of_contractorNTI.Quantity</i>
2	<i>Machine_of_contractorNTI.Machine_requirement_of_unit_operating_work</i>
3	<i>Machine_of_contractorNTI.Total_work_of_performing</i>
4	<i>Human_of_contractorNTI.Quantity</i>
5	<i>Human_of_contractorNTI.Human_requirement_of_unit_work</i>

6	<i>Human_of_contractorNTI.Total_work_of_performing (observation)</i>
7	<i>Material_of_contractorNTI.Quantity</i>
8	<i>Material_of_contractorNTI.Material_requirement_of_unit_component</i>
9	<i>Material_of_contractorNTI.Total_component</i>

Figures 4-14.a to 4-14.i synthesize the marginal probability distributions of the nine attributes about time, cost and quality of the final three products (*Detailed_design_NTI*, *Regulation_document_NTI*, and *Building_project_NTI*) in level 1 (figure 4-13). Black, grey, and white columns correspondent with three scenarios: all attributes of instances of *Environment* in level 1 are prior centred distribution, all attributes of instances of *Environment* in level 1 are centred excepted climate SN, and scenario_{project}.

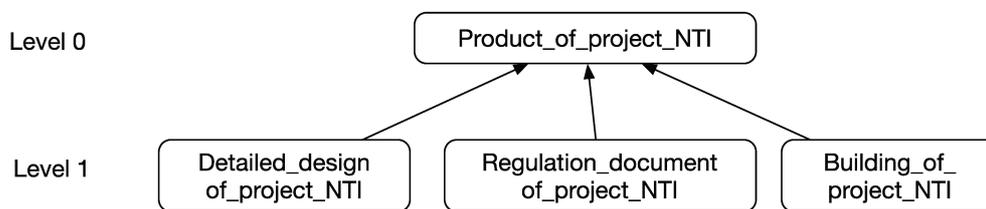
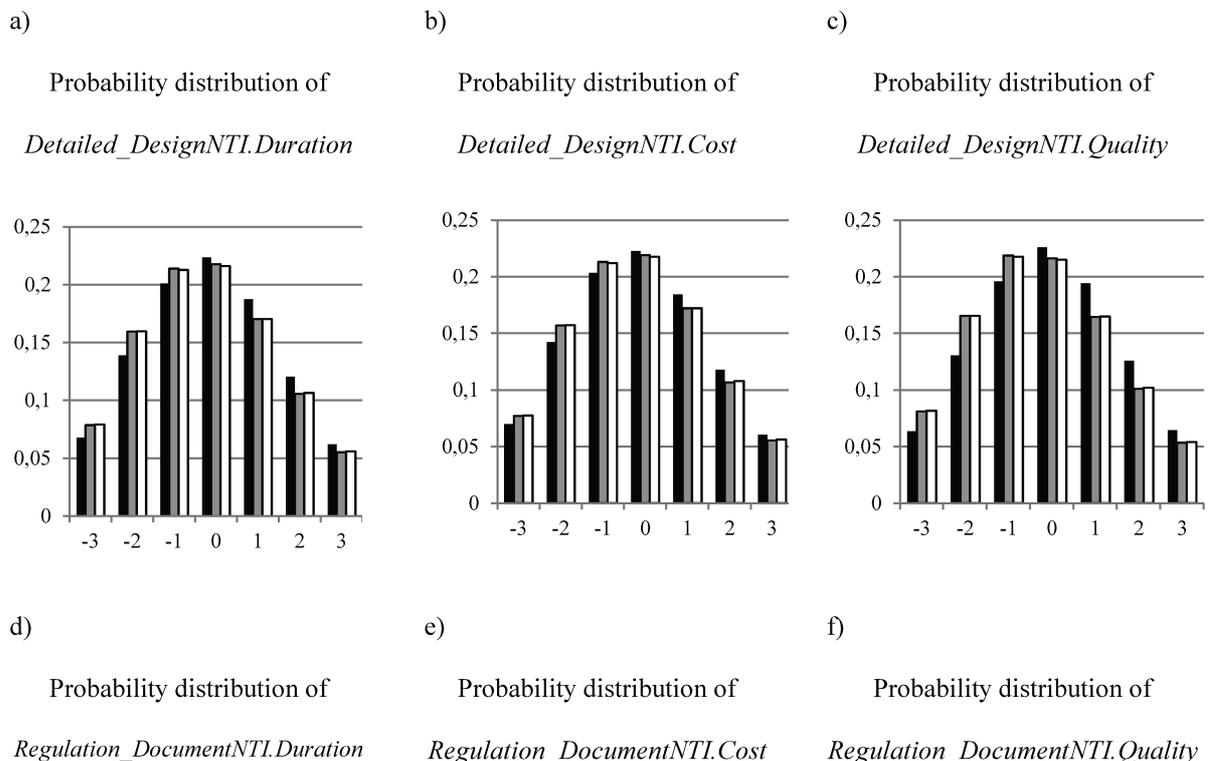
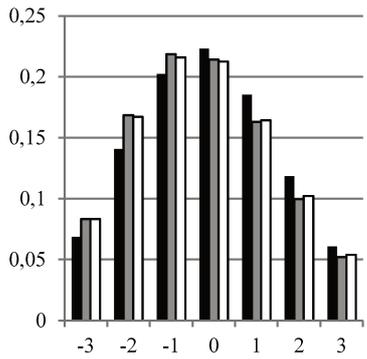


Figure 4-13 : Instances of product in level 0 and 1.

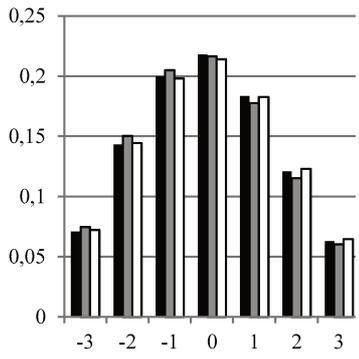
Otherwise, with scenario in level 0, **Scenario_{project+}** (obtained from scenario of level 1), all results are negatively skewed to the left side (figure 4-15).





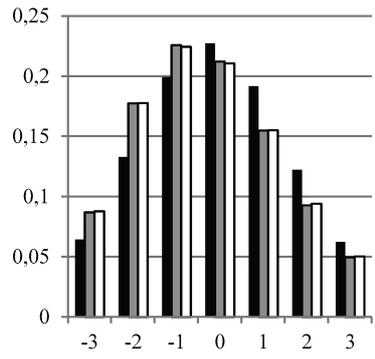
g)

Probability distribution of
PIP_BuildingNTI.Duration



h)

Probability distribution of
PIP_BuildingNTI.Cost



i)

Probability distribution of
PIP_BuildingNTI.Quality

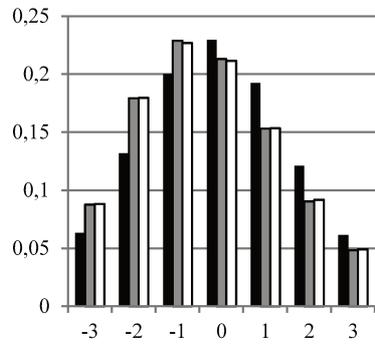
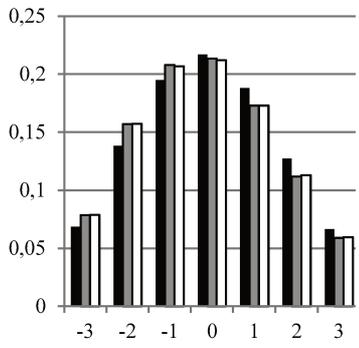
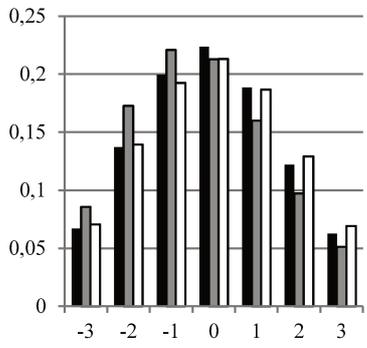


Figure 4-14 : Marginal probability distribution in level 1 of (a) the duration, (b) the cost and (c) the quality of three instances (*Detailed_DesignNTI*, *Regulation_DocumentNTI*, *BuildingNTI*) in level 1 of *Product of project NTI* when all attributes of instances of *Environment* are prior centred distribution (in black), all centred excepted climate SN (in grey), and scenario_{project} (in white).

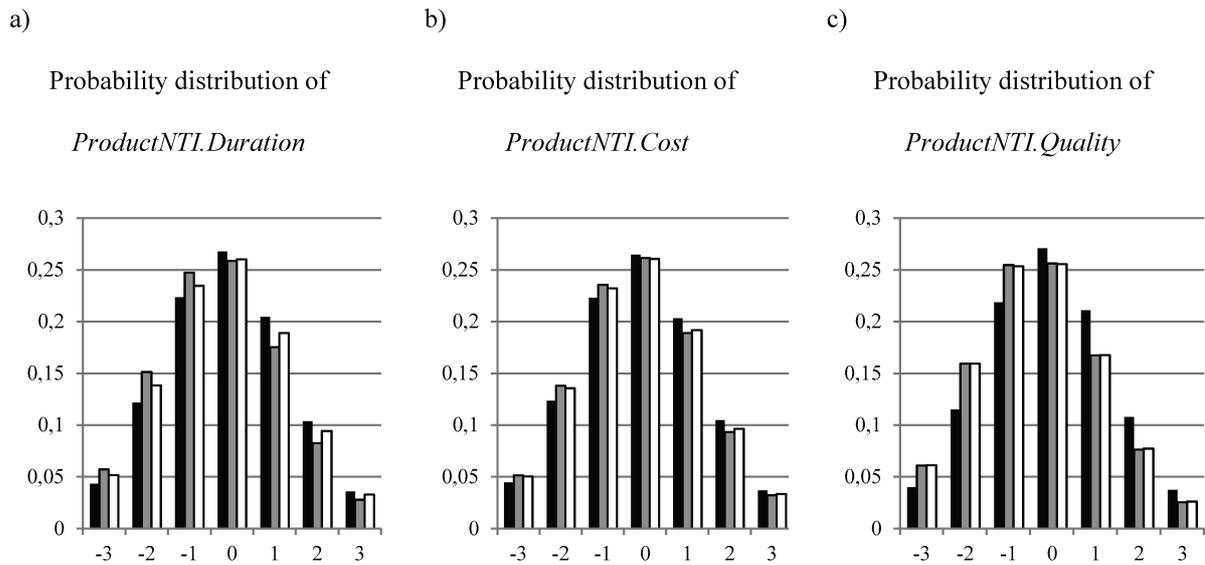


Figure 4-15 : Marginal probability distribution through model covering level 1 and 0 of (a) the duration, (b) the quality and (c) the cost of *product of project NTI* in level 0 given when all attributes of instances of *Environment* are prior centred distribution (in black), all centred excepted climate SN (in grey), and scenario_{project+} (in white).

From all results that we get from model covering level 0 and 1, we can observe all probability distribution of products of project NTI from detail (level 1) to general level (level 0) which obtained from level 1 in a logical way.

4.3.4.2. Analysing the consistency of product of project NTI between the three levels

Generic model consists of three levels, CPTs at each level are defined separately. By checking the consistency of model, we will analyse the consistency at the couple of different levels: macro-meso and meso-micro which based on figure 4-18. It means that, we will:

- analyse the difference between probability distribution of $P(\text{Building_NTI.Duration} \mid \text{ClimateNTI.Intensity})$ obtained at only level meso (level 1) and that obtained by the transition at level meso-micro.

- analyse the difference between probability distribution of $P(\text{Product_NTI.Duration} \mid \text{Environment}(E)_ProjectNTI.Aggressiveness)$ obtained at only level macro (level 0) and that obtained by the transition at level macro-meso. Moreover, scenario in upper-level are inferred from its level.

All input and output of those works are presented in table 4-18 and 4-19.

Table 4-18 : Input and output in model meso-micro and level 1 of project NTI

	Model covering level 2 and 1	Model level 1
Input	- $CPT_2^7(a_2, \beta_2, r_2)$ - Input variable (scenario): + <i>PrecipitationNTI</i> . <i>LevelOfPrecipitation=SSN</i>	- $CPT_1^8(a_1, \beta_1, r_1)$ - Input variable (scenario): is the output variable in the model covering level 2 and 1 <i>ClimateNTI.Intensity</i>
Output	- Output variable: <i>ClimateNTI.Intensity</i> , - Output variable: <i>BuildingNTI</i> . <i>DurationOfBuilding</i>	<i>BuildingNTI</i> . <i>DurationOfBuilding</i>
Compare	<i>BuildingNTI</i> . <i>DurationOfBuilding</i> in two models	

Table 4-19 : Input and output in model covering level macro-meso and model level 0 of project NTI

	Model covering level 0 and 1	Model of level 0
Input	- $CPT_1(a_1, \beta_1, r_1)$ - input variable (scenario): is the output variable in the model covering level 2 and 1 <i>ClimateNTI.Intensity</i> ,	- $CPT_0^9(a_0, \beta_0, r_0)$ - Input variable (scenario): is the output variable in the model covering level 0 and 1 <i>E_ProjectNTI</i> . <i>Aggressiveness</i>
Output	- <i>E_ProjectNTI</i> . <i>Aggressiveness</i> - Output variable: <i>PIP.Duration</i>	+ Output variables in level 0 : <i>PIP.Duration</i>
Compare	<i>PIP.Duration</i> in two models	

The results will be shown in the figure 4-16 and 4-17 with the first scenario is *PrecipitationNTI*. *LevelOfPrecipitation=SSN*.

⁷ CPT_2 consists of all CPTs in level 2

⁸ CPT_1 consists of all CPTs in level 1

⁹ CPT_0 consists of all CPTs in level 0

From two levels of description (meso-macro and micro-meso), figure 4-16 plots the marginal probability distribution of interest variables *BuildingNTI. DurationOfBuilding* regarding scenario *PrecipitationNTI. LevelOfPrecipitation=SSN* (macro) and *ClimateNTI.Intensity* = [0.123,0.198,0.229,0.198,0.135,0.078,0.039] (meso) respectively. The skewness of distributions on grey column moves towards the left.

From two other levels of description (macro-meso), figure 4-17 plots the marginal probability distribution of interest variables *PIP.Duration* regarding scenario *ClimateNTI.Intensity* = [0.123,0.198,0.229,0.198,0.135,0.078,0.039] (meso) and *E_ProjectNTI.Agressiveness* = [0.031,0.091,0.219,0.341,0.204,0.086,0.028] respectively. The skewness of distributions on grey column also moves towards the left. Correspondent with figure 4-16, in micro-meso model, *PrecipitationNTI* is not the only one instance of *Environment* which impacts on the output result, there are other instances like *Temperature, Department, National* and *International economy*. If the impacts of these instances (*Temperature, Department, National* and *International economy*) are not so negative like *Precipitation*, the result (*BuildingNTI. DurationOfBuilding*) will be lightly skewed. In figure 4-17, in meso model, number of instances of *Environment* is less than in micro model (*Climate, Administration, and Economy*), so, when just an instance negatively impacts (*Climate*), the result will be skewed stronger than that one in figure 4-16.

These results highlight that:

- model at micro or meso levels provides a more specific, finer model than its upper model.
- The model at one level and the model at two levels seem to be consistent to the extend that probability distributions corresponding to common variables.

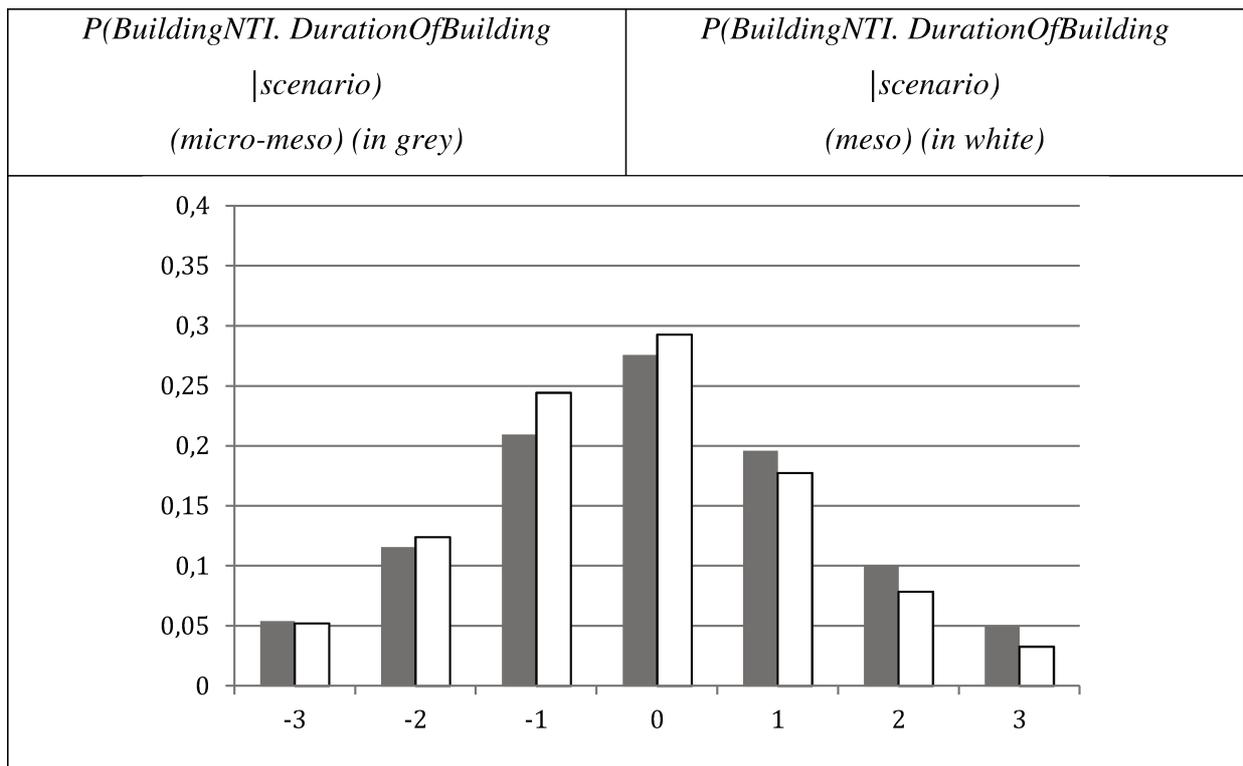


Figure 4-16 : Comparing $P(\text{BuildingNTI. DurationOfBuilding} | \text{scenario})$ taken from level micro-meso (grey column), meso level (white column).

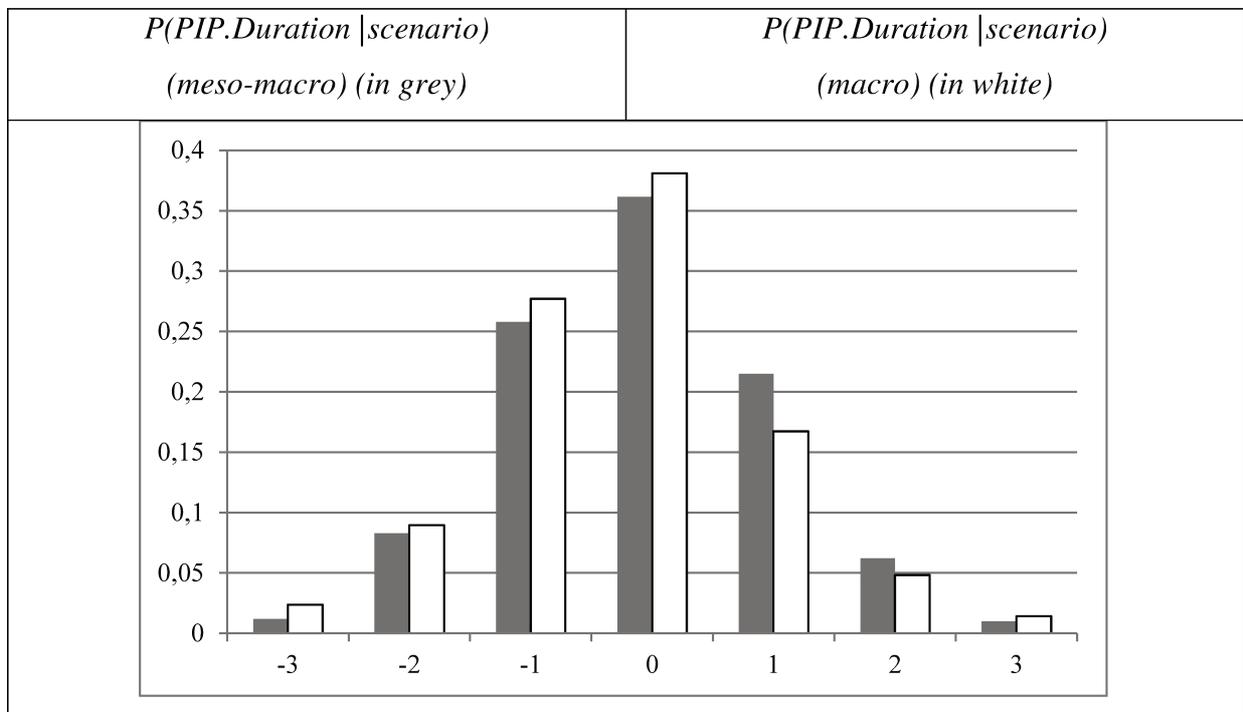


Figure 4-17 : Comparing $P(\text{PIP. Duration} | \text{scenario})$ taken from meso-macro (grey column) and macro level (white column)

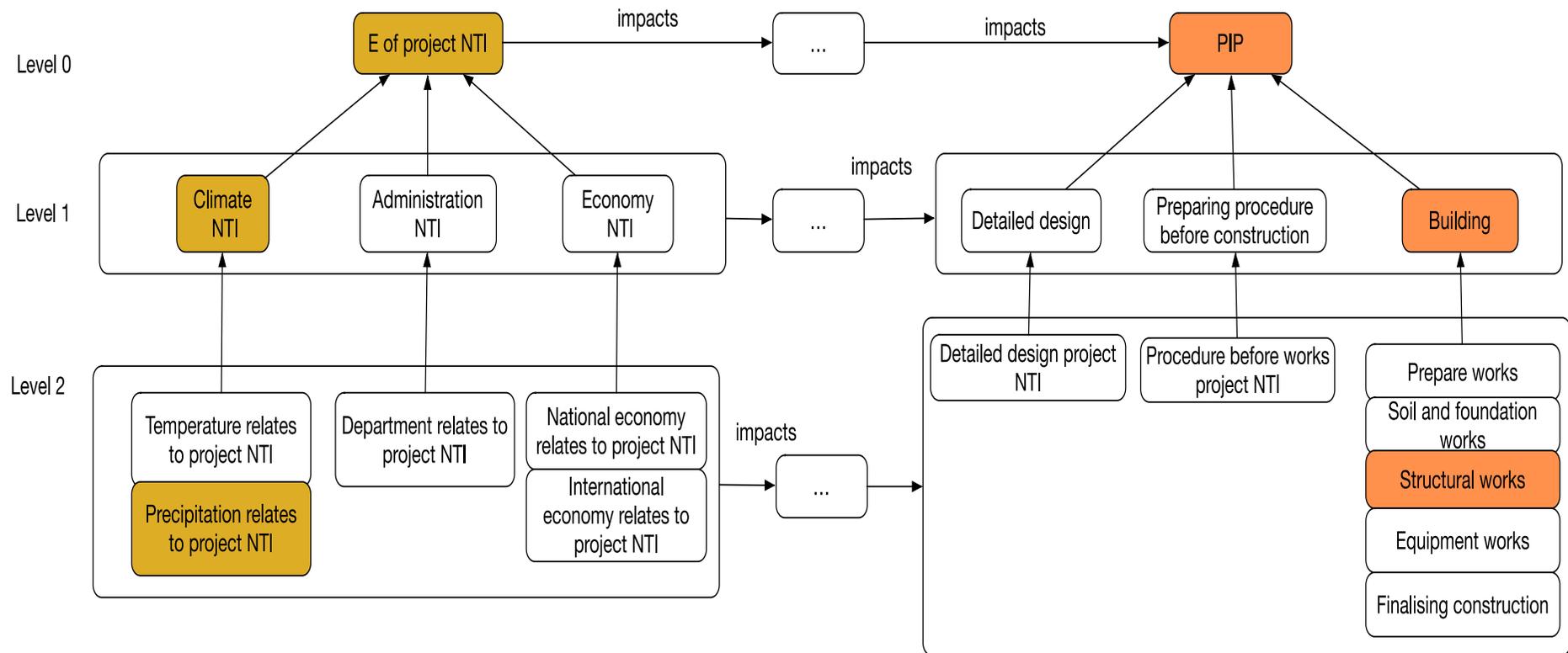


Figure 4-18 : Input variables (light orange) and output variables (bright orange) attached with instances in 3 levels.

4.4. Results and discussion

In this chapter, we applied PRMs to analyse and simulate the propagation of uncertainties in two real construction projects. Through the achieved results, they demonstrate the capacity of model in simulating behaviour of project when facing uncertainty, at different detailed levels of description. In the first project is a bridge project in Hue city (Vietnam), we analysed the the sensibility of output variables which are based on scenario in separated level. The second project consists in the construction of a nursing training institute located in the South-West of France, we analysed the consistency of model when combine two levels (macro-meso, meso-micro). With the support of O3PRM language, the simulation results can inform the project risk manager in controlling risks of construction projects. About the computing time that seeks to be reduced (section 3.3.2.2), we have indeed observed problems of calculation time a posteriori and not a priori.

Conclusion and perspectives

- Contribution summary

Risk modelling in construction projects is a complex challenge because of the variety of uncertainty sources and the complexity of interactions between involved entities. Reproducing the coupled effects of interactions inside the project performances requires a holistic and a relevant description of the system. We have proposed in this thesis a generic model which is supported by the development of a domain ontology, defining and describing all relevant entities in the context of risk management in construction. This model has been extended by means of the formalism of probabilistic relational model (PRM) in order to define a dependency network between entities, attributes and to quantify uncertainty over this network. The model has been implemented with the purpose of checking its practical feasibility and consistency. A generic holistic model has been developed allowing to:

- implement any kind of construction project,
- take uncertainty into account,
- simulate the uncertainties propagation in the project processing.

We proposed a generic model by using the ontology formalism. It provides a structured representation of any kind of construction project. The challenge is then to ensure consistency in relations between attributes and entities which are defined at different detailed levels.

We have illustrated and highlighted the interest of our approach by instantiating the model according to two case studies: a road and bridge project renovation in Hue (Vietnam) and a Nursing training institute (NTI) project in France.

The first difficulty we face was to develop a general semantic model considering all possible entity of a construction project and their relations which can represent for all types of construction project. Hence, a thorough analysis of literature (international journal, standard, etc.) and experience about risks of construction projects help us in developing a comprehensive knowledge which contains a set of concepts with their attributes and their relations.

The next difficulty was to develop a model able to formalize a project according to detailed levels of detail levels. The knowledge base at each detailed level must be sufficiently general to cover all construction projects, and can be adapted to any particular project. Three levels of detail were considered.

The third difficulty is to ensure the consistency between many the concepts, their attributes, concepts' objects, and their relation defined at different levels of detail. PRMs must assure in simulating this complex stochastic dynamical systems.

The model was implemented by using pyAgrUm and the O3PRM language which is dedicated to the PRM. The model was instantiated on two real projects that have yielded promising results.

- Perspectives

We have proposed in this thesis a generic model which is supported by the development of a domain ontology, defining and describing all relevant entities in the context of risk management in construction. This model has been extended by means of the formalism of probabilistic relational model (PRM) in order to define a dependency network between all attributes of all entities and to quantify uncertainty over this network in different detailed levels. The proposed generic holistic model has been developed allowing to (1) implement any kind of construction project, (2) to take uncertainty into account and (3) to do simulations.

Regarding to all works which have been done in this research, we recommend some perspective below:

- The model can be extended for more than three levels that we analysed and also be applied for other types of construction project.
- The knowledge base supporting the model has to be consolidated and completed (more concepts, attributes, objects, and their relations).
- The behaviour of a construction project can be described which is based on other scenarios.
- The scale to assess attributes can be modified (e.g. by increasing the number of score, by specifying the scale according to the attribute, etc.)
- The model could be used for other case-study in order to demonstrate the sustainability of the model.
- Analysing the consistency between different levels of description : calibrating (α , β , r) coefficients of CPTs. We will give our orientation like below:

The choice of CPT to formalize the dependencies between attributes, was performed separately for the three detail levels. Two questions then arise: are the CPT consistent

between the different levels? Is it a rule to build CPT ensuring the consistency between different levels? In order to answer those question, figure 5-1 exposes a simple example: we consider a given distribution for *C1.a* (we can infer the corresponding distributions for *C11.a* and *C12.a*) and we want to analyse the impact on the distribution of *C2.b* according to the chosen CPT₁ (we assume that the CPT₁ is the same for every relation of the level 1). For instance, how should be the CPT₀ given a CPT₁ if we want to find consistent results between (*C1.a*)->(C2.b) (Figure 5-1.a) and (*C1.a*)->(C11.a and C12.a)->...->(C2.b) (Figure 5-1.b).

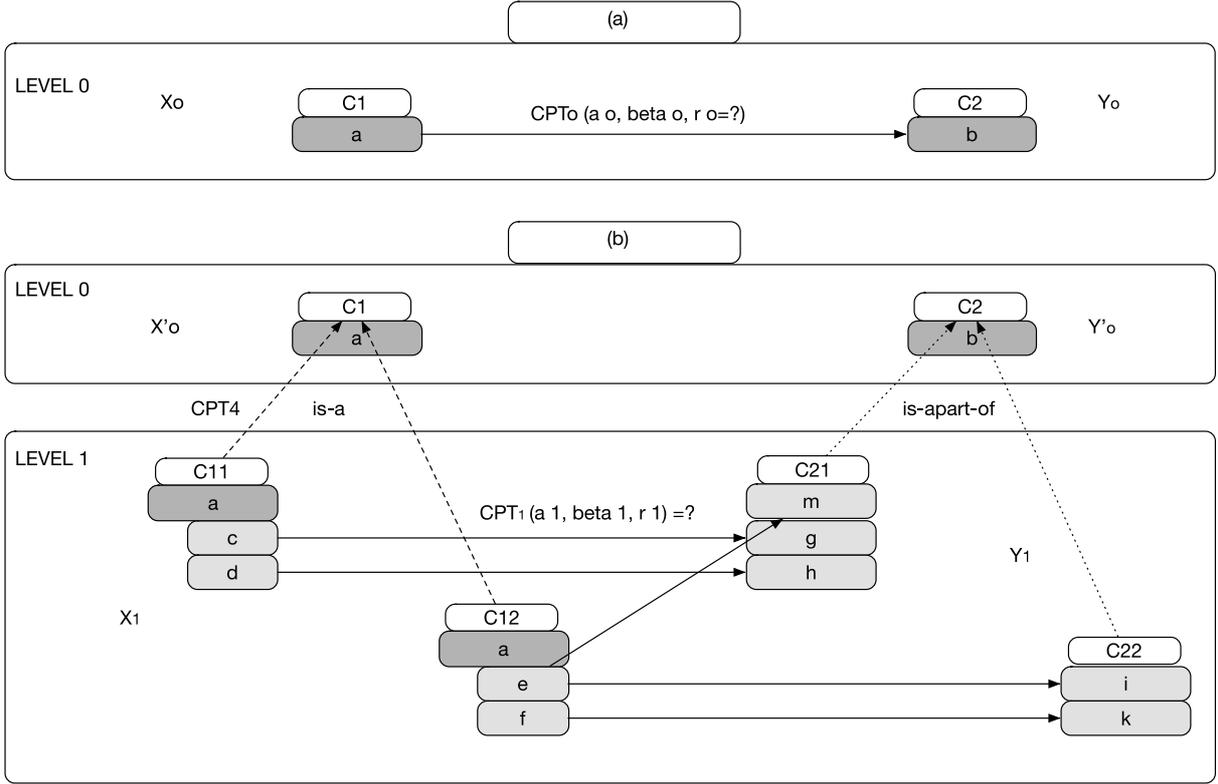


Figure 5-1: An example of simple model and CPTs in each level.

In order to solve these questions, we need firstly to propose a criterion of consistency. So, we defined the consistency from a deviation indicator (D): more D is small, more the system is consistent. D is compute as the sum of two indicators:

- ADP: Average Deviation between two distribution Probabilities.

$$ADP = \text{sum } (DP_i) / 7$$

where DP_i ($i=[-3,3]$) are the deviations between the probabilities which belong to each state (figure 5-2.a).

- ADCP: Average Deviation between Cumulative distribution Probabilities.

$$ADCP = \text{sum } (DCP_i) / 7$$

where DCP_i ($i=[-3,3]$) are the deviations between the cumulative probabilities which belong to each state (figure 5-2.b).

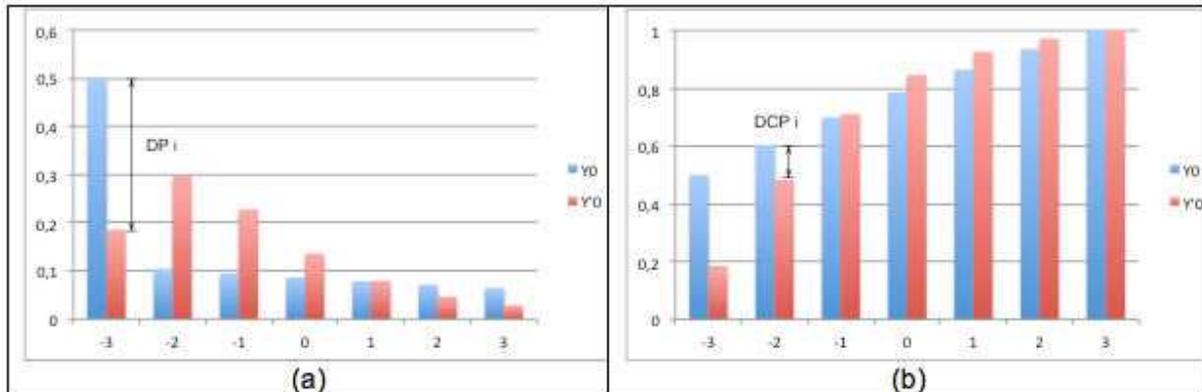


Figure 5-2: ADP and ADCP.

Thus, the checking of consistency between description at levels 0 and 1 is done by measuring D , which must be as low as possible.

The question is then, to know if it is possible to build a generic rule to ensure the consistency (i.e. to minimize D) between the value obtained by the model at different level. We assume that the example of figure 5-1 is simpler than the complete real model, but is sufficient to perform a first analysis. We formalized the problem as exposed in the table 5-1. The system description (thus the model) is consistent as distance between the probability distribution of $C2.b$ obtained directly at level 0 (Y_0) and that obtained by the transition at level 1 (Y'_0) is minimized.

Table 5-1: Input, output information in the model covering level 0, 1 and model level 0.

In model of level 0 and 1	
Input	- $CPT_1(a_1, \beta_1, r_1)$: All level 1 CPTs are identical. - $X1$: Priori probability distributions for $C11.c, C11.d, C12.e, C12.d$.
Output	- $CPT_0(a_0, \beta_0, r_0)$: The CPT_0 which minimize the deviation D between Y_0 and Y'_0 .

The optimization is performed by a discretization of the solution space and a complete exploration of it.

In order to simplify the problem, the possible values of the input parameters were limited to a finite number of values:

- $a_0, a_1 = \{0.5; 0.6; 0.7; 0.8; 0.9; 1\}$

• $\beta_0, \beta_1 = \{0.1; 0.2; 0.3; 0.4; 0.5\}$

• $r_0, r_1 = \{2; 3; 4; 5; 6\}$

X1 is chosen from one of the following four distributions:

Value	X1 ₁ Identity	X1 ₂ Pessimistic	X1 ₃ Optimistic	X1 ₄ Symmetric
-3	0	1	0	0,05
-2	0	0	0	0,1
-1	0	0	0	0,15
0	1	0	0	0,4
1	0	0	0	0,15
2	0	0	0	0,1
3	0	0	1	0,05

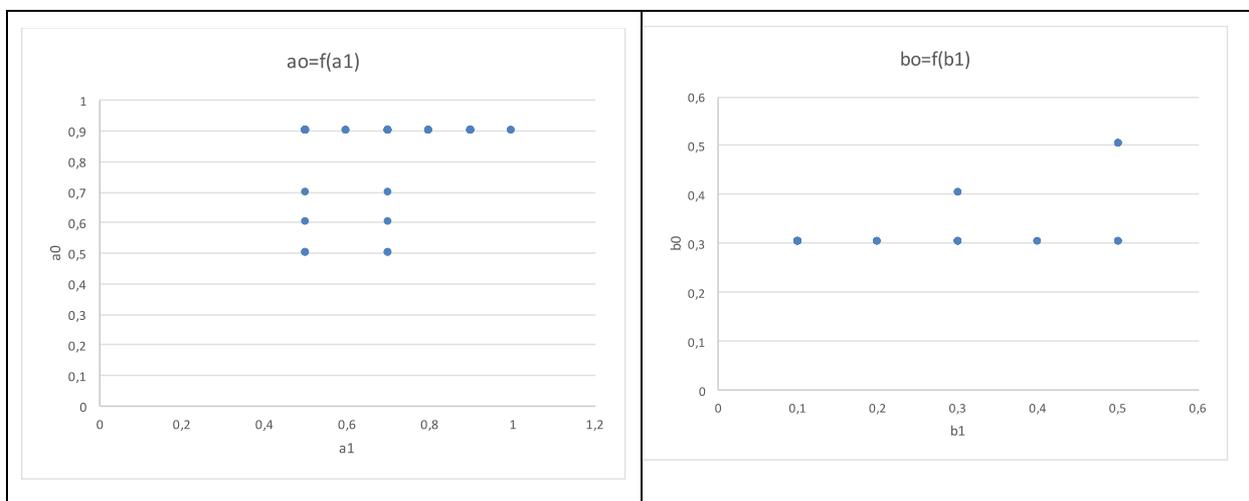
To find the variable set $\{a_0, \beta_0, r_0\}$ to minimize the difference between Y_0 and Y'_0 , we used a method by discretization of the solution space (identical to that of the starting variables) and by calculation of all possible solutions (total exploration). We used a macro under Excel to facilitate the process. By varying the input data, here are the responses obtained for 50 sets of input variables (the CPT0 corresponds to the one that minimizes the previously defined deviation):

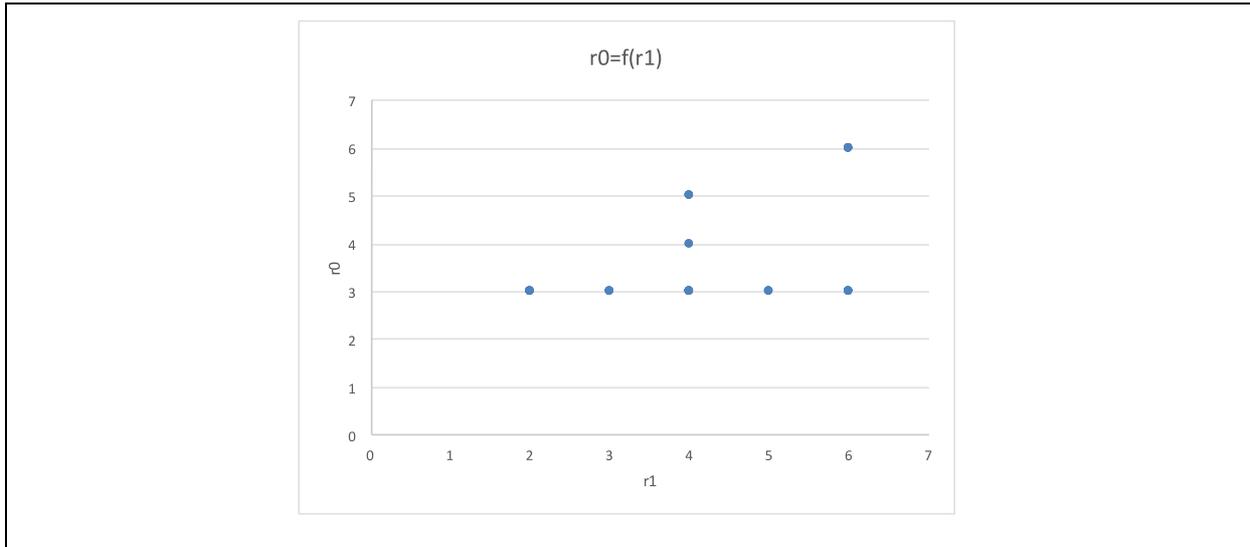
X1	CPT1 (input)			CPT0 (output)		
	a_0	β_0	r_0	a_1	β_1	r_1
1	0,5	0,1	2	0,9	0,3	3
1	0,5	0,1	4	0,9	0,3	5
1	0,5	0,1	6	0,9	0,3	6
1	0,5	0,3	6	0,9	0,4	6
1	0,5	0,3	4	0,5	0,3	4
1	0,5	0,3	2	0,9	0,4	3
1	0,5	0,5	2	0,5	0,5	3
1	0,5	0,5	4	0,6	0,5	5
1	0,5	0,5	6	0,7	0,5	6
1	0,7	0,1	2	0,9	0,3	3
1	0,7	0,1	4	0,9	0,3	5
1	0,7	0,1	6	0,9	0,3	6
1	0,7	0,3	2	0,9	0,4	3
1	0,7	0,3	4	0,5	0,3	4
1	0,7	0,3	6	0,9	0,4	6
1	0,7	0,5	2	0,5	0,5	3
1	0,7	0,5	4	0,6	0,5	5
1	0,7	0,5	6	0,7	0,5	6
1	0,9	0,1	2	0,9	0,3	3
1	0,9	0,1	4	0,9	0,3	3
1	0,9	0,1	6	0,9	0,3	3
1	0,9	0,3	2	0,9	0,3	3

1	0,9	0,3	4	0,9	0,3	3
1	0,9	0,3	6	0,9	0,3	3
1	0,9	0,5	2	0,9	0,3	3
1	0,9	0,5	4	0,9	0,3	3
1	0,9	0,5	6	0,9	0,3	3
2	0,7	0,3	4	0,9	0,3	3
2	0,5	0,1	6	0,9	0,3	3
3	0,7	0,1	5	0,9	0,3	3
4	0,5	0,1	6	0,9	0,3	3
4	0,8	0,2	6	0,9	0,3	3
4	0,5	0,2	2	0,9	0,3	3
4	1	0,1	3	0,9	0,3	3
4	1	0,3	5	0,9	0,3	3
4	0,6	0,2	5	0,9	0,3	3
4	0,6	0,5	4	0,9	0,3	3
4	0,8	0,2	3	0,9	0,3	3
4	0,8	0,4	6	0,9	0,3	3
4	0,8	0,5	5	0,9	0,3	3
3	0,7	0,3	4	0,9	0,3	3
3	0,5	0,1	4	0,9	0,3	3
3	0,9	0,1	2	0,9	0,3	3
2	0,9	0,2	6	0,9	0,3	3
2	0,5	0,2	4	0,9	0,3	3
2	0,5	0,3	5	0,9	0,3	3
2	0,6	0,4	3	0,9	0,3	3
3	0,8	0,4	4	0,9	0,3	3
3	0,5	0,1	3	0,9	0,3	3
3	0,5	0,5	3	0,9	0,3	3

* Blue: Plan of experiment with $X_1 = 1$; in red: a randomized sample with other X_1 s to confirm the trend that seemed to be taking shape.

A first idea (and which seems logical) would be to look at the relation between a_0 and a_1 , β_0 and β_1 , r_0 and r_1 respectively. Here are the graphs obtained:





On a simplified example, there is no answer was found. So finding a rule would be even more complex in the generic model or the cases are much more varied (number of parents, heterogeneity of the CPT, etc.).

Hence, all possible works that we can do are listed as below:

- (a) we must find a multilinear relation allowing to consider more complex relations (dependence) between the variables ...
- (b) the problem does not arise from the CPTs but from the overall structuring of the model (CPTs as well as the structure of the model is based on expert knowledge and could be questioned)
- (c) it is necessary to accept having two distinct models (1 macro, 1 micro) whose coherence should be ensured by the ability of experts to provide good CPT assessments. A possible inconsistency can be assumed, but it can be evaluated and indicated to the expert as a control variable without, however, telling him/her what to do.

Appendix

Appendix 1. Developed ontology in construction project

This Appendix summarizes the main characteristics of several ontologies that have been proposed by several authors.

Table 1 : Domain Taxonomy for Construction Concepts

(El-Diraby, Lima, and Feis 2005)

	Domain Taxonomy for Construction Concepts: towards a Formal Ontology for Construction Knowledge
Orientation	Developing taxonomy as the foundation of domain ontology for construction including semantic relationships and axioms.
Entities	Project, Actor, Process, Product, Resource, and Systems. + Project : is a collection of processes. + Actors : are the major players in construction. + Products : are physical and managerial. They are produced or used for construction and management processes. + System : is a collection of heterogeneous concepts that relate to a entity.
Attributes	Project : start time, finish time, duration, quality standard, productivity level, life cycle and life cycle cost. Process : start time, finish time, duration, quality standard, productivity level, life cycle and life cycle cost.
Value	Do not mention
Level (Scale)	Not clear for all entities.
Taxonomy	« is a/an », « is a part of », ...
Partonomy	Do not mention
Associative	Not clear
Attributes' relations	Do not mention
Instance	Do not mention
Conclusion	- There was not the difference between taxonomy and partonomy. - Relations between entities in different level

Table 2 : Taxonomy for change causes and effects in construction projects

(Sun and Meng 2009)

Taxonomy for change causes and effects in construction projects	
Purpose	Developing two taxonomies for change causes and change effect.
Entities	Group of causes : External causes, Organizational causes, Project internal causes
Attributes	Do not mention
Value	Do not mention
Level (Scale)	<p>3 levels</p> <p>External causes :</p> <ul style="list-style-type: none"> + Second level consists of: environmental, political, social, economical and technological factors. + Third level consists of: Conservation restrictions, Weather conditions, natural disaster, geological conditions, unforeseen ground conditions (environmental factors); changes in government policies, changes in legislations on employment and working conditions, delays in planning permission approval (political factors); demography change and its impact on labour demand and supply, skill shortage on certain trades, opposition of neighbouring community (Social factors); economic development cycle and its impact on demand, inflation impact on material, equipment and labour price fluctuation, market competition (economical factors); new materials, new construction methods, technology complexity (technological factors). <p>Organizational causes :</p> <ul style="list-style-type: none"> + Second level consists of : process, people, technology. + Third level consists of : Organisation business strategy, business procedures, including payment practice, quality assurance procedures (process); Competence and skills, culture and ethics (people); IT and communication systems, technical supports (technology). <p>Project internal causes :</p> <ul style="list-style-type: none"> + second level consists of : Client generated, design consultant generated, contractor/subcontractor generated, others.

	+ third level consists of : Requirement change and variation, Funding change, i.e., shortage of funding, Slow decision making, Payment delays, Difficulty in site acquisition (Client generated) ; Poor, incomplete drawings, Design changes due to poor brief, errors and omissions, Inconsistent site conditions (design consultant generated) ; Poor project plan/schedule, Poor site/project management skills, Delays in appointing subcontractor, Delay of subcontractors' work, Poor workmanship, Low productivity, Poor logistic control (contractor/subcontractor generated) ; Poor interdisciplinary communication, Team instability, i.e., disputes, bankruptcy, etc., Inappropriate project organisational structure (others).
Taxonomy	Developing hierarchy structure without word « is a/an »
Partonomy	Do not mention
Associative	Do not mention
Attributes' relations	Do not mention
Instance	Supermarket building project.
Conclusion	This paper only concerned in developing hierarchy structure of entities, without their interactions.

Table 3 : A study of ontology-based risk management framework of construction projects
(Tserng et al. 2009)

	A study of ontology-based risk management framework of construction projects through project life cycle
Purpose	Improve model and structuration base on ontology.
Entities	External risk, Site condition, Owner-Contractor Agreement, Owner Condition, Subcontractor Condition, Project Execution, Project preparation and planning, Contracting and Administration procedure.
Attributes	Do not list but there are some potential attributes. <ul style="list-style-type: none"> - Attribute of material price is fluctuation. - Attribute of owner is credibility, indefinite, communication, cooperation. - Attribute of engineer is inexperience. - Attribute of activity is accuracy logic.

Value	Do not mention
Level (Scale)	<p>2 levels</p> <ul style="list-style-type: none"> - External risk : <ul style="list-style-type: none"> + second level consists of : physical factor, neighbor, material price fluctuation, material supply chain management. - Site condition : <ul style="list-style-type: none"> + second level consists of : site surrounding condition, site geotechnical condition, regional planning of construction site, land property - Owner-Contractor Agreement : <ul style="list-style-type: none"> + second level consists of : project characteristics, requirement of advance payment, special contract agreement, approval of change order, processing of change order, definite receiving procedure - Owner Condition : <ul style="list-style-type: none"> + second level consists of : Owner credibility, indefinite owner demand, owner composition complexity, owner cooperation, owner communication, communication with owner. - Subcontractor Condition : <ul style="list-style-type: none"> + second level consists of : geotechnical subcontractor expertise, main contractors integration, subcontractor human resource management, subcontractors integration. Project Execution : <ul style="list-style-type: none"> + second level consists of : Inexperienced engineer, construction impact to environment, management of safety and health, accuracy of activity logic, engineering completion variance. - Project preparation and planning : <ul style="list-style-type: none"> + second level consists of : accuracy of the budge/cost planning, accuracy of the design reference document, planning of suitable method, insufficient human resource in the project intiation, insufficient human resource - Contracting and Administration procedure <ul style="list-style-type: none"> + second level consists of : land acquisition schedule, constrained contracting, administation delay, planning rework, billing progress,

	closure procedure.
Taxonomy	Developing hierarchy structure without word « is a/an »
Partonomy	Do not mention
Associative	Do not mention
Attributes' relations	Do not mention
Instance	Do not mention

Table 4 : Ontology for Relating Risk and Vulnerability to Cost Overrun in International Projects (Fidan and Dikmen 2011)

Ontology for Relating Risk and Vulnerability to Cost Overrun in International Projects	
Purpose	Presenting an ontology for relating risk-related concepts to cost overrun.
Entities	War or hostilities, terrorism, natural catastrophe, social unrest, labor strike, currency rates, inflation, tax rate, laws and regulation, government, engineer, designer, client, technology method, contractor, financial, weather condition, geological conditions, site conditions, client's staff, labor, material, equipment, subcontractor, work, infrastructure, consultant.
Attributes	<ul style="list-style-type: none"> - Availability of labor - Availability of material - Availability of equipment - Availability of subcontractor - Availability of infrastructure - Quantity of work - Quality of work - Bureaucracy of client. - Attitude of client - Instability of economic condition - Instability of government - Instability of international relation - Instability of social conditions.

	<ul style="list-style-type: none"> - Immaturity of legal system - Complexity in design - Incomplete design - Assessibility of site - Inadequate geotechnical investigation - Inadequate climate conditions - Strict requirement - Vagueness of contract - Technical incompetency of designer, consultant. - Experience of client, partner - Quantity of staff - Manageability by experience with client. - Size, budget, duration of project
Value	String for name Float for unit of mesure (e.g duration, budget, ...) Boolean for state
Level (Scale)	Do not mention
Taxonomy	Developing hierarchy structure of risk without word « is a/an »
Partonomy	Do not mention
Associative	Do not have relations between entities were mentioned above
Attributes' relations	Do not mention
Instance	Do not mention

Table 5 : Dynamic and multi-perspective risk management of construction projects using tailor-made Risk Breakdown Structures (Mehdizadeh Rasool 2012)

	Dynamic and multi-perspective risk management of construction projects using tailor-made Risk Breakdown Structures
Purpose	One of purposes in this research is to develop tailor-made Risk Breakdown Structure
Entities	Project stakeholders, external risks, phase
Attributes	Do not list but attributes were mentioned. + Attributes of Contractors/ Subcontractors (Project

	<p>stakeholders) are : performance, management, financial, poor workmanship or function of labors and experts.</p> <ul style="list-style-type: none"> + Attributes of Consultants (Project stakeholders) are : performance, characteristics, management, financial. + Attributes of Legal (external risks) are : change in law and standards, fault in law standards, conflict of law and standards + Other attributes : skill deficiency in management, poor communication, complexity of task.
Value	Integer values of risk note about time, delay and performance [0,5] ([positive, negative]).
Level (Scale)	<p>2 levels (except external risks : 3 levels)</p> <ul style="list-style-type: none"> - Project stakeholders : <ul style="list-style-type: none"> + second level consists of : Designers, Financiers, Owner/Clients, Contractor/Sub-contractors, Suppliers, Consultants. - External risks : <ul style="list-style-type: none"> + second level consists of : Economic/Financial (price and available resources of resource, market, macro economical context, financial), political, legal and regularities, natural hazards, unexpected weather, force majeure, context (third party, social and cultural, technology context, site context, resources context). - Phase : <ul style="list-style-type: none"> + second level consists of : Feasibility, Contract, Design, Implementation, Operation, Management.
Taxonomy	Developing hierarchy structure without word « is a/an »
Partonomy	Do not mention
Associative	Do not mention
Attributes' relations	Do not mention
Instance	LineB of Lyon Metro (Lyon city)

Table 6 : On the risk management of construction project : a knowledge-based approach.
(Khartabil, Breysse, and Taillandier 2013)

	On the risk management of construction project : a knowledge-based approach.
Purpose	Developing ontology which represents a formal shared conceptualization of construction project.
Entities	<p>Project, actor, process, product, activity, resource, environment.</p> <ul style="list-style-type: none"> - Project is « a temporary endeavor undertaken to construct a building, a tunnel, a highway ... » - Actor is « a participant involved in the implementation of project » - Process is a « construction process such as, excavate a working shaft, construct a foundation ... » - Product is an « an output/result of a process, such as, working shaft, foundation, column ... » - Activity is « a building block in the project that consumes time, cost, and resource. Example : steel fixing of columns. » - Resource is « something needed to perform an activity such as, concrete, loader, and steel-fixer ». - Environment are « elements or factors around the project that can influence or be influenced by it. Examples : regulations, codes, economic situation. »
Attributes	Do not mention
Value	Do not mention
Level (Scale)	<p>2 levels</p> <ul style="list-style-type: none"> - Actor : + second level consists of : Contractor, Owner, Consultant, Subcontractor, Supplier. - Resource : + second level consists of : Labor, Material, Equipment, Subcontractor, document. - Environment : + second level consists of : Economic, Financial, regulatory, political,

	social, weather, site, location, contract
Taxonomy	« is a/an »
Partonomy	Do not mention
Associative	Project – Process ; process-product ; process-activity ; activity-resource ; project – product ; product-product classification
Attributes' relations	Do not mention
Instance	Do not mention

Table 7 : A case study of a construction project utilizing a risk mapping tool
(Yildiz, Dikmen, and Birgonul 2014)

	Using expert opinion for risk assessment: a case study of a construction project utilizing a risk mapping tool
Purpose	One of purposes of this paper is to develop risk mapping tool.
Entities	Design, project, geologic, contract, engineer, client, site conditions, contractor, economic, laws and regulations, client, contractor, local resources, work.
Attributes	<ul style="list-style-type: none"> - Complexity of project - Uncertainty of geological problems - Incompetency of engineer - Incompetency of client - Experience, skill of contractor - Performance of client - Performance of contractor - Availability of local resources - Productivity - Amount, quality, unit cost of work - Cost of project
Value	Notes [0,10]
Level (Scale)	Do not mention
Taxonomy	Do not mention
Partonomy	Do not mention
Associative	Do not mention

Attributes' relations	Mentioned but not clear. For example : Availability of local resources – Unit Cost of work – Cost of project .
Instance	Do not mention

Table 8 : Formalized and systemic risk management process for complex and strategic construction projects (Esra Tepeli 2014)

	PROCESSUS FORMALISE ET SYSTEMIQUE DE MANAGEMENT DES RISQUES POUR DES PROJETS DE CONSTRUCTION COMPLEXES ET STRATEGIQUES
Purpose	One of purposes of this research is to monitor process variance of all attributes in a construction project
Entities	Environment, Steps, Activity, Actor, Resource, Contract. + Activity : is the basic element of decomposition of a project.
Attributes	<ul style="list-style-type: none"> - Attributes of step are : Start date, end date, duration. - Attributes of phase are : name, number, previous phase, degree of complexity, priority, degree of avancement. - Attributes of sous-phase are : name, number, previous phase, degree of complexity, priority, degree of avancement. - Attributes of executable activity are : Attachment to which sub-phase, task duration, start and end date, previous tasks, stage of completion, complexity, priority, actors, quantity and quality of resources, cost of resources, avancement of activities, degree of quality and cost. - Attributes of milestones activity are : Attachment to which sub-phase, duration milestone, start and end date, previous milestones, validation <p>Attributes of organizations, departments, stakeholders (actors) are : hierarchical attachment to which department or service, paid by which organization, degree of skill, experience of working, availability.</p> <ul style="list-style-type: none"> - Attributes of actor are : Skill, experience, available - Attributes of actor are : Skill, feedback, available (*) - Attributes of organization are : name, address, telephone, fax

	<ul style="list-style-type: none"> - Attributes of departments are : name, number, address. - Attributes of intervenant : name, surname. - Attributes of resources : Quality, supply capacity, time of acquisition, time of utilisation, unit cost <ul style="list-style-type: none"> - Attributes of human resource, financial resource, equipment, materials, consommables, documents, space (resources) are : required quantity, available quantity, quantity searching, required quality, available quality, type of acquisition, supplier reliability, time of acquisition, time of utilisation, unit cost, cost. - Attributes of contract : Contract length, start date and end date, actors involved: who pays whom, who control who, missions-responsibilities, Cost
Value	<p>Almost each attribute has its own value.</p> <p>For example :</p> <p>Materials : Kg, m, l</p> <p>Consommable : Watt, m</p> <p>Espace : m</p> <p>Cost : €</p> <p>...</p>
Level (Scale)	<p>There are different levels (from 2 to 4 levels)</p> <ul style="list-style-type: none"> - Environment : <ul style="list-style-type: none"> + second level consists of : Politic, economic, culture social, variance of technic and materials, administrative - Actors : <ul style="list-style-type: none"> + second level consists of : main actors or organizations (the building owner, the contractor, construction company, etc.). + third level consist of : services or departments (the pole direction pole design, study pole, pole management financial, legal pole, etc.) + fourth level consist of : stakeholders (architect, designers, etc.) - Resources : <ul style="list-style-type: none"> + second level consists of : human resource, financial resource, equipment, materials, consommables, documents, space + third level consists of : project manager, architect, designers,

	<p>director of studies, project manager, engineers, conductors work, workers (human resource) ; cranes, vehicles, formwork, scaffolding, shovel, concrete mixer (equipments) ; concrete, cement, steel, wood, aggregates, sealing (materials), electricity, fuel, water, gas, telephone, internet (consommables) ; dossier tender, contracts, implementation plans (documents) ; ground, office, waste space (space).</p> <ul style="list-style-type: none"> - Steps : + second level consists of : Phase + third level consists of : sous-phase + fourth level consists of : executable tasks and milestones tasks
Taxonomy	« is a/an »
Partonomy	do not mention
Associative	Activity-Activity, Actor-Activity, Actor-Actor, Resource-Activity, Resource Actor.
Attributes' relations	Do not mention
Instance	Do not mention

Table 9: Developing taxonomy for the domain ontology of construction contractual semantics: A case study on the AIA A201 document (Jia Niu and Issa 2015)

	<p>Developing taxonomy for the domain ontology of construction contractual semantics: A case study on the AIA A201 document (Jia Niu and Issa 2015)</p>
Purpose	Developing taxonomy in the domain of construction contractual semantics
Entities	<p>Environment, Actor, Product, Resource, Behavior, Process, Promise, Remedy.</p> <ul style="list-style-type: none"> + Environment : are things out of project Actors' control and it affect substantially the execution of the contract. + Project : is a collection of processes. + Actors : are the major players involved in the contract. + Products : are all needed items to be provided by Actor as required by the contract. + Resource : is an entity that has value, requires effort to obtain, and

	<p>is something indispensable</p> <ul style="list-style-type: none"> + Behavior: are the actions and/or inactions of the Actors which may lead to certain contractual consequences. + Process : consists of procedures that should be followed by Actors for activities. + Promise : is contractual relationships of Actors. + Remedy : is a makeup for extra and excusable Resource consumption
Attributes	Do not mention
Value	Do not mention
Level (Scale)	<p>3 levels (except Promise: 4 levels, remedy : 2 levels)</p> <ul style="list-style-type: none"> - External environment <ul style="list-style-type: none"> + second level consists of : Legal environment, Physical environment, force majeure. + third level consists of : Applicable laws, statutes, ordinances, codes, rules and regulations, lawful orders of public authorities (Legal environment) ; site conditions, existing construction (Physical environment) ; weather delay, labor dispute (force majeure). - Actor : <ul style="list-style-type: none"> + second level consists of : Party, organization, agent, non-party, role + third level consists of : Contractor’s superintendent, Architect’s project representative (Party) ; contractors (organization) ; owner’s authorized representative, Contractor’s authorized representative, superintendent (agent) ; government agencies, municipality (non-party) ; initial decision maker, surety (role) - Product: <ul style="list-style-type: none"> + second level consists of : Document, construction work, service. + third level consists of : Instruments of service, submittals, schedules, evidence, record (document) ; the Project, the Work, construction or operations (construction work) ; access to work, design service (service). - Resource:

	<p>+ second level consists of : Labor, Materials, Equipment, Time and Money.</p> <p>+ third level consists of : carpenters, masons (Labor) ; plywood, cement, concrete (Materials) ; crane, scaffold (Equipment) ; work day (Time) ; dollars (Money)</p> <p>- Behavior:</p> <p>+ second level consists of : Action, Inaction.</p> <p>+ third level consists of : authorize, execute, etc. (Action) ; fail to, withhold, delay, ignore, etc. (Inaction).</p> <p>- Process:</p> <p>+ second level consists of : Administration Process, Legal Process, Construction Process, Time process.</p> <p>+ third level consists of : Communications facilitating contract administration (Administration Process) ; Mediation, Arbitration (Legal Process); Construction means, methods, techniques, sequences (Construction Process), bids are received, award of the Contract, commencement of the Work (Time process).</p> <p>- Promise:</p> <p>+ second level consists of : Contractual relationship, manipulation, documentation.</p> <p>+ third level consists of : Right, entitlement, authority, obligation, responsibility, liability (Contractual relationship) ; Exception, Condition, Limitation (manipulation) ; documentation (documentation).</p> <p>+ fourth level consist of copyright, ownership, mechanic's lien right, right to stop the Work (Right) ; rely on the accuracy, increase in Contract Sum or extension of Contract Time, Change Order, reimbursement (Entitlement); consent, enforce obligation against (Authority); report promptly, reasonable infer, secure and pay, indemnification (Obligation) ; jobsite safety, loss and damage, warranty, acts and omission of agent (Responsibility); pay avoidable costs and damages, loss caused by patent or copyright infringement (Liability); damage or defect caused by abuse, improper or insufficient maintenance (Exception); failure of payment, material change in the Work</p>
--	--

	(Condition); extent of indemnification (Limitation); Contract Documents, Change Orders, Construction Change Directives (Documentation). - Remedy: + second level consists of: Contract Time, Contract Sum, Indemnification.
Taxonomy	Developing hierarchy structure without word « is a/an »
Partonomy	Do not mention
Associative	Do not mention
Attributes' relations	Do not mention
Instance	AIA A201 General Conditions of the Contract for Construction (2007) document
Conclusion	This paper only concerned in developing hierarchy structure of entities, without their interactions.

Table 10 : A new agent-based model to manage construction project risks (Franck Taillandier et al. 2016)

	A new agent-based model to manage construction project risks – application to the crossroad of Bab El Karmadine at Tlemcen (Franck Taillandier et al. 2016)
Purpose	One of purpose of this research is to improve model and structuration base on the definition of agent on an ontology.
Entities	Stakeholder, Activity, Product, Contract, Resource, Skill, Exterior environment. + Stakeholder : is an organization or individual that influence or is impacted by the construction project. + Activity : is a « process belonging to the construction project, aiming at delivering a product » + Product : is a result of an activity. + Contract is a « physical element that has a legal value and that specifies the link between stakeholders and activities and the particular conditions in which the activity has to be completed ».

	<ul style="list-style-type: none"> + Resource is an « element owned by a stakeholder and allowing to carry out an activity ». + Skill : is « knowledge, expertise or know-how necessary to carry out the activity and/or owned by a human resource ». + Exterior environment : are « all the factors, elements, situations which are exterior to the project and that can have an impact on it ».
Attributes	Attributes of resources are : required quality, allocated quality, quantity
Value	5 Value (Very low, low, Average, high, very high).
Level (Scale)	<p>There are different levels (from 2 to 3 levels)</p> <ul style="list-style-type: none"> - Stakeholder : <ul style="list-style-type: none"> + 2nd level consist of : company, association, local authority, prime contractor, project manager. - Activity : <ul style="list-style-type: none"> + 2nd level consist of : operational, financial, managerial and contractual. + 3rd level consist of : study, structural works (operational) ; payment of a stakeholder by another one or purchasing activity (financial), supervision of a task by a subcontractor (managerial) and drawing up of a contract assigning a stakeholder to a given activity for a defined amount (contractual). - Product : <ul style="list-style-type: none"> + 2nd level consist of : concrete structure, architectural plan, decision, information, etc. - Resource : <ul style="list-style-type: none"> + 2nd level consist of : Human resources, materials resources + 3rd level consist of : Designers, workers, ... (Human resources) ; crane, concrete (materials resources). - Exterior environment : <ul style="list-style-type: none"> + 2nd level consist of : weather, economical context, third-parties.
Taxonomy	Developing hierarchy structure without word « is a/an »
Partonomy	Do not mention
Associative	Do not mention

Attributes' relations	Do not mention
Instance	Crossroad of Bab El Karmadine at Tlemcen

Table 15: Synthesis table of researched ontology in construction project

Factors	Table 1	Table 2	Table 3	Table 4	Table 5	Table 6	Table 7	Table 8	Table 9	Table 10
Concept	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Attribute	✓	✗	✓	✓	✓	✗	✓	✓	✗	✓
Value	✗	✗	✗	✓	✓	✗	✓	✓	✗	✓
Level (Scale)	✓	✗	✓	✗	✓	✓	✗	✓	✓	✓
Taxonomy	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓
Partonomy	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗
Associative	✗	✗	✗	✗	✗	✓	✗	✓	✗	✗
Attributes' relation	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗
Instance	✗	✓	✗	✗	✓	✗	✗	✗	✓	✓

Appendix 2. Entities, attributes, and their significations in level 1

Entity in level 0	Entity level 1	Entity's signification	Attribute of entities in level 1	Attributes' signification
Environment	Economy	Economy affects the cost of construction project	Aggresiveness	
			Instability	Instability is a property which is used to show how long impacts are likely to last (number of months, years).
			Inflation	Inflation is linked to the value of a currency, or to the number of monetary units to buy a commodity
	Climate	describes the average weather in a place over a periodical time (temparature, precipitation, wind, humidity, etc.)	Aggresiveness	
			Frequency	Frequency is the number of occurrences of a repeating natural event per unit time
			Intensity	Intensity is a property which used to reflect level impact of natural event on entities of construction project
	Administration	Administration is a place to supply construction and investment license of construction	Aggresiveness	
			Inertia	Inertia of administration is the delay time of administration in resolving procedures.
			Corruption	Corruption is the money (out of plan) must be paid to administration if they want to do procedure faster.
Actors	Owner	Owner is an individual or an organization who/which performs, manages project and linked by a contract. Owner has responsible about finance for project.	Productivity	
			Productivity in organizing project	Productivity in operating is the velocity of owner in working, organizing work, giving desicions, etc.
			Productivity in managing project	Productivity in managing is the velocity of owner in updating and managing time, cost, and quality of construction project
			Capacity	
			Capacity in organizing project	Capacity in organizing is the ability in working, arranging work, giving desicions, etc.

			Capacity in managing project	Capacity in managing is the ability in managing time, cost, and quality	
			Cost		
			Fixed cost	is the cost must be paid which not depend on scale of construction project (cost of lodgement, regulation cost of doing procedure, etc.)	
			Variable cost	is the cost must be paid which depend on scale of construction project (sum of salaries, energy, etc.)	
			Experience		
			Experience in organizing project	is the cumulated skill of organizing project acquired over time	
			Experience in managing project	is the cumulated skill of managing project acquired over time	
	Designer	Designer is an individual or organization who/which designs structure, architecture of project and linked by a design contract. Designer must ensure bearing structure of the building under the impact of load (people, furniture, concussion, ...)		Productivity	
				Productivity in designing	is the velocity of designer in designing (dimension, layout, etc)
				Productivity in calculating	is the velocity of designer in calculating (weight, impact force, etc)
				Capacity	
				Capacity in designing	is the ability in designing dimension, layout, etc. of construction project
				Capacity in calculating	is the ability in calculating weight, impact force, etc of construction project
				Cost	
Design cost	is the necessary cost of designer in designing construction project				
Serving cost for designing	is the cost which is used to serve for design				
Experience					

			Experience in designing	is the cumulated skill for designing acquired over time	
			Past qualification assessment about designing	is the statistic on the effectiveness of designing projects in the past	
	Contractor	Contractor is an individual or organization who/which performs building, installing construction and linked by a building contract	Productivity		
			Productivity in arranging work	is the velocity of contractor in arranging construction work	
			Productivity in building project	is the velocity of contractor in building process	
			Capacity		
			Capacity in arranging work	is the ability in arranging construction work	
			Capacity in building project	is the ability in building construction project	
			Cost		
			Building cost	is the necessary cost of contractor to perform construction project	
			Serving cost for constructing	is the cost which is used to serve for constructing work of contractor	
			Experience		
	Experience in building project	is the cumulated skill of building project acquired over time			
	Past qualification assessment about building	is the statistic on the effectiveness of building projects in the past			
	Supplier	Supplier is an individual or organization who supplies resources : materials, machines, human for construction project and linked by a supply contract	Productivity		
Productivity in transportation			is the velocity of supplier in transporting resource for construction project		
Productivity in supplying information			is the velocity of supplier in supplying information of resource		
Capacity					
Capacity in adapting resource requirement	is the ability in adapting requirement (quality, quantity) of resource				

			Capacity in supplying	is the ability in supplying material (supply material in time, communication with buyers about characteristic of material) for construction project
			Cost	
			Supplying cost	is the necessary cost of supplier to supply material for construction project
			Serving cost for supplying	is the cost which is used to serve for supplying
			Experience	
			Experience in supplying	is the cumulated skill of supplying resource for construction project acquired over time
			Past qualification assessment about supplying	is the statistic on the effectiveness of supplying resource for construction projects in the past
			Past qualification assessment about consulting	is the statistic on the effectiveness of consulting for construction projects in the past
			Experience in managing work	is the cumulated skill of managing construction project acquired over time
			Past qualification assessment about managing project	is the statistic on the effectiveness of managing construction projects in the past
Resources	Machine	A machine is an engine device that transforms the direction or magnitude of force, and it helps human resources in performing hard or difficult works	Quantity	
			Machine requirement of unit operating work	is the regulation about the minimum quantity of machine per unit work
			Total work of operating	is the real quantity of machine work (m3, m2, etc.)
			Quality	
			Conformity	is the convenient for machine control
			Characteristic	is the characteristic of machine about productivity, equipment, emissions, etc.
			UnitCost	
			Depreciation	is the reducing original cost of machine after a period time of using

			Repair cost	is the cost of periodic repairing machine or when it break	
			Fuel-energy cost	is the cost of fuel-energy when machine operates	
	Human resource	Human resource is the labor force which performs activities and have labor contract with hires.	Quantity		
			Human requirement of unit work	is the regulation about the minimum quantity of human per unit work (number of human in each group, number of working group)	
			Total work of performing	is the real quantity of human work (m3, m2, etc.)	
			Quality		
			Skill in operating	Skill in operating is the ability in working, organizing work, etc.	
			UnitCost		
			Working time cost	is the cost must pay when human works in regulated normal schedule	
			Overtime cost	is the cost must pay when human works overtime	
	Material	Material is the component participates in structures, whether natural or man-made	Quantity		
			Material requirement of unit component	is the regulation about the minimum quantity of material per unit of component (m3, kg, ton, etc)	
			Total component	is the real quantity of component which consist of material (m3, m2, etc.)	
			Quality		
			Imported characteristic	is the characteristic of material when import in construction site	
			Storage environment	is the condition to store material	
			UnitCost		
			Original cost	is the cost got from dealers	
			Transportation cost	is the cost of transportation	
			Storage cost	is the cost of building storage in the site of construction when storing material	
Contract	Building contract	Building Contract is a legal document ; it	Magnitude		

		combines obligations and responsibilities between hiring and hired person in performing building activities of construction	Project scale	correspondents to the physical size of the construction project (volume, geographical area, number of built surfaces, etc.)
			Building cost	is the limit price for constructing a project which is not exceeded
			Complexity	
			Vagueness in process of building	is the unclear about schedule of construction activity, uncertainty link between that one, etc.
			Time for building completion	is the unclear milestone, required days of activities, etc.
			Progress payment	is the information about schedule of payment which is mentioned in building contract
	Supply contract	Supply Contract is legal document ; it combines obligations and responsibilities of supplier in supplying resource for construction project	Magnitude	
			Required volume	is the volume of material which is regulated in supply contract (tons, kg, m3, etc.)
			Supplying cost	is the limit price for supplying resource for a project which is not exceeded
			Complexity	
			Vagueness of resource requirement	is the unclear about requirement of resource
			Vagueness in schedule of supplying	is the unclear milestone, required days of activities supplying, etc.
	Design contract	Design Contract is legal document ; it combines obligations and responsibilities of designers in designing activities of construction project	Magnitude	
			Design scale	correspondents to the physical size of the designed construction project (volume, geographical area, number of built surfaces, etc.)
			Designing cost	is the limit price for designing a project which is not exceeded
			Complexity	

Activities			Vagueness in design idea	is the unclear about design idea of construction project	
			Number of alternative design solutions	is the number of design drawing which are used to choose the best one	
			Submittal time	is the information about time of submitting	
	Activites of feasibility phase	are actions (design the feasibility drawing, analyses needs, legal, technical, scoping social, finance, ...) which performed by some owner, designer, consultant, etc and resources (human, machine) are used to create products (field work, feasibility design, the best option about efficient economic for project) of the first phase of construction project.		Duration	
				Duration to perform work	is the time process to perform work in feasibility phase
				Duration to adjust work	is the time process to adjust work in feasibility phase if it appears errors
				Quality	
				Impact of feasibility work	is the impact of works of feasibility phase on nature and society
				Technique of research and performing work	is the technique which is applied in researching and performing in feasibility phase
				Cost	
				Cost to perform work	is the process of costing to perform work in feasibility phase
				Cost to adjust work	is the process of costing to adjust work in feasibility phase if it appears error(s)
	Activities of implementaion phase	are actions (preparing procedures : loan for investing, clearance, bidding, signing contract, designing detailed drawing, main construction process) which performed by owner, designer, contractor, consultant, etc and resources (human, machine, and material) are used to create products (detailed design, regulation document, building) of the second phase of construction project.		Duration	
				Duration to perform work	is the time process to perform work in implementation phase
				Duration to repair precedent work	is the time process to repair precedent work in implementation phase if it appears errors or unsuitable characteristic
Quality					
Impact of implementation work				is the impact of works of implementation phase on nature and society	

			Technique of work	is the technique which is applied in performing work in implementation phase	
			Cost		
			Cost to perform work	is the process of costing to perform work in implementation phase	
			Cost to repair precedent work	is the process of costing to adjust work in implementation phase if it appears error(s) or unsuitable characteristic	
	Activities of operation phase	are maintenance actions (monitoring, repairing, etc) which performed by owner, contractor, supplier, etc and resources (machine, human, and material) are used to create the last products (document of maintenance, document of repairing errors) of the last phase of construction project.		Duration	
				Duration to perform maintain work	is the time process to perform maintain work in operational phase
				Duration to repair errors	is the time process to adjust or repair works in operational phase if some error(s) appear
				Quality	
				Impact of operation work	is the impact of maintenance works of operational phase on nature and society
				Technique of repairing error	is the technique which is applied to repair error(s) during operational phase
Cost					
Cost to maintain				is the process of costing to maintain work in operational phase	
Cost to repair errors	is the process of costing to adjust or repair work in operational phase if it appears error(s)				
Products	Products of feasibility phase	Product of feasibility phase is the result about efficiency about geological survey, feasibility design, economical research which satisfies predefined needs.	Duration		
			Duration of performing feasibility work	Time to perform works of feasibility phase	
			Duration of adjusting feasibility work	Time to adjust works of feasibility phase if that works have error	
			Quality		

			Satisfaction of owner about researching and performing feasibility work	Satisfaction of owner when receives results of researching and performing feasibility work
			Right regulation about performing feasibility work	Assessment of administration about respecting regulation about tax, environment, etc. when a product of feasibility phase finishes
			Cost	
			Cost of performing feasibility work	Sum of cost to perform works of feasibility phase
			Cost of adjusting feasibility work	Sum of cost to adjust works of feasibility phase if that works have error
	Products of implementation phase	Product of implementation phase is result about detailed design, doing procedure of construction, construction process which satisfies predefined needs.	Duration	
			Duration of performing implementation work	Number of time to perform works of implementation phase
			Duration of repairing precedent work	Number of time to adjust or repair error of precedent works which are not suitable with the works of implementation phase
			Quality	
			Satisfaction of owner about implementation work	Satisfaction of owner when receives results of implementation work
			Right regulation about implementation work	Assessment of administration about respecting regulation about tax, environment, etc. when a product of implementation phase finishes
			Cost	
			Cost of performing implementation work	Sum of cost to perform works of implementation phase
			Cost of repairing precedent work	Sum of cost to adjust works of implementation phase if that works have error
	Product of operation	Product of operation phase is the result of	Duration	

	phase	maintenance phase (ex process of monitoring and repairing errors during operational phase which satisfies predefined needs.	Duration of performing maintenance	Time to perform maintenance work of operational phase
			Duration of repairing errors	Number of time to repair errors during the operational phase
			Quality	
			Satisfaction of owner about maintenance process	Satisfaction of owner when receives results of maintenance process
			Right regulation about maintenance	Assessment of administration about respecting regulation of maintenance
			Cost	
			Cost of maintaining	Sum of cost to maintain works of operation phase
			Cost of repairing errors	Sum of cost to repair works during operational phase

Appendix 3. Entities, attributes, and their significations in level 2.

Entity level 1	Entity level 2	Explanation	Attribute	Explanation
Economy	National economy	is the economy of a country. It encompasses the value of all goods and services manufactured within a nation.	Aggresiveness	
			Instability	
			Fluctuations in National Stock Markets	The changes in national share prices can cause widespread economic fluctuation
			Changes in Interest Rates	is the change of cost of borrowing money in a country
			Inflation	
			Demand pull inflation	is caused by strong consumer demand
			Cost push inflation	is the increases of cost of goods or services where no suitable alternative is available.
	International economy	is the interaction between economies among countries all over the world, ex: international invesment, import and export tax, etc.	Aggresiveness	
			Instability	
			Fluctuations in International Stock Markets	The changes in international share prices can cause widespread economic fluctuation
			Changes of interest rate of international bank	is the change of cost of borrowing money in a international bank
			Inflation	
			Monetary policy	is how central banks manage liquidity to create economic growth.
			Politics	when politic change negatively, quantity of imported materials will be limited
Climate	Temperature	is a measure of hotness and coldness. It is measured by a thermometer	Aggresiveness	
			Frequency	
			Frequency of degree	is the repetitive time of a level of degree (days, weeks, years)
			Intensity	
			Level of degree	is the degree of temperature (°C)
	Period duration of degree	is the duration of a level of degree		
	Precipitation	amount of falling of water. It includes	Aggresiveness	

		rain, sleet, snow, hail, and drizzle	Frequency	
			Frequency of precipitation	is the repetitive time of a level of precipitation (days, weeks, years)
			Intensity	
			Level of precipitation	is the level of precipitation (mm)
			Period duration of precipitation	is the duration of a level of precipitation
Administration	Ministry	is the Government's lead advisor on a particular domain, shaping direction, providing and contributing to the Government's goals.	Aggressiveness	
			Inertia	
			Complex ministry decentralization	is the complexity in organizational structure of operating of Ministry
			Qualification of ministry's public official	is the qualification of ministry's public official in solving procedure of construction project
			Corruption	
			Wages of public officials	is the wage which is paid for ministry's public official every month
	Department	is the specialized agency under the direction, guidance, inspection, professional inspection of Ministry. It advises and assists the provincial People's Committees in performing the state management in the province.	Aggressiveness	
			Inertia	
			Complex department decentralization	is the complexity in organizational structure of operating of Department
			Qualification of department's public official	is the qualification of department's public official in solving procedure of construction project
			Corruption	
			Wages of department's public official	is the wage which is paid for department's public official every month
Owner	Owner	Owner is an individual or an organization who performs, manages project and linked by a contract. Owner has responsible about finance for project.	Productivity	
			Productivity in organizing project	
			Upgrading technology in organizing project	is the productivity in applying new technology in organizing (performing, planning, etc.) works of project
			Reasonable priority construction work	is the productivity in arranging works of project reasonably

		Productivity in managing project	
		Productivity in managing time	is the productivity in managing time of all construction works
		Productivity in managing cost	is the productivity in managing cost of all construction works
		Productivity in managing quality	is the productivity in managing quality of all construction works
		Capacity	
		Capacity in organizing project	
		Capacity in organizing work	is the capacity in organizing (performing, planning, etc.) construction work
		Capacity in arranging human work	is the capacity in arranging works of human in project
		Capacity in managing project	
		Capacity in managing time	is the capacity in managing time of all construction works
		Capacity in managing cost	is the capacity in managing cost of all construction works
		Capacity in managing quality	is the capacity in managing quality of all construction works
		Cost	
		Fixed cost	
		Fixed cost in building	is the cost in building must be paid which not depend on scale of construction project (cost of lodgement, interest rate, etc.)
		Fixed cost in doing procedure	is the cost in doing procedure must be paid which not depend on scale of construction project (regulation about cost of doing license of investment, license of building, etc)
		Variable cost	
		Variable cost in building	is the cost in building must be paid which depend on scale of construction project (sum of salaries, energy, etc.)
		Variable cost in doing procedure	is the cost in doing procedure must be paid which depend on scale of construction project (cost pays for communication, corruption, etc)
		Experience	
Experience in organizing project			

			Experience in arranging construction work	is the cumulative addition skill of arranging construction work acquired over time
			Experience in arranging human work	is the cumulative addition skill of arranging works of human acquired over time
			Experience in managing project	
			Experience in managing construction work	is the cumulative addition skill of managing construction work acquired over time
			Experience in managing human resource	is the cumulative addition skill of managing human resource acquired over time
Designer	Structural designer	is an individual or organization who designs structure of project and linked by a structural design contract. Structural designer must ensure bearing structure of the building under the impact of load (people, furniture, concussion, ...)	Productivity	
			Productivity in designing	
			Productivity in defining weight	is the velocity of structural designer in defining weight (loading) of construction project
			Productivity in using designing software	is the velocity of structural designer in using designing software
			Productivity in calculating	
			Productivity in choosing suitable calculation parametre	is the velocity of structural designer in choosing suitable calculation parametre
			Productivity in using calculation software	is the velocity of structural designer in using calculation software
			Capacity	
			Capacity in designing	
			Capacity in defining weight	is the ability in defining weight (loading) of construction project
			Capacity in using designing structural software	is the ability in using designing structural software
			Capacity in calculating	
			Capacity in choosing suitable calculation parametre	is the ability in choosing suitable calculation parametre
			Capacity in using calculation software	is the ability in using calculation software
			Cost	
Design cost				

		Main cost of structural design	is the necessary main cost of structural designer in designing structure of construction project
		Extra cost for structural design	is the necessary extra cost of structural designer in designing structure of construction project
		Serving cost for designing	
		Food service for structural design	is the cost which is used to serve food for structural design
		Health care for structural design	is the cost which is used to serve health care for structural design
		Experience	
		Experience in designing	
		Experience of structural design	is the cumulative addition skill of structural design acquired over time
		Experience in calculating structure	is the cumulative addition skill of calculating structure acquired over time
		Past qualification assessment about designing	
		Qualification about structural design	is the statistic on the effectiveness of designing structure of construction in the past
		Qualification about structural calculation	is the statistic on the effectiveness of calculating structure of construction projects in the past
		Architectural designer	is an individual or organization who designs architecture of project and linked by a architectural design contract. Architectural designer must ensure dimension and plan which are suitable with the regulation
Productivity in designing			
Productivity in designing layout	is the velocity of architectural designer in designing layout of construction project		
Productivity in using architectural software	is the velocity of architectural designer in using designing architectural software		
Productivity in calculating			
Productivity in choosing suitable architectural parametre	is the velocity of architectural designer in choosing suitable architectural parametre		
Productivity in using calculation architectural software	is the velocity of architectural designer in using calculation architectural software		

		Capacity	
		Capacity in designing	
		Capacity in designing layout	is the ability in designing layout of construction project
		Capacity in using architectural software	is the ability in using architectural software
		Capacity in calculating	
		Capacity in choosing suitable architectural parametre	is the ability in choosing suitable architectural parametre
		Capacity in using calculation architectural software	is the ability in using calculation architectural software
		Cost	
		Design cost	
		Main cost of architectural design	is the necessary main cost of architectural designer in designing architecture of construction project
		Extra cost for architectural design	is the necessary extra cost of architectural designer in designing architecture of construction project
		Serving cost for designing	
		Food service for architectural design	is the cost which is used to serve food for architectural design
		Health care for architectural design	is the cost which is used to serve health care for architectural design
		Experience	
		Experience in designing	
		Experience in design layout	is the cumulative addition skill of designing layout acquired over time
		Experience in using architectural software	is the cumulative addition skill of using architectural software acquired over time
		Past qualification assessment about designing	
		Qualification in design layout	is the statistic on the effectiveness of designing layout of construction in the past

			Qualification in using architectural software	is the statistic on the effectiveness of using architectural software of construction projects in the past
Contractor	Building contractor	is an individual or organization who builds construction project and linked by a building contract	Productivity	
			Productivity in arranging work	
			Effective teamwork	is the effective in co-operation work of a team
			Applicating suitable software in building	is the velocity of building contractor in applicating suitable software in building
			Productivity in building project	
			Productivity in using new technology in building	is the velocity of building contractor in using new techonology in building construction project
			Productivity in arranging reasonable priority building work	is the velocity of building contractor in arranging construction work reasonably
			Productivity in optimizing workplace of building	is the velocity of building contractor in optimizing workplace of building
			Capacity	
			Capacity in arranging work	
			Capacity of teamwork	is the ability in co-operating in a team to arrange work
			Capacity in using software	is the ability in using software in arranging work
			Capacity in building project	
			Capacity in using new technology	is the ability in using technology of building project
			Flexibility in building work	is the flexibility in solving all problem happening in process of building construction project
			Cost	
			Building cost	
			Main building cost	is the necessary cost of building contractor to build construction project
			Cost of managing for building work	is the necessary cost of building contractor to manage construction work
			Serving cost for constructing	
Cleaning building construction site	is the cost which is used to cleaning construction site			

		Health service of building	is the cost which is used to serve health for human during the process of building construction project	
		Experience		
		Experience in building project		
		Experience in arranging construction work	is the cumulative addition skill of arranging construction work acquired over time	
		Experience in building project	is the cumulative addition skill of building main part of project acquired over time	
		Past qualification assessment about building		
		Qualification in arranging construction work	is the statistic on the effectiveness of arranging construction works in the past	
		Qualification in building project	is the statistic on the effectiveness of building projects in the past	
	Installing contractor	is an individual or organization who installs water, electrical system of construction project and linked by a installing contract	Productivity	
			Productivity in arranging work	
			Effective communication in teamwork	is the effective in communicating between members of teamwork installing
			Applying suitable software in installing	is the velocity of installing contractor in applying suitable software in installing
			Productivity in building project	
			Productivity in using new technology in installing	is the velocity of installing contractor in using new technology in installing water and electrical system of construction project
Productivity in arranging reasonable priority installing work			is the velocity of installing contractor in arranging construction work reasonably	
Productivity in optimizing workplace of installing			is the velocity of installing contractor in optimizing workplace	
Capacity				
Capacity in arranging work				
Capacity of communication	is the ability in communicating with other actors to arranging work			
Capacity in using software of	is the ability in using software in installing work			

			installing work	
			Capacity in building project	
			Capacity in using new technology in installing	is the ability in using technology of installing water and electrical system of construction project
			Flexibility in installing work	is the flexibility in solving all problem happening in process of installing construction project
			Cost	
			Building cost	
			Main installation cost	is the necessary cost of installing contractor to install water and electrical system of construction project
			Cost of managing for installing work	is the necessary cost of installing contractor to manage installing work
			Serving cost for constructing	
			Cleaning site of installing	is the cost which is used to cleaning construction site of installing
			Health service of installing	is the cost which is used to serve health for human during the process of installing construction project
			Experience	
			Experience in building project	
			Experience in arranging installation work	is the cumulative addition skill of arranging installation work acquired over time
			Experience in installing project	is the cumulative addition skill of installing main part of project acquired over time
			Past qualification assessment about building	
			Qualification in arranging installation work	is the statistic on the effectiveness of arranging installation works in the past
			Qualification in installing project	is the statistic on the effectiveness of installing projects in the past
Supplier	Machine supplier	is an individual or organization who supplies machine for construction project	Productivity	
			Productivity in transportation	

	and linked by a machine supply contract	Distance of transporting machine	is the transportation distance from machine dealer to construction site
		Schedule of transporting machine	is the schedule of machine transportation
		Productivity in supplying information	
		Update machine information in website	is the velocity of machine supplier in updating machine information in website
		Communication with buyers about technology of machine	is the velocity of machine supplier in supplying information of technology of machine to buyers
		Capacity	
		Capacity in adapting resource requirement	
		Adapting machine requirement about quality	is the ability in adapting requirement about quality of machine
		Adapting machine requirement about quantity	is the ability in adapting requirement about quantity of machine
		Capacity in supplying	
		Capacity in supplying machine in time	is the ability in supplying machine in time for construction project
		Capacity in communicating about characteristic of machine	is the ability in supplying information of machine's characteristic to buyers
		Cost	
		Supplying cost	
		Main cost of supplying machine	is the necessary cost of machine supplier to supply machine for construction project
		Extra cost of supplying machine	is the extra cost of machine supplier to supply machine for construction project
		Serving cost for supplying	
		Food service for supplying machine	is the cost which is used to serve food for supplying machine
		Health care for supplying machine	is the cost which is used to serve health care for human in supplying machine
		Experience	

		Experience in supplying	
		Experience in supplying machine	is the cumulative addition skill of supplying machine for construction project acquired over time
		Experience in communicating with buyers about machine	is the cumulative addition skill in supplying information to buyers of supplying machine for construction project acquired over time
		Past qualification assessment about supplying	
		Qualification about time of supplying machine	is the statistic on the effectiveness of supplying machine in time for construction projects in the past
		Qualification about cost of supplying machine	is the statistic on the effectiveness about machine's cost of supplying machine for construction projects in the past
		Qualification about quality of supplying machine	is the statistic on the effectiveness about machine's quality of supplying machine for construction projects in the past
Material supplier	is an individual or organization who supplies material for construction project and linked by a material supply contract	Productivity	
		Productivity in transportation	
		Distance of transporting material	is the transportation distance from material dealer to construction site
		Schedule of transporting material	is the schedule of material transportation
		Productivity in supplying information	
		Update material information in website	is the velocity of material supplier in updating material information in website
		Communication with buyers about material	is the velocity of material supplier in supplying information of characteristic of material to buyers
		Capacity	
		Capacity in adapting resource requirement	
		Adapting material requirement about quality	is the ability in adapting requirement about quality of material
		Adapting material requirement about quantity	is the ability in adapting requirement about quantity of material
		Capacity in supplying	

			Capacity in supplying material in time	is the ability in supplying material in time for construction project
			Capacity in communicating about characteristic of material	is the ability in supplying information of material's characteristic to buyers
			Cost	
			Supplying cost	
			Main cost of supplying material	is the necessary cost of material supplier to supply material for construction project
			Extra cost of supplying material	is the extra cost of material supplier to supply material for construction project
			Serving cost for supplying	
			Food service for supplying material	is the cost which is used to serve food for supplying material
			Health care for supplying material	is the cost which is used to serve health care for human in supplying material
			Experience	
			Experience in supplying	
			Experience in supplying material	is the cumulative addition skill of supplying material for construction project acquired over time
			Experience in communicating with buyers about material	is the cumulative addition skill in supplying information to buyers of supplying material for construction project acquired over time
			Past qualification assessment about supplying	
			Qualification about time of supplying material	is the statistic on the effectiveness of supplying material in time for construction projects in the past
			Qualification about cost of supplying material	is the statistic on the effectiveness about material's cost of supplying machine for construction projects in the past
			Qualification about quality of supplying material	is the statistic on the effectiveness about material's quality of supplying machine for construction projects in the past
Machine	Contruction machine (heavy equipment)	is a specially desgined engine that transforms the direction or magnitude of force, and it helps human resources in	Quantity	
			Machine requirement of unit operating work	

performing hard or difficult works

Main construction machine	is the regulation about the minimum quantity of main machine per unit work
Assistance machine	is the regulation about the minimum quantity of assistance machine per unit work
Total work of operating	
Scale of construction work	is the scale of construction work which is executed by construction machine (m3, m2, etc.)
Number of construction work	is the number of construction work which is performed by construction machine
Quality	
Conformity	
Conformity in transporting	is the conformity in transporting of construction machine
Conformity in operating	is the conformity in operating of construction machine
Characteristic	
Productivity in performing construction work	is the productivity of construction machine in performing construction work
Replaced equipment of construction machine	is the equipment which is used to replace when construction machine has errors
Emission pollution	is the emission of construction machine which can create pollution for environment
UnitCost	
Depreciation	
Original construction machine cost	is the original cost of construction machine when it has just been bought
Recovery construction machine cost	is the residual value of construction machine after using for a period time
Standard work hours per time	is the work hours per time of construction machine which is regulated by law or norm
Percent of depreciation	is the percent of depreciation of each year of construction machine which is regulated by law or norm
Repair cost	

		Repaired cost of important part of machine	is the cost of periodic repairing important part of machine or when it break
		Repaired cost of extra part of machine	is the cost of periodic repairing important extra-part of machine or when it break
		Fuel-energy cost	
		Energy consumption each time of construction work	is the quantity consumption of fuel-energy when construction machine operates
		Unit cost of fuel-energy	is the unit cost of fuel-energy when construction machine operates
Office machines	A machine is a engine device helps human resources in performing office works faster	Quantity	
		Machine requirement of unit operating work	
		Number of office machine	is the estimation about the quantity of office machine per unit work
		Quality of office machine	is the quirement about quality of office machine
		Total work of operating	
		Number of report document	is the number of report document which need to be drafted, printed, etc.
		Quality	
		Conformity	
		Conformity in manipulating	is the conformity in manipulating of office machine
		Conformity in moving	is the conformity in moving of office machine
		Characteristic	
		Productivity in solving document	is the productivity of in drafting, printing, etc. of office machine
		Replaced equipment of office machine	is the equipment which is used to replace when office machine has errors
		UnitCost	
		Depreciation	
		Original office machine cost	is the original cost of office machine when it has just been bought
		Recovery office machine cost	is the residual value of office machine after using for a period time

			Percent of depreciation	is the percent of depreciation of each year of office machine which is regulated by law or norm
			Repair cost	
			Repaired cost of important part of office machine	is the cost of periodic repairing important part of office machine or when it break
			Repaired cost of extra part of office machine	is the cost of periodic repairing important extra-part of office machine or when it break
			Fuel-energy cost	
			Energy consumption each time of office work	is the quantity consumption of energy when office machine operates
			Unit cost of electricity	is the unit cost of energy when office machine operates
Human	Worker	Worker is a person who hired to execute construction activities directly.	Quantity	
			Human requirement of unit work	
			Main worker for unit work	is the regulation about the minimum quantity of worker per unit work (number of worker in each group, number of group of worker)
			Assistance for main worker	is the regulation about the quantity of assistance workers for main worker per unit work
			Total work of performing	
			Number of main work of performing	is the main work which is performed by workers (building, installing)
			Number of extra work of performing	is the extra works which is performed by workers (cleaning, serving)
			Quality	
			Skill in operating	
			Skill in executing construction work	is the ability in executing construction work of worker
			Ability in teamwork	is the ability in co-operating in a teamwork
			Cost	
			Working time cost	
Regulated performing time	is the regulated normal schedule for all worker			

		Salary of each unit of time performing	is the unit cost must pay when workers execute work in normal schedule
		Overtime cost	
		Over time of construction performing	is the quantity over time of worker
		Salary of each over time of performing	is the unit cost must pay when worker works overtime
Engineer	Engineer is a person who hired to design, research, manage in all construction activities.	Quantity	
		Human requirement of unit work	
		Number of engineer for unit work	is the regulation about the minimum quantity of engineer per unit work
		Total work of performing	
		Number of designing process of work	is the main work (design plan of work) which is performed by engineer
		Number of manage work of construction process	is the management work which is performed by engineer
		Quality	
		Skill in operating	
		Ability in arranging construction work	is the ability of engineer in arranging work
		Flexibility in treating incident	is the ability of engineer in solving problem when it occurs
		Updating information about construction work	is the ability of engineer in updating information of construction work
		Cost	
		Working time cost	
		Regulated working time	is the regulated normal schedule for engineer
		Salary of each time of working	is the unit cost must pay when engineer executes work in normal schedule
Overtime cost			
Over time of work	is the quantity over time of engineer		
Salary of each over time of working	is the unit cost must pay when engineer works overtime		
Office staff	is a person who hired to perform	Quantity	
		Human requirement of unit work	

		construction activities in office, ex: accountant, office document manager	Number of staff for unit work	is the regulation about the minimum quantity of office staff per unit construction work
			Total work of performing	
			Number of procedure attaches with construction work	is the number of procedure of construction project which is performed by staff
			Quality	
			Skill in operating	
			Skill in handling document	is the ability in handling document of office staff
			Flexibility in solving data	is the ability of staff in solving problem date when there has error
			Cost	
			Working time cost	
			Regulated office working time	is the regulated normal schedule for office staff
			Salary of each time of office working	is the unit cost must pay when office staff executes work in normal schedule
			Overtime cost	
			Over time of office work	is the quantity over time of office staff
			Salary of each over time of office working	is the unit cost must pay when office staff works overtime
Material	Reusable material	is the material can be reused several times in many works in the same construction project or in different one.	Quantity	
			Material requirement of unit component	
			Main reusable material for unit component	is the regulation about the necessary quantity of reusable material per unit of component (m3, kg, ton, etc)
			Extra reusable material for unit component	is the regulation about the extra quantity of reusable material per unit of component (m3, kg, ton, etc)
			Total component	
			Installed component	is the real quantity of installed component which needs the support of reusable material
			Failure component	is the quantity of failure component which is repaired with the support of reusable material

		Quality	
		Imported characteristic	
		Original characteristic	is the original characteristic of reusable material when buying from dealer
		Characteristic after transport process	is the characteristic of reusable material after transporting to construction site
		Storage environment	
		Equipment of storage	is the equipment which is used to store reusable material
		Internal and external storage environment	is the condition environment which is adjusted to store reusable material
		Original cost	
		Reusable material cost after tax	is the cost after tax of reusable material got from dealers
		Transportation cost	
		Cost of fuel-energy of transport process	is the cost of fuel-energy during process transporting
		Traffic charges	is the traffic charges must be paid during process transporting
		Storage cost	
		Cost of storage equipment	is the cost to buy equipment for storing reusable material
		Cost of storehouse	is the cost of building storage in the site of construction when storing reusable material
Consumable material	is the material participates in structures, whether natural or man-made. It is consumed once used.	Quantity	
		Material requirement of unit component	
		Number of consumable material for unit component	is the regulation about the necessary quantity of consumable material per unit of component
		Total component	
		Build component	is the real quantity of built component which consist of consumable material
		Failure component	is the quantity of failure component which consist of consumable material
		Quality	
Imported characteristic			

			Original characteristic	is the original characteristic of consumable material when buying from dealer
			Characteristic after transport process	is the characteristic of consumable material after transporting to construction site
			Storage environment	
			Equipment of storage	is the equipment which is used to store consumable material
			Internal and external storage environment	is the condition environment which is adjusted to store consumable material
			Original cost	
			Consumable material cost after tax	is the cost after tax of consumable material got from dealers
			Transportation cost	
			Cost of fuel-energy of transport process	is the cost of fuel-energy during process transporting
			Traffic charges	is the traffic charges must be paid during process transporting
			Storage cost	
			Cost of storage equipment	is the cost to buy equipment for storing consumable material
			Cost of storehouse	is the cost of building storage in the site of construction when storing consumable material
Building contract	Main building contract	is a legal document; it combines obligations and responsibilities between hiring and hired person in performing main building activities of construction	Magnitude	
			Project scale	
			Complexity in technique	is the level complexity in technique of main building process
			Acreage (m2, ha, etc.)	is the acreage of construction project (km, m2, m3, ha, ...)
			Building cost	
			Main building cost	is the limit price for building main part of a construction project which is not exceeded
			Punished cost of delay in building	is the punished cost for delay in building main part of a construction project
			Complexity	
			Vagueness in process of building	

		Vagueness about order of building activities	is the unclear about order of building activity, uncertainty link between that one, etc.	
		Vagueness about applied technology	is the unclear about applied technology in building main part of construction project	
		Time for building completion		
		Time for arranging order of building activities	is the length of time for arranging order of building activities	
		Time for choosing building technology	is the length of time for choosing building technology	
		Progress payment		
		Achievement of certain milestones in the building work	the progress payment bases on regulated milestone of building work	
		Stipulated amounts of building on set calendar dates	the progress payment bases on quantity of building work	
	Installing contract	is a legal document; it combines obligations and responsibilities between hiring and hired person in installing water and electrical system of construction project	Magnitude	
			Project scale	
			Complexity of installed component	is the level complexity in technique of installing process
			Number of component	is the quantity of water and electrical system
			Building cost	
			Main installing cost	is the limit price for installing water and electrical system of a construction project which is not exceeded
			Punished cost of delay in installing	is the punished cost for delay in installing water and electrical system of a construction project
Complexity				
Vagueness in process of building				
Vagueness about order of installing	is the unclear about order of installing activity, uncertainty link between that one, etc.			
Vagueness about installing technique	is the unclear about applied technology in installing of construction project			
Time for building completion				
Time for arranging order of installing activities	is the length of time for arranging order of installing activities			

			Time for choosing installing technology	is the length of time for choosing installing technology
			Progress payment	
			Achievement of certain milestones in the installing work	the progress payment bases on regulated milestone of installing work
			Stipulated amounts of installing on set calendar dates	the progress payment bases on quantity of installing work
Supply contract	Machine supply contract	is a legal document; it combines obligations and responsibilities of supplier in supplying machine for construction project	Magnitude	
			Required volume	
			Number of desired machine	is the volume of machine which is regulated in machine supply contract
			Qualification of machine	is the quality of machine which is regulated in machine supply contract
			Supplying cost	
			Machine cost	is the limit price for supplying machine for a project which is not exceeded
			Punished cost of delay in machine supply	is the punished cost for delay in supplying machine for a project
			Complexity	
			Vagueness of resource requirement	
			Vagueness about qualification of machine	is the unclear about quality of supplied machine
			Vagueness about quantity of machine	is the unclear about quantity of supplied machine
			Vagueness in schedule of supplying	
			Vagueness in milestone of machine supply	is the unclear milestone of activities machine supplying
			Vagueness in duration of machine supply	is the unclear required duration of activities machine supplying
			Payment schedule	
			Achievement of certain machine	the progress payment bases on number of machine
			Full information of supplied machine	the progress payment bases on full information of machine (information about characteristic) which is supplied
	Material supply	is a legal document; it combines	Magnitude	

	contract	obligations and responsibilities of supplier in supplying material for construction project	<table border="1"> <tr> <td colspan="2">Required volume</td> </tr> <tr> <td>Number of desired material</td> <td>is the volume of material which is regulated in material supply contract</td> </tr> <tr> <td>Qualification of material</td> <td>is the quality of material which is regulated in material supply contract</td> </tr> <tr> <td colspan="2">Supplying cost</td> </tr> <tr> <td>Material cost</td> <td>is the limit price for supplying material for a project which is not exceeded</td> </tr> <tr> <td>Punished cost of delay in material supply</td> <td>is the punished cost for delay in supplying material for a project</td> </tr> <tr> <td colspan="2">Complexity</td> </tr> <tr> <td colspan="2">Vagueness of resource requirement</td> </tr> <tr> <td>Vagueness about qualification of material</td> <td>is the unclear about quality of supplied material</td> </tr> <tr> <td>Vagueness about quantity of material</td> <td>is the unclear about quantity of supplied material</td> </tr> <tr> <td colspan="2">Vagueness in schedule of supplying</td> </tr> <tr> <td>Vagueness in milestone of material supply</td> <td>is the unclear milestone of activities material supplying</td> </tr> <tr> <td>Vagueness in duration of material supply</td> <td>is the unclear required duration of activities material supplying</td> </tr> <tr> <td colspan="2">Payment schedule</td> </tr> <tr> <td>Achievement of certain material</td> <td>the progress payment bases on number of material</td> </tr> <tr> <td>Full information of supplied material</td> <td>the progress payment bases on full information of material (information about characteristic) which is supplied</td> </tr> </table>	Required volume		Number of desired material	is the volume of material which is regulated in material supply contract	Qualification of material	is the quality of material which is regulated in material supply contract	Supplying cost		Material cost	is the limit price for supplying material for a project which is not exceeded	Punished cost of delay in material supply	is the punished cost for delay in supplying material for a project	Complexity		Vagueness of resource requirement		Vagueness about qualification of material	is the unclear about quality of supplied material	Vagueness about quantity of material	is the unclear about quantity of supplied material	Vagueness in schedule of supplying		Vagueness in milestone of material supply	is the unclear milestone of activities material supplying	Vagueness in duration of material supply	is the unclear required duration of activities material supplying	Payment schedule		Achievement of certain material	the progress payment bases on number of material	Full information of supplied material	the progress payment bases on full information of material (information about characteristic) which is supplied
Required volume																																			
Number of desired material	is the volume of material which is regulated in material supply contract																																		
Qualification of material	is the quality of material which is regulated in material supply contract																																		
Supplying cost																																			
Material cost	is the limit price for supplying material for a project which is not exceeded																																		
Punished cost of delay in material supply	is the punished cost for delay in supplying material for a project																																		
Complexity																																			
Vagueness of resource requirement																																			
Vagueness about qualification of material	is the unclear about quality of supplied material																																		
Vagueness about quantity of material	is the unclear about quantity of supplied material																																		
Vagueness in schedule of supplying																																			
Vagueness in milestone of material supply	is the unclear milestone of activities material supplying																																		
Vagueness in duration of material supply	is the unclear required duration of activities material supplying																																		
Payment schedule																																			
Achievement of certain material	the progress payment bases on number of material																																		
Full information of supplied material	the progress payment bases on full information of material (information about characteristic) which is supplied																																		
Design contract	Structural design contract	is a legal document; it combines obligations and responsibilities of structural designers in construction project	<table border="1"> <tr> <td colspan="2">Magnitude</td> </tr> <tr> <td colspan="2">Design scale</td> </tr> <tr> <td>Weight (Load)</td> <td>is the necessary load of construction project which needs to be designed (km, m2, m3, ha, ...)</td> </tr> <tr> <td>Reliability</td> <td>is the parameter of reliability which is used to design structure of construction project</td> </tr> <tr> <td colspan="2">Designing cost</td> </tr> </table>	Magnitude		Design scale		Weight (Load)	is the necessary load of construction project which needs to be designed (km, m2, m3, ha, ...)	Reliability	is the parameter of reliability which is used to design structure of construction project	Designing cost																							
Magnitude																																			
Design scale																																			
Weight (Load)	is the necessary load of construction project which needs to be designed (km, m2, m3, ha, ...)																																		
Reliability	is the parameter of reliability which is used to design structure of construction project																																		
Designing cost																																			

		Main structural design cost	is the limit price for designing main structure of a project which is not exceeded
		Punished cost of structural design	is the punished cost for delay in designing structure
		Complexity	
		Vagueness in design idea	
		Vagueness about weight (load)	is the unclear about weight (load) of construction project
		Vagueness about reliability	is the unclear about parametre of reliability
		Vagueness about technique	is the unclear about technique of designing structure of construction project
		Number of alternative design solutions	
		Variation of impact force	is the variance of impact force which impacts on structure of construction project
		Variation parameters of reliability	is the variance of parameter of reliability which impacts on structure of construction project
		Submittal time	
		Milestone of submitting structural design	is the information about milestone of submitting structural design
		Duration of structural design	is the information about duration of structural design
		Architectural design contract	is a legal document; it combines obligations and responsibilities of architectural designers in construction project
Design scale			
Height	is the necessary information about height of construction project which needs to be designed		
Width	is the necessary information about width of construction project which needs to be designed		
Depth	is the necessary information about depth of construction project which needs to be designed		
Designing cost			
Main architectural design cost	is the limit price for designing architecture of a construction project which is not exceeded		

			Punished cost of architectural design	is the punished cost for delay in designing architecture
			Complexity	
			Vagueness in design idea	
			Vagueness about height	is the unclear about height of construction project
			Vagueness about width	is the unclear about width of construction project
			Vagueness about depth	is the unclear about depth of construction project
			Number of alternative design solutions	
			Changing dimension	is the variance of dimension of construction project's architecture
			Number of perspective	is the variance of perspective which correspondents to each architectural solution of construction project
			Submittal time	
			Milestone of submitting architectural design	is the information about milestone of submitting architectural design
			Duration of architectural design	is the information about duration of architectural design
			Duration	
			Duration to perform work	
			Duration of survey	is the time process to survey work
			Duration of experimenting	is the time process to do experimentation
			Duration to adjust work	
			Duration of adjusting location of survey	is the time process to adjust location of survey if there exists problems with old location
			Duration of re-experimenting	is the time process to re-experiment
			Quality	
			Impact of feasibility work	
			Impact of field work on nature	is the impact of field work on nature and society
			Impact of field work on creating employment opportunities for society	is the impact of field work on creating employment opportunities for society
Activities of feasibility phase	Field work	are actions of investigating geological condition in construction site, etc. which performed by some owner, consultant, etc and resources (human, machine) are used to create report document of site survey.		

			<p>Technique of research and performing work</p> <p>Technique of surveying is the technique which is applied in surveying</p> <p>Technique of experimenting is the technique which is applied in experimenting</p> <p>Cost</p> <p>Cost to perform work</p> <p>Cost of survey is the process of costing to perform survey</p> <p>Cost of experimenting is the process of costing to do experimentation</p> <p>Cost to adjust work</p> <p>Cost of re-survey is the process of costing to do re-survey</p> <p>Cost of re-experimenting is the process of costing to re-experiment</p>
	Preliminary design	are actions of designing the feasibility drawing, which performed by owner, designer, consultant, etc and resources (human, machine) are used to create feasibility design	<p>Duration</p> <p>Duration to perform work</p> <p>Duration of preliminary designing is the time process to design the preliminary drawing</p> <p>Number of alternative options is the number of alternative preliminary drawings</p> <p>Duration to adjust work</p> <p>Duration of re-designing is the time process to adjust preliminary drawings</p> <p>Duration of preliminary calculation is the time process to calculate necessary parameters in preliminary design</p> <p>Quality</p> <p>Impact of feasibility work</p> <p>Impact of preliminary design on nature is the impact of preliminary design on nature</p> <p>Impact of preliminary design on creating employment opportunities for society is the impact of preliminary design on creating employment opportunities for society</p> <p>Technique of research and performing work</p> <p>Technique of designing is the technique which is applied in designing the preliminary drawing</p> <p>Technique in using design software is the technique which is used to design software</p>

		Cost	
		Cost to perform work	
		Cost of research of design solution	is the process of costing to research solutions of design
		Cost of designing	is the process of costing to design the preliminary drawings
		Cost to adjust work	
		Cost of re-research design solution	is the process of costing to re-research solutions of design
		Cost of re-design	is the process of costing to re-design the preliminary drawings
Economic research	are actions of analyzing legal, technical, scoping social, investigating finance market which performed by owner, consultant and resources (human, machine) are used to create document of economic efficiency	Duration	
		Duration to perform work	
		Duration of survey economy	is the time process to survey economy which can impact on construction project
		Duration of calculating effective economy	is the duration of calculating effective economy
		Duration to adjust work	
		Duration of supplement data	is the time process to add more necessary data in researching economy
		Duration of re-calculating	is the time process to re-calculate effective economy
		Quality	
		Impact of feasibility work	
		Impact of economic research on nature	is the impact of economic research on nature
		Impact of economic research on creating employment opportunities for society	is the impact of economic research on creating employment opportunities for society
		Technique of research and performing work	
		Technique of data processing	is the technique which is applied in processing data
		Technique of using calculation software	is the technique in using economic calculation software
		Cost	
		Cost to perform work	

			Cost of calculating effective economy	is the process of costing to calculate effective economy
			Cost to adjust work	
			Cost of re-surveying data	is the process of costing to re-survey data of economy
			Cost of re-calculating	is the process of costing to re-calculate effective economy
Activities of implementation phase	Detailed design	are actions of designing detailed drawing which performed by designer, consultant, etc and resources (human, machine) are used to create detailed design	Duration	
			Duration to perform work	
			Duration of architectural design	is the time process to design architecture of detailed drawing
			Duration of structural design	is the time process to design structure of detailed drawing
			Duration to repair precedent work	
			Duration of adjusting architectural design	is the time process to repair precedent architectural design
			Duration of adjusting structural design	is the time process to repair precedent structural design
			Quality	
			Impact of implementation work	
			Impact of detailed design on nature	is the impact of detailed design on nature
			Impact of detailed design on creating employment opportunities for society	is the impact of detailed design on creating employment opportunities for society
			Technique of work	
			Technique of architectural design	is the technique which is applied in designing architecture
			Technique of structural design	is the technique which is applied in designing structure
			Cost	
			Cost to perform work	
			Cost to design architecture	is the process of costing to design architecture
			Cost to design structure	is the process of costing to design structure
			Cost to repair precedent work	
	Cost to check data of precedent work	is the process of costing to check precedent design if it appears error(s) or unsuitable characteristic		
Cost to repair error of precedent work	is the process of costing to repair errors of precedent design			
	Preparing	are actions of preparing procedures: loan	Duration	

procedure before construction	for investing, clearance, bidding, signing contract, etc. which performed by owner, consultant, etc and resources (human, machine) are used to have procedure document	Duration to perform work	
		Duration of preparing procedure	is the time process to prepare procedure
		Duration of waiting	is the time process to wait to do procedure
		Duration to repair precedent work	
		Duration of check data of procedure	is the time process to check data of procedure if there exists problem with it
		Duration of repairing error of procedure	is the time process to repair error of procedure
		Quality	
		Impact of implementation work	
		Impact of doing procedure on nature	is the impact of doing procedure on nature
		Impact of doing procedure on creating employment opportunities for society	is the impact of doing procedure on creating employment opportunities for society
		Technique of work	
		Technique of preparing work	is the technique which is used to prepare procedure
		Technique of solving procedure problem	is the technique which is applied in solving procedure problem
		Cost	
		Cost to perform work	
		Cost of preparing work	is the process of costing to preparing procedure before constructing
		Cost of solving procedure problem	is the process of costing to solving procedure problem
		Cost to repair precedent work	
		Cost to check data of precedent work	is the process of costing to check data of procedure if it exists errors
		Cost to repairing error of precedent work	is the process of costing to repair errors of doing procedure
Construction	are actions of building which performed by owner, designer, contractor, consultant, etc and resources (human, machine, and material) are used to create the last building	Duration	
		Duration to perform work	
		Duration of arranging construction works	is the time process to arrange construction works
		Duration of performing construction work	is the time process to perform a construction work

			Duration to repair precedent work	
			Duration of adjusting order of construction works	is the time process to adjust order of construction works
			Duration of adjusting a construction work	is the time process to adjust a construction work
			Quality	
			Impact of implementation work	
			Impact of construction work on nature	is the impact of construction work on nature
			Impact of construction work on creating employment opportunities for society	is the impact of construction work on creating employment opportunities for society
			Technique of work	
			Technique of ordering sequence of construction work	is the technique which is applied in ordering sequence of construction work
			Technique of performing construction work	is the technique which is applied to perform construction works
			Cost	
			Cost to perform work	
			Cost to arranging construction work	is the process of costing to arrange construction works
			Cost to performing construction work	is the process of costing to perform construction works
			Cost to repair precedent work	
			Cost to adjust order of construction work	is the process of costing to adjust order of construction works
			Cost to adjust construction work	is the process of costing to adjust construction works
Activities of operation phase	Operation monitoring	are monitoring actions during the operation phase which performed by owner, contractor, designer etc and resources (machine, human) are used to create the document of operation monitoring	Duration	
			Duration to perform maintain work	
			Duration of installing monitoring equipment	is the time process to installing monitoring equipment
			Period time of checking	is the time process to check operational activities
			Duration to repair errors	

		Duration of checking error of monitoring	is the time process to check errors of process monitoring
		Duration of re-installing monitoring equipment	is the time process to re-install monitoring equipment
		Quality	
		Impact of implementation work	
		Impact of construction monitoring on nature	is the impact of construction monitoring on nature
		Impact of construction monitoring on creating employment opportunities for society	is the impact of construction monitoring on creating employment opportunities for society
		Technique of repairing error	
		Technique of checking error of monitoring	is the technique which is applied to check errors of monitoring
		Technique of replacing monitoring equipment	is the technique which is applied to replace monitoring equipment
		Cost	
		Cost to maintain	
		Duration of checking error of monitoring	is the process of costing to check errors of monitoring
		Duration of installing monitoring equipment	is the process of costing to install monitoring equipment
		Cost to repair errors	
		Cost of checking error of monitoring	is the process of costing to check errors of monitoring
Cost of re-installing monitoring equipment	is the process of costing to re-install monitoring equipment		
Performance of maintain work	are repairing actions which performed by owner, contractor, supplier, etc and resources (machine, human, and material) are used to create the report document of performing maintain work	Duration	
		Duration to perform maintain work	
		Duration of reporting failure	is the time process to report failure
		Duration of preparing resource to repair errors	is the time process to prepare resource to repair errors
		Duration to repair errors	
		Duration of checking reason of failure	is the time process to check reasons of failure

			Duration of repairing failure	is the time process to repair failure
			Quality	
			Impact of implementation work	
			Impact of maintain work on nature	is the impact of maintain work on nature
			Impact of maintain work on creating employment opportunities for society	is the impact of maintain work on creating employment opportunities for society
			Technique of repairing error	
			Technique of checking reason of failure	is the technique which is applied to check reasons of failure
			Technique of repairing failure	is the technique which is applied to repair failure
			Cost	
			Cost to maintain	
			Cost of reporting failure	is the process of costing to report failure
			Cost of preparing resource to repair errors	is the process of costing to prepare resource to repair errors
			Cost to repair errors	
			Cost of of checking reason of failure	is the process of costing to check reasons of failures
			Cost of repairing failure	is the process of costing to repair failures
Products of feasibility phase - survey document	Document of site survey	is the result of geological survey which satisfies predefined needs.	Duration	
			Duration of performing feasibility work	
			Duration to finish survey document	is the number of time to finish survey document
			Duration to have result of experimentation	is the number of time to have result of experimentation
			Duration of adjusting feasibility work	
			Duration of document about adjusting location of survey	is the duration to have document about adjusting location of survey
			Duration of document of re-experimenting	is the duration of document of re-experimenting
			Quality	

			Satisfaction of owner about researching and performing feasibility work	
			Satisfaction about result in survey document	is the satisfaction about result in survey document
			Satisfaction about result of experimentation	is the satisfaction about result of experimentation
			Right regulation about performing feasibility work	
			Right regulation about survey	is the right regulation about process of survey
			Right regulation about experimentation	is the right regulation about process of experimentation
			Cost	
			Cost of performing feasibility work	
			Cost to have a survey document	is the sum of cost to have a survey document
			Cost to have a result of experimentation	is the sum of cost to have a result of experimentation
			Cost of adjusting feasibility work	
			Cost to have document about adjusting location of survey	is the sum of cost to have document about adjusting location of survey
			Cost to have document of re-experiencing	is the sum of cost to have document of re-experiencing
Preliminary design	is the drawing of feasibility design which satisfies predefined needs.		Duration	
			Duration of performing feasibility work	
			Duration to have preliminary design	is the number of time to have preliminary design
			Duration to have all option of design	is the number of time to have all options of design
			Duration of adjusting feasibility work	
			Duration to have drawing of re-designing	is the duration to have drawing of re-designing
			Report of preliminary calculation	is the duration to have report of preliminary calculation
			Quality	

			Satisfaction of owner about researching and performing feasibility work	
			Satisfaction about drawing of preliminary design	is the satisfaction about drawing of preliminary design
			Satisfaction about preliminary calculation	is the satisfaction about preliminary calculation
			Right regulation about performing feasibility work	
			Right regulation about standard of drawing	is the right regulation about standard of drawing
			Right regulation about planning	is the right regulation about planning
			Cost	
			Cost of performing feasibility work	
			Cost to have preliminary design	is the sum of cost to have preliminary design
			Cost to have options of design	is the sum of cost to have options of design
			Cost of adjusting feasibility work	
			Cost to have drawing of re-designing	is the sum of cost to have drawing of re-designing
			Cost of preliminary calculation	is the sum of cost of preliminary calculation
			Duration	
			Duration of performing feasibility work	
			Duration to document about survey economy	is the number of time to have document about survey economy
			Duration to result of effective economy	is the number of time to have result of effective economy
			Duration of adjusting feasibility work	
			Duration of document about supplementing data	is the duration to have document about supplementing data
			Duration to have result of re-calculating	is the duration to have result of re-calculating
			Quality	
Document of economic efficiency	is the efficiency result about economical research which satisfies predefined needs.			

			Satisfaction of owner about researching and performing feasibility work	
			Satisfaction about document of survey economy	is the satisfaction about document of survey economy
			Satisfaction about result of effective economy	is the satisfaction about result of effective economy
			Right regulation about performing feasibility work	
			Right regulation survey	is the right regulation about process of survey economy
			Right regulation about parametre of economy	is the right regulation about parametre of economy
			Cost	
			Cost of performing feasibility work	
			Cost to have data of economic survey	is the sum of cost to have data of economic survey
			Cost to have document of economic result	is the sum of cost to have document of economic result
			Cost of adjusting feasibility work	
			Cost to have document about supplementing data	is the sum of cost to have document about supplementing data
			Cost to have result of re-calculating	is the sum of cost to have result of re-calculating
Products of implementation phase - Building	Detailed design	is the drawing of detailed design which satisfies predefined needs.	Duration	
			Duration of performing implementation work	
			Duration to have architectural design	is the number of time to have architectural design
			Duration to have structural design	is the number of time to have structural design
			Duration of repairing precedent work	
			Duration to have adjusted drawing of architecture	is the number of time to adjust or repair errors in architectural drawing
			Duration to have adjusted drawing of structure	is the number of time to adjust or repair errors in structural drawing
			Quality	
			Satisfaction of owner about implementation work	

		Satisfaction about architectural drawing	is the satisfaction about architectural drawing
		Satisfaction about structural drawing	is the satisfaction about structural drawing
		Right regulation about implementation work	
		Right regulation about architectural drawing	is the right regulation about architectural drawing
		Right regulation about structural drawing	is the right regulation about structural drawing
		Cost	
		Cost of performing implementation work	
		Cost to have architectural drawing	is the sum of cost to have architectural drawing
		Cost to have structural drawing	is the sum of cost to have structural drawing
		Cost of repairing precedent work	
		Cost to have adjusted drawing of architecture	is the sum of cost to have adjusted drawing of architecture
		Cost to have adjusted drawing of structure	is the sum of cost to have adjusted drawing of structure
Procedure document	is the licence of construction project which satisfies predefined needs.	Duration	
		Duration of performing implementation work	
		Duration of procedure document	is the number of time to have procedure document
		Duration to have licence	is the number of time to have licence
		Duration of repairing precedent work	
		Duration to list of data need to be checked	is the number of time to list of data which needs to be checked
		Duration to have complement document	is the number of time to have complement document
		Quality	
		Satisfaction of owner about implementation work	
		Satisfaction about procedure document	is the satisfaction about procedure document

		Satisfaction about time of received licence	is the satisfaction about time of received licence
		Right regulation about implementation work	
		Right regulation about procedure document	is the right regulation about procedure document
		Right regulation about time of receiving	is the right regulation about time of receiving
		Cost	
		Cost of performing implementation work	
		Cost to have procedure document	is the sum of cost to have procedure document
		Cost to have licence	is the sum of cost to have licence
		Cost of repairing precedent work	
		Cost to have list of data need to be checked	is the sum of cost to have list of data need to be checked
		Cost to have complement document	is the sum of cost to have complement document
Building	is the last building which satisfies predefined needs.	Duration	
		Duration of performing implementation work	
		Duration of have plan drawing of all construction works	is the number of time to have plan drawing of all construction works
		Duration to have plan of each construction work	is the number of time to have plan of each construction work
		Duration of repairing precedent work	
		Duration to have adjusted plan drawing of all construction works	is the number of time to have adjusted plan drawing of all construction works
		Duration to have adjusted plan of each construction work	is the number of time to have adjusted plan of each construction work
		Quality	
		Satisfaction of owner about implementation work	
		Satisfaction about plan of all construction works	is the satisfaction about plan of all construction works
		Satisfaction about plan of each	is the satisfaction about plan of each construction work

			construction work	
			Right regulation about implementation work	
			Right regulation about planning	is the right regulation about planning
			Right regulation about impact of construction work	is the right regulation about impact of construction work
			Cost	
			Cost of performing implementation work	
			Cost to have plan drawing of all construction works	is the sum of cost to have plan drawing of all construction works
			Cost to have plan of each construction work	is the sum of cost to have plan of each construction work
			Cost of repairing precedent work	
			Cost to have adjusted plan drawing of all construction works	is the sum of cost to have adjusted plan drawing of all construction works
			Cost to have adjusted plan of each construction work	is the sum of cost to have adjusted plan of each construction work
Product of operation phase - report of maintenance process	Document of operation monitoring	is the report document about monitoring of operational phase which satisfies predefined needs.	Duration	
			Duration of performing maintenance	
			Duration to have report about installing monitoring equipment	is the number of time to have report about installing monitoring equipment
			Period report of checking	is the number of time to have period report of checking
			Duration of repairing errors	
			Duration to have report about error of monitoring	is the number of time to have report about error of monitoring
			Duration to have report about re-installing monitoring equipment	is the number of time to have report about re-installing monitoring equipment
			Quality	
			Satisfaction of owner about maintenance process	
			Satisfaction about process of installing monitoring equipment	is the satisfaction about process of installing monitoring equipment
			Satisfaction about period report of checking	is the satisfaction about period report of checking

			Right regulation about process of repairing failure	is the right regulation about process of repairing failure
			Cost	
			Cost of maintaining	
			Document of cost for reporting failure	is the sum of cost to have document of cost for reporting failure
			Document of cost for preparing resource to repair failure	is the sum of cost to have document of cost for preparing resource to repair failure
			Cost of repairing errors	
			Cost to have report about reason of failure	is the sum of cost to have report about reason of failure
			Cost to have document about repairing failure	is the sum of cost to have document about repairing failure

Appendix 4. Concepts' relations in level 1

No.Level 0	No.Level 1	Entity source	Entity target
1		EE	Contract
	1	Climate	Building Contract
	2	Climate	Supply Contract
	3	Climate	Design Contract
	4	Economy	Building Contract
	5	Economy	Supply Contract
	6	Economy	Design Contract
2		EE	Actor
	7	Administration	Owner
	8	Climate	Owner
	9	Climate	Contractor
	10	Climate	Supplier
	11	Economy	Owner
3		EE	Resource
	12	Economy	Machine

	13	Economy	Human
	14	Economy	Material
	15	Climate	Machine
	16	Climate	Human
	17	Climate	Material
4		Contract	Actor
	18	Design Contract	Designer
	19	Building Contract	Contractor
	20	Supply Contract	Supplier
5		Actor	Contract
	21	Owner	Building Contract
	22	Contractor	Supply Contract
	23	Owner	Design Contract
6		Actor	Resource
	24	Owner	Machine
	25	Designer	Machine
	26	Contractor	Machine
	27	Owner	Human
	28	Designer	Human
	29	Contractor	Human
	30	Contractor	Material
	31	Supplier	Material
7		Resource	Actor
	32	Human	Owner
	33	Machine	Designer
	34	Human	Designer
	35	Machine	Contractor
	36	Human	Contractor
	37	Material	Contractor

	38	Material	Supplier
8		Resource	Activity
	39	Machine	AFP
	40	Human	AFP
	41	Machine	AIP
	42	Human	AIP
	43	Material	AIP
	44	Machine	AOP
	45	Human	AOP
	46	Material	AOP
9		Actor	Activity
	47	Owner	AFP
	48	Designer	AFP
	49	Designer	AIP
	50	Contractor	AIP
	51	Supplier	AIP
	52	Contractor	AOP
	53	Supplier	AOP
10		Product	Activity
	54	PFP	AIP
	55	PIP	AOP
11		Activity	Product
	56	AFP	PFP
	57	AIP	PIP
	58	AOP	POP
12		Activity	Activity
	59	AFP	AIP
	60	AIP	AOP
13		Actor	Actor

	61	Supplier	Contractor
--	----	----------	------------

Appendix 5. Concepts' relations in level 2

No. Level 0	No. Level 1	No. Level 2	Entity source	Entity target
1			EE	Contract
	1		<i>Climate</i>	<i>Building Contract</i>
		1	Temperature	Main Building Contract
		2	Temperature	Installing Contract
		3	Precipitation	Main Building Contract
		4	Precipitation	Installing Contract
	2		<i>Climate</i>	<i>Supply Contract</i>
		5	Temperature	Material supply contract
		6	Precipitation	Material supply contract
	3		<i>Climate</i>	<i>Design Contract</i>
		7	Temperature	Structural design contract
		8	Temperature	Architectural design contract
		9	Precipitation	Structural design contract
		10	Precipitation	Architectural design contract
	4		<i>Economy</i>	<i>Building Contract</i>
		11	National economy	Main building contract
		12	International economy	Main building contract
		13	National economy	Installing Contract
		14	International economy	Installing Contract
	5		<i>Economy</i>	<i>Supply Contract</i>
		15	National economy	Material supply contract
		16	International economy	Material supply contract
	6		<i>Economy</i>	<i>Design Contract</i>
		17	National economy	Structural design contract

		18	National economy	Architectural design contract
2		19	EE	Actor
	7		<i>Administration</i>	<i>Owner</i>
		20	Ministry	Owner
		21	Department	Owner
	8		<i>Climate</i>	<i>Owner</i>
		22	Temperature	Owner
		23	Precipitation	Owner
	9		<i>Climate</i>	<i>Contractor</i>
		24	Temperature	Building Contractor
		25	Precipitation	Installing Contractor
	10		<i>Climate</i>	<i>Supplier</i>
		26	Temperature	Material Supplier
		27	Precipitation	Material Supplier
	11		<i>Economy</i>	<i>Owner</i>
		28	National economy	Owner
		29	International economy	Owner
3			EE	Resource
	12		<i>Economy</i>	<i>Machine</i>
		30	National economy	Office Machine
		31	National economy	Construction Machine
		32	International economy	Construction Machine
		33	International economy	Office Machine
	13		<i>Economy</i>	<i>Human</i>
		34	International economy	Worker
		35	International economy	Engineer
		36	National economy	Office Staff
		37	International economy	Office Staff
		38	National economy	Worker

		39	National economy	Engineer
	14		<i>Economy</i>	<i>Material</i>
		40	International economy	Reusable Material
		41	International economy	Consumable Material
		42	National economy	Reusable Material
		43	National economy	Consumable Material
	15		<i>Climate</i>	<i>Machine</i>
		44	Precipitation	Construction Machine
		45	Temperature	Office Machine
	16		<i>Climate</i>	<i>Human</i>
		46	Temperature	Worker
		47	Precipitation	Worker
		48	Temperature	Engineer
		49	Precipitation	Engineer
		50	Temperature	Office Staff
		51	Precipitation	Office Staff
	17		<i>Climate</i>	<i>Material</i>
		52	Temperature	Reusable Material
		53	Precipitation	Reusable Material
		54	Temperature	Consumable Material
		55	Precipitation	Consumable Material
4			<i>Contract</i>	<i>Actor</i>
	18		<i>Design Contract</i>	<i>Designer</i>
		56	Structural design contract	Structural designer
		57	Architectural design contract	Architectural designer
	19		<i>Building Contract</i>	<i>Contractor</i>
		58	Main building contract	Building contractor
		59	Installing contract	Installing contractor
	20		<i>Supply Contract</i>	<i>Supplier</i>

		60	Material supply contract	Material supply
5			Actor	Contract
	21		<i>Owner</i>	<i>Building Contract</i>
		61	Owner	Main building contract
		62	Owner	Installing contract
	22		<i>Contractor</i>	<i>Supply Contract</i>
		63	Building contractor	Material supply contract
		64	Installing contractor	Material supply contract
	23		<i>Owner</i>	<i>Design Contract</i>
		65	Owner	Structural design contract
		66	Owner	Architectural design contract
6			Actor	Resource
	24		<i>Owner</i>	<i>Machine</i>
		67	Owner	Construction machine
		68	Owner	Office machine
	25		<i>Designer</i>	<i>Machine</i>
		69	Structural designer	Office machine
		70	Architectural designer	Office machine
	26		<i>Contractor</i>	<i>Machine</i>
		71	Building contractor	Construction machine
		72	Building contractor	Office machine
		73	Installing contractor	Construction machine
		74	Installing contractor	Office machine
	27		<i>Owner</i>	<i>Human</i>
		75	Owner	Worker
		76	Owner	Office staff
		77	Owner	Engineer
	28		<i>Designer</i>	<i>Human</i>
		78	Structural designer	Worker

		79	Architectural designer	Worker
		80	Structural designer	Engineer
		81	Architectural designer	Engineer
	29		Contractor	Human
		82	Building contractor	Worker
		83	Building contractor	Engineer
		84	Building contractor	Office staff
		85	Installing contractor	Worker
		86	Installing contractor	Engineer
		87	Installing contractor	Office staff
	30		Contractor	Material
		88	Building contractor	Reusable material
		89	Building contractor	Consumable material
		90	Installing contractor	Reusable material
		91	Installing contractor	Consumable material
	31		Supplier	Material
		92	Material supplier	Reusable material
7			Resource	Actor
	32		Human	Owner
		93	Worker	Owner
		94	Engineer	Owner
		95	Office staff	Owner
	33		Machine	Designer
		96	Office machine	Structural designer
		97	Office machine	Architectural designer
	34		Human	Designer
		98	Engineer	Structural designer
		99	Office staff	Architectural designer
		100	Engineer	Structural designer

		101	Office staff	Architectural designer
	35		Machine	Contractor
		102	Construction machine	Building contractor
		103	Office machine	Building contractor
		104	Construction machine	Installing contractor
		105	Office machine	Installing contractor
	36		Human	Contractor
		106	Worker	Building contractor
		107	Engineer	Building contractor
		108	Office staff	Building contractor
		109	Worker	Installing contractor
		110	Engineer	Installing contractor
		111	Office staff	Installing contractor
	37		Material	Contractor
		112	Reusable material	Building contractor
		113	Consumable material	Building contractor
		114	Reusable material	Installing contractor
		115	Consumable material	Installing contractor
	38		Material	Supplier
		116	Reusable material	Material supplier
		117	Consumable material	Material supplier
8			Resource	Activity
	39		Machine	AFP
		118	Construction machine	Field work
		119	Office machine	Preliminary design
		120	Office machine	Economic research
	40		Human	AFP
		121	Worker	Field work
		122	Engineer	Field work

		123	Engineer	Preliminary design
		124	Office staff	Preliminary design
		125	Engineer	Economic research
		126	Office staff	Economic research
	41		Machine	AIP
		127	Office machine	Detailed design
		128	Office machine	Preparing procedure before construction
		129	Office machine	Construction
		130	Construction machine	Construction
	42		Human	AIP
		131	Engineer	Detailed design
		132	Office staff	Detailed design
		133	Engineer	Preparing procedure before construction
		134	Office staff	Preparing procedure before construction
		135	Worker	Construction
		136	Engineer	Construction
		137	Office staff	Construction
	43		Material	AIP
		138	Reusable material	Construction
		139	Consumable material	Construction
	44		Machine	AOP
		140	Office machine	Operation monitoring
		141	Construction machine	Performance of maintain work
		142	Office machine	Performance of maintain work
	45		Human	AOP
		143	Worker	Operation monitoring
		144	Engineer	Operation monitoring
		145	Office staff	Operation monitoring
		146	Worker	Performance of maintain work

		147	Engineer	Performance of maintain work
		148	Office staff	Performance of maintain work
	46		Material	AOP
		149	Reusable material	Performance of maintain work
		150	Consumable material	Performance of maintain work
9			Actor	Activity
	47		Owner	AFP
		151	Owner	Field work
		152	Owner	Preliminary design
		153	Owner	Economic research
	48		Designer	AFP
		154	Structural designer	Field work
		155	Architectural designer	Field work
		156	Structural designer	Preliminary design
		157	Architectural designer	Preliminary design
		158	Structural designer	Economic research
		159	Architectural designer	Economic research
	49		Designer	AIP
		160	Structural designer	Detailed design
		161	Architectural designer	Detailed design
		162	Structural designer	Preparing procedure before construction
		163	Architectural designer	Preparing procedure before construction
		164	Structural designer	Construction
		165	Architectural designer	Construction
	50		Contractor	AIP
		166	Building contractor	Detailed design
		167	Installing contractor	Detailed design
		168	Building contractor	Preparing procedure before construction
		169	Installing contractor	Preparing procedure before construction

		170	Building contractor	Construction
		171	Installing contractor	Construction
	51		Supplier	AIP
		172	Material supplier	Detailed design
		173	Material supplier	Preparing procedure before construction
		174	Material supplier	Construction
	52		Contractor	AOP
		175	Building contractor	Operation monitoring
		176	Installing contractor	Operation monitoring
		177	Building contractor	Performance of maintain work
		178	Installing contractor	Performance of maintain work
	53		Supplier	AOP
		179	Material supplier	Performance of maintain work
10			Product	Activity
	54		PFP	AIP
		180	Document of site survey	Detailed design
		181	Preliminary design	Detailed design
		182	Document of economic efficiency	Detailed design
		183	Document of site survey	Preparing procedure before construction
		184	Preliminary design	Preparing procedure before construction
		185	Document of economic efficiency	Preparing procedure before construction
		186	Document of site survey	Construction
		187	Preliminary design	Construction
		188	Document of economic efficiency	Construction
	55		PIP	AOP
		189	Detailed design	Operation monitoring
		190	Procedure document	Operation monitoring
		191	Building	Operation monitoring
		192	Detailed design	Performance of maintain work

		193	Procedure document	Performance of maintain work
		194	Building	Performance of maintain work
11			Activity	Product
	56		AFP	PPF
		195	Field work	Document of site survey
		196	Preliminary design	Preliminary design
		197	Economic research	Document of economic efficiency
	57		AIP	PIP
		198	Detailed design	Detailed design
		199	Preparing procedure before construction	Procedure document
		200	Construction	Building
	58		AOP	POP
		201	Operation monitoring	Document of operation monitoring
		202	Performance of maintain work	Document of performing maintain work
12			Activity	Activity
	59		AFP	AIP
		203	Field work	Detailed design
		204	Preliminary design	Detailed design
		205	Field work	Preparing procedure before construction
		206	Preliminary design	Preparing procedure before construction
		207	Economic research	Preparing procedure before construction
		208	Field work	Construction
		209	Preliminary design	Construction
	60		AIP	AOP
		210	Construction	Operation monitoring
		211	Construction	Performance of maintain work

13			Actor	Actor
	61		<i>Supplier</i>	<i>Contractor</i>
		212	Material supplier	Building contractor
		213	Material supplier	Installing contractor

Appendix 6. Attributes' relations in level 0 and their signification

No	Entity source	Attribute source	Entity target	Attribute target	Explanation
Relations between attributes of different entities					
1	EE	Aggressiveness	Contract	Complexity	Schedule, claims which are mentioned in contract can be changed because of impacts of external environment. For example: Flood comes (EE.Aggressiveness), schedule of contract (Contract.Complexity) will be prolonged than plan.
2	EE	Aggressiveness	Contract	Magnitude	Regulated cost or scale in contract can be impacted by external environment. For example: If economy increases (inflation, tax, ..), regulated cost in contract will be changed or scale of construction project can be adjusted to be smaller.
3	EE	Aggressiveness	Actor	Productivity	Productivity in working of actor is impacted by EE For example: if the temperature of workplace performance up to so high, it (EE.Aggressiveness) will impact on productivity in operating and/or managing of contractor (Actor.Productivity)
4	EE	Aggressiveness	Actor	Cost	Issues in corruption make cost of actor arises. For example: Embezzlement of administration (EE.Aggressiveness) contributes to increase fee (Actor.Cost) of owner
5	EE	Aggressiveness	Resource	Quantity	For example: Flood comes (EE.Aggressiveness), quantity of sand (Resource.Quantity) reduces because of being washed away
6	EE	Aggressiveness	Resource	Quality	For example: Flood comes (EE.Aggressiveness), quantity of sand (Resource.Quantity) reduces because of being washed away

7	EE	Aggressiveness	Resource	Unit Cost	For example: A decrease in value of currency (because of changing tax, salaries policy, etc.) will make the prices (Resource.UnitCost) of machines rise
8	Contract	Complexity	Actor	Productivity	For example: The more complex claims of owner, productivity of contractors can not be high.
9	Contract	Magnitude	Actor	Cost	Scale and cost of construction project which are mentioned in contract impact directly on cost of actor who signs that contract.
10	Contract	Complexity	Actor	Capacity	For example: The more complex claims of owner, capacity in organizing works of contractors must be clearer and more careful.
11	Actor	Capacity	Contract	Complexity	For example: If owner proposes many ambiguous and/or insufficient requirements, contract will be complex
12	Actor	Capacity	Resource	Quantity	For example: If contractor calculates uncarefully insufficient resources (machines, materials, workers), quantity of resource will not be enough to work.
13	Actor	Capacity	Resource	Quality	For example: If contractor chooses wrong machine's parameters, efficiency of works will not be high.
14	Resource	UnitCost	Actor	Cost	Actor calculates his/her cost based on unit cost of resource
15	Resource	Quantity	Actor	Cost	The more quantity of resources, the higher cost must be paid
16	Resource	Quantity	Activity	Duration	For example: the more machines, the shorter duration of activity
17	Resource	Quality	Activity	Duration	For example: if a machine has good quality at productivity, duration will be shorter
18	Resource	Quality	Activity	Quality	For example: If workers install steels carefully and consistently, quality of foundation structure will be good
19	Actor	Productivity	Activity	Duration	For example: If owner explores geological conditions so slow, duration of a this work will be longer than expectation
20	Actor	Capacity	Activity	Duration	Capacity in organizing, ordering workers affects to duration of activity
21	Actor	Cost	Activity	Cost	Cost of an activity is decided by cost of actor.
22	Product	Quality	Activity	Duration	For example: If foundation structure is damaged, it will take time to fix errors. So, duration of the next activity will be shortened.

23	Product	Quality	Activity	Cost	For example: If foundation structure is damaged, the next work will be pay more money to fix errors before continuing. Duration, Quality and Cost of product are affected by Duration, Quality, and Cost of activity respectively.
24	Activity	Cost	Product	Cost	
25	Activity	Quality	Product	Quality	
26	Activity	Duration	Product	Duration	
Relations between attributes of the same entities					
27	Resource	Quality	Resource	Unit Cost	The higher quality, the higher cost of each resource
28	Actor	Experience	Actor	Productivity	Experience of actor is a prerequisite factor decide his/her productivity
29	Actor	Experience	Actor	Capacity	Experience of actor is a prerequisite factor decide his/her capacity
Relations between the same attributes of different instances					
30*	Activity	Duration	Activity	Duration	Duration of exploring site of construction impacts on milestone of designing
31*	Actor	Productivity	Actor	Productivity	Productivity of supplier impacts on productivity of contractor

Appendix 7. Attributes' relations in level 1

No Level 0	No Level 1	Entity source	Attribute source	Entity target	Attribute target
Relations between attributes of different entities					
1		EE	Aggressiveness	Contract	Complexity
	1.1	Climate	Frequency	Building	Time for building completion
	1.2			Contract	Progress payment
	1.3		Intensity	Building	Time for building completion
	1.4			Contract	Progress payment
	1.5	Climate	Frequency	Supply Contract	Payment schedule
	1.6		Intensity	Supply Contract	Payment schedule
	1.7	Climate	Frequency	Design Contract	Submittal time
	1.8		Intensity	Design Contract	Submittal time
2		EE	Aggressiveness	Contract	Magnitude
	2.1	Economy	Instability	Building	Project Scale

	2.2			Contract	Building Cost
	2.3		Inflation	Building Contract	Project Scale
	2.4				Building Cost
	2.5	Economy	Instability	Supply Contract	Required volumn
	2.6				Supply Cost
	2.7		Inflation	Supply Contract	Required volumn
	2.8				Supply Cost
	2.9	Economy	Instability	Design Contract	Design Scale
	2.10				Designing Cost
	2.11		Inflation	Design Contract	Design Scale
	2.12				Designing Cost
3		EE	Aggressiveness	Actor	Productivity
		Administration	Inertia	Owner	Productivity In Organizing Project
	3.1	Climate	Frequency	Owner	Productivity In Organizing Project
	3.2				Productivity In Managing Project
	3.3		Intensity	Owner	Productivity In Organizing Project
	3.4				Productivity In Managing Project
	3.5	Climate	Frequency	Contractor	Productivity In Building Project
	3.6		Intensity	Contractor	Productivity In Building Project
	3.7	Climate	Frequency	Supplier	Productivity In Transportation
	3.8		Intensity	Supplier	Productivity In Transportation
4		EE	Aggressiveness	Actor	Cost
	4.1	Economy	Instability	Owner	Fixed Cost
	4.2				Variable Cost
	4.3		Inflation	Owner	Fixed Cost
	4.4				Variable Cost
	4.5	Administration	Corruption	Owner	Fixed Cost

5		EE	Aggressiveness	Resource	Quantity
	5.1	Economy	Instability	Machine	Machine Requirement Of Unit Operating Work
	5.2		Inflation	Machine	Machine Requirement Of Unit Operating Work
	5.3	Economy	Instability	Human	Human Requirement Of Unit Work
	5.4		Inflation	Human	Human Requirement Of Unit Work
	5.5	Climate	Frequency	Human	Total Work Of Performing
	5.6		Intensity	Human	Total Work Of Performing
	5.7	Economy	Instability	Material	Material Requirement Of Unit Component
	5.8		Inflation	Material	Material Requirement Of Unit Component
	5.9	Climate	Frequency	Material	Total Component
	5.10		Intensity	Material	Total Component
6		EE	Aggressiveness	Resource	Quality
	6.1	Climate	Frequency	Machine	Conformity
	6.2				Characteristic
	6.3		Intensity	Machine	Conformity
	6.4				Characteristic
	6.5	Climate	Frequency	Human	Skill In Operating
	6.6		Intensity	Human	Skill In Operating
	6.7	Climate	Frequency	Material	Imported Characteristic
	6.8				Storage environment
	6.9		Intensity	Material	Imported Characteristic
	6.10				Storage environment
7		EE	Aggressiveness	Resource	Unit Cost
	7.1	Economy	Instability	Machine	Depreciation
	7.2				repair Cost

	7.3				Fuel-energy cost
	7.4				Depreciation
	7.5				repair Cost
	7.6		Inflation	Machine	Fuel-energy cost
	7.7	Economy	Instability	Human	Working Time Cost
	7.8				Overtime Cost
	7.9		Inflation	Human	Working Time Cost
	7.10				Overtime Cost
	7.11	Economy	Instability	Material	Original Cost
	7.12				Transportation Cost
	7.13				Storage Cost
	7.14		Inflation	Material	Original Cost
	7.15				Transportation Cost
	7.16				Storage Cost
8		Contract	Complexity	Actor	Productivity
	8.1	Design Contract	Vagueness In Design Idea	Designer	Productivity In Designing
	8.2				Productivity In Calculating
			Number Of Alternative Design Solutions	Designer	Productivity In Designing
	8.3				Productivity In Calculating
	8.4	Submitttal Time	Designer	Productivity In Calculating	
		Building Contract	Vagueness In Process Of Building	Contractor	Productivity In Arranging Work
	8.5				Productivity In Arranging Work
	8.6		Time For Building Completion	Contractor	Productivity In Building Project
	8.7				

	8.8		Progress payment	Contractor	Productivity In Arranging Work
	8.9	Supply Contract	Vagueness Of Resource Requirement	Supplier	Productivity In Supplying Information
	8.10		Vagueness In Schedule Of Supplying	Supplier	Productivity In Supplying Information
	8.11			Supplier	Productivity In Transportation
	8.12			Supplier	Productivity In Supplying Information
	8.13			Supplier	Productivity In Transportation
9		Contract	Magnitude	Actor	Cost
	9.1	Design Contract	Designing Cost	Designer	Design Cost
	9.2	Design Contract	Design Scale	Designer	Serving Cost For Designing
	9.3	Building Contract	Building Cost	Contractor	Building Cost
	9.4	Building Contract	Project Scale	Contractor	Serving Cost For Constructing
	9.5	Supply Contract	Required Volumn	Supplier	Supplying Cost
	9.6				Serving Cost For Supplying
	9.7		Supplying Cost		
	9.8		Serving Cost For Supplying		
10		Contract	Complexity	Actor	Capacity
	10.1	Design Contract	Vagueness In Design Idea	Designer	Capacity In Designing
	10.2				Capacity In Calculating

			Number Of Alternative Design Solutions	Designer	
	10.3				Capacity In Designing
	10.4		Submittal Time	Designer	Capacity In Calculating
	10.5	Building Contract	Vagueness In Process Of Building	Contractor	Capacity In Arranging Work
	10.6		Time For Building Completion	Contractor	Capacity In Arranging Work
	10.7		Progress Payment	Contractor	Capacity In Building Project
	10.8				Capacity In Arranging Work
	10.9				Capacity In Building Project
	10.10	Supply Contract	Vagueness Of Resource Requirement	Supplier	Capacity In Adapting Resource Requirement
	10.11				Capacity In Supplying
	10.12		Vagueness In Schedule Of Supplying	Supplier	Capacity In Adapting Resource Requirement
	10.13				Capacity In Supplying
	10.14		Payment Schedule	Supplier	Capacity In Adapting Resource Requirement
	10.15				Capacity In Supplying
11		Actor	Capacity	Contract	Complexity
	11.1	Owner	Capacity In Organizing Project	Building Contract	Vagueness In Process Of Building
	11.2				Time for building completion
	11.3				Progress payment
	11.4	Contractor	Capacity In	Supply Contract	Vagueness Of Resource Requirement

	11.5		Arranging Work		Vagueness In Schedule Of Supplying
	11.6				Payment schedule
	11.7	Owner	Capacity In Organizing Project	Design Contract	Vagueness In Design Idea
	11.8				Number Of Alternative Design Solutions
	11.9				Submittal time
12		Actor	Capacity	Resource	Quantity
	12.1	Owner	Capacity In Organizing Project	Machine	Machine Requirement Of Unit Operating Work
	12.2				Total Work Of Operating
	12.3		Capacity In Managing Project	Machine	Total Work Of Operating
	12.4	Designer	Capacity In Designing	Machine	Machine Requirement Of Unit Operating Work
	12.5		Capacity In Calculating	Machine	Machine Requirement Of Unit Operating Work
	12.6	Contractor	Capacity In Arranging Work	Machine	Machine Requirement Of Unit Operating Work
	12.7				Total Work Of Operating
	12.8		Capacity In Building Project	Machine	Total Work Of Operating
	12.9	Owner	Capacity In Organizing Project	Human	Human Requirement Of Unit Work
	12.10		Capacity In Managing Project		Total Work Of Performing
	12.11	Designer	Capacity In Designing	Human	Human Requirement Of Unit Work

	12.12		Capacity In Designing		Total Work Of Performing
	12.13	Contractor	Capacity In Arranging Work	Human	Human Requirement Of Unit Work
	12.14		Capacity In Building Project		Total Work Of Performing
	12.15	Contractor	Capacity In Arranging Work	Material	Material Requirement Of Unit Component
	12.16	Supplier	Capacity In Adapting Resource Requirement	Material	Total Component
	12.17		Capacity In Supplying	Material	Total Component
13		Actor	Capacity	Resource	Quality
	13.1	Owner	Capacity In Managing Project	Machine	Conformity
	13.2				Characteristic
	13.3	Contractor	Capacity In Arranging Work	Machine	Conformity
	13.4				Characteristic
	13.5	Owner	Capacity In Organizing Project	Human	Skill In Operating
	13.6	Designer	Capacity In Designing	Human	Skill In Operating
	13.7	Contractor	Capacity In Arranging Work	Human	Skill In Operating
	13.8	Contractor	Capacity In Arranging Work	Material	Storage environment

	13.9	Supplier	Capacity In Adapting Resource Requirement	Material	Imported Characteristic
	13.10		Capacity In Supplying	Material	Imported Characteristic
	13.11		Storage environment		
14		Resource	UnitCost	Actor	Cost
	14.1	Human	Working Time Cost	Owner	Variable Cost
	14.2	Machine	Depreciation	Designer	Design Cost
	14.3		Repair Cost	Designer	Design Cost
	14.4	Human	Working Time Cost	Designer	Design Cost
	14.5	Machine	Repair Cost	Contractor	Serving Cost For Constructing
	14.6		Fuel-energy Cost	Contractor	Building Cost
	14.7	Human	Working Time Cost	Contractor	Building Cost
	14.8		Overtime Cost	Contractor	Serving Cost For Constructing
	14.9	Material	Original Cost	Contractor	Building Cost
	14.10		Storage Cost	Contractor	Serving Cost For Constructing
	14.11	Material	Original Cost	Supplier	Supplying Cost
	14.12		Transportation Cost		Supplying Cost
	14.13		Storage Cost		Serving Cost For Supplying
15		Resource	Quantity	Actor	Cost
	15.1	Human	Total Work Of Performing	Owner	Variable Cost

	15.2	Machine	Total Work Of Operating	Designer	Serving Cost For Designing
	15.3	Human	Total Work Of Performing	Designer	Serving Cost For Designing
	15.4	Machine	Machine Requirement Of Unit Operating Work	Contractor	Serving Cost For Constructing
	15.5	Material	Material Requirement Of Unit Component	Supplier	Serving Cost For Supplying
	15.6		Total Component	Supplier	Serving Cost For Supplying
16		Resource	Quantity	Activity	Duration
	16.1	Human	Human Requirement Of Unit Work	AIP	Duration To Perform Work
	16.2		Total Work Of Performing		Duration To Repair Precedent Work
	16.3	Human	Human Requirement Of Unit Work	AOP	Duration To Perform Maintain Work
	16.4		Total Work Of Performing		Duration To Perform Maintain Work
	16.5				Duration To Repair Errors
17		Resource	Quality	Activity	Duration
	17.1	Human	Skill In Operating	AFP	Duration To Perform Work
	17.2				Duration To Adjust Work
	17.3	Machine	Conformity	AIP	Duration To Perform Work

	17.4	Human	Skill In Operating	AIP	Duration To Repair Precedent Work
	17.5	Human	Skill In Operating	AOP	Duration To Perform Maintain Work
	17.6				Duration To Repair Errors
18		Resource	Quality	Activity	Quality
	18.1	Machine	Characteristic	AFP	Pollution Of Feasibility Work
	18.2				Technique Of Research And Performing Work
	18.3	Human	Skill In Operating	AFP	Technique Of Research And Performing Work
	18.4	Machine	Conformity	AIP	Technique of Work
	18.5		Pollution Of Work		
	18.6		Characteristic	AIP	Technique of Work
	18.7	Human	Skill In Operating	AIP	Technique of Work
	18.8	Material	Imported Characteristic	AIP	Technique of Work
	18.9	Machine	Conformity	AOP	Technique of Repairing Error
	18.10		Pollution Of Work		
	18.11		Characteristic	AOP	Technique of Repairing Error
	18.12	Human	Skill In Operating	AOP	Technique of Repairing Error
	18.13	Material	Imported Characteristic	AOP	Technique of Repairing Error
19		Actor	Productivity	Activity	Duration
	19.1	Owner	Productivity In Organizing Project	AFP	Duration To Perform Work

	19.2		Productivity In Mananging Project	AFP	Duration To Adjust Work
	19.3	Designer	Productivity In Calculating	AFP	Duration To Adjust Work
	19.4	Designer	Productivity In Calculating	AIP	Duration To Repair Precedent Work
	19.5	Supplier	Productivity In Transportation	AIP	Duration To Perform Work
	19.6	Contractor	Productivity In Arranging Work	AOP	Duration To Repair Errors
	19.7		Productivity In Building Project	AOP	Duration To Repair Errors
20		Actor	Capacity	Activity	Duration
	20.1	Owner	Capacity In Organizing Project	AFP	Duration To Perform Work
	20.2	Owner	Capacity In Mananging Project	AFP	Duration To Adjust Work
	20.3	Designer	Capacity In Calculating	AFP	Duration To Perform Work
	20.4	Designer	Capacity In Designing	AIP	Duration To Repair Precedent Work
	20.5	Contractor	Capacity In Arranging Work	AIP	Duration To Perform Work
	20.6	Contractor	Capacity In Building Project	AOP	Duration To Perform Maintain Work
21	21.1	Actor	Cost	Activity	Cost

	21.2	Owner	Fixed Cost	AFP	Cost To Perform Work
	21.3				Cost To Adjust Work
	21.4		Variable Cost	AFP	Cost To Perform Work
	21.5				Cost To Adjust Work
	21.6	Designer	Design Cost	AFP	Cost To Perform Work
	21.7				Cost To Adjust Work
	21.8		Serving Cost For Designing	AFP	Cost To Perform Work
	21.9				Cost To Adjust Work
	21.10	Designer	Design Cost	AIP	Cost To Perform Work
	21.11				Cost To Repair Precedent Work
	21.12		Serving Cost For Designing	AIP	Cost To Repair Precedent Work
	21.13	Contractor	Building Cost	AIP	Cost To Perform Work
	21.14	Supplier	Supplying Cost	AIP	Cost To Perform Work
	21.15		Serving Cost For Supplying	AIP	Cost To Perform Work
	21.16	Contractor	Building Cost	AOP	Cost To Repair Errors
	21.17		Serving Cost For Constructing	AOP	Cost To Maintain
	21.18				Cost To Repair Errors
	21.19	Supplier	Supplying Cost	AOP	Cost To Repair Errors
22		Product	Quality	Activity	Duration
	22.1	PFP	Satisfaction Of Owner	AIP	Duration To Repair Precedent Work
	22.2	PIP	Satisfaction Of Owner	AOP	Duration To Repair Errors
23		Product	Quality	Activity	Cost

	23.1	PFP	Satisfaction Of Owner	AIP	Cost To Perform Work
	23.2		Right Regulation		Cost To Repair Precedent Work
		PIP	Satisfaction Of Owner	AOP	Cost To Repair Errors
24		Activity	Cost	Product	Cost
	24.1	AFP	Cost To Perform Work	PFP	Cost Of Performing Feasibility Work
	24.2	AFP	Cost To Adjust Work	PFP	Cost Of Adjusting Feasibility Work
	24.3	AIP	Cost To Perform Work	PIP	Cost Of Performing Implementation Work
	24.4	AIP	Cost To Repair Precedent Work	PIP	Cost Of Repairing Precedent Work
	24.5	AOP	Cost To Maintain	POP	Cost Of Maintaining
	24.6	AOP	Cost To Repair Errors	POP	Cost Of Repairing Errors
25		Activity	Quality	Product	Quality
	25.1	AFP	Impact Of Feasibility Work	PFP	Satisfaction Of Owner
	25.2				Right Regulation
	25.3		Technique Of Research	PFP	Satisfaction Of Owner
	25.4				Right Regulation
	25.5	AIP	Impact Of Implementation Work	PIP	Satisfaction Of Owner

	25.6				Right Regulation
	25.7		Technique Of Work	PIP	Satisfaction Of Owner
	25.8				Right Regulation
	25.9	AOP	Impact Of Operation Work	POP	Satisfaction Of Owner
	25.10				Right Regulation
	25.11		Technique Of Repairing Error	POP	Satisfaction Of Owner
	25.12				Right Regulation
26		Activity	Duration	Product	Duration
	26.1	AFP	Duration To Perform Work	PFP	Duration Of Performing Feasibility Work
	26.2		Duration To Adjust Work		Duration Of Adjusting Feasibility Work
	26.3	AIP	Duration To Perform Work	PIP	Duration Of Performing Implementation Work
	26.4		Duration To Repair Precedent Work		Duration Of Repairing Precedent Work
	26.5	AOP	Duration To Perform Work	POP	Duration Of Performing Maintenance
	26.6		Duration To Repair Errors		Duration Of Repairing Errors
Relations between attributes of the same entities					
27		Resource	Quality	Resource	Unit Cost
	27.1	Machine	Conformity	Machine	Depreciation
	27.2				repair Cost
	27.3				Fuel-energy cost

	27.4		Characteristic	Machine	Depreciation
	27.5				repair Cost
	27.6				Fuel-energy cost
	27.7	Human	Skill In Operating	Human	Working Time Cost
	27.8				Overtime Cost
	27.9	Material	Imported Characteristic	Material	Original Cost
	27.10				Transportation Cost
	27.11				Storage Cost
	27.12		Storage Environment	Material	Original Cost
	27.13				Transportation Cost
	27.14				Storage Cost
28		Actor	Experience	Actor	Productivity
	28.1	Owner	Experience In Organizing Project	Owner	Productivity In Organizing Project
	28.2		Experience In Mananing Project		Productivity In Managing Project
	28.3	Designer	Experience In Designing	Designer	Productivity In Designing
	28.4				Productivity In Calculating
	28.5			Past Qualification Assessment About Designing	Designer

	28.6				Productivity In Calculating
	28.7	Contractor	Experience In Building Project	Contractor	Productivity In Arranging Work
	28.8				Productivity In Building Project
	28.9		Past Qualification Assessment About Building	Contractor	Productivity In Arranging Work
	28.10				Productivity In Building Project
	28.11	Supplier	Experience In Supplying	Supplier	Productivity In Transportation
	28.12		Past Qualification Assessment About Supplying		Productivity In Supplying Information
29		Actor	Experience	Actor	Capacity
	29.1	Owner	Experience In Organizing Project	Owner	Capacity In Organizing Project
	29.2		Experience In Mananing Project		Capacity In Managing Project
	29.3	Designer	Experience In Designing	Designer	Capacity In Designing
	29.4				Capacity In Calculating

	29.5		Past Qualification Assessment About Designing	Designer	Capacity In Designing
	29.6				Capacity In Calculating
	29.7	Contractor	Experience In Building Project	Contractor	Capacity In Arranging Work
	29.8				Capacity In Building Project
	29.9		Past Qualification Assessment About Building	Contractor	Capacity In Arranging Work
	29.10				Capacity In Building Project

Appendix 8. Attributes' relations in level 2

No Level 0	No Level 1	Entity source	Attribute source	Entity target	Attribute target
1		EE	Aggressiveness	Contract	Complexity
	1.1	Climate	Frequency	Building Contract	Time for building completion
		Temperature	Frequency Of Degree	Main Building Contract	Time for arranging order of building activities
					Time for choosing building technology
				Installing Contract	Time for arranging order of installing activities
					Time for choosing installing technology
		Precipitation	Frequency Of Precipitation	Main Building Contract	Time for arranging order of building activities
					Time for choosing building technology
				Installing Contract	Time for arranging order of installing activities

					Time for choosing installing technology
	1.2	<i>Climate</i>	<i>Frequency</i>	<i>Building Contract</i>	<i>Progress payment</i>
		Temperature	Frequency Of Degree	Main Building Contract	Achievement of certain milestones in the building work
					Stipulated amounts of building on set calendar dates
				Installing Contract	Achievement of certain milestones in the installing work
					Stipulated amounts of installing on set calendar dates
		Precipitation	Frequency Of Precipitation	Main Building Contract	Achievement of certain milestones in the building work
					Stipulated amounts of building on set calendar dates
				Installing Contract	Achievement of certain milestones in the installing work
					Stipulated amounts of installing on set calendar dates
	1.3	<i>Climate</i>	<i>Intensity</i>	<i>Building Contract</i>	<i>Time for building completion</i>
		Temperature	Level Of Degree	Main Building Contract	Time for choosing building technology
			Period Duration Of Degree		Time for arranging order of building activities
		Temperature	Level Of Degree	Installing Contract	Time for choosing installing technology
			Period Duration Of Degree		Time for arranging order of installing activities
		Precipitation	Level of precipitation	Main Building Contract	Time for choosing building technology
			Period duration of precipitation		Time for arranging order of building activities
		Precipitation	Level of precipitation	Installing Contract	Time for choosing installing technology
			Period duration of precipitation		Time for arranging order of installing activities
	1.4	<i>Climate</i>	<i>Intensity</i>	<i>Building Contract</i>	<i>Progress payment</i>
		Temperature	Level Of Degree	Main Building Contract	Stipulated amounts of building on set calendar dates

			Period Duration Of Degree		Achievement of certain milestones in the building work
		Temperature	Level Of Degree	Installing Contract	Stipulated amounts of installing on set calendar dates
			Period Duration Of Degree		Achievement of certain milestones in the installing work
		Precipitation	Level of precipitation	Main Building Contract	Stipulated amounts of building on set calendar dates
			Period duration of precipitation		Achievement of certain milestones in the building work
		Precipitation	Level of precipitation	Installing Contract	Stipulated amounts of installing on set calendar dates
			Period duration of precipitation		Achievement of certain milestones in the installing work
	1.5	Climate	Frequency	Supply Contract	Payment schedule
		Temperature	Frequency of degree	Material supply contract	Achievement of certain material
		Precipitation	Frequency of precipitation	Material supply contract	Full information of supplied material
	1.6	Climate	Intensity	Supply Contract	Payment schedule
		Temperature	Level Of Degree	Material supply contract	Full information of supplied material
			Period Duration Of Degree		Achievement of certain material
		Precipitation	Level of precipitation	Material supply contract	Full information of supplied material
			Period duration of precipitation		Achievement of certain material
	1.7	Climate	Frequency	Design Contract	Submittal time
		Temperature	Frequency of degree	Structural design contract	Duration of structural design
				Architectural design contract	Duration of architectural design
		Precipitation	Frequency of precipitation	Structural design contract	Milestone of submitting structural design
				Architectural design contract	Milestone of submitting architectural design
	1.8	Climate	Intensity	Design Contract	Submittal time
		Temperature	Level Of Degree	Structural design contract	Duration of structural design
			Period Duration Of Degree		Milestone of submitting structural design
		Precipitation	Level of precipitation	Structural design contract	Duration of structural design
			Period duration of precipitation		Milestone of submitting structural design

		Temperature	Level Of Degree	Architectural design contract	Duration of architectural design
			Period Duration Of Degree		Milestone of submitting architectural design
		Precipitation	Level of precipitation	Architectural design contract	Duration of architectural design
			Period duration of precipitation		Milestone of submitting architectural design
2		EE	Aggressiveness	Contract	Magnitude
	2.1	Economy	Instability	Building Contract	Project Scale
		National economy	Changes in Interest Rates of national bank	Main building contract	Acreage (m2, ha, etc.)
			Increasing national tax		Complexity in technique
		International economy	Changes of interest rate of international bank	Main building contract	Acreage (m2, ha, etc.)
			Increasing international tax		Complexity in technique
		National economy	Changes in Interest Rates of national bank	Installing Contract	Number of component
			Increasing national tax		Complexity of installed component
		International economy	Changes of interest rate of international bank	Installing Contract	Number of component
			Increasing international tax		Complexity of installed component
	2.2	Economy	Instability	Building Contract	Building Cost
		National economy	Changes in Interest Rates of national bank	Main building contract	Punished cost of delay in building
			Increasing national tax		Main building cost
		International economy	Changes of interest rate of international bank	Main building contract	Punished cost of delay in building
			Increasing international tax		Main building cost
		National economy	Changes in Interest Rates of national bank	Installing Contract	Punished cost of delay in installing
			Increasing national tax		Main installing cost
		International economy	Changes of interest rate of international bank	Installing Contract	Punished cost of delay in installing
			Increasing international tax		Main installing cost
	2.3	Economy	Inflation	Building Contract	Project Scale

		National economy	Demand pull inflation	Main building contract	Acreage (m2, ha, etc.)
			Cost push inflation		Complexity in technique
		International economy	Monetary policy	Main building contract	Acreage (m2, ha, etc.)
			Politic		Complexity in technique
		National economy	Demand pull inflation	Installing Contract	Number of component
			Cost push inflation		Complexity of installed component
		International economy	Monetary policy	Installing Contract	Number of component
			Politic		Complexity of installed component
	2.4	Economy	Inflation	Building Contract	Building Cost
		National economy	Demand pull inflation	Main building contract	Punished cost of delay in building
			Cost push inflation		Main building cost
		International economy	Monetary policy	Main building contract	Punished cost of delay in building
			Politic		Main building cost
		National economy	Demand pull inflation	Installing Contract	Punished cost of delay in installing
			Cost push inflation		Main installing cost
		International economy	Monetary policy	Installing Contract	Punished cost of delay in installing
			Politic		Main installing cost
	2.5	Economy	Instability	Supply Contract	Required volumn
		National economy	Changes in Interest Rates of national bank	Material supply contract	Qualification of material
			Increasing national tax		Number of desired material
		International economy	Changes of interest rate of international bank	Material supply contract	Qualification of material
			Increasing international tax		Number of desired material
	2.6	Economy	Instability	Supply Contract	Supply Cost
		National economy	Changes in Interest Rates of national bank	Material supply contract	Punished cost of delay in material supply
			Increasing national tax		Material cost

		International economy	Changes of interest rate of international bank	Material supply contract	Punished cost of delay in material supply
			Increasing international tax		Material cost
	2.7	Economy	Inflation	Supply Contract	Required volumn
		National economy	Demand pull inflation	Material supply contract	Qualification of material
			Cost push inflation		Number of desired material
		International economy	Monetary policy	Material supply contract	Qualification of material
			Politic		Number of desired material
	2.8	Economy	Inflation	Supply Contract	Supply Cost
		National economy	Demand pull inflation	Material supply contract	Punished cost of delay in material supply
			Cost push inflation		Material cost
		International economy	Monetary policy	Material supply contract	Punished cost of delay in material supply
			Politic		Material cost
	2.9	Economy	Instability	Design Contract	Design Scale
		National economy	Changes in Interest Rates of national bank	Structural design contract	Weight (Load)
					Reliability
			Increasing national tax	Structural design contract	Weight (Load)
					Reliability
		National economy	Changes in Interest Rates of national bank	Architectural design contract	Height
					Width
			Increasing national tax	Architectural design contract	Height
					Width
	2.10	Economy	Instability	Design Contract	Designing Cost
		National economy	Changes in Interest Rates of national bank	Structural design contract	Main structural design cost
					Punished cost of structural design
			Increasing national tax	Structural design contract	Main structural design cost
					Punished cost of structural design

		National economy	Changes in Interest Rates of national bank	Architectural design contract	Main architectural design cost
					Punished cost of architectural design
			Increasing national tax	Architectural design contract	Main architectural design cost
					Punished cost of architectural design
	2.11	Economy	Inflation	Design Contract	Design Scale
		National economy	Demand pull inflation	Structural design contract	Weight (Load)
					Reliability
				Architectural design contract	Height
					Width
			Cost push inflation	Structural design contract	Weight (Load)
					Reliability
				Architectural design contract	Height
					Width
	2.12	Economy	Inflation	Design Contract	Designing Cost
		National economy	Demand pull inflation	Structural design contract	Main structural design cost
					Punished cost of structural design
				Architectural design contract	Main architectural design cost
					Punished cost of architectural design
			Cost push inflation	Structural design contract	Main structural design cost
					Punished cost of structural design
				Architectural design contract	Main architectural design cost
					Punished cost of architectural design
3		EE	Aggressiveness	Actor	Productivity
	3.1	Administration	Inertia	Owner	Productivity In Organizing Project
		Ministry	Complex ministry decentralization	Owner	Reasonable priority construction work
		Department	Qualification of department's public official	Owner	Upgrading technology in organizing project
	3.2	Climate	Frequency	Owner	Productivity In Organizing Project
		Temperature	Frequency of degree	Owner	Upgrading technology in organizing project
	3.3	Climate	Frequency	Owner	Productivity In Managing Project

		Temperature	Frequency of degree	Owner	Productivity in managing time
					Productivity in managing cost
					Productivity in managing quality
	3.4	Climate	Intensity	Owner	Productivity In Organizing Project
		Temperature	Level Of Degree	Owner	Reasonable priority construction work
		Precipitation	Level Of Precipitation	Owner	Reasonable priority construction work
			Period Duration Of Precipitation	Owner	Upgrading technology in organizing project
	3.5	Climate	Intensity	Owner	Productivity In Managing Project
		Temperature	Period Duration Of Degree	Owner	Productivity in managing time
					Productivity in managing quality
		Precipitation	Level Of Precipitation	Owner	Productivity in managing time
					Productivity in managing quality
			Period Duration Of Precipitation	Owner	Productivity in managing cost
	3.6	Climate	Frequency	Contractor	Productivity In Building Project
		Temperature	Frequency of degree	Building Contractor	Productivity in arranging reasonable priority building work
		Precipitation	Frequency of precipitation	Installing Contractor	Productivity in using new technology in installing
					Productivity in arranging reasonable priority installing work
	3.7	Climate	Intensity	Contractor	Productivity In Building Project
		Temperature	Level Of Degree	Building Contractor	Productivity in arranging reasonable priority building work
			Period Duration Of Degree		Productivity in using new technology in building
		Precipitation	Level Of Precipitation	Building Contractor	Productivity in arranging reasonable priority building work
			Period Duration Of Precipitation		Productivity in using new technology in building
		Temperature	Level Of Degree	Installing Contractor	Productivity in arranging reasonable priority installing work
			Period Duration Of Degree		Productivity in using new technology in installing

		Precipitation	Level Of Precipitation	Installing Contractor	Productivity in arranging reasonable priority installing work
			Period Duration Of Precipitation		Productivity in using new technology in installing
	3.8	Climate	Frequency	Supplier	Productivity In Transportation
		Precipitation	Frequency of precipitation	Material Supplier	Distance of transporting material
					Velocity of transporting material
	3.9	Climate	Intensity	Supplier	Productivity In Transportation
		Temperature	Level Of Degree	Material Supplier	Velocity of transporting material
			Period Duration Of Degree		Distance of transporting material
		Precipitation	Level Of Precipitation	Material Supplier	Velocity of transporting material
			Period Duration Of Precipitation		Distance of transporting material
4		EE	Aggressiveness	Actor	Cost
	4.1	Economy	Instability	Owner	Fixed Cost
		International economy	Changes of interest rate of international bank	Owner	Fixed cost in doing procedure
	4.2	Economy	Instability	Owner	Variable Cost
		National economy	Increasing national tax	Owner	Variable cost in building
		International economy	Increasing international tax	Owner	Variable cost in building
	4.3	Economy	Inflation	Owner	Fixed Cost
		National economy	Demand pull inflation	Owner	Fixed cost in doing procedure
		International economy	Monetary policy	Owner	Fixed cost in doing procedure
	4.4	Economy	Inflation	Owner	Variable Cost
		National economy	Demand pull inflation	Owner	Variable cost in building
	4.5	Administration	Corruption	Owner	Fixed Cost
		Ministry	Wages of public officials	Owner	Fixed cost in doing procedure
		Department	Chain reaction of department's public official	Owner	Fixed cost in building
5		EE	Aggressiveness	Resource	Quantity
	5.1	Economy	Instability	Machine	Machine Requirement Of Unit Operating Work

		National economy	Changes in Interest Rates of national bank	Office Machine	Assistance equipment
			Increasing national tax		Number of office machine
	5.2	Economy	Inflation	Machine	Machine Requirement Of Unit Operating Work
		National economy	Demand pull inflation	Construction Machine	Assistance machine
			Cost push inflation		Main construction machine
		International economy	Monetary policy	Construction Machine	Assistance machine
			Politic		Main construction machine
		International economy	Monetary policy	Office Machine	Assistance equipment
			Politic		Number of office machine
	5.3	Economy	Instability	Human	Human Requirement Of Unit Work
		International economy	Changes of interest rate of international bank	Worker	Assistance for main worker
			Increasing international tax		Main worker for unit work
		National economy	Changes in Interest Rates of national bank	Engineer	Number of engineer for unit work
		National economy	Changes in Interest Rates of national bank	Office Staff	Number of staff for unit work
	5.4	Economy	Inflation	Human	Human Requirement Of Unit Work
		National economy	Demand pull inflation	Worker	Assistance for main worker
			Cost push inflation		Main worker for unit work
		National economy	Demand pull inflation	Office Staff	Number of staff for unit work
	5.5	Climate	Frequency	Human	Total Work Of Performing
		Precipitation	Frequency of precipitation	Worker	Number of main work of performing
		Temperature	Frequency of degree	Engineer	Number of designing process of work
					Number of manage work of construction process
		Precipitation	Frequency of precipitation	Office Staff	Number of solved construction work
	5.6	Climate	Intensity	Human	Total Work Of Performing
		Temperature	Level Of Degree	Worker	Number of extra work of performing

			Period Duration Of Degree		Number of main work of performing
		Precipitation	Level Of Precipitation	Worker	Number of extra work of performing
		Temperature	Level Of Degree	Engineer	Number of manage work of construction process
		Precipitation	Period Duration Of Precipitation	Engineer	Number of designing process of work
		Temperature	Level Of Degree	Office Staff	Number of solved construction work
		Precipitation	Period Duration Of Precipitation	Office Staff	Number of procedure attaches with construction work
	5.7	Economy	Instability	Material	Material Requirement Of Unit Component
		International economy	Changes of interest rate of international bank	Reusable Material	Extra reusable material for unit component
			Increasing international tax		Main reusable material for unit component
		International economy	Increasing international tax	Consumable Material	Number of consumable material for unit component
	5.8	Economy	Inflation	Material	Material Requirement Of Unit Component
		National economy	Demand pull inflation	Reusable Material	Extra reusable material for unit component
			Cost push inflation		Main reusable material for unit component
		National economy	Cost push inflation	Consumable Material	Number of consumable material for unit component
	5.9	Climate	Frequency	Material	Total Component
		Temperature	Frequency of degree	Reusable Material	Failure component
		Precipitation	Frequency of precipitation	Reusable Material	Installed component
		Temperature	Frequency of degree	Consumable Material	Lost component
		Precipitation	Frequency of precipitation	Consumable Material	Build component
	5.10	Climate	Intensity	Material	Total Component
		Temperature	Level Of Degree	Reusable Material	Failure component
			Period Duration Of Degree		Installed component
		Precipitation	Level Of Precipitation	Reusable Material	Failure component
			Period Duration Of Precipitation		Installed component
		Temperature	Level Of Degree	Consumable Material	Lost component
			Period Duration Of Degree		Build component
		Precipitation	Level Of Precipitation	Consumable Material	Lost component

			Period Duration Of Precipitation		Build component
6		EE	Aggressiveness	Resource	Quality
	6.1	Climate	Frequency	Machine	Conformity
		Precipitation	Frequency of precipitation	Construction Machine	Conformity in transporting
					Conformity in operating
		Temperature	Frequency of degree	Office Machine	Conformity in manipulating
					Conformity in moving
	6.2	Climate	Frequency	Machine	Characteristic
		Precipitation	Frequency of precipitation	Construction Machine	Productivity in performing construction work
					Emission pollution
		Temperature	Frequency of degree	Office Machine	Productivity in solving document
	6.3	Climate	Intensity	Machine	Conformity
		Temperature	Level Of Degree	Construction Machine	Conformity in operating
		Precipitation	Level Of Precipitation	Construction Machine	Conformity in operating
			Period Duration Of Precipitation		Conformity in transporting
		Temperature	Period Duration Of Degree	Office Machine	Conformity in manipulating
		Precipitation	Level Of Precipitation	Office Machine	Conformity in moving
			Period Duration Of Precipitation		Conformity in manipulating
	6.4	Climate	Intensity	Machine	Characteristic
		Temperature	Level Of Degree	Construction Machine	Emission pollution
			Period Duration Of Degree		Productivity in performing construction work
		Temperature	Level Of Degree	Office Machine	Replaced equipment of office machine
		Precipitation	Level Of Precipitation	Office Machine	Replaced equipment of office machine
			Period Duration Of Precipitation		Productivity in solving document
	6.5	Climate	Frequency	Human	Skill In Operating
		Temperature	Frequency of degree	Worker	Skill in executing construction work
					Ability in teamwork
		Temperature	Frequency of degree	Engineer	Ability in arranging construction work
		Precipitation	Frequency of precipitation	Office Machine	Skill in handling document

	6.6	Climate	Intensity	Human	Skill In Operating
		Temperature	Level Of Degree	Worker	Ability in teamwork
			Period Duration Of Degree		Skill in executing construction work
		Precipitation	Level Of Precipitation	Worker	Ability in teamwork
		Temperature	Level Of Degree	Engineer	Flexibility in treating incident
			Period Duration Of Degree		Ability in arranging construction work
		Precipitation	Period Duration Of Precipitation	Engineer	Ability in arranging construction work
		Temperature	Level Of Degree	Office Staff	Flexibility in solving data
			Period Duration Of Degree		Skill in handling document
		Precipitation	Level Of Precipitation	Office Staff	Flexibility in solving data
	6.7	Climate	Frequency	Material	Imported Characteristic
		Temperature	Frequency of degree	Reusable Material	Characteristic after transport process
		Precipitation	Frequency of precipitation	Reusable Material	Original characteristic
		Temperature	Frequency of degree	Consumable Material	Characteristic after transport process
		Precipitation	Frequency of precipitation	Consumable Material	Original characteristic
	6.8	Climate	Frequency	Material	Storage environment
		Temperature	Frequency of degree	Reusable Material	Internal and external storage environment
		Precipitation	Frequency of precipitation		Equipment of storage
		Temperature	Frequency of degree	Consumable Material	Internal and external storage environment
		Precipitation	Frequency of precipitation		Equipment of storage
	6.9	Climate	Intensity	Material	Imported Characteristic
		Temperature	Level Of Degree	Reusable Material	Characteristic after transport process
			Period Duration Of Degree		Original characteristic
		Precipitation	Level Of Precipitation	Reusable Material	Characteristic after transport process
			Period Duration Of Precipitation		Original characteristic
		Temperature	Level Of Degree	Consumable Material	Characteristic after transport process
			Period Duration Of Degree		Original characteristic
		Precipitation	Level Of Precipitation	Consumable Material	Characteristic after transport process
			Period Duration Of Precipitation		Original characteristic
	6.10	Climate	Intensity	Material	Storage environment
		Temperature	Level Of Degree	Reusable Material	Internal and external storage environment

			Period Duration Of Degree		Equipment of storage
		Precipitation	Level Of Precipitation	Reusable Material	Internal and external storage environment
			Period Duration Of Precipitation		Equipment of storage
		Temperature	Level Of Degree	Consumable Material	Internal and external storage environment
			Period Duration Of Degree		Equipment of storage
		Precipitation	Level Of Precipitation	Consumable Material	Internal and external storage environment
			Period Duration Of Precipitation		Equipment of storage
7		EE	Aggressiveness	Resource	Unit Cost
	7.1	Economy	Instability	Machine	Depreciation
		National economy	Changes in Interest Rates of national bank	Construction Machine	Recovery construction machine cost
			Increasing national tax		Original construction machine cost
		National economy	Changes in Interest Rates of national bank	Office Machine	Recovery office machine cost
			Increasing national tax		Original office machine cost
	7.2	Economy	Instability	Machine	Repair Cost
		National economy	Demand pull inflation	Construction Machine	Repair cost of extra part of machine
			Cost push inflation		Repair cost of important part of machine
		International economy	Changes of interest rate of international bank	Construction Machine	Repair cost of extra part of machine
			Increasing international tax		Repair cost of important part of machine
		National economy	Increasing national tax	Office Machine	Repair cost of important part of office machine
			Changes in Interest Rates of national bank		Repair cost of extra part of office machine
		International economy	Politics	Office Machine	Repair cost of important part of office machine
			Monetary policy		Repair cost of extra part of office machine
	7.3	Economy	Instability	Machine	Fuel-energy cost
		National economy	Changes in Interest Rates of national bank	Construction Machine	Unit cost of fuel-energy

			Increasing national tax		Energy consumption each time of construction work
		International economy	Politics	Construction Machine	Energy consumption each time of construction work
			Monetary policy		Unit cost of fuel-energy
		National economy	Changes in Interest Rates of national bank	Office Machine	Unit cost of electricity
			Increasing national tax		Energy consumption each time of office work
		International economy	Politics	Office Machine	Energy consumption each time of office work
			Monetary policy		Unit cost of electricity
	7.4	Economy	Inflation	Machine	Depreciation
		National economy	Changes in Interest Rates of national bank	Construction Machine	Recovery construction machine cost
			Increasing national tax		Original construction machine cost
		International economy	Politics	Construction Machine	Original construction machine cost
			Monetary policy		Recovery construction machine cost
		National economy	Changes in Interest Rates of national bank	Office Machine	Recovery office machine cost
			Increasing national tax		Original office machine cost
		International economy	Politics	Office Machine	Original office machine cost
			Monetary policy		Recovery office machine cost
	7.5	Economy	Inflation	Machine	Repair Cost
		National economy	Demand pull inflation	Construction Machine	Repaired cost of extra part of machine
			Cost push inflation		Repaired cost of important part of machine
		National economy	Changes in Interest Rates of national bank	Office Machine	Repaired cost of important part of office machine
			Increasing national tax		Repaired cost of extra part of office machine
		International economy	Politics	Office Machine	Repaired cost of important part of office machine

			Monetary policy		Repaired cost of extra part of office machine
	7.6	Economy	Inflation	Machine	Fuel-energy cost
		National economy	Changes in Interest Rates of national bank	Construction Machine	Unit cost of fuel-energy
			Increasing national tax		Energy consumption each time of construction work
		International economy	Politics	Construction Machine	Energy consumption each time of construction work
			Monetary policy		Unit cost of fuel-energy
		National economy	Changes in Interest Rates of national bank	Office Machine	Unit cost of electricity
			Increasing national tax		Energy consumption each time of office work
		International economy	Politics	Office Machine	Energy consumption each time of office work
			Monetary policy		Unit cost of electricity
	7.7	Economy	Instability	Human	Working Time Cost
		National economy	Changes in Interest Rates of national bank	Worker	Salary of each unit of time performing
			Increasing national tax		Regulated performing time
		National economy	Changes in Interest Rates of national bank	Engineer	Salary of each unit of time of working
			Increasing national tax		Regulated working time
		National economy	Changes in Interest Rates of national bank	Office Staff	Salary of each time of office working
			Increasing national tax		Regulated office working time
	7.8	Economy	Instability	Human	Overtime Cost
		International economy	Changes of interest rate of international bank	Worker	Salary of each overtime of performing
			Increasing international tax		Overtime of construction performing
		International economy	Changes of interest rate of international bank	Engineer	Salary of each overtime of office working

			Changes of interest rate of international bank		Overtime of office work
			Increasing international tax	Engineer	Salary of each overtime of office working
			Increasing international tax		Overtime of office work
		National economy	Changes in Interest Rates of national bank	Office Staff	Overtime of office work
			Increasing national tax		Salary of each overtime of office working
		International economy	Changes of interest rate of international bank	Office Staff	Salary of each overtime of office working
			Increasing international tax		Overtime of office work
	7.9	Economy	Inflation	Human	Working Time Cost
		International economy	Politics	Worker	Regulated performing time
			Monetary policy		Salary of each unit of time performing
		International economy	Politics	Engineer	Regulated performing time
			Monetary policy		Regulated performing time
			Politics		Salary of each unit of time performing
			Monetary policy		Salary of each unit of time performing
		International economy	Politics	Office Staff	Regulated office working time
			Monetary policy		Salary of each time of office working
	7.10	Economy	Inflation	Human	Overtime Cost
		National economy	Demand pull inflation	Worker	Salary of each overtime of performing
			Cost push inflation		Overtime of construction performing
		National economy	Demand pull inflation	Engineer	Salary of each overtime of working
			Cost push inflation		Overtime of working
		National economy	Demand pull inflation	Office Staff	Salary of each overtime of office working
			Cost push inflation		Overtime of office work
		International economy	Politics	Office Staff	Overtime of office work
			Monetary policy		Salary of each overtime of office working

	7.11	<i>Economy</i>	<i>Instability</i>	<i>Material</i>	<i>Original Cost</i>
		National economy	Changes in Interest Rates of national bank	Reusable Material	Reusable material cost after tax
			Increasing national tax		Reusable material cost after tax
		International economy	Increasing international tax		Reusable material cost after tax
		National economy	Changes in Interest Rates of national bank	Consumable Material	Consumable material cost after tax
		International economy	Increasing international tax		Consumable material cost after tax
	7.12	<i>Economy</i>	<i>Instability</i>	<i>Material</i>	<i>Transportation Cost</i>
		National economy	Changes in Interest Rates of national bank	Reusable Material	Traffic charges
			Increasing national tax		Cost of fuel-energy of transport process
		International economy	Changes of interest rate of international bank	Reusable Material	Traffic charges
			Increasing international tax		Cost of fuel-energy of transport process
		National economy	Changes in Interest Rates of national bank	Consumable Material	Traffic charges
			Increasing national tax		Cost of fuel-energy of transport process
	7.13	<i>Economy</i>	<i>Instability</i>	<i>Material</i>	<i>Storage Cost</i>
		National economy	Changes in Interest Rates of national bank	Reusable Material	Cost of storehouse
			Increasing national tax		Cost of storage equipment
		International economy	Changes of interest rate of international bank	Reusable Material	Cost of storehouse
			Increasing international tax		Cost of storage equipment
		International economy	Changes of interest rate of international bank	Consumable Material	Cost of storehouse
			Increasing international tax		Cost of storage equipment
	7.14	<i>Economy</i>	<i>Inflation</i>	<i>Material</i>	<i>Original Cost</i>
		National economy	Cost push inflation	Consumable Material	Consumable material cost after tax

		International economy	Politics	Consumable Material	Consumable material cost after tax
	7.15	Economy	Inflation	Material	Transportation Cost
		National economy	Demand pull inflation	Reusable Material	Traffic charges
			Cost push inflation		Cost of fuel-energy of transport process
		International economy	Politics	Reusable Material	Cost of fuel-energy of transport process
			Monetary policy		Traffic charges
		International economy	Politics	Consumable Material	Cost of fuel-energy of transport process
			Monetary policy		Traffic charges
	7.16	Economy	Inflation	Material	Storage Cost
		National economy	Demand pull inflation	Reusable Material	Cost of storehouse
			Cost push inflation		Cost of storage equipment
		International economy	Politics	Reusable Material	Cost of storehouse
			Monetary policy		Cost of storage equipment
		National economy	Demand pull inflation	Consumable Material	Cost of storehouse
			Cost push inflation		Cost of storage equipment
8		Contract	Complexity	Actor	Productivity
	8.1	Design Contract	Vagueness In Design Idea	Designer	Productivity In Designing
		Structural design contract	Vagueness about load	Structural designer	Productivity in using designing software
			Vagueness about reliability		Productivity in defining weight
		Architectural design contract	Vagueness about height	Architectural designer	Productivity in using calculation architectural software
			Vagueness about width		Productivity in designing layout
	8.2	Design Contract	Vagueness In Design Idea	Designer	Productivity In Calculating
		Structural design contract	Vagueness about load	Structural designer	Productivity in using calculation software
			Vagueness about reliability		Productivity in choosing suitable calculation parameter

		Architectural design contract	Vagueness about height	Architectural designer	Productivity in using calculation architectural software
			Vagueness about width		Productivity in choosing suitable architectural parameter
	8.3	Design Contract	Number Of Alternative Design Solutions	Designer	Productivity In Designing
		Structural design contract	Variation of impact force	Structural designer	Productivity in using designing software
			Variation of parameters of reliability		Productivity in defining weight
		Architectural design contract	Changing dimension	Architectural designer	Productivity in using calculation architectural software
			Number of perspective		Productivity in designing layout
	8.4	Design Contract	Submittal Time	Designer	Productivity In Calculating
		Structural design contract	Milestone of submitting structural design	Structural designer	Productivity in using calculation software
			Duration of structural design		Productivity in choosing suitable calculation parameter
		Architectural design contract	Milestone of submitting architectural design	Architectural designer	Productivity in using calculation architectural software
			Duration of architectural design		Productivity in choosing suitable architectural parameter
	8.9	Supply Contract	Vagueness Of Resource Requirement	Supplier	Productivity In Supplying Information
		Material supply contract	Vagueness about qualification of material	Material supply	Communication with buyers about material
			Vagueness about quantity of material		Update material information in website
	8.10	Supply Contract	Vagueness In Schedule Of Supplying	Supplier	Productivity In Supplying Information
		Material supply contract	Vagueness in duration of material supply	Material supply	Communication with buyers about material
					Update material information in website
	8.11	Supply Contract	Vagueness In Schedule Of Supplying	Supplier	Productivity In Transportation
		Material supply contract	Vagueness in milestone of material supply	Material supply	Velocity of transporting material
			Vagueness in duration of material supply		Distance of transporting material

	8.12	Supply Contract	Payement Schedule	Supplier	Productivity In Supplying Information
		Material supply contract	Achievement of certain material	Material supply	Communication with buyers about material
			Full information of supplied material		Update material information in website
	8.13	Supply Contract	Payement Schedule	Supplier	Productivity In Transportation
		Material supply contract	Achievement of certain material	Material supply	Velocity of transporting material
			Full information of supplied material		Distance of transporting material
9		Contract	Magnitude	Actor	Cost
	9.1	Design Contract	Designing Cost	Designer	Design Cost
		Structural design contract	Main structural design cost	Structural design	Main cost of structural design
			Punished cost of structural design		Extra cost for structural design
		Architectural design contract	Main architectural design cost	Architectural design	Main cost of architectural design
			Punished cost of architectural design		Extra cost for architectural design
	9.2	Design Contract	Design Scale	Designer	Serving Cost For Designing
		Structural design contract	Weight (Load)	Structural design	Food service for structural design
			Reliability		Health care for structural design
		Architectural design contract	Height	Architectural design	Food service for architectural design
			Width		Health care for architectural design
	9.3	Building Contract	Building Cost	Contractor	Building Cost
		Main building contract	Punished cost of delay in building	Building contractor	Main building cost
		Installing contract	Main installing cost	Installing contractor	Cost of managing for installing work
			Punished cost of delay in installing		Main installation cost
	9.4	Building Contract	Project Scale	Contractor	Serving Cost For Constructing
		Main building contract	Complexity in technique	Building contractor	Health service of building
			Acreage (m2, ha, etc.)		Cleaning building construction site
		Installing contract	Complexity of installed component	Installing contractor	Health service of installing

			Number of component		Cleaning site of installing
	9.5	Supply Contract	Required Volumn	Supplier	Supplying Cost
		Material supply contract	Number of desired material	Material supplier	Main cost of supplying material
			Qualification of material		Extra cost of supplying material
	9.6	Supply Contract	Required Volumn	Supplier	Serving Cost For Supplying
		Material supply contract	Number of desired material	Material supplier	Health care for supplying material
	9.7	Supply Contract	Supplying Cost	Supplier	Supplying Cost
		Material supply contract	Punished cost of delay in material supply	Material supplier	Main cost of supplying material
	9.8	Supply Contract	Supplying Cost	Supplier	Serving Cost For Supplying
		Material supply contract	Material cost	Material supplier	Health care for supplying material
10		Contract	Complexity	Actor	Capacity
	10.1	Design Contract	Vagueness In Design Idea	Designer	Capacity In Designing
		Structural design contract	Vagueness about weight (load)	Structural designer	Capacity in defining weight
			Vagueness about reliability		Capacity in using designing structural software
		Architectural design contract	Vagueness about height	Architectural designer	Capacity in designing layout
			Vagueness about width		Capacity in using architectural software
	10.2	Design Contract	Vagueness In Design Idea	Designer	Capacity In Calculating
		Structural design contract	Vagueness about weight (load)	Structural designer	Capacity in choosing suitable calculation parametre
			Vagueness about reliability		Capacity in using calculation software
		Architectural design contract	Vagueness about height	Architectural designer	Capacity in choosing suitable architectural parametre
			Vagueness about width		Capacity in using calculation architectural software
	10.3	Design Contract	Number Of Alternative Design Solutions	Designer	Capacity In Designing

		Structural design contract	Variation of impact force	Structural designer	Capacity in defining weight
			Variation parameters of reliability		Capacity in using designing structural software
		Architectural design contract	Changing dimension	Architectural designer	Capacity in designing layout
			Number of perspective		Capacity in using architectural software
	10.4	Design Contract	Submittal Time	Designer	Capacity In Calculating
		Structural design contract	Milestone of submitting structural design	Structural designer	Capacity in choosing suitable calculation parametre
			Duration of structural design		Capacity in using calculation software
		Architectural design contract	Milestone of submitting architectural design	Architectural designer	Capacity in choosing suitable architectural parametre
			Duration of architectural design		Capacity in using calculation architectural software
	10.10	Supply Contract	Vagueness Of Resource Requirement	Supplier	Capacity In Adapting Resource Requirement
		Material supply contract	Vagueness about qualification of material	Material supplier	Adapting material requirement about quality
			Vagueness about quantity of material		Adapting material requirement about quantity
	10.11	Supply Contract	Vagueness Of Resource Requirement	Supplier	Capacity In Supplying
		Material supply contract	Vagueness about qualification of material	Material supplier	Capacity in supplying material in time
			Vagueness about quantity of material		Capacity in communicating about characteristic of material
	10.12	Supply Contract	Vagueness In Schedule Of Supplying	Supplier	Capacity In Adapting Resource Requirement
		Material supply contract	Vagueness in milestone of material supply	Material supplier	Adapting material requirement about quality
			Vagueness in duration of material supply		Adapting material requirement about quantity
	10.13	Supply Contract	Vagueness In Schedule Of Supplying	Supplier	Capacity In Supplying
		Material supply contract	Vagueness in milestone of material supply	Material supplier	Capacity in supplying material in time

			Vagueness in duration of material supply		Capacity in communicating about characteristic of material
	10.14	Supply Contract	Payment Schedule	Supplier	Capacity In Adapting Resource Requirement
		Material supply contract	Achievement of certain material	Material supplier	Adapting material requirement about quality
			Full information of supplied material		Adapting material requirement about quantity
	10.15	Supply Contract	Payment Schedule	Supplier	Capacity In Supplying
		Material supply contract	Achievement of certain material	Material supplier	Capacity in supplying material in time
			Achievement of certain material		Capacity in communicating about characteristic of material
			Full information of supplied material		Capacity in supplying material in time
			Full information of supplied material		Capacity in communicating about characteristic of material
11		Actor	Capacity	Contract	Complexity
	11.1	Owner	Capacity In Organizing Project	Building Contract	Vagueness In Process Of Building
		Owner	Capacity in organizing work	Main building contract	Vagueness about order of building activities
			Capacity in organizing work		Vagueness about applied technology
			Capacity in arranging human work	Installing contract	Vagueness about order of building activities
			Capacity in arranging human work		Vagueness about applied technology
		Owner	Capacity in organizing work	Installing contract	Vagueness about order of installing
			Capacity in organizing work		Vagueness about installing technique
			Capacity in arranging human work	Installing contract	Vagueness about order of installing
			Capacity in arranging human work		Vagueness about installing technique
	11.2	Owner	Capacity In Organizing Project	Building Contract	Time for building completion
		Owner	Capacity in organizing work	Main building contract	Time for choosing building technology
			Capacity in arranging human work		Time for arranging order of building activities
		Owner	Capacity in organizing work	Installing contract	Time for choosing installing technology

			Capacity in arranging human work		Time for arranging order of installing activities
	11.3	Owner	Capacity In Organizing Project	Building Contract	Progress payment
		Owner	Capacity in organizing work	Main building contract	Stipulated amounts of building on set calendar dates
			Capacity in arranging human work		Achievement of certain milestones in the building work
		Owner	Capacity in organizing work	Installing contract	Stipulated amounts of installing on set calendar dates
			Capacity in arranging human work		Achievement of certain milestones in the installing work
	11.4	Contractor	Capacity In Arranging Work	Supply Contract	Vagueness Of Resource Requirement
		Building contractor	Capacity of teamwork	Material supply contract	Vagueness about qualification of material
			Capacity of teamwork		Vagueness about quantity of material
			Capacity in using software	Material supply contract	Vagueness about qualification of material
			Capacity in using software		Vagueness about quantity of material
		Installing contractor	Capacity of communication	Material supply contract	Vagueness about qualification of material
			Capacity of communication		Vagueness about quantity of material
			Capacity in using software of installing work	Material supply contract	Vagueness about qualification of material
			Capacity in using software of installing work		Vagueness about quantity of material
	11.5	Contractor	Capacity In Arranging Work	Supply Contract	Vagueness In Schedule Of Supplying
		Building contractor	Capacity of teamwork	Material supply contract	Vagueness in milestone of material supply
			Capacity of teamwork		Vagueness in duration of material supply
			Capacity in using software	Material supply contract	Vagueness in milestone of material supply
			Capacity in using software		Vagueness in duration of material supply
		Installing contractor	Capacity of communication	Material supply contract	Vagueness in milestone of material supply
			Capacity of communication		Vagueness in duration of material supply
			Capacity in using software of installing work	Material supply contract	Vagueness in milestone of material supply
			Capacity in using software of installing work		Vagueness in duration of material supply

	11.6	Contractor	Capacity In Arranging Work	Supply Contract	Payment schedule
		Building contractor	Capacity of teamwork	Material supply contract	Full information of supplied material
			Capacity in using software		Achievement of certain material
		Installing contractor	Capacity of communication	Material supply contract	Full information of supplied material
			Capacity in using software of installing work		Achievement of certain material
	11.7	Owner	Capacity In Organizing Project	Design Contract	Vagueness In Design Idea
		Owner	Capacity in organizing work	Structural design contract	Vagueness about weight (load)
			Capacity in organizing work		Vagueness about reliability
			Capacity in arranging human work	Structural design contract	Vagueness about weight (load)
			Capacity in arranging human work		Vagueness about reliability
		Owner	Capacity in organizing work	Architectural design contract	Vagueness about height
			Capacity in organizing work		Vagueness about width
			Capacity in arranging human work	Architectural design contract	Vagueness about height
			Capacity in arranging human work		Vagueness about width
	11.8	Owner	Capacity In Organizing Project	Design Contract	Number Of Alternative Design Solutions
		Owner	Capacity in organizing work	Structural design contract	Variation of impact force
			Capacity in organizing work		Variation parameters of reliability
			Capacity in arranging human work	Structural design contract	Variation of impact force
			Capacity in arranging human work		Variation parameters of reliability
		Owner	Capacity in organizing work	Architectural design contract	Changing dimension
			Capacity in organizing work		Number of perspective
			Capacity in arranging human work	Architectural design contract	Changing dimension
			Capacity in arranging human work		Number of perspective
	11.9	Owner	Capacity In Organizing Project	Design Contract	Submittal time
		Owner	Capacity in organizing work	Structural design contract	Duration of structural design
			Capacity in arranging human work		Milestone of submitting structural design
		Owner	Capacity in organizing work	Architectural design contract	Duration of architectural design
			Capacity in arranging human work		Milestone of submitting architectural design
12		Actor	Capacity	Resource	Quantity

	12.1	Owner	Capacity In Organizing Project	Machine	Machine Requirement Of Unit Operating Work
		Owner	Capacity in organizing work	Construction machine	Assistance machine
			Capacity in arranging human work		Main construction machine
		Owner	Capacity in organizing work	Office machine	Assistance equipment
			Capacity in arranging human work		Number of office machine
	12.2	Owner	Capacity In Organizing Project	Machine	Total Work Of Operating
		Owner	Capacity in arranging human work	Construction machine	Scale of construction work
			Capacity in organizing work	Office machine	Number of report document
	12.3	Owner	Capacity In Managing Project	Machine	Total Work Of Operating
		Owner	Capacity in managing time	Construction machine	Number of construction work
			Capacity in managing quality		Number of construction work
		Owner	Capacity in managing quality	Office machine	Number of report document
	12.6	Contractor	Capacity In Arranging Work	Machine	Machine Requirement Of Unit Operating Work
		Building contractor	Capacity of teamwork	Construction machine	Assistance machine
			Capacity in using software		Main construction machine
		Building contractor	Capacity of teamwork	Office machine	Assistance equipment
			Capacity in using software		Number of office machine
		Installing contractor	Capacity of communication	Construction machine	Assistance machine
			Capacity in using software of installing work		Main construction machine
		Installing contractor	Capacity of communication	Office machine	Assistance equipment
			Capacity in using software of installing work		Number of office machine
	12.7	Contractor	Capacity In Arranging Work	Machine	Total Work Of Operating
		Building contractor	Capacity in using software	Construction machine	Scale of construction work

		Building contractor	Capacity in using software	Office machine	Number of report document
		Installing contractor	Capacity of communication	Construction machine	Number of construction work
			Capacity in using software of installing work		Scale of construction work
12.8	Contractor	Capacity In Building Project	Machine	Total Work Of Operating	
		Building contractor	Capacity in using new technology	Construction machine	Number of construction work
			Flexibility in building work		Scale of construction work
		Building contractor	Capacity in using new technology	Office machine	Number of report document
		Installing contractor	Capacity in using new technology in installing	Construction machine	Number of construction work
			Flexibility in installing work		Scale of construction work
		Installing contractor	Capacity in using new technology	Office machine	Number of report document
12.9	Owner	Capacity In Organizing Project	Human	Human Requirement Of Unit Work	
		Owner	Capacity in organizing work	Worker	Assistance for main worker
			Capacity in arranging human work		Main worker for unit work
		Owner	Capacity in arranging human work	Office staff	Number of staff for unit work
12.10	Owner	Capacity In Managing Project		Total Work Of Performing	
		Owner	Capacity in managing time	Worker	Number of extra work of performing
			Capacity in managing quality	Worker	Number of extra work of performing
		Owner	Capacity in managing cost	Engineer	Number of designing process of work
			Capacity in managing quality		Number of manage work of construction process
12.11	Designer	Capacity In Designing	Human	Human Requirement Of Unit Work	
		Structural designer	Capacity in using designing structural software	Worker	Main worker for unit work
		Architectural designer	Capacity in designing layout	Worker	Assistance for main worker
		Structural designer	Capacity in defining weight	Engineer	Number of engineer for unit work
		Architectural designer	Capacity in designing layout	Engineer	Number of engineer for unit work
12.13	Contractor	Capacity In Arranging Work	Human	Human Requirement Of Unit Work	
		Building contractor	Capacity in using software	Worker	Main worker for unit work

		Building contractor	Capacity in using software	Engineer	Number of engineer for unit work
		Building contractor	Capacity in using software	Office staff	Number of staff for unit work
		Installing contractor	Capacity of communication	Worker	Assistance for main worker
		Installing contractor	Capacity in using software of installing work	Engineer	Number of engineer for unit work
		Installing contractor	Capacity of communication	Office staff	Number of staff for unit work
	12.14	Contractor	Capacity In Building Project	Human	Total Work Of Performing
		Building contractor	Capacity in using new technology	Worker	Number of extra work of performing
		Building contractor	Flexibility in building work	Engineer	Number of designing process of work
		Building contractor	Flexibility in building work	Office staff	Number of procedure attaches with construction work
		Installing contractor	Flexibility in installing work	Worker	Number of main work of performing
		Installing contractor	Flexibility in installing work	Engineer	Number of designing process of work
		Installing contractor	Flexibility in installing work	Office staff	Number of procedure attaches with construction work
	12.15	Contractor	Capacity In Arranging Work	Material	Material Requirement Of Unit Component
		Building contractor	Capacity of teamwork	Reusable material	Extra reusable material for unit component
			Capacity in using software		Main reusable material for unit component
		Building contractor	Capacity in using software	Consumable material	Number of consumable material for unit component
		Installing contractor	Capacity of communication		Extra reusable material for unit component
			Capacity in using software of installing work		Main reusable material for unit component
		Installing contractor	Capacity in using software of installing work	Consumable material	Number of consumable material for unit component
	12.16	Supplier	Capacity In Adapting Resource Requirement	Material	Total Component
		Material supplier	Adapting material requirement about quality	Reusable material	Failure component
			Adapting material requirement about quantity		Installed component
		Material supplier	Adapting material requirement about quality	Consumable material	Lost component

			Adapting material requirement about quantity		Build component
	12.17	Supplier	Capacity In Supplying	Material	Total Component
		Material supplier	Capacity in supplying material in time	Reusable material	Failure component
			Capacity in communicating about characteristic of material		Installed component
		Material supplier	Capacity in supplying material in time	Consumable material	Lost component
			Capacity in communicating about characteristic of material		Build component
13		Actor	Capacity	Resource	Quality
	13.1	Owner	Capacity In Managing Project	Machine	Conformity
		Owner	Capacity in managing quality	Construction machine	Conformity in transporting
			Capacity in managing cost		Conformity in operating
		Owner	Capacity in managing cost	Office machine	Conformity in manipulating
			Capacity in managing quality		Conformity in moving
	13.2	Owner	Capacity In Managing Project	Machine	Characteristic
		Owner	Capacity in managing cost	Construction machine	Productivity in performing construction work
			Capacity in managing quality		Emission pollution
			Capacity in managing time		Emission pollution
		Owner	Capacity in managing cost	Office machine	Productivity in solving document
			Capacity in managing quality		Replaced equipment of office machine
			Capacity in managing time		Replaced equipment of office machine
	13.3	Contractor	Capacity In Arranging Work	Machine	Conformity
		Building contractor	Capacity in using software	Construction machine	Conformity in transporting
		Building contractor	Capacity of teamwork	Office machine	Conformity in moving
		Installing contractor	Capacity in using software of installing work	Construction machine	Conformity in transporting
		Installing contractor	Capacity of communication	Office machine	Conformity in manipulating
			Capacity in using software of installing work		Conformity in moving
	13.4	Contractor	Capacity In Arranging Work	Machine	Characteristic

		Building contractor	Capacity in using software	Construction machine	Productivity in performing construction work
		Building contractor	Capacity in using software	Office machine	Productivity in solving document
		Installing contractor	Capacity of communication	Construction machine	Productivity in performing construction work
			Capacity in using software of installing work		Emission pollution
		Installing contractor	Capacity of communication	Office machine	Productivity in solving document
			Capacity in using software of installing work		Replaced equipment of office machine
	13.5	Owner	Capacity In Organizing Project	Human	Skill In Operating
		Owner	Capacity in arranging human work	Worker	Skill in executing construction work
			Capacity in organizing work	Engineer	Flexibility in treating incident
			Capacity in arranging human work	Office staff	Skill in handling document
	13.6	Designer	Capacity In Designing	Human	Skill In Operating
		Structural designer	Capacity in using designing structural software	Worker	Skill in executing construction work
		Structural designer	Capacity in defining weight	Engineer	Flexibility in treating incident
		Structural designer	Capacity in defining weight	Office staff	Flexibility in solving data
		Architectural designer	Capacity in designing layout	Worker	Ability in teamwork
			Capacity in designing layout	Engineer	Flexibility in treating incident
			Capacity in using architectural software	Office staff	Skill in handling document
	13.7	Contractor	Capacity In Arranging Work	Human	Skill In Operating
		Building contractor	Capacity of teamwork	Worker	Ability in teamwork
			Capacity of teamwork	Engineer	Ability in arranging construction work
				Office staff	Flexibility in solving data
		Installing contractor	Capacity in using software of installing work	Worker	Skill in executing construction work
		Installing contractor	Capacity of communication	Engineer	Ability in arranging construction work
			Capacity of communication		Flexibility in treating incident

		Installing contractor	Capacity in using software of installing work	Office staff	Skill in handling document
			Capacity of communication		Flexibility in solving data
13.8	Contractor		Capacity In Arranging Work	Material	Storage environment
		Building contractor	Capacity of teamwork	Reusable material	Equipment of storage
			Capacity in using software		Internal and external storage environment
		Building contractor	Capacity of teamwork	Consumable material	Equipment of storage
			Capacity in using software		Internal and external storage environment
		Installing contractor	Capacity in using software of installing work	Reusable material	Equipment of storage
		Installing contractor	Capacity in using software of installing work	Consumable material	Equipment of storage
13.9	Supplier		Capacity In Adapting Resource Requirement	Material	Imported Characteristic
		Material supplier	Adapting material requirement about quality	Reusable material	Original characteristic
			Adapting material requirement about quantity		Characteristic after transport process
		Material supplier	Adapting material requirement about quality	Consumable material	Original characteristic
			Adapting material requirement about quantity		Characteristic after transport process
13.10	Supplier		Capacity In Supplying	Material	Imported Characteristic
		Material supplier	Capacity in supplying material in time	Reusable material	Original characteristic
			Capacity in communicating about characteristic of material		Characteristic after transport process
		Material supplier	Capacity in supplying material in time	Consumable material	Original characteristic
			Capacity in communicating about characteristic of material		Characteristic after transport process
13.11	Supplier		Capacity In Supplying	Material	Storage environment
		Material supplier	Capacity in supplying material in time	Reusable material	Internal and external storage environment
		Material supplier	Capacity in supplying material in time	Consumable material	Internal and external storage environment
14	Resource		UnitCost	Actor	Cost
	14.1	Human	Working Time Cost	Owner	Variable Cost

		Worker	Regulated performing time	Owner	Variable cost in building
			Salary of each unit of time performing		Variable cost in doing procedure
		Engineer	Regulated working time		
			Salary of each time of working		
		Office staff	Regulated office working time		
			Salary of each time of office working		
	14.2	Machine	Depreciation	Designer	Design Cost
		Construction machine	Original construction machine cost	Structural designer	Main cost of structural design
			Recovery construction machine cost		Extra cost for structural design
		Office machine	Original office machine cost	Architectural designer	Main cost of architectural design
			Recovery office machine cost		Extra cost for architectural design
	14.3	Machine	Repair Cost	Designer	Design Cost
		Construction machine	Repaired cost of important part of machine	Structural designer	Main cost of structural design
			Repaired cost of extra part of machine		Extra cost for structural design
		Office machine	Repaired cost of important part of office machine	Architectural designer	Main cost of architectural design
			Repaired cost of extra part of office machine		Extra cost for architectural design
	14.4	Human	Working Time Cost	Designer	Design Cost
		Worker	Regulated performing time	Structural designer	Main cost of structural design
			Salary of each unit of time performing		Extra cost for structural design
		Engineer	Regulated working time	Architectural designer	Main cost of architectural design
			Salary of each time of working		Extra cost for architectural design
		Office staff	Regulated office working time		
			Salary of each time of office working		
	14.5	Machine	Repair Cost	Contractor	Serving Cost For Constructing
		Construction machine	Repaired cost of important part of machine	Building contractor	Cleaning building construction site
			Repaired cost of extra part of machine		Health service of building
		Office machine	Repaired cost of important part of office machine	Installing contractor	Cleaning site of installing

			Repaired cost of extra part of office machine		Health service of installing
14.6	Machine		Fuel-energy Cost	Contractor	Building Cost
		Construction machine	Energy consumption each time of construction work	Building contractor	Main building cost
			Unit cost of fuel-energy		Cost of managing for building work
		Office machine	Energy consumption each time of office work	Installing contractor	Main installation cost
			Unit cost of electricity		Cost of managing for installing work
14.7	Human		Working Time Cost	Contractor	Building Cost
		Worker	Regulated performing time	Building contractor	Main building cost
			Salary of each unit of time performing		Cost of managing for building work
		Engineer	Regulated working time	Installing contractor	Main installation cost
			Salary of each time of working		Cost of managing for installing work
		Office staff	Regulated office working time		
			Salary of each time of office working		
14.8	Human		Overtime Cost	Contractor	Serving Cost For Constructing
		Worker	Over time of construction performing	Building contractor	Cleaning building construction site
			Salary of each over time of performing		Health service of building
		Engineer	Over time of work	Installing contractor	Cleaning site of installing
			Salary of each over time of working		Health service of installing
		Office staff	Over time of office work		
			Salary of each over time of office working		
14.9	Material		Original Cost	Contractor	Building Cost
		Reusable material	Reusable material cost after tax	Building contractor	Main building cost
					Cost of managing for building work
		Consumable material	Consumable material cost after tax	Installing contractor	Main installation cost
					Cost of managing for installing work
14.10	Material		Storage Cost	Contractor	Serving Cost For Constructing
		Reusable material	Cost of storage equipment	Building contractor	Cleaning building construction site

			Cost of storehouse		Health service of building
		Consumable material	Equipment of storage	Installing contractor	Cleaning site of installing
			Internal and external storage environment		Health service of installing
	14.11	Material	Original Cost	Supplier	Supplying Cost
		Reusable material	Reusable material cost after tax	Material supplier	Main cost of supplying material
		Consumable material	Consumable material cost after tax		Extra cost of supplying material
	14.12	Material	Transportation Cost	Supplier	Supplying Cost
		Reusable material	Cost of fuel-energy of transport process	Material supplier	Main cost of supplying material
			Traffic charges		Extra cost of supplying material
		Consumable material	Equipment of storage		
			Internal and external storage environment		
	14.13	Material	Storage Cost	Supplier	Serving Cost For Supplying
		Reusable material	Cost of storage equipment	Material supplier	Food service for supplying material
			Cost of storehouse		Health care for supplying material
		Consumable material	Cost of storage equipment		
			Cost of storehouse		
15		Resource	Quantity	Actor	Cost
	15.1	Human	Total Work Of Performing	Owner	Variable Cost
		Worker	Number of main work of performing	Owner	Variable cost in building
			Number of extra work of performing		Variable cost in doing procedure
		Engineer	Number of designing process of work		
			Number of manage work of construction process		
		Office staff	Number of procedure attaches with construction work		

			Number of solved construction work		
15.2	Machine		Total Work Of Operating	Designer	Serving Cost For Designing
	Construction machine		Scale of construction work	Structural designer	Food service for structural design
			Number of construction work		Health care for structural design
	Office machine		Number of report document	Architectural designer	Food service for architectural design
					Health care for architectural design
15.3	Human		Total Work Of Performing	Designer	Serving Cost For Designing
	Worker		Number of main work of performing	Structural designer	Food service for structural design
			Number of extra work of performing		Health care for structural design
	Engineer		Number of designing process of work	Architectural designer	Food service for architectural design
			Number of manage work of construction process		Health care for architectural design
	Office staff		Number of procedure attaches with construction work		
			Number of solved construction work		
15.4	Machine		Machine Requirement Of Unit Operating Work	Contractor	Serving Cost For Constructing
	Construction machine		Main construction machine	Building contractor	Cleaning building construction site
			Assistance machine		Health service of building
	Office machine		Number of office machine	Installing contractor	Cleaning site of installing
			Assistance equipment		Health service of installing
15.5	Material		Material Requirement Of Unit Component	Supplier	Serving Cost For Supplying
	Reusable material		Main reusable material for unit component	Material supplier	Food service for supplying material
			Extra reusable material for unit component		Health care for supplying material
	Consumable material		Number of consumable material for unit component	Material supplier	Food service for supplying material
					Health care for supplying material
15.6	Material		Total Component	Supplier	Serving Cost For Supplying

		Reusable material	Installed component	Material supplier	Food service for supplying material
			Failure component		Health care for supplying material
		Consumable material	Build component	Material supplier	Food service for supplying material
			Lost component		Health care for supplying material
16		Resource	Quantity	Activity	Duration
	16.1	Human	Human Requirement Of Unit Work	AIP	Duration To Perform Work
		Worker	Main worker for unit work	Detailed design	Duration of architectural design
			Assistance for main worker		Duration of structural design
		Engineer	Number of engineer for unit work	Preparing procedure before construction	Duration of preparing procedure
		Office staff	Number of staff for unit work		Duration of waiting
				Construction	Duration of arranging construction works
					Duration of performing construction work
	16.2	Human	Total Work Of Performing	AIP	Duration To Repair Precedent Work
		Worker	Number of main work of performing	Detailed design	Duration of adjusting architectural design
			Number of extra work of performing		Duration of adjusting structural design
		Engineer	Number of designing process of work	Preparing procedure before construction	Duration of check data of procedure
			Number of manage work of construction process		Duration of repairing error of procedure
		Office staff	Number of procedure attaches with construction work	Construction	Duration of adjusting order of construction works
			Number of solved construction work		Duration of adjusting a construction work
	16.3	Human	Human Requirement Of Unit Work	AOP	Duration To Perform Maintain Work
		Worker	Main worker for unit work	Operation monitoring	Duration of installing monitoring equipment
			Assistance for main worker		Period time of checking
		Engineer	Number of engineer for unit work	Performance of maintain work	Duration of reporting failure
		Office staff	Number of staff for unit work		Duration of preparing resource to repair errors

	16.4	Human	Total Work Of Performing	AOP	Duration To Perform Maintain Work
		Worker	Number of main work of performing	Operation monitoring	Duration of installing monitoring equipment
			Number of extra work of performing		Period time of checking
		Engineer	Number of designing process of work	Performance of maintain work	Duration of reporting failure
			Number of manage work of construction process		Duration of preparing resource to repair errors
		Office staff	Number of procedure attaches with construction work		
			Number of solved construction work		
	16.5	Human	Total Work Of Performing	AOP	Duration To Repair Errors
		Worker	Number of main work of performing	Operation monitoring	Duration of checking error of monitoring
			Number of extra work of performing		Duration of re-installing monitoring equipment
		Engineer	Number of designing process of work	Performance of maintain work	Duration of checking reason of failure
			Number of manage work of construction process		Duration of repairing failure
		Office staff	Number of procedure attaches with construction work		
			Number of solved construction work		
17		Resource	Quality	Activity	Duration
	17.1	Human	Skill In Operating	AFP	Duration To Perform Work
		Worker	Skill in executing construction work	Field work	Duration of survey
			Ability in teamwork		Duration of experimenting
		Engineer	Ability in arranging construction work	Preliminary design	Duration of preliminary designing
			Flexibility in treating incident		Number of alternative options
		Office staff	Skill in handling document	Economic research	Duration of survey economy
			Flexibility in solving data		Duration of calculating effective economy
	17.2	Human	Skill In Operating	AFP	Duration To Adjust Work
		Worker	Skill in executing construction work	Field work	Duration of adjusting location of survey
			Ability in teamwork		Duration of re-experimenting
		Engineer	Ability in arranging construction work	Preliminary design	Duration of re-designing
			Flexibility in treating incident		Duration of preliminary calculation

		Office staff	Skill in handling document	Economic research	Duration of supplement data
			Flexibility in solving data		Duration of re-calculating
	17.3	Machine	Conformity	AIP	Duration To Perform Work
		Construction machine	Conformity in transporting	Detailed design	Duration of architectural design
			Conformity in operating		Duration of structural design
		Office machine	Conformity in manipulating	Preparing procedure before construction	Duration of preparing procedure
			Conformity in moving		Duration of waiting
				Construction	Duration of arranging construction works
					Duration of performing construction work
	17.4	Human	Skill In Operating	AIP	Duration To Repair Precedent Work
		Worker	Skill in executing construction work	Detailed design	Duration of adjusting architectural design
			Ability in teamwork		Duration of adjusting structural design
		Engineer	Ability in arranging construction work	Preparing procedure before construction	Duration of check data of procedure
			Flexibility in treating incident		Duration of repairing error of procedure
		Office staff	Skill in handling document	Construction	Duration of adjusting order of construction works
			Flexibility in solving data		Duration of adjusting a construction work
	17.5	Human	Skill In Operating	AOP	Duration To Perform Maintain Work
		Worker	Skill in executing construction work	Operation monitoring	Duration of installing monitoring equipment
			Ability in teamwork		Period time of checking
		Engineer	Ability in arranging construction work	Performance of maintain work	Duration of reporting failure
			Flexibility in treating incident		Duration of preparing resource to repair errors
		Office staff	Skill in handling document		
			Flexibility in solving data		
	17.6	Human	Skill In Operating	AOP	Duration To Repair Errors
		Worker	Skill in executing construction work	Operation monitoring	Duration of checking error of monitoring
			Ability in teamwork		Duration of re-installing monitoring equipment

		Engineer	Ability in arranging construction work	Performance of maintain work	Duration of checking reason of failure
			Flexibility in treating incident		Duration of repairing failure
		Office staff	Skill in handling document		
			Flexibility in solving data		
18		Resource	Quality	Activity	Quality
	18.1	Machine	Characteristic	AFP	Pollution Of Feasibility Work
		Construction machine	Productivity in performing construction work	Field work	Impact of field work on nature
			Emission pollution		Impact of field work on creating employment opportunities for society
		Office machine	Productivity in solving document	Preliminary design	Impact of preliminary design on nature
			Replaced equipment of office machine		Impact of preliminary design on creating employment opportunities for society
				Economic research	Impact of economic research on nature
					Impact of economic research on creating employment opportunities for society
	18.2	Machine	Characteristic	AFP	Technique Of Research And Performing Work
		Construction machine	Productivity in performing construction work	Field work	Technique of surveying
			Emission pollution		Technique of experimenting
		Office machine	Productivity in solving document	Preliminary design	Technique of desiging
			Replaced equipment of office machine		Technique in using design software
				Economic research	Technique of data processing
					Technique of using calculation software
	18.3	Human	Skill In Operating	AFP	Technique Of Research And Performing Work
		Worker	Skill in executing construction work	Field work	Technique of surveying
			Ability in teamwork		Technique of experimenting
		Engineer	Ability in arranging construction work	Preliminary design	Technique of desiging
			Flexibility in treating incident		Technique in using design software
		Office staff	Skill in handling document	Economic research	Technique of data processing
			Flexibility in solving data		Technique of using calculation software

	18.4	Machine	Conformity	AIP	Technique of Work
		Construction machine	Conformity in transporting	Detailed design	Technique of architectural design
			Conformity in operating		Technique of structural design
		Office machine	Conformity in manipulating	Preparing procedure before construction	Technique of preparing work
			Conformity in moving		Technique of solving procedure problem
				Construction	Technique of ordering sequence of construction work
					Technique of performing construction work
	18.5	Machine	Characteristic	AIP	Pollution Of Work
		Construction machine	Productivity in performing construction work	Detailed design	Impact of detailed design on nature
			Emission pollution		Impact of detailed design on creating employment opportunities for society
		Office machine	Productivity in solving document	Preparing procedure before construction	Impact of doing procedure on nature
			Replaced equipment of office machine		Impact of doing procedure on creating employment opportunities for society
				Construction	Impact of construction work on nature
					Impact of construction work on creating employment opportunities for society
	18.6	Machine	Characteristic	AIP	Technique of Work
		Construction machine	Productivity in performing construction work	Detailed design	Technique of architectural design
			Emission pollution		Technique of structural design
		Office machine	Productivity in solving document	Preparing procedure before construction	Technique of preparing work
			Replaced equipment of office machine		Technique of solving procedure problem
				Construction	Technique of ordering sequence of construction work
					Technique of performing construction work
	18.7	Human	Skill In Operating	AIP	Technique of Work
		Worker	Skill in executing construction work	Detailed design	Technique of architectural design

			Ability in teamwork		Technique of structural design
		Engineer	Ability in arranging construction work	Preparing procedure before construction	Technique of preparing work
			Flexibility in treating incident		Technique of solving procedure problem
		Office staff	Skill in handling document	Construction	Technique of ordering sequence of construction work
			Flexibility in solving data		Technique of performing construction work
18.8	Material	Imported Characteristic	AIP	Technique of Work	
		Reusable material	Original characteristic	Detailed design	Technique of architectural design
			Characteristic after transport process		Technique of structural design
		Consumable material	Original characteristic	Preparing procedure before construction	Technique of preparing work
			Characteristic after transport process		Technique of solving procedure problem
				Construction	Technique of ordering sequence of construction work
					Technique of performing construction work
18.9	Machine	Conformity	AOP	Technique of Repairing Error	
		Construction machine	Conformity in transporting	Operation monitoring	Technique of checking error of monitoring
			Conformity in operating		Technique of replacing monitoring equipment
		Office machine	Conformity in manipulating	Performance of maintain work	Technique of checking reason of failure
			Conformity in moving		Technique of repairing failure
18.10	Machine	Characteristic	AOP	Pollution Of Work	
		Construction machine	Productivity in performing construction work	Operation monitoring	Impact of construction monitoring on nature
			Emission pollution		Impact of construction monitoring on creating employment opportunities for society
		Office machine	Productivity in solving document	Performance of maintain work	Impact of maintain work on nature
			Replaced equipment of office machine		Impact of maintain work on creating employment opportunities for society
18.11	Machine	Characteristic	AOP	Technique of Repairing Error	

		Construction machine	Productivity in performing construction work	Operation monitoring	Technique of checking error of monitoring
			Emission pollution		Technique of replacing monitoring equipment
		Office machine	Productivity in solving document	Performance of maintain work	Technique of checking reason of failure
			Replaced equipment of office machine		Technique of repairing failure
	18.12	Human	Skill In Operating	AOP	Technique of Repairing Error
		Worker	Skill in executing construction work	Operation monitoring	Technique of checking error of monitoring
			Ability in teamwork		Technique of replacing monitoring equipment
		Engineer	Ability in arranging construction work	Performance of maintain work	Technique of checking reason of failure
			Flexibility in treating incident		Technique of repairing failure
		Office staff	Skill in handling document		
			Flexibility in solving data		
	18.13	Material	Imported Characteristic	AOP	Technique of Repairing Error
		Reusable material	Original characteristic	Operation monitoring	Technique of checking error of monitoring
			Characteristic after transport process		Technique of replacing monitoring equipment
		Consumable material	Original characteristic	Performance of maintain work	Technique of checking reason of failure
			Characteristic after transport process		Technique of repairing failure
19		Actor	Productivity	Activity	Duration
	19.1	Owner	Productivity In Organizing Project	AFP	Duration To Perform Work
		Owner	Upgrading technology in organizing project	Field work	Duration of survey
			Reasonable priority construction work		Duration of experimenting
		Owner	Upgrading technology in organizing project	Preliminary design	Duration of preliminary designing
			Reasonable priority construction work		Number of alternative options
		Owner	Upgrading technology in organizing project	Economic research	Duration of survey economy
			Reasonable priority construction work		Duration of calculating effective economy
	19.2	Owner	Productivity In Mananging Project	AFP	Duration To Adjust Work

		Owner	Productivity in managing time	Field work	Duration of adjusting location of survey
		Owner	Productivity in managing time	Preliminary design	Duration of re-designing
		Owner	Productivity in managing time	Economic research	Duration of supplement data
	19.3	Designer	Productivity In Calculating	AFP	Duration To Adjust Work
		Structural designer	Productivity in choosing suitable calculation parametre	Field work	Duration of adjusting location of survey
			Productivity in using calculation software		Duration of re-experimenting
		Architectural designer	Productivity in choosing suitable architectural parametre	Preliminary design	Duration of re-designing
			Productivity in using calculation architectural software		Duration of preliminary calculation
				Economic research	Duration of supplement data
					Duration of re-calculating
	19.4	Designer	Productivity In Calculating	AIP	Duration To Repair Precedent Work
		Structural designer	Productivity in using calculation software	Detailed design	Duration of adjusting architectural design
		Structural designer	Productivity in using calculation software	Preparing procedure before construction	Duration of check data of procedure
		Structural designer	Productivity in using calculation software	Construction	Duration of adjusting order of construction works
	19.5	Supplier	Productivity In Transportation	AIP	Duration To Perform Work
		Material supplier	Velocity of transporting material	Detailed design	Duration of architectural design
		Material supplier	Velocity of transporting material	Preparing procedure before construction	Duration of preparing procedure
		Material supplier	Velocity of transporting material	Construction	Duration of arranging construction works
	19.6	Contractor	Productivity In Arranging Work	AOP	Duration To Repair Errors
		Building contractor	Effective teamwork	Operation monitoring	Duration of checking error of monitoring
		Installing contractor	Effective communication in teamwork	Operation monitoring	Duration of re-installing monitoring equipment
		Building contractor	Effective teamwork	Performance of maintain work	Duration of checking reason of failure
		Installing contractor	Effective communication in teamwork	Performance of maintain work	Duration of repairing failure
	19.7	Contractor	Productivity In Building Project	AOP	Duration To Repair Errors

		Building contractor	Productivity in arranging reasonable priority building work	Operation monitoring	Duration of re-installing monitoring equipment
		Installing contractor	Productivity in arranging reasonable priority installing work	Operation monitoring	Duration of checking error of monitoring
		Building contractor	Productivity in arranging reasonable priority building work	Performance of maintain work	Duration of repairing failure
		Installing contractor	Productivity in arranging reasonable priority installing work	Performance of maintain work	Duration of checking reason of failure
20		Actor	Capacity	Activity	Duration
	20.1	Owner	Capacity In Organizing Project	AFP	Duration To Perform Work
		Owner	Capacity in organizing work	Field work	Duration of experimenting
		Owner	Capacity in organizing work	Preliminary design	Number of alternative options
		Owner	Capacity in organizing work	Economic research	Duration of calculating effective economy
	20.2	Owner	Capacity In Managing Project	AFP	Duration To Adjust Work
		Owner	Capacity in managing cost	Field work	Duration of re-experimenting
		Owner	Capacity in managing cost	Preliminary design	Duration of preliminary calculation
		Owner	Capacity in managing cost	Economic research	Duration of re-calculating
	20.3	Designer	Capacity In Calculating	AFP	Duration To Perform Work
		Structural designer	Capacity in using calculation software	Field work	Duration of survey
		Architectural designer	Capacity in using calculation architectural software	Field work	Duration of survey
		Structural designer	Capacity in using calculation software	Preliminary design	Duration of preliminary designing
		Architectural designer	Capacity in using calculation architectural software	Preliminary design	Duration of preliminary designing
		Structural designer	Capacity in using calculation software	Economic research	Duration of survey economy
		Architectural designer	Capacity in using calculation architectural software	Economic research	Duration of survey economy
	20.4	Designer	Capacity In Designing	AIP	Duration To Repair Precedent Work
		Structural designer	Capacity in defining weight	Detailed design	Duration of adjusting structural design
		Structural designer	Capacity in defining weight	Preparing procedure before construction	Duration of repairing error of procedure
		Structural designer	Capacity in defining weight	Construction	Duration of adjusting a construction work
	20.5	Contractor	Capacity In Arranging Work	AIP	Duration To Perform Work

		Building contractor	Capacity of teamwork	Detailed design	Duration of structural design
		Installing contractor	Capacity in using software of installing work	Detailed design	Duration of architectural design
		Building contractor	Capacity of teamwork	Preparing procedure before construction	Duration of preparing procedure
		Installing contractor	Capacity in using software of installing work	Preparing procedure before construction	Duration of preparing procedure
		Building contractor	Capacity of teamwork	Construction	Duration of performing construction work
		Installing contractor	Capacity in using software of installing work	Construction	Duration of arranging construction works
	20.6	Contractor	Capacity In Building Project	AOP	Duration To Perform Maintain Work
		Building contractor	Capacity in using new technology	Operation monitoring	Period time of checking
		Installing contractor	Flexibility in installing work	Operation monitoring	Duration of installing monitoring equipment
		Building contractor	Capacity in using new technology	Performance of maintain work	Duration of preparing resource to repair errors
		Installing contractor	Flexibility in installing work	Performance of maintain work	Duration of reporting failure
21	21.1	Actor	Cost	Activity	Cost
	21.2	Owner	Fixed Cost	AFP	Cost To Perform Work
		Owner	Fixed cost in doing procedure	Field work	Cost of survey
		Owner	Fixed cost in doing procedure	Preliminary design	Cost of research of design solution
		Owner	Fixed cost in doing procedure	Economic research	Cost of collecting data
	21.3	Owner	Fixed Cost	AFP	Cost To Adjust Work
		Owner	Fixed cost in doing procedure	Field work	Cost of re-survey
		Owner	Fixed cost in doing procedure	Preliminary design	Cost of re-research design solution
		Owner	Fixed cost in doing procedure	Economic research	Cost of re-surveying data
	21.4	Owner	Variable Cost	AFP	Cost To Perform Work
		Owner	Variable cost in building	Field work	Cost of survey
			Variable cost in doing procedure		Cost of experimenting
		Owner	Variable cost in building	Preliminary design	Cost of research of design solution
			Variable cost in doing procedure		Cost of designing
		Owner	Variable cost in building	Economic research	Cost of collecting data

			Variable cost in doing procedure		Cost of calculating effective economy
	21.5	Owner	Variable Cost	AFP	Cost To Adjust Work
		Owner	Variable cost in building	Field work	Cost of re-survey
			Variable cost in doing procedure		Cost of re-experimenting
		Owner	Variable cost in building	Preliminary design	Cost of re-research design solution
			Variable cost in doing procedure		Cost of re-design
		Owner	Variable cost in building	Economic research	Cost of re-surveying data
			Variable cost in doing procedure		Cost of re-calculating
	21.6	Designer	Design Cost	AFP	Cost To Perform Work
		Structural designer	Extra cost for structural design	Field work	Cost of survey
		Architectural designer	Main cost of architectural design	Field work	Cost of experimenting
		Structural designer	Extra cost for structural design	Preliminary design	Cost of research of design solution
		Architectural designer	Main cost of architectural design	Preliminary design	Cost of designing
		Structural designer	Main cost of structural design	Economic research	Cost of calculating effective economy
		Architectural designer	Extra cost for architectural design	Economic research	Cost of collecting data
	21.7	Designer	Design Cost	AFP	Cost To Adjust Work
		Structural designer	Main cost of structural design	Field work	Cost of re-survey
			Extra cost for structural design		Cost of re-experimenting
		Architectural designer	Main cost of architectural design	Field work	Cost of re-survey
			Extra cost for architectural design		Cost of re-experimenting
		Structural designer	Main cost of structural design	Preliminary design	Cost of re-research design solution
			Extra cost for structural design		Cost of re-design
		Architectural designer	Main cost of architectural design	Preliminary design	Cost of re-research design solution
			Extra cost for architectural design		Cost of re-design
		Structural designer	Main cost of structural design	Economic research	Cost of re-surveying data
			Extra cost for structural design		Cost of re-calculating

		Architectural designer	Main cost of architectural design	Economic research	Cost of re-surveying data
			Extra cost for architectural design		Cost of re-calculating
	21.8	Designer	Serving Cost For Designing	AFP	Cost To Perform Work
		Structural designer	Food service for structural design	Field work	Cost of survey
			Health care for structural design		Cost of experimenting
		Architectural designer	Food service for architectural design	Field work	Cost of survey
			Health care for architectural design		Cost of experimenting
		Structural designer	Food service for structural design	Preliminary design	Cost of research of design solution
			Health care for structural design		Cost of designing
		Architectural designer	Food service for architectural design	Preliminary design	Cost of research of design solution
			Health care for architectural design		Cost of designing
		Structural designer	Food service for structural design	Economic research	Cost of collecting data
			Health care for structural design		Cost of calculating effective economy
		Architectural designer	Food service for architectural design	Economic research	Cost of collecting data
			Health care for architectural design		Cost of calculating effective economy
	21.9	Designer	Serving Cost For Designing	AFP	Cost To Adjust Work
		Structural designer	Food service for structural design	Field work	Cost of re-experimenting
		Architectural designer	Food service for architectural design	Field work	Cost of re-survey
			Health care for architectural design		Cost of re-experimenting
		Structural designer	Food service for structural design	Preliminary design	Cost of re-design
		Architectural designer	Food service for architectural design	Preliminary design	Cost of re-research design solution
			Health care for architectural design		Cost of re-design
		Structural designer	Food service for structural design	Economic research	Cost of re-calculating
		Architectural designer	Food service for architectural design	Economic research	Cost of re-surveying data
			Health care for architectural design		Cost of re-calculating

	21.10	<i>Designer</i>	<i>Design Cost</i>	<i>AIP</i>	<i>Cost To Perform Work</i>
		Structural designer	Main cost of structural design	Detailed design	Cost to design structure
		Architectural designer	Main cost of architectural design	Detailed design	Cost to design architecture
		Structural designer	Main cost of structural design	Preparing procedure before construction	Cost of solving procedure problem
		Architectural designer	Main cost of architectural design	Preparing procedure before construction	Cost of preparing work
		Structural designer	Main cost of structural design	Construction	Cost to arrange construction work
		Architectural designer	Main cost of architectural design	Construction	Cost to performing construction work
	21.11	<i>Designer</i>	<i>Design Cost</i>	<i>AIP</i>	<i>Cost To Repair Precedent Work</i>
		Structural designer	Extra cost for structural design	Detailed design	Cost to check data of precedent work
		Architectural designer	Extra cost for architectural design	Detailed design	Cost to check data of precedent work
		Structural designer	Extra cost for structural design	Preparing procedure before construction	Cost to check data of precedent work
		Architectural designer	Extra cost for architectural design	Preparing procedure before construction	Cost to check data of precedent work
		Structural designer	Extra cost for structural design	Construction	Cost to adjust order of construction work
		Architectural designer	Extra cost for architectural design	Construction	Cost to adjust order of construction work
	21.12	<i>Designer</i>	<i>Serving Cost For Designing</i>	<i>AIP</i>	<i>Cost To Repair Precedent Work</i>
		Structural designer	Food service for structural design	Detailed design	Cost to repair error of precedent work
		Architectural designer	Food service for architectural design	Detailed design	Cost to repair error of precedent work
		Structural designer	Food service for structural design	Preparing procedure before construction	Cost to repair error of precedent work
		Architectural designer	Food service for architectural design	Preparing procedure before construction	Cost to repair error of precedent work
		Structural designer	Food service for structural design	Construction	Cost to adjust construction work
		Architectural designer	Food service for architectural design	Construction	Cost to adjust construction work
	21.13	<i>Contractor</i>	<i>Building Cost</i>	<i>AIP</i>	<i>Cost To Perform Work</i>

		Building contractor	Cost of managing for building work	Detailed design	Cost to design architecture
		Installing contractor	Main installation cost	Detailed design	Cost to design architecture
		Building contractor	Cost of managing for building work	Preparing procedure before construction	Cost of preparing work
		Installing contractor	Cost of managing for installing work	Preparing procedure before construction	Cost of preparing work
		Building contractor	Cost of managing for building work	Construction	Cost to arranging construction work
		Installing contractor	Cost of managing for installing work	Construction	Cost to arranging construction work
	21.14	Supplier	Supplying Cost	AIP	Cost To Perform Work
		Material supplier	Main cost of supplying material	Detailed design	Cost to design architecture
			Extra cost of supplying material		Cost to design structure
		Material supplier	Main cost of supplying material	Preparing procedure before construction	Cost of preparing work
			Extra cost of supplying material		Cost of solving procedure problem
		Material supplier	Main cost of supplying material	Construction	Cost to arranging construction work
			Extra cost of supplying material		Cost to performing construction work
	21.15	Supplier	Serving Cost For Supplying	AIP	Cost To Perform Work
		Material supplier	Food service for supplying material	Detailed design	Cost to design architecture
			Health care for supplying material		Cost to design structure
		Material supplier	Food service for supplying material	Preparing procedure before construction	Cost of preparing work
			Health care for supplying material		Cost of solving procedure problem
		Material supplier	Food service for supplying material	Construction	Cost to arranging construction work
			Health care for supplying material		Cost to performing construction work
	21.16	Contractor	Building Cost	AOP	Cost To Repair Errors
		Building contractor	Main building cost	Operation monitoring	Cost of repairing error of monitoring
			Cost of managing for building work		Cost of repairing monitoring equipment
		Installing contractor	Main installation cost	Performance of maintain work	Cost of of checking reason of failure
			Cost of managing for installing work		Cost of repairing failure
	21.17	Contractor	Serving Cost For Constructing	AOP	Cost To Maintain
		Building contractor	Cleaning building construction site	Operation monitoring	Cost of checking error of monitoring
			Cleaning building construction site		Cost of re-installing monitoring equipment

			Health service of building	Operation monitoring	Cost of checking error of monitoring
			Health service of building		Cost of re-installing monitoring equipment
		Installing contractor	Cleaning site of installing	Operation monitoring	Cost of checking error of monitoring
			Cleaning site of installing		Cost of re-installing monitoring equipment
			Health service of installing	Operation monitoring	Cost of checking error of monitoring
			Health service of installing		Cost of re-installing monitoring equipment
		Building contractor	Cleaning building construction site	Performance of maintain work	Cost of reporting failure
			Cleaning building construction site		Cost of preparing resource to repair errors
			Health service of building	Performance of maintain work	Cost of reporting failure
			Health service of building		Cost of preparing resource to repair errors
		Installing contractor	Cleaning site of installing	Performance of maintain work	Cost of reporting failure
			Cleaning site of installing		Cost of preparing resource to repair errors
			Health service of installing	Performance of maintain work	Cost of reporting failure
			Health service of installing		Cost of preparing resource to repair errors
	21.18	Contractor	Serving Cost For Constructing	AOP	Cost To Repair Errors
		Building contractor	Health service of building	Operation monitoring	Cost of repairing error of monitoring
		Installing contractor	Health service of installing	Operation monitoring	Cost of repairing error of monitoring
		Building contractor	Health service of building	Performance of maintain work	Cost of of checking reason of failure
		Installing contractor	Health service of installing	Performance of maintain work	Cost of repairing failure
	21.19	Supplier	Supplying Cost	AOP	Cost To Repair Errors
		Material supplier	Main cost of supplying material	Operation monitoring	Cost of repairing error of monitoring
			Extra cost of supplying material		Cost of repairing monitoring equipment
		Material supplier	Main cost of supplying material	Performance of maintain work	Cost of of checking reason of failure
			Extra cost of supplying material		Cost of repairing failure
22		Product	Quality	Activity	Duration
	22.1	PFP	Satisfaction Of Owner	AIP	Duration To Repair Precedent Work
		Document of site survey	Satisfaction about result of experimentation	Detailed design	Duration of adjusting architectural design
		Preliminary design	Satisfaction about drawing of preliminary design	Detailed design	Duration of adjusting structural design

		Document of economic efficiency	Satisfaction about document of survey economy	Detailed design	Duration of adjusting structural design
		Document of site survey	Satisfaction about result of experimentation	Preparing procedure before construction	Duration of check data of procedure
		Preliminary design	Satisfaction about drawing of preliminary design	Preparing procedure before construction	Duration of check data of procedure
		Document of economic efficiency	Satisfaction about document of survey economy	Preparing procedure before construction	Duration of repairing error of procedure
		Document of site survey	Satisfaction about result of experimentation	Construction	Duration of adjusting order of construction works
		Preliminary design	Satisfaction about drawing of preliminary design	Construction	Duration of adjusting a construction work
		Document of economic efficiency	Satisfaction about document of survey economy	Construction	Duration of adjusting a construction work
	22.2	PIP	Satisfaction Of Owner	AOP	Duration To Repair Errors
		Detailed design	Satisfaction about structural drawing	Operation monitoring	Duration of re-installing monitoring equipment
		Procedure document	Satisfaction about procedure document	Operation monitoring	Duration of checking error of monitoring
		Building	Satisfaction about plan of each construction work	Operation monitoring	Duration of checking error of monitoring
		Detailed design	Satisfaction about structural drawing	Performance of maintain work	Duration of repairing failure
		Procedure document	Satisfaction about procedure document	Performance of maintain work	Duration of checking reason of failure
		Building	Satisfaction about plan of each construction work	Performance of maintain work	Duration of checking reason of failure
23		Product	Quality	Activity	Cost
	23.1	PFP	Satisfaction Of Owner	AIP	Cost To Perform Work
	23.2	PFP	Right Regulation	AIP	Cost To Repair Precedent Work
		Document of site survey	Right regulation about survey	Detailed design	
		Preliminary design	Right regulation about standard of drawing	Detailed design	
		Document of economic efficiency	Satisfaction about result of effective economy	Detailed design	Cost to check data of precedent work

		Document of site survey	Right regulation about survey	Preparing procedure before construction	Cost to repairing error of precedent work
		Preliminary design	Right regulation about standard of drawing	Preparing procedure before construction	Cost to repairing error of precedent work
		Document of economic efficiency	Satisfaction about result of effective economy	Preparing procedure before construction	Cost to repairing error of precedent work
		Document of site survey	Right regulation about survey	Construction	Cost to adjust order of construction work
		Preliminary design	Right regulation about standard of drawing	Construction	Cost to adjust order of construction work
		Document of economic efficiency	Satisfaction about document of survey economy	Construction	Cost to adjust order of construction work
		PIP	Satisfaction Of Owner	AOP	Cost To Repair Errors
		Detailed design	Satisfaction about architectural drawing	Operation monitoring	Cost of repairing monitoring equipment
			Satisfaction about architectural drawing	Performance of maintain work	Cost of repairing failure
		Procedure document	Satisfaction about time of received licence	Operation monitoring	Cost of repairing error of monitoring
			Satisfaction about time of received licence	Performance of maintain work	Cost of of checking reason of failure
		Building	Satisfaction about plan of all construction works	Operation monitoring	Cost of repairing monitoring equipment
			Satisfaction about plan of each construction work		Cost of repairing error of monitoring
24		Activity	Cost	Product	Cost
	24.1	AFP	Cost To Perform Work	PFP	Cost Of Performing Feasibility Work
		Field work	Cost of survey	Document of site survey	Cost to have a survey document
			Cost of survey		Cost to have a result of experimentation
			Cost of experimenting	Document of site survey	Cost to have a survey document
			Cost of experimenting		Cost to have a result of experimentation
		Preliminary design	Cost of research of design solution	Preliminary design	Cost to have preliminary design
			Cost of research of design solution		Cost to have options of design
			Cost of designing	Preliminary design	Cost to have preliminary design

			Cost of designing		Cost to have options of design
		Economic research	Cost of collecting data	Document of economic efficiency	Cost to have data of economic survey
			Cost of collecting data		Cost to have document of economic result
			Cost of calculating effective economy	Document of economic efficiency	Cost to have data of economic survey
			Cost of calculating effective economy		Cost to have document of economic result
	24.2	AFP	Cost To Adjust Work	PFP	Cost Of Adjusting Feasibility Work
		Field work	Cost of re-survey	Document of site survey	Cost to have document about adjusting location of survey
			Cost of re-survey		Cost to have document of re-experimenting
			Cost of re-experimenting	Document of site survey	Cost to have document about adjusting location of survey
			Cost of re-experimenting		Cost to have document of re-experimenting
		Preliminary design	Cost of re-research design solution	Preliminary design	Cost to have drawing of re-designing
			Cost of re-research design solution		Cost of preliminary calculation
			Cost of re-design	Preliminary design	Cost to have drawing of re-designing
			Cost of re-design		Cost of preliminary calculation
		Economic research	Cost of re-surveying data	Document of economic efficiency	Cost to have document about supplementing data
			Cost of re-surveying data		Cost to have result of re-calculating
			Cost of re-calculating	Document of economic efficiency	Cost to have document about supplementing data
			Cost of re-calculating		Cost to have result of re-calculating
	24.3	AIP	Cost To Perform Work	PIP	Cost Of Performing Implementation Work
		Detailed design	Cost to design architecture	Detailed design	Cost to have architectural drawing
			Cost to design architecture		Cost to have structural drawing
			Cost to design structure	Detailed design	Cost to have architectural drawing
			Cost to design structure		Cost to have structural drawing

		Preparing procedure before construction	Cost of preparing work	Procedure document	Cost to have procedure document
			Cost of preparing work		Cost to have licence
			Cost of solving procedure problem	Procedure document	Cost to have procedure document
			Cost of solving procedure problem		Cost to have licence
		Construction	Cost to arranging construction work	Building	Cost to have plan drawing of all construction works
			Cost to arranging construction work		Cost to have plan of each construction work
			Cost to performing construction work	Building	Cost to have plan drawing of all construction works
			Cost to performing construction work		Cost to have plan of each construction work
	24.4	AIP	Cost To Repair Precedent Work	PIP	Cost Of Repairing Precedent Work
		Detailed design	Cost to check data of precedent work	Detailed design	Cost to have adjusted drawing of architecture
			Cost to check data of precedent work		Cost to have adjusted drawing of structure
			Cost to repair error of precedent work	Detailed design	Cost to have adjusted drawing of architecture
			Cost to repair error of precedent work		Cost to have adjusted drawing of structure
		Preparing procedure before construction	Cost to check data of precedent work	Procedure document	Cost to have list of data need to be checked
			Cost to check data of precedent work		Cost to have complement document
			Cost to repairing error of precedent work	Procedure document	Cost to have list of data need to be checked
			Cost to repairing error of precedent work		Cost to have complement document
		Construction	Cost to adjust order of construction work	Building	Cost to have adjusted plan drawing of all construction works
			Cost to adjust order of construction work		Cost to have adjusted plan of each construction work
			Cost to adjust construction work	Building	Cost to have adjusted plan drawing of all construction works
			Cost to adjust construction work		Cost to have adjusted plan of each construction work
	24.5	AOP	Cost To Maintain	POP	Cost Of Maintaining

		Operation monitoring	Cost of checking error of monitoring	Document of operation monitoring	Cost to have report about installing monitoring equipment
			Cost of checking error of monitoring		Cost to have period report of checking
			Cost of re-installing monitoring equipment	Document of operation monitoring	Cost to have report about installing monitoring equipment
			Cost of re-installing monitoring equipment		Cost to have period report of checking
		Performance of maintain work	Cost of reporting failure	Document of performing maintain work	Document of cost for reporting failure
			Cost of reporting failure		Document of cost for preparing resource to repair failure
			Cost of preparing resource to repair errors	Document of performing maintain work	Document of cost for reporting failure
			Cost of preparing resource to repair errors		Document of cost for preparing resource to repair failure
	24.6	AOP	Cost To Repair Errors	POP	Cost Of Repairing Errors
		Operation monitoring	Cost of repairing error of monitoring	Document of operation monitoring	Cost to have report about error of monitoring
			Cost of repairing error of monitoring		Cost to have report about re-installing monitoring equipment
			Cost of repairing monitoring equipment	Document of operation monitoring	Cost to have report about error of monitoring
			Cost of repairing monitoring equipment		Cost to have report about re-installing monitoring equipment
		Performance of maintain work	Cost of of checking reason of failure	Document of performing maintain work	Cost to have report about reason of failure
			Cost of of checking reason of failure		Cost to have document about repairing failure
			Cost of repairing failure	Document of performing maintain work	Cost to have report about reason of failure
			Cost of repairing failure		Cost to have document about repairing failure
25		Activity	Quality	Product	Quality
	25.1	AFP	Impact Of Feasibility Work	PFP	Satisfaction Of Owner
		Field work	Impact of field work on nature	Document of site survey	Satisfaction about result in survey document

			Impact of field work on nature		Satisfaction about result of experimentation
			Impact of field work on creating employment opportunities for society	Document of site survey	Satisfaction about result in survey document
			Impact of field work on creating employment opportunities for society		Satisfaction about result of experimentation
		Preliminary design	Impact of preliminary design on nature	Preliminary design	Satisfaction about drawing of preliminary design
			Impact of preliminary design on nature		Satisfaction about preliminary calculation
			Impact of preliminary design on creating employment opportunities for society	Preliminary design	Satisfaction about drawing of preliminary design
			Impact of preliminary design on creating employment opportunities for society		Satisfaction about preliminary calculation
		Economic research	Impact of economic research on nature	Document of economic efficiency	Satisfaction about document of survey economy
			Impact of economic research on nature		Satisfaction about result of effective economy
			Impact of economic research on creating employment opportunities for society	Document of economic efficiency	Satisfaction about document of survey economy
			Impact of economic research on creating employment opportunities for society		Satisfaction about result of effective economy
	25.2	AFP	Impact Of Feasibility Work	PFP	Right Regulation
		Field work	Impact of field work on nature	Document of site survey	Right regulation about survey
			Impact of field work on nature		Right regulation about experimentation
			Impact of field work on creating employment opportunities for society	Document of site survey	Right regulation about survey
			Impact of field work on creating employment opportunities for society		Right regulation about experimentation
		Preliminary design	Impact of preliminary design on nature	Preliminary design	Right regulation about standard of drawing
			Impact of preliminary design on nature		Right regulation about planning

			Impact of preliminary design on creating employment opportunities for society	Preliminary design	Right regulation about standard of drawing
			Impact of preliminary design on creating employment opportunities for society		Right regulation about planning
		Economic research	Impact of economic research on nature	Document of economic efficiency	Right regulation survey
			Impact of economic research on nature		Right regulation about parametre of economy
			Impact of economic research on creating employment opportunities for society	Document of economic efficiency	Right regulation survey
			Impact of economic research on creating employment opportunities for society		Right regulation about parametre of economy
	25.3	AFP	Technique Of Research	PPF	Satisfaction Of Owner
		Field work	Technique of surveying	Document of site survey	Satisfaction about result in survey document
			Technique of surveying		Satisfaction about result of experimentation
			Technique of experimenting	Document of site survey	Satisfaction about result in survey document
			Technique of experimenting		Satisfaction about result of experimentation
		Preliminary design	Technique of desiging	Preliminary design	Satisfaction about drawing of preliminary design
			Technique of desiging		Satisfaction about preliminary calculation
			Technique in using design software	Preliminary design	Satisfaction about drawing of preliminary design
			Technique in using design software		Satisfaction about preliminary calculation
		Economic research	Technique of data processing	Document of economic efficiency	Satisfaction about document of survey economy
			Technique of data processing		Satisfaction about result of effective economy
			Technique of using calculation software	Document of economic efficiency	Satisfaction about document of survey economy

			Technique of using calculation software		Satisfaction about result of effective economy
25.4	AIP		Technique Of Research	PPF	Right Regulation
		Field work	Technique of surveying	Document of site survey	Right regulation about survey
			Technique of surveying		Right regulation about experimentation
			Technique of experimenting	Document of site survey	Right regulation about survey
			Technique of experimenting		Right regulation about experimentation
		Preliminary design	Technique of desiging	Preliminary design	Right regulation about standard of drawing
			Technique of desiging		Right regulation about planning
			Technique in using design software	Preliminary design	Right regulation about standard of drawing
			Technique in using design software		Right regulation about planning
		Economic research	Technique of data processing	Document of economic efficiency	Right regulation survey
			Technique of data processing		Right regulation about parametre of economy
			Technique of using calculation software	Document of economic efficiency	Right regulation survey
			Technique of using calculation software		Right regulation about parametre of economy
25.5	AIP		Impact Of Implementation Work	PIP	Satisfaction Of Owner
		Detailed design	Impact of detailed design on nature	Detailed design	Satisfaction about architectural drawing
			Impact of detailed design on creating employment opportunities for society		Satisfaction about structural drawing
		Preparing procedure before construction	Impact of doing procedure on nature	Procedure document	Satisfaction about procedure document
			Impact of doing procedure on creating employment opportunities for society		Satisfaction about time of received licence
		Construction	Impact of construction work on nature	Building	Satisfaction about plan of all construction works
			Impact of construction work on creating employment opportunities for society		Satisfaction about plan of each construction work
25.6	AIP		Impact Of Implementation Work	PIP	Right Regulation

		Detailed design	Impact of detailed design on nature	Detailed design	Right regulation about architectural drawing
			Impact of detailed design on nature		Right regulation about structural drawing
			Impact of detailed design on creating employment opportunities for society	Detailed design	Right regulation about architectural drawing
			Impact of detailed design on creating employment opportunities for society		Right regulation about structural drawing
		Preparing procedure before construction	Impact of doing procedure on nature	Procedure document	Right regulation about procedure document
			Impact of doing procedure on nature		Right regulation about time of receiving
			Impact of doing procedure on creating employment opportunities for society	Procedure document	Right regulation about procedure document
			Impact of doing procedure on creating employment opportunities for society		Right regulation about time of receiving
		Construction	Impact of construction work on nature	Building	Right regulation about planning
			Impact of construction work on nature		Right regulation about impact of construction work
			Impact of construction work on creating employment opportunities for society	Building	Right regulation about planning
			Impact of construction work on creating employment opportunities for society		Right regulation about impact of construction work
	25.7	AIP	Technique Of Work	PIP	Satisfaction Of Owner
		Detailed design	Technique of architectural design	Detailed design	Satisfaction about architectural drawing
			Technique of architectural design		Satisfaction about structural drawing
			Technique of structural design	Detailed design	Satisfaction about architectural drawing
			Technique of structural design		Satisfaction about structural drawing
		Preparing procedure before construction	Technique of preparing work	Procedure document	Satisfaction about procedure document
			Technique of preparing work		Satisfaction about time of received licence
			Technique of solving procedure problem	Procedure document	Satisfaction about procedure document
			Technique of solving procedure problem		Satisfaction about time of received licence

		Construction	Technique of ordering sequence of construction work	Building	Satisfaction about plan of all construction works
			Technique of ordering sequence of construction work		Satisfaction about plan of each construction work
			Technique of performing construction work	Building	Satisfaction about plan of all construction works
			Technique of performing construction work		Satisfaction about plan of each construction work
	25.8	AIP	Technique Of Work	PIP	Right Regulation
		Detailed design	Technique of architectural design	Detailed design	Right regulation about architectural drawing
			Technique of architectural design		Right regulation about structural drawing
			Technique of structural design	Detailed design	Right regulation about architectural drawing
			Technique of structural design		Right regulation about structural drawing
		Preparing procedure before construction	Technique of preparing work	Procedure document	Right regulation about procedure document
			Technique of preparing work		Right regulation about time of receiving
			Technique of solving procedure problem	Procedure document	Right regulation about procedure document
			Technique of solving procedure problem		Right regulation about time of receiving
		Construction	Technique of ordering sequence of construction work	Building	Right regulation about planning
			Technique of ordering sequence of construction work		Right regulation about impact of construction work
			Technique of performing construction work	Building	Right regulation about planning
			Technique of performing construction work		Right regulation about impact of construction work
	25.9	AOP	Impact Of Operation Work	POP	Satisfaction Of Owner
		Operation monitoring	Impact of construction monitoring on nature	Document of operation monitoring	Satisfaction about process of installing monitoring equipment
			Impact of construction monitoring on nature		Satisfaction about period report of checking

			Impact of construction monitoring on creating employment opportunities for society	Document of operation monitoring	Satisfaction about process of installing monitoring equipment
			Impact of construction monitoring on creating employment opportunities for society		Satisfaction about period report of checking
		Performance of maintain work	Impact of maintain work on nature	Document of performing maintain work	Satisfaction about report of failure
			Impact of maintain work on nature		Satisfaction about process of repairing failure
			Impact of maintain work on creating employment opportunities for society	Document of performing maintain work	Satisfaction about report of failure
			Impact of maintain work on creating employment opportunities for society		Satisfaction about process of repairing failure
	25.10	AOP	Impact Of Operation Work	POP	Right Regulation
		Operation monitoring	Impact of construction monitoring on nature	Document of operation monitoring	Right regulation about process of installing monitoring equipment
			Impact of construction monitoring on nature		Right regulation about period report of checking
			Impact of construction monitoring on creating employment opportunities for society	Document of operation monitoring	Right regulation about process of installing monitoring equipment
			Impact of construction monitoring on creating employment opportunities for society		Right regulation about period report of checking
		Performance of maintain work	Impact of maintain work on nature	Document of performing maintain work	Right regulation about reporting failure
			Impact of maintain work on nature		Right regulation about process of repairing failure
			Impact of maintain work on creating employment opportunities for society	Document of performing maintain work	Right regulation about reporting failure
			Impact of maintain work on creating employment opportunities for society		Right regulation about process of repairing failure
	25.11	AOP	Technique Of Repairing Error	POP	Satisfaction Of Owner
		Operation monitoring	Technique of checking error of monitoring	Document of operation monitoring	Satisfaction about process of installing monitoring equipment

			Technique of checking error of monitoring		Satisfaction about period report of checking
			Technique of replacing monitoring equipment	Document of operation monitoring	Satisfaction about process of installing monitoring equipment
			Technique of replacing monitoring equipment		Satisfaction about period report of checking
		Performance of maintain work	Technique of checking reason of failure	Document of performing maintain work	Satisfaction about report of failure
			Technique of checking reason of failure		Satisfaction about process of repairing failure
			Technique of repairing failure	Document of performing maintain work	Satisfaction about report of failure
			Technique of repairing failure		Satisfaction about process of repairing failure
	25.12	AOP	Technique Of Repairing Error	POP	Right Regulation
		Operation monitoring	Technique of checking error of monitoring	Document of operation monitoring	Right regulation about process of installing monitoring equipment
			Technique of checking error of monitoring		Right regulation about period report of checking
			Technique of replacing monitoring equipment	Document of operation monitoring	Right regulation about process of installing monitoring equipment
			Technique of replacing monitoring equipment		Right regulation about period report of checking
		Performance of maintain work	Technique of checking reason of failure	Document of performing maintain work	Right regulation about reporting failure
			Technique of checking reason of failure		Right regulation about process of repairing failure
			Technique of repairing failure	Document of performing maintain work	Right regulation about reporting failure
			Technique of repairing failure		Right regulation about process of repairing failure
26		Activity	Duration	Product	Duration
	26.1	AFP	Duration To Perform Work	PFP	Duration Of Performing Feasibility Work
		Field work	Duration of survey	Document of site survey	Duration to finish survey document
			Duration of survey		Duration to have result of experimentation

			Duration of experimenting	Document of site survey	Duration to finish survey document
			Duration of experimenting		Duration to have result of experimentation
		Preliminary design	Duration of preliminary designing	Preliminary design	Duration to have preliminary design
			Duration of preliminary designing		Duration to have all option of design
			Number of alternative options	Preliminary design	Duration to have preliminary design
			Number of alternative options		Duration to have all option of design
		Economic research	Duration of survey economy	Document of economic efficiency	Duration to document about survey economy
			Duration of survey economy		Duration to result of effective economy
			Duration of calculating effective economy	Document of economic efficiency	Duration to document about survey economy
			Duration of calculating effective economy		Duration to result of effective economy
	26.2	AFP	Duration To Adjust Work	PFP	Duration Of Adjusting Feasibility Work
		Field work	Duration of adjusting location of survey	Document of site survey	Duration of document about adjusting location of survey
			Duration of adjusting location of survey		Duration of document of re-experimenting
			Duration of re-experimenting	Document of site survey	Duration of document about adjusting location of survey
			Duration of re-experimenting		Duration of document of re-experimenting
		Preliminary design	Duration of re-designing	Preliminary design	Duration to have drawing of re-designing
			Duration of re-designing		Report of preliminary calculation
			Duration of preliminary calculation	Preliminary design	Duration to have drawing of re-designing
			Duration of preliminary calculation		Report of preliminary calculation
		Economic research	Duration of supplement data	Document of economic efficiency	Duration of document about supplementing data
			Duration of supplement data		Duration to have result of re-calculating
			Duration of re-calculating	Document of economic efficiency	Duration of document about supplementing data
			Duration of re-calculating		Duration to have result of re-calculating
	26.3	AIP	Duration To Perform Work	PIP	Duration Of Performing Implementation Work

		Detailed design	Duration of architectural design	Detailed design	Duration to have architectural design
			Duration of architectural design		Duration to have structural design
			Duration of structural design	Detailed design	Duration to have architectural design
			Duration of structural design		Duration to have structural design
		Preparing procedure before construction	Duration of preparing procedure	Procedure document	Duration of procedure document
			Duration of preparing procedure		Duration to have licence
			Duration of waiting	Procedure document	Duration of procedure document
			Duration of waiting		Duration to have licence
		Construction	Duration of arranging construction works	Building	Duration of have plan drawing of all construction works
			Duration of arranging construction works		Duration to have plan of each construction work
			Duration of performing construction work	Building	Duration of have plan drawing of all construction works
			Duration of performing construction work		Duration to have plan of each construction work
	26.4	AIP	Duration To Repair Precedent Work	PIP	Duration Of Repairing Precedent Work
		Detailed design	Duration of adjusting architectural design	Detailed design	Duration to have adjusted drawing of architecture
			Duration of adjusting architectural design		Duration to have adjusted drawing of structure
			Duration of adjusting structural design	Detailed design	Duration to have adjusted drawing of architecture
			Duration of adjusting structural design		Duration to have adjusted drawing of structure
		Preparing procedure before construction	Duration of check data of procedure	Procedure document	Duration to list of data need to be checked
			Duration of check data of procedure		Duration to have complement document
			Duration of repairing error of procedure	Procedure document	Duration to list of data need to be checked
			Duration of repairing error of procedure		Duration to have complement document
		Construction	Duration of adjusting order of construction works	Building	Duration to have adjusted plan drawing of all construction works

			Duration of adjusting order of construction works		Duration to have adjusted plan of each construction work
			Duration of adjusting a construction work	Building	Duration to have adjusted plan drawing of all construction works
			Duration of adjusting a construction work		Duration to have adjusted plan of each construction work
	26.5	AOP	Duration To Perform Work	POP	Duration Of Performing Maintenance
		Operation monitoring	Duration of installing monitoring equipment	Document of operation monitoring	Duration to have report about installing monitoring equipment
			Duration of installing monitoring equipment		Period report of checking
			Period time of checking	Document of operation monitoring	Duration to have report about installing monitoring equipment
			Period time of checking		Period report of checking
		Performance of maintain work	Duration of reporting failure	Document of performing maintain work	Duration to have report about failure
			Duration of reporting failure		Duration to have report about resource repair error
			Duration of preparing resource to repair errors	Document of performing maintain work	Duration to have report about failure
			Duration of preparing resource to repair errors		Duration to have report about resource repair error
	26.6	AOP	Duration To Repair Errors	POP	Duration Of Repairing Errors
		Operation monitoring	Duration of checking error of monitoring	Document of operation monitoring	Duration to have report about error of monitoring
			Duration of checking error of monitoring		Duration to have report about re-installing monitoring equipment
			Duration of re-installing monitoring equipment	Document of operation monitoring	Duration to have report about error of monitoring
			Duration of re-installing monitoring equipment		Duration to have report about re-installing monitoring equipment
		Performance of maintain work	Duration of checking reason of failure	Document of performing maintain work	Duration to have report about reason of failure
			Duration of checking reason of failure		Duration to have document about repairing failure

			Duration of repairing failure	Document of performing maintain work	Duration to have report about reason of failure
			Duration of repairing failure		Duration to have document about repairing failure
27		Resource	Quality	Resource	Unit Cost
	27.1	Machine	Conformity	Machine	Depreciation
		Construction machine	Conformity in transporting	Construction machine	Original construction machine cost
			Conformity in operating		Recovery construction machine cost
		Office machine	Conformity in manipulating	Office machine	Original office machine cost
			Conformity in moving		Recovery office machine cost
	27.2	Machine	Conformity	Machine	repair Cost
		Construction machine	Conformity in transporting	Construction machine	Repaired cost of important part of machine
			Conformity in operating		Repaired cost of extra part of machine
		Office machine	Conformity in manipulating	Office machine	Repaired cost of important part of office machine
			Conformity in moving		Repaired cost of extra part of office machine
	27.3	Machine	Conformity	Machine	Fuel-energy cost
		Construction machine	Conformity in transporting	Construction machine	Energy consumption each time of construction work
			Conformity in operating		Unit cost of fuel-energy
		Office machine	Conformity in manipulating	Office machine	Energy consumption each time of office work
			Conformity in moving		Unit cost of electricity
	27.4	Machine	Characteristic	Machine	Depreciation
		Construction machine	Productivity in performing construction work	Construction machine	Original construction machine cost
			Emission pollution		Recovery construction machine cost
		Office machine	Productivity in solving document	Office machine	Original office machine cost
			Replaced equipment of office machine		Recovery office machine cost

	27.5	Machine	Characteristic	Machine	repair Cost
		Construction machine	Productivity in performing construction work	Construction machine	Repaired cost of important part of machine
			Emission pollution		Repaired cost of extra part of machine
		Office machine	Productivity in solving document	Office machine	Repaired cost of important part of office machine
			Replaced equipment of office machine		Repaired cost of extra part of office machine
	27.6	Machine	Characteristic	Machine	Fuel-energy cost
		Construction machine	Productivity in performing construction work	Construction machine	Energy consumption each time of construction work
			Emission pollution		Unit cost of fuel-energy
		Office machine	Productivity in solving document	Office machine	Energy consumption each time of office work
			Replaced equipment of office machine		Unit cost of electricity
	27.7	Human	Skill In Operating	Human	Working Time Cost
		Worker	Skill in executing construction work	Worker	Regulated performing time
			Skill in executing construction work		Salary of each unit of time performing
			Ability in teamwork	Worker	Regulated performing time
			Ability in teamwork		Salary of each unit of time performing
		Engineer	Ability in arranging construction work	Engineer	Regulated working time
			Flexibility in treating incident		Salary of each time of working
		Office staff	Skill in handling document	Office staff	Regulated office working time
			Flexibility in solving data		Salary of each time of office working
	27.8	Human	Skill In Operating	Human	Overtime Cost
		Worker	Skill in executing construction work	Worker	Over time of construction performing
			Skill in executing construction work		Salary of each over time of performing
			Ability in teamwork	Worker	Over time of construction performing
			Ability in teamwork		Salary of each over time of performing
		Engineer	Ability in arranging construction work	Engineer	Over time of work
			Flexibility in treating incident		Salary of each over time of working
		Office staff	Skill in handling document	Office staff	Over time of office work

			Flexibility in solving data		Salary of each over time of office working
	27.9	Material	Imported Characteristic	Material	Original Cost
		Reusable material	Characteristic after transport process	Reusable material	Reusable material cost after tax
		Consumable material	Characteristic after transport process	Consumable material	Consumable material cost after tax
	27.10	Material	Imported Characteristic	Material	Transportation Cost
		Reusable material	Original characteristic	Reusable material	Traffic charges
		Consumable material	Original characteristic	Consumable material	Cost of fuel-energy of transport process
			Characteristic after transport process		Traffic charges
	27.11	Material	Imported Characteristic	Material	Storage Cost
		Reusable material	Original characteristic	Reusable material	Cost of storehouse
		Consumable material	Original characteristic	Consumable material	Cost of storage equipment
			Characteristic after transport process		Cost of storehouse
	27.12	Material	Storage Environment	Material	Original Cost
		Reusable material	Equipment of storage	Reusable material	Reusable material cost after tax
	27.13	Material	Storage Environment	Material	Transportation Cost
		Reusable material	Internal and external storage environment	Reusable material	Cost of fuel-energy of transport process
		Consumable material	Equipment of storage	Consumable material	Cost of fuel-energy of transport process
			Internal and external storage environment		Traffic charges
	27.14	Material	Storage Environment	Material	Storage Cost
		Reusable material	Internal and external storage environment	Reusable material	Cost of storage equipment
		Consumable material	Equipment of storage	Consumable material	Cost of storage equipment
			Internal and external storage environment		Cost of storehouse
28		Actor	Experience	Actor	Productivity
	28.1	Owner	Experience In Organizing Project	Owner	Productivity In Organizing Project

		Owner	Experience in arranging human work	Owner	Upgrading technology in organizing project
	28.2	Owner	<i>Experience In Mananing Project</i>	Owner	<i>Productivity In Managing Project</i>
		Owner	Experience in managing construction work	Owner	Productivity in managing time
			Experience in managing human resource		Productivity in managing cost
			Experience in managing construction work		Productivity in managing quality
	28.3	Designer	<i>Experience In Designing</i>	Designer	<i>Productivity In Designing</i>
		Structural designer	Experience of structural design	Structural designer	Productivity in defining weight
			Experience in calculating structure		Productivity in using designing software
		Architectural designer	Experience in design layout	Architectural designer	Productivity in designing layout
			Experience in using architectural software		Productivity in using architectural software
	28.4	Designer	<i>Experience In Designing</i>	Designer	<i>Productivity In Calculating</i>
		Structural designer	Experience of structural design	Structural designer	Productivity in choosing suitable calculation parametre
			Experience in calculating structure		Productivity in using calculation software
		Architectural designer	Experience in design layout	Architectural designer	Productivity in choosing suitable architectural parametre
			Experience in using architectural software		Productivity in using calculation architectural software
	28.5	Designer	<i>Past Qualification Assessment About Designing</i>	Designer	<i>Productivity In Designing</i>
		Structural designer	Qualification about structural design	Structural designer	Productivity in defining weight
			Qualification about structural calculation		Productivity in using designing software
		Architectural designer	Qualification in design layout	Architectural designer	Productivity in designing layout
			Qualification in using architectural software		Productivity in using architectural software
	28.6	Designer	<i>Past Qualification Assessment About Designing</i>	Designer	<i>Productivity In Calculating</i>

		Structural designer	Qualification about structural design	Structural designer	Productivity in choosing suitable calculation parametre
			Qualification about structural calculation		Productivity in using calculation software
		Architectural designer	Qualification in design layout	Architectural designer	Productivity in choosing suitable architectural parametre
			Qualification in using architectural software		Productivity in using calculation architectural software
	28.7	Contractor	Experience In Building Project	Contractor	Productivity In Arranging Work
		Building contractor	Experience in arranging construction work	Building contractor	Effective teamwork
			Experience in arranging construction work		Applicating suitable software in building
			Experience in building project	Building contractor	Effective teamwork
			Experience in building project		Applicating suitable software in building
		Installing contractor	Experience in arranging installationn work	Installing contractor	Effective communication in teamwork
			Experience in arranging installationn work		Applicating suitable software in installing
			Experience in installing project	Installing contractor	Effective communication in teamwork
			Experience in installing project		Applicating suitable software in installing
	28.8	Contractor	Experience In Building Project	Contractor	Productivity In Building Project
		Building contractor	Experience in arranging construction work	Building contractor	Productivity in using new technology in building
			Experience in building project		Productivity in arranging reasonable priority building work
		Installing contractor	Experience in arranging installationn work	Installing contractor	Productivity in using new technology in installing
			Experience in installing project		Productivity in arranging reasonable priority installing work
	28.9	Contractor	Past Qualification Assessment About Building	Contractor	Productivity In Arranging Work
		Building contractor	Qualification in arranging construction work	Building contractor	Effective teamwork

			Qualification in arranging construction work		Applicating suitable software in building
			Qualification in building project	Building contractor	Effective teamwork
			Qualification in building project		Applicating suitable software in building
		Installing contractor	Qualification in arranging installation work	Installing contractor	Effective communication in teamwork
			Qualification in arranging installation work		Applicating suitable software in installing
			Qualification in installing project	Installing contractor	Effective communication in teamwork
			Qualification in installing project		Applicating suitable software in installing
	28.10	Contractor	<i>Past Qualification Assessment About Building</i>	Contractor	<i>Productivity In Building Project</i>
		Building contractor	Qualification in arranging construction work	Building contractor	Productivity in using new technology in building
			Qualification in building project		Productivity in arranging reasonable priority building work
		Installing contractor	Qualification in arranging installation work	Installing contractor	Productivity in using new technology in installing
			Qualification in installing project		Productivity in arranging reasonable priority installing work
	28.11	Supplier	<i>Experience In Supplying</i>	Supplier	<i>Productivity In Transportation</i>
		Material supplier	Experience in supplying material	Material supplier	Distance of transporting material
			Experience in communicating with buyers about material		Velocity of transporting material
	28.12	Supplier	<i>Past Qualification Assessment About Supplying</i>	Supplier	<i>Productivity In Supplying Information</i>
		Material supplier	Qualification about cost of supplying material	Material supplier	Update material information in website
			Qualification about time of supplying material		Communication with buyers about material
			Qualification about quality of supplying material		Communication with buyers about material
29		Actor	Experience	Actor	Capacity
	29.1	Owner	<i>Experience In Organizing Project</i>	Owner	<i>Capacity In Organizing Project</i>

		Owner	Experience in arranging construction work	Owner	Capacity in organizing work
			Experience in arranging construction work		Capacity in arranging human work
	29.2	Owner	Experience In Mananing Project	Owner	Capacity In Managing Project
		Owner	Experience in managing construction work	Owner	Capacity in managing time
			Experience in managing human resource		Capacity in managing cost
			Experience in managing construction work		Capacity in managing quality
	29.3	Designer	Experience In Designing	Designer	Capacity In Designing
		Structural designer	Experience of structural design	Structural designer	Capacity in defining weight
			Experience in calculating structure		Capacity in using designing structural software
		Architectural designer	Experience in design layout	Architectural designer	Capacity in designing layout
			Experience in using architectural software		Capacity in using architectural software
	29.4	Designer	Experience In Designing	Designer	Capacity In Calculating
		Structural designer	Experience of structural design	Structural designer	Capacity in choosing suitable calculation parametre
			Experience in calculating structure		Capacity in using calculation software
		Architectural designer	Experience in design layout	Architectural designer	Capacity in choosing suitable architectural parametre
			Experience in using architectural software		Capacity in using calculation architectural software
	29.5	Designer	Past Qualification Assessment About Designing	Designer	Capacity In Designing
		Structural designer	Qualification about structural design	Structural designer	Capacity in defining weight
			Qualification about structural calculation		Capacity in using designing structural software
		Architectural designer	Qualification in design layout	Architectural designer	Capacity in designing layout

			Qualification in using architectural software		Capacity in using architectural software
	29.6	Designer	Past Qualification Assessment About Designing	Designer	Capacity In Calculating
		Structural designer	Qualification about structural design	Structural designer	Capacity in choosing suitable calculation parametre
			Qualification about structural calculation		Capacity in using calculation software
		Architectural designer	Qualification in design layout	Architectural designer	Capacity in choosing suitable architectural parametre
			Qualification in using architectural software		Capacity in using calculation architectural software
	29.7	Contractor	Experience In Building Project	Contractor	Capacity In Arranging Work
		Building contractor	Experience in arranging construction work	Building contractor	Capacity of teamwork
			Experience in arranging construction work		Capacity in using software
			Experience in building project	Building contractor	Capacity of teamwork
			Experience in building project		Capacity in using software
		Installing contractor	Experience in arranging installationn work	Installing contractor	Capacity of communication
			Experience in arranging installationn work		Capacity in using software of installing work
			Experience in installing project	Installing contractor	Capacity of communication
			Experience in installing project		Capacity in using software of installing work
	29.8	Contractor	Experience In Building Project	Contractor	Capacity In Building Project
		Building contractor	Experience in arranging construction work	Building contractor	Capacity in using new technology
			Experience in arranging construction work		Flexibility in building work
			Experience in building project	Building contractor	Capacity in using new technology
			Experience in building project		Flexibility in building work
		Installing contractor	Experience in arranging installationn work	Installing contractor	Capacity in using new technology in installing

			Experience in arranging installationn work		Flexibility in installing work
			Experience in installing project	Installing contractor	Capacity in using new technology in installing
			Experience in installing project		Flexibility in installing work
	29.9	Contractor	<i>Past Qualification Assessment About Building</i>	Contractor	<i>Capacity In Arranging Work</i>
		Building contractor	Qualification in arranging construction work	Building contractor	Capacity of teamwork
			Qualification in arranging construction work		Capacity in using software
			Qualification in building project	Building contractor	Capacity of teamwork
			Qualification in building project		Capacity in using software
		Installing contractor	Qualification in arranging installation work	Installing contractor	Capacity of communication
			Qualification in arranging installation work		Capacity in using software of installing work
			Qualification in installing project	Installing contractor	Capacity of communication
			Qualification in installing project		Capacity in using software of installing work
	29.10	Contractor	<i>Past Qualification Assessment About Building</i>	Contractor	<i>Capacity In Building Project</i>
		Building contractor	Qualification in arranging construction work	Building contractor	Capacity in using new technology
			Qualification in arranging construction work		Flexibility in building work
			Qualification in building project	Building contractor	Capacity in using new technology
			Qualification in building project		Flexibility in building work
		Installing contractor	Qualification in arranging installation work	Installing contractor	Capacity in using new technology in installing
			Qualification in arranging installation work		Flexibility in installing work
			Qualification in installing project	Installing contractor	Capacity in using new technology in installing
			Qualification in installing project		Flexibility in installing work

Appendix 9. Signification of attributes' states in level 2

Entity level 2	Attribute	Negative	Positive
National economic	Aggresiveness		
	Instability		
	Fluctuation in National Market	Increasing	Reducing
	National tax	Increasing	Reducing
	Inflation		
	Demand pull inflation	Increasing	Reducing
	Cost push inflation	Increasing	Reducing
International economic	Aggresiveness		
	Instability		
	Fluctuation in International Market	Increasing	Reducing
	International tax	Increasing	Reducing
	Inflation		
	Monetary policy	Exchanging currency increases	Exchanging currency decreases
	Politic	Imported increasing material	Imported reducing material
Ministry	Aggresiveness		
	Inertia		
	Complex ministry decentralization	Increasing	Reducing
	Qualification of ministry's public official	Increasing	Reducing
	Corruption		
	Wages of public officials	Increasing	Reducing
	Chain reaction public officials	Increasing	Reducing
Department	Aggresiveness		
	Inertia		

	Complex department decentralization	Increasing	Reducing
	Qualification of department's public official	Increasing	Reducing
	Corruption		
	Wages of department's public official	Increasing	Reducing
	Chain reaction of department's public official	Increasing	Reducing
Temperature	Aggresiveness		
	Frequency		
	Frequency of degree	Likely	Unlikely
	Intensity		
	Level of degree	High	Low
Precipitation	Period duration of degree	Long	Short
	Aggresiveness		
	Frequency		
	Frequency of precipitation	Likely	Unlikely
	Intensity		
Owner	Level of precipitation	So much	Little
	Period duration of precipitation	Long	Short
	Productivity		
	Productivity in organizing project		
	Upgrading technology in organizing project	Slow	Fast
	Reasonable priority construction work	Slow	Fast
	Productivity in managing project		
	Productivity in managing time	Slow	Fast
	Productivity in managing cost	Slow	Fast
	Productivity in managing quality	Slow	Fast
	Capacity		
	Capacity in organizing project		
Capacity in organizing work	Inefficient	Efficient	
Capacity in arranging human work	Inefficient	Efficient	

	Capacity in managing project		
	Capacity in managing time	Inefficient	Efficient
	Capacity in managing cost	Inefficient	Efficient
	Capacity in managing quality	Inefficient	Efficient
	Cost		
	Fixed cost		
	Fixed cost in building	High	Low
	Fixed cost in doing procedure	High	Low
	Variable cost		
	Variable cost in building	High	Low
	Variable cost in doing procedure	High	Low
	Experience		
	Experience in organizing project		
	Experience in arranging construction work	Bad	Good
	Experience in arranging human work	Bad	Good
	Experience in managing project		
	Experience in managing construction work	Bad	Good
	Experience in managing human resource	Bad	Good
Structural designer	Productivity		
	Productivity in designing		
	Productivity in defining weight	Slow	Fast
	Productivity in using designing software	Slow	Fast
	Productivity in calculating		
	Productivity in choosing suitable calculation parametre	Slow	Fast
	Productivity in using calculation software	Slow	Fast
	Capacity		
	Capacity in designing		
	Capacity in defining weight	Inefficient	Efficient
Capacity in using designing structural software	Inefficient	Efficient	

	Capacity in calculating		
	Capacity in choosing suitable calculation parametre	Inefficient	Efficient
	Capacity in using calculation software	Inefficient	Efficient
	Cost		
	Design cost		
	Main cost of structural design	High	Low
	Extra cost for structural design	High	Low
	Serving cost for designing		
	Food service for structural design	High	Low
	Health care for structural design	High	Low
	Experience		
	Experience in designing		
	Experience of structural design	Bad	Good
	Experience in calculating structure	Bad	Good
	Past qualification assessment about designing		
Qualification about structural design	Bad	Good	
Qualification about structural calculation	Bad	Good	
Architectural designer	Productivity		
	Productivity in designing		
	Productivity in designing layout	Slow	Fast
	Productivity in using architectural software	Slow	Fast
	Productivity in calculating		
	Productivity in choosing suitable architectural parametre	Slow	Fast
	Productivity in using calculation architectural software	Slow	Fast
	Capacity		
	Capacity in designing		
	Capacity in designing layout	Inefficient	Efficient
Capacity in using architectural software	Inefficient	Efficient	

	Capacity in calculating		
	Capacity in choosing suitable architectural parametre	Inefficient	Efficient
	Capacity in using calculation architectural software	Inefficient	Efficient
	Cost		
	Design cost		
	Main cost of architectural design	High	Low
	Extra cost for architectural design	High	Low
	Serving cost for designing		
	Food service for architectural design	High	Low
	Health care for architectural design	High	Low
	Experience		
	Experience in designing		
	Experience in design layout	Bad	Good
	Experience in using architectural software	Bad	Good
	Past qualification assessment about designing		
Qualification in design layout	Bad	Good	
Qualification in using architectural software	Bad	Good	
Building contractor	Productivity		
	Productivity in arranging work		
	Effective teamwork	Inefficient	Efficient
	Applicating suitable software in building	Unsuitable	Suitable
	Productivity in building project		
	Productivity in using new technology in building	Slow	Fast
	Productivity in arranging reasonable priority building work	Slow	Fast
	Capacity		
	Capacity in arranging work		
	Capacity of teamwork	Low	High
Capacity in using software	Low	High	

	Capacity in building project		
	Capacity in using new technology	Low	High
	Flexibility in building work	Low	High
	Cost		
	Building cost		
	Main building cost	High	Low
	Cost of managing for building work	High	Low
	Serving cost for constructing		
	Cleaning building construction site	High	Low
	Health service of building	High	Low
	Experience		
	Experience in building project		
	Experience in arranging construction work	Bad	Good
	Experience in building project	Bad	Good
	Past qualification assessment about building		
Qualification in arranging construction work	Bad	Good	
Qualification in building project	Bad	Good	
Installing contractor	Productivity		
	Productivity in arranging work		
	Effective communication in teamwork	Slow	Fast
	Applicating suitable software in installing	Slow	Fast
	Productivity in building project		
	Productivity in using new technology in installing	Slow	Fast
	Productivity in arranging reasonable priority installing work	Slow	Fast
	Capacity		
	Capacity in arranging work		
	Capacity of communication	Inefficient	Efficient
Capacity in using software of installing work	Inefficient	Efficient	

	Capacity in building project		
	Capacity in using new technology in installing	Inefficient	Efficient
	Flexibility in installing work	Inefficient	Efficient
	Cost		
	Building cost		
	Main installation cost	High	Low
	Cost of managing for installing work	High	Low
	Serving cost for constructing		
	Cleaning site of installing	High	Low
	Health service of installing	High	Low
	Experience		
	Experience in building project		
	Experience in arranging installation work	Bad	Good
	Experience in installing project	Bad	Good
	Past qualification assessment about building		
Qualification in arranging installation work	Bad	Good	
Qualification in installing project	Bad	Good	
Material supplier	Productivity		
	Productivity in transportation		
	Distance of transporting material	Slow	Fast
	Velocity of transporting material	Slow	Fast
	Productivity in supplying information		
	Update material information in website	Slow	Fast
	Communication with buyers about material	Slow	Fast
	Capacity		
	Capacity in adapting resource requirement		
	Adapting material requirement about quality	Inefficient	Efficient
	Adapting material requirement about quantity	Inefficient	Efficient
Capacity in supplying			

	Capacity in supplying material in time	Inefficient	Efficient
	Capacity in communicating about characteristic of material	Inefficient	Efficient
	Cost		
	Supplying cost		
	Main cost of supplying material	High	Low
	Extra cost of supplying material	High	Low
	Serving cost for supplying		
	Food service for supplying material	High	Low
	Health care for supplying material	High	Low
	Experience		
	Experience in supplying		
	Experience in supplying material	Bad	Good
	Experience in communicating with buyers about material	Bad	Good
	Past qualification assessment about supplying		
	Qualification about time of supplying material	Bad	Good
	Qualification about cost of supplying material	Bad	Good
	Qualification about quality of supplying material	Bad	Good
Construction machine (heavy equipment)	Quantity		
	Machine requirement of unit operating work		
	Main construction machine	Increasing	Reducing
	Assistance machine	Increasing	Reducing
	Total work of operating		
	Scale of construction work	Increasing	Reducing
	Number of construction work	Increasing	Reducing
	Quality		
	Conformity		
Conformity in transporting	Low	High	

	Conformity in operating	Low	High
	Characteristic		
	Productivity in performing construction work	Low	Fast
	Emission pollution	High	Low
	UnitCost		
	Depreciation		
	Original construction machine cost	High	Low
	Recovery construction machine cost	High	Low
	repair cost		
	Repaired cost of important part of machine	High	Low
	Repaired cost of extra part of machine	High	Low
	Fuel-energy cost		
	Energy consumption each time of construction work	High	Low
	Unit cost of fuel-energy	High	Low
Office machines	Quantity		
	Machine requirement of unit operating work		
	Number of office machine	Increasing	Reducing
	Assistance equipment	Increasing	Reducing
	Total work of operating		
	Number of report document	Increasing	Reducing
	Quality		
	Conformity		
	Conformity in manipulating	Low	High
	Conformity in moving	Low	High
	Characteristic		
	Productivity in solving document	Low	Fast
	Replaced equipment of office machine	Bad	Good
	UnitCost		
Depreciation			

	Original office machine cost	High	Low
	Recovery office machine cost	High	Low
	repair cost		
	Repaired cost of important part of office machine	High	Low
	Repaired cost of extra part of office machine	High	Low
	Fuel-energy cost		
	Energy consumption each time of office work	High	Low
	Unit cost of electricity	High	Low
Worker	Quantity		
	Human requirement of unit work		
	Main worker for unit work	Increasing	Reducing
	Assistance for main worker	Increasing	Reducing
	Total work of performing		
	Number of main work of performing	Increasing	Reducing
	Number of extra work of performing	Increasing	Reducing
	Quality		
	Skill in operating		
	Skill in executing construction work	Low	High
	Ability in teamwork	Low	High
	Cost		
	Working time cost		
	Regulated performing time	High	Low
	Salary of each unit of time performing	High	Low
	Overtime cost		
Over time of construction performing	High	Low	
Salary of each over time of performing	High	Low	
Engineer	Quantity		
	Human requirement of unit work		
	Number of engineer for unit work	Increasing	Reducing

	Total work of performing		
	Number of designing process of work	Increasing	Reducing
	Number of manage work of construction process	Increasing	Reducing
	Quality		
	Skill in operating		
	Ability in arranging construction work	Low	High
	Flexibility in treating incident	Low	High
	Cost		
	Working time cost		
	Regulated working time	High	Low
	Salary of each time of working	High	Low
	Overtime cost		
	Over time of work	High	Low
	Salary of each over time of working	High	Low
Office staff	Quantity		
	Human requirement of unit work		
	Number of staff for unit work	Increasing	Reducing
	Total work of performing		
	Number of procedure attaches with construction work	Increasing	Reducing
	Number of solved construction work	Increasing	Reducing
	Quality		
	Skill in operating		
	Skill in handling document	Low	High
	Flexibility in solving data	Low	High
	Cost		
	Working time cost		
	Regulated office working time	High	Low
	Salary of each time of office working	High	Low
Overtime cost			

	Over time of office work	High	Low
	Salary of each over time of office working	High	Low
Reusable material	Quantity		
	Material requirement of unit component		
	Main reusable material for unit component	Increasing	Reducing
	Extra reusable material for unit component	Increasing	Reducing
	Total component		
	Installed component	Increasing	Reducing
	Failure component	Increasing	Reducing
	Quality		
	Imported characteristic		
	Original characteristic	Bad	Good
	Characteristic after transport process	Bad	Good
	Storage environment		
	Equipment of storage	Wrong	Right
	Internal and external storage environment	Wrong	Right
	Original cost		
	Reusable material cost after tax	High	Low
	Transportation cost		
	Cost of fuel-energy of transport process	High	Low
	Traffic charges	High	Low
	Storage cost		
Cost of storage equipment	High	Low	
Cost of storehouse	High	Low	
Consumable material	Quantity		
	Material requirement of unit component		
	Number of consumable material for unit component	Increasing	Reducing
	Total component		
	Build component	Increasing	Reducing

	Lost component	Increasing	Reducing
	Quality		
	Imported characteristic		
	Original characteristic	Bad	Good
	Characteristic after transport process	Bad	Good
	Storage environment		
	Equipment of storage	Wrong	Right
	Internal and external storage environment	Wrong	Right
	Original cost		
	Consumable material cost after tax	High	Low
	Transportation cost		
	Cost of fuel-energy of transport process	High	Low
	Traffic charges	High	Low
	Storage cost		
	Cost of storage equipment	High	Low
Cost of storehouse	High	Low	
Main building contract	Magnitude		
	Project scale		
	Complexity in technique	Increasing	Reducing
	Acreage (m2, ha, etc.)	Increasing	Reducing
	Building cost		
	Main building cost	High	Low
	Punished cost of delay in building	High	Low
	Complexity		
	Vagueness in process of building		
	Vagueness about order of building activities	Increasing	Reducing
	Vagueness about applied technology	Increasing	Reducing
	Time for building completion		
	Time for arranging order of building activities	Long	Short

	Time for choosing building technology	Long	Short
	Progress payment		
	Achievement of certain milestones in the building work	Late	Soon
	Stipulated amounts of building on set calendar dates	Late	Soon
Installing contract	Magnitude		
	Project scale		
	Complexity of installed component	Increasing	Reducing
	Number of component	Increasing	Reducing
	Building cost		
	Main installing cost	High	Low
	Punished cost of delay in installing	High	Low
	Complexity		
	Vagueness in process of building		
	Vagueness about order of installing	Increasing	Reducing
	Vagueness about installing technique	Increasing	Reducing
	Time for building completion		
	Time for arranging order of installing activities	Long	Short
	Time for choosing installing technology	Long	Short
	Progress payment		
	Achievement of certain milestones in the installing work	Late	Soon
Stipulated amounts of installing on set calendar dates	Late	Soon	
Material supply contract	Magnitude		
	Required volume		
	Number of desired material	Increasing	Reducing
	Qualification of material	Increasing	Reducing
	Supplying cost		
	Material cost	High	Low
Punished cost of delay in material supply	High	Low	

	Complexity		
	Vagueness of resource requirement		
	Vagueness about qualification of material	Increasing	Reducing
	Vagueness about quantity of material	Increasing	Reducing
	Vagueness in schedule of supplying		
	Vagueness in milestone of material supply	Increasing	Reducing
	Vagueness in duration of material supply	Increasing	Reducing
	Payment schedule		
	Achievement of certain material	Late	Soon
	Full information of supplied material	Late	Soon
Structural design contract	Magnitude		
	Design scale		
	Weight (Load)	Increasing	Reducing
	Reliability	Increasing	Reducing
	Designing cost		
	Main structural design cost	High	Low
	Punished cost of structural design	High	Low
	Complexity		
	Vagueness in design idea		
	Vagueness about weight (load)	Increasing	Reducing
	Vagueness about reliability	Increasing	Reducing
	Number of alternative design solutions		
	Variation of impact force	Many	Little
	Variation parameters of reliability	Many	Little
	Submittal time		
	Milestone of submitting structural design	Late	Soon
	Duration of structural design	Late	Soon
Architectural design contract	Magnitude		
	Design scale		

	Height	Increasing	Reducing
	Width	Increasing	Reducing
	Designing cost		
	Main architectural design cost	High	Low
	Punished cost of architectural design	High	Low
	Complexity		
	Vagueness in design idea		
	Vagueness about height	Increasing	Reducing
	Vagueness about width	Increasing	Reducing
	Number of alternative design solutions		
	Changing dimension	Many	Little
	Number of perspective	Many	Little
	Submittal time		
	Milestone of submitting architectural design	Late	Soon
	Duration of architectural design	Late	Soon
	Field work	Duration	
Duration to perform work			
Duration of survey		Long	Short
Duration of experimenting		Long	Short
Duration to adjust work			
Duration of adjusting location of survey		Long	Short
Duration of re-experimenting		Long	Short
Quality			
Impact of feasibility work			
Impact of field work on nature		Many	Little
Impact of field work on creating employment opportunities for society		Little	Many
Technique of research and performing work			

	Technique of surveying	Low	High
	Technique of experimenting	Low	High
	Cost		
	Cost to perform work		
	Cost of survey	High	Low
	Cost of experimenting	High	Low
	Cost to adjust work		
	Cost of re-survey	High	Low
	Cost of re-experimenting	High	Low
	Duration		
Duration to perform work			
Duration of preliminary designing	Long	Short	
Number of alternative options	Long	Short	
Duration to adjust work			
Duration of re-designing	Long	Short	
Duration of preliminary calculation	Long	Short	
Quality			
Impact of feasibility work			
Impact of preliminary design on nature	Many	Little	
Impact of preliminary design on creating employment opportunities for society	Little	Many	
Technique of research and performing work			
Technique of designing	Low	High	
Technique in using design software	Low	High	
Cost			
Cost to perform work			
Cost of research of design solution	High	Low	
Cost of designing	High	Low	
Cost to adjust work			

Preliminary design

	Cost of re-research design solution	High	Low
	Cost of re-design	High	Low
Economic research	Duration		
	Duration to perform work		
	Duration of survey economy	Long	Short
	Duration of calculating effective economy	Long	Short
	Duration to adjust work		
	Duration of supplement data	Long	Short
	Duration of re-calculating	Long	Short
	Quality		
	Impact of feasibility work		
	Impact of economic research on nature	Many	Little
	Impact of economic research on creating employment opportunities for society	Little	Many
	Technique of research and performing work		
	Technique of data processing	Low	High
	Technique of using calculation software	Low	High
	Cost		
	Cost to perform work		
	Cost of collecting data	High	Low
	Cost of calculating effective economy	High	Low
	Cost to adjust work		
	Cost of re-surveying data	High	Low
Cost of re-calculating	High	Low	
Detailed design	Duration		
	Duration to perform work		
	Duration of architectural design	Long	Short
	Duration of structural design	Long	Short
	Duration to repair precedent work		

	Duration of adjusting architectural design	Long	Short
	Duration of adjusting structural design	Long	Short
	Quality		
	Impact of implementation work		
	Impact of detailed design on nature	Many	Little
	Impact of detailed design on creating employment opportunities for society	Little	Many
	Technique of work		
	Technique of architectural design	Low	High
	Technique of structural design	Low	High
	Cost		
	Cost to perform work		
	Cost to design architecture	High	Low
	Cost to design structure	High	Low
	Cost to repair precedent work		
	Cost to check data of precedent work	High	Low
Cost to repair error of precedent work	High	Low	
Preparing procedure before construction	Duration		
	Duration to perform work		
	Duration of preparing procedure	Long	Short
	Duration of waiting	Long	Short
	Duration to repair precedent work		
	Duration of check data of procedure	Long	Short
	Duration of repairing error of procedure	Long	Short
	Quality		
	Impact of implementation work		
	Impact of doing procedure on nature	Many	Little
Impact of doing procedure on creating employment opportunities for society	Little	Many	

	Technique of work		
	Technique of preparing work	Low	High
	Technique of solving procedure problem	Low	High
	Cost		
	Cost to perform work		
	Cost of preparing work	High	Low
	Cost of solving procedure problem	High	Low
	Cost to repair precedent work		
	Cost to check data of precedent work	High	Low
	Cost to repairing error of precedent work	High	Low
Construction	Duration		
	Duration to perform work		
	Duration of arranging construction works	Long	Short
	Duration of performing construction work	Long	Short
	Duration to repair precedent work		
	Duration of adjusting order of construction works	Long	Short
	Duration of adjusting a construction work	Long	Short
	Quality		
	Impact of implementation work		
	Impact of construction work on nature	Many	Little
	Impact of construction work on creating employment opportunities for society	Little	Many
	Technique of work		
	Technique of ordering sequence of construction work	Low	High
	Technique of performing construction work	Low	High
	Cost		
	Cost to perform work		
	Cost to arranging construction work	High	Low
	Cost to performing construction work	High	Low

	Cost to repair precedent work		
	Cost to adjust order of construction work	High	Low
	Cost to adjust construction work	High	Low
Operation monitoring	Duration		
	Duration to perform maintain work		
	Duration of installing monitoring equipment	Long	Short
	Period time of checking	Long	Short
	Duration to repair errors		
	Duration of checking error of monitoring	Long	Short
	Duration of re-installing monitoring equipment	Long	Short
	Quality		
	Impact of implementation work		
	Impact of construction monitoring on nature	Many	Little
	Impact of construction monitoring on creating employment opportunities for society	Little	Many
	Technique of repairing error		
	Technique of checking error of monitoring	Low	High
	Technique of replacing monitoring equipment	Low	High
	Cost		
	Cost to maintain		
	Cost of checking error of monitoring	High	Low
Cost of re-installing monitoring equipment	High	Low	
Cost to repair errors			
Cost of repairing error of monitoring	High	Low	
Cost of repairing monitoring equipment	High	Low	
Performance of maintain work	Duration		
	Duration to perform maintain work		
	Duration of reporting failure	Long	Short
	Duration of preparing resource to repair errors	Long	Short

	Duration to repair errors		
	Duration of checking reason of failure	Long	Short
	Duration of repairing failure	Long	Short
	Quality		
	Impact of implementation work		
	Impact of maintain work on nature	Many	Little
	Impact of maintain work on creating employment opportunities for society	Little	Many
	Technique of repairing error		
	Technique of checking reason of failure	Low	High
	Technique of repairing failure	Low	High
	Cost		
	Cost to maintain		
	Cost of reporting failure	High	Low
	Cost of preparing resource to repair errors	High	Low
	Cost to repair errors		
Cost of of checking reason of failure	High	Low	
Cost of repairing failure	High	Low	
Document of site survey	Duration		
	Duration of performing feasibility work		
	Duration to finish survey document	Long	Short
	Duration to have result of experimentation	Long	Short
	Duration of adjusting feasibility work		
	Duration of document about adjusting location of survey	Long	Short
	Duration of document of re-experiencing	Long	Short
	Quality		
Satisfaction of owner about researching and performing feasibility work			

	Satisfaction about result in survey document	Little	Many
	Satisfaction about result of experimentation	Little	Many
	Right regulation about performing feasibility work		
	Right regulation about survey	Wrong	Right
	Right regulation about experimentation	Wrong	Right
	Cost		
	Cost of performing feasibility work		
	Cost to have a survey document	High	Low
	Cost to have a result of experimentation	High	Low
	Cost of adjusting feasibility work		
	Cost to have document about adjusting location of survey	High	Low
	Cost to have document of re-experiencing	High	Low
Preliminary design	Duration		
	Duration of performing feasibility work		
	Duration to have preliminary design	Long	Short
	Duration to have all option of design	Long	Short
	Duration of adjusting feasibility work		
	Duration to have drawing of re-designing	Long	Short
	Report of preliminary calculation	Long	Short
	Quality		
	Satisfaction of owner about researching and performing feasibility work		
	Satisfaction about drawing of preliminary design	Little	Many
	Satisfaction about preliminary calculation	Little	Many
	Right regulation about performing feasibility work		
	Right regulation about standard of drawing	Wrong	Right
	Right regulation about planning	Wrong	Right
	Cost		

	Cost of performing feasibility work		
	Cost to have preliminary design	High	Low
	Cost to have options of design	High	Low
	Cost of adjusting feasibility work		
	Cost to have drawing of re-designing	High	Low
	Cost of preliminary calculation	High	Low
Document of economic efficiency	Duration		
	Duration of performing feasibility work		
	Duration to document about survey economy	Long	Short
	Duration to result of effective economy	Long	Short
	Duration of adjusting feasibility work		
	Duration of document about supplementing data	Long	Short
	Duration to have result of re-calculating	Long	Short
	Quality		
	Satisfaction of owner about researching and performing feasibility work		
	Satisfaction about document of survey economy	Little	Many
	Satisfaction about result of effective economy	Little	Many
	Right regulation about performing feasibility work		
	Right regulation survey	Wrong	Right
	Right regulation about parametre of economy	Wrong	Right
	Cost		
	Cost of performing feasibility work		
	Cost to have data of economic survey	High	Low
	Cost to have document of economic result	High	Low
	Cost of adjusting feasibility work		
	Cost to have document about supplementing data	High	Low
Cost to have result of re-calculating	High	Low	
Detailed design	Duration		

	Duration of performing implementation work		
	Duration to have architectural design	Long	Short
	Duration to have structural design	Long	Short
	Duration of repairing precedent work		
	Duration to have adjusted drawing of architecture	Long	Short
	Duration to have adjusted drawing of structure	Long	Short
	Quality		
	Satisfaction of owner about implementation work		
	Satisfaction about architectural drawing	Little	Many
	Satisfaction about structural drawing	Little	Many
	Right regulation about implementation work		
	Right regulation about architectural drawing	Wrong	Right
	Right regulation about structural drawing	Wrong	Right
	Cost		
	Cost of performing implementation work		
	Cost to have architectural drawing	High	Low
	Cost to have structural drawing	High	Low
	Cost of repairing precedent work		
	Cost to have adjusted drawing of architecture	High	Low
	Cost to have adjusted drawing of structure	High	Low
Procedure document	Duration		
	Duration of performing implementation work		
	Duration of procedure document	Long	Short
	Duration to have licence	Long	Short
	Duration of repairing precedent work		
	Duration to list of data need to be checked	Long	Short
	Duration to have complement document	Long	Short
	Quality		
	Satisfaction of owner about implementation work		

	Satisfaction about procedure document	Little	Many
	Satisfaction about time of received licence	Little	Many
	Right regulation about implementation work		
	Right regulation about procedure document	Wrong	Right
	Right regulation about time of receiving	Wrong	Right
	Cost		
	Cost of performing implementation work		
	Cost to have procedure document	High	Low
	Cost to have licence	High	Low
	Cost of repairing precedent work		
	Cost to have list of data need to be checked	High	Low
	Cost to have complement document	High	Low
Building	Duration		
	Duration of performing implementation work		
	Duration of have plan drawing of all construction works	Long	Short
	Duration to have plan of each construction work	Long	Short
	Duration of repairing precedent work		
	Duration to have adjusted plan drawing of all construction works	Long	Short
	Duration to have adjusted plan of each construction work	Long	Short
	Quality		
	Satisfaction of owner about implementation work		
	Satisfaction about plan of all construction works	Little	Many
	Satisfaction about plan of each construction work	Little	Many
	Right regulation about implementation work		
	Right regulation about planning	Wrong	Right
	Right regulation about impact of construction work	Wrong	Right
	Cost		

	Cost of performing implementation work		
	Cost to have plan drawing of all construction works	High	Low
	Cost to have plan of each construction work	High	Low
	Cost of repairing precedent work		
	Cost to have adjusted plan drawing of all construction works	High	Low
	Cost to have adjusted plan of each construction work	High	Low
Document of operation monitoring	Duration		
	Duration of performing maintenance		
	Duration to have report about installing monitoring equipment	Long	Short
	Period report of checking	Long	Short
	Duration of repairing errors		
	Duration to have report about error of monitoring	Long	Short
	Duration to have report about re-installing monitoring equipment	Long	Short
	Quality		
	Satisfaction of owner about maintenance process		
	Satisfaction about process of installing monitoring equipment	Little	Many
	Satisfaction about period report of checking	Little	Many
	Right regulation about maintenance		
	Right regulation about process of installing monitoring equipment	Wrong	Right
	Right regulation about period report of checking	Wrong	Right
	Cost		
	Cost of maintaining		
Cost to have report about installing monitoring equipment	High	Low	

	Cost to have period report of checking	High	Low
	Cost of repairing errors		
	Cost to have report about error of monitoring	High	Low
	Cost to have report about re-installing monitoring equipment	High	Low
Document of performing maintain work	Duration		
	Duration of performing maintenance		
	Duration to have report about failure	Long	Short
	Duration to have report about resource repair error	Long	Short
	Duration of repairing errors		
	Duration to have report about reason of failure	Long	Short
	Duration to have document about repairing failure	Long	Short
	Quality		
	Satisfaction of owner about maintenance process		
	Satisfaction about report of failure	Little	Many
	Satisfaction about process of repairing failure	Little	Many
	Right regulation about maintenance		
	Right regulation about reporting failure	Wrong	Right
	Right regulation about process of repairing failure	Wrong	Right
	Cost		
	Cost of maintaining		
	Document of cost for reporting failure	High	Low
	Document of cost for preparing resource to repair failure	High	Low
	Cost of repairing errors		
	Cost to have report about reason of failure	High	Low
Cost to have document about repairing failure	High	Low	

Appendix 10. List of instances in level 1 of project 2BS.

No	Entity in level 0	Entity level 1	Intances
1	<i>Environment</i>	<i>Economy</i>	Economy of project 2BS
2		<i>Administration</i>	Administration of project 2BS
3		<i>Climate</i>	Climate of project 2BS
4	<i>Actors</i>	<i>Owner</i>	Owner of project 2BS
5		<i>Designer</i>	Road and bridge designer project 2BS
6		<i>Contractor</i>	Road contractor project 2BS
7			Bridge contractor project 2BS
8			Light contractor project 2BS
9	<i>Supplier</i>	Material supplier project 2BS	
10	<i>Resources</i>	<i>Machine</i>	Machine of owner project 2BS
11			Machine of designer project 2BS
12			Machine of contractor project 2BS
13		<i>Human resource</i>	Human of owner project 2BS
14			Human of designer project 2BS
15			Human of contractor project 2BS
16		<i>Material</i>	Material for implementation phase project 2BS
17			Material for operation phase project 2BS
18		<i>Contract</i>	<i>Building contract</i>
19	Bridge building contract project 2BS		
20	Installing light system contract project 2BS		
21	<i>Supply contract</i>		Material supply contract of road contractor project 2BS
22			Material supply contract of bridge

			contractor project 2BS	
23		<i>Design contract</i>	Road and bridge design contract project 2BS	
24	<i>Activities</i>	<i>Activites of feasibility phase</i>	Fieldwork project 2BS	
25			Preliminary design project 2BS	
26			Economic research project 2BS	
27		<i>Activities of implementaion phase</i>	Detailed design project 2BS	
28			Preparing procedure before construction project 2BS	
29			Construction project 2BS	
30		<i>Activities of operation phase</i>	Construction monitoring project 2BS	
31			Reparing errors project 2BS	
32		<i>Products</i>	<i>Products of feasibility phase - survey document</i>	Document of site survey project 2BS
33				Preliminary design project 2BS
34				Document of economic efficiency project 2BS
35	<i>Products of implementation phase - Building</i>		Detailed design project 2BS	
36			Regulation document project 2BS	
37			Building project 2BS	
38	<i>Product of operation phase - report of maintenance process</i>		Document of maintenance project 2BS	
39			Document of maintained error project 2BS	

Appendix 11. List of instances in level 2 of project 2BS

No	Entity level 2	Instances
1	<i>National economic</i>	National economic project 2BS
2	<i>International economic</i>	International economic project 2BS
3	<i>Ministry</i>	Ministry relates to project 2BS

4	<i>Department</i>	Department relates to project 2BS
5	<i>Temperature</i>	Temperature relates to project 2BS
6	<i>Precipitation</i>	Precipitation relates to project 2BS
7	<i>Owner</i>	UITC
8	<i>Structural designer</i>	CDT
9	<i>Architectural designer</i>	CDT
10	<i>Building contractor</i>	MRCC
11		R1
12	<i>Installing contractor</i>	TN
13	<i>Material supplier</i>	LT
14		UN
15		AA
16		TV
17	<i>Construction machine</i>	Construction machine of UITC
18		Construction machine of MRCC
19		Construction machine of R1
20		Construction machine of TN
21	<i>Office machines</i>	Office machine of UITC
22		Office machine of MRCC
23		Office machine of R1
24		Office machine of TN
25		Office machine of CDT
26	<i>Worker</i>	Worker of UITC
27		Worker of MRCC
28		Worker of R1
29		Worker of TN
30	<i>Engineer</i>	Engineer of UITC
31		Engineer of MRCC
32		Engineer of R1

33		Engineer of TN
34		Engineer of CDT
35	<i>Office staff</i>	Office staff of UITC
36		Office staff of MRCC
37		Office staff of R1
38		Office staff of TN
39		Office staff of CDT
40		<i>Reusable material</i>
41	Reusable material for building road surface	
42	Reusable material for building traffic safety	
43	Reusable material for building roadside	
44	Reusable material for building culverts	
45	Reusable material for building water sumps	
46	Reusable material for building vertical drains	
47	Reusable material for building bridge Lich Doi	
48	Reusable material for installing lighting system	
49	<i>Consumable material</i>	Consumable material for building roadbed
50		Consumable material for building road surface
51		Consumable material for building traffic safety
52		Consumable material for building roadside
53		Consumable material for building culverts
54		Consumable material for building water sumps
55		Consumable material for building vertical drains
56		Consumable material for building bridge Lich Doi
57		Consumable material for installing lighting system
58	<i>Main building contract</i>	UITC-MRCC
59		UITC-R1
60	<i>Installing contract</i>	UITC-TN
61	<i>Material supply contract</i>	MRCC-LT

62		MRCC-UN
63		MRCC-AA
64		MRCC-TV
65		R1-LT
66		R1-UN
67		R1-AA
68		R1-TV
69		TN-LT
70		TN-UN
71		TN-AA
72		TN-TV
73	<i>Structural design contract</i>	UITC-CDT
74	<i>Architectural design contract</i>	UITC-CDT
75	<i>Field work</i>	Exploration
76		Site survey
77	<i>Preliminary design</i>	Preliminary design
78	<i>Economic research</i>	Economic research
79	<i>Detailed design</i>	Detailed design
80	<i>Preparing procedure before construction</i>	Licence of investment
81		Licence of constructing
82		Compensation
83		Bidding
84		Signing contract
85		Preparing for constructing
86	<i>Construction</i>	Building roadbed
87		Building road surface
88		Building traffic safety
89		Building roadside
90		Building and installing culverts

91		Building and installing water sumps
92		Building and installing vertical drains
93		Destroying old bridge Lich Doi
94		Building bridge Lich Doi
95		Installing lighting system
96	<i>Operation monitoring</i>	Monitoring operation of road and bridge
97	<i>Performance of maintain work</i>	Repairing errors of road and bridge
98		Completion of maintenance
99	<i>Document of site survey</i>	Report of exploration project 2BS
100		Report of survey project 2BS
101	<i>Preliminary design</i>	Preliminary design project 2BS
102	<i>Document of economic efficiency</i>	Document of economic efficiency project 2BS
103	<i>Detailed design</i>	Detailed design of project 2BS
104	<i>Procedure document</i>	Licence of investment of project 2BS
105		Licence of constructing of project 2BS
106		Empty site of project 2BS
107		Choosing contractor
108		Agreement of contract
109		Site of construction project 2BS
110		<i>Building</i>
111	Road surface	
112	Traffic safety	
113	Roadside	
114	System of culvert	
115	Water sumps	
116	Vertical drains	
117	Clear site of bridge Lich Doi	
118	Bridge Lich Doi	

119		Lighting system
120	<i>Document of operation monitoring</i>	Document of monitoring operation
121	<i>Document of performing maintain work</i>	Document of errors
122		Handling project 2BS

Appendix 12. List of instances in level 1 of project NTI

Entity in level 0	Entity level 1	Intances
<i>Environment</i>	Economy	Economy of project NTI
	Administration	Administration of project NTI
	Climate	Climate of project NTI
<i>Actors</i>	Owner	Owner of project NTI
	Designer	Structural designer of project NTI
		Architectural designer of project NTI
	Contractor	Building contractor project NTI
		Installing contractor project NTI
Supplier	Material supplier project NTI	
<i>Resources</i>	Machine	Machine of owner project NTI
		Machine of designer project NTI
		Machine of contractor project NTI
	Human resource	Human of owner project NTI
		Human of designer project NTI
		Human of contractor project NTI
	Material	Material for implementation phase project NTI
<i>Contract</i>	Building contract	Building contract project NTI
		Installing contract project NTI
	Supply contract	Material supply contract of building NTI
	Design contract	Architectural design contract project NTI
		Structural design contract project NTI

<i>Activities</i>	Activites of feasibility phase	Fieldwork project NTI
		Preliminary design project NTI
		Economic research project NTI
	Activities of implementaion phase	Detailed design project NTI
		Preparing procedure before construction project NTI
		Construction project NTI
<i>Products</i>	Products of feasibility phase - survey document	Document of site survey project NTI
		Preliminary design project NTI
		Document of economic efficiency project NTI
	Products of implementation phase - Building	Detailed design project NTI
		Regulation document project NTI
		Building project NTI

Appendix 13. List of instances in level 2 of project NTI

Entity level 2	Instances
<i>National economic</i>	National economic project NTI
<i>International economic</i>	International economic project NTI
<i>Ministry</i>	Ministry relates to project NTI
<i>Department</i>	Department relates to project NTI
<i>Temperature</i>	Temperature relates to project NTI
<i>Precipitation</i>	Precipitation relates to project NTI
<i>Owner</i>	NE
<i>Structural designer</i>	BT
<i>Architectural designer</i>	DC
<i>Building contractor</i>	CP
<i>Installing contractor</i>	CS
<i>Material supplier</i>	MS1
	MS2
	MS3

<i>Contruaction machine</i>	Contruaction machine of CP
	Contruaction machine of CS
<i>Office machines</i>	Office machine of CHR
	Office machine of BT
	Office machine of DC
<i>Worker</i>	Worker team of CP
	Worker team of CS
<i>Engineer</i>	Engineer of BT
	Engineer of DC
	Engineer of CP
	Engineer of CS
<i>Office staff</i>	Office staff of CHR
	Office staff of BT
	Office staff of DC
	Office staff of CP
	Office staff of CS
	Office staff of MS1
	Office staff of MS2
	Office staff of MS3
<i>Reusable material</i>	Reusable material for work site installation
	Reusable material for foundation work
	Reusable material for structure work
	Reusable material for equipment work
<i>Consumable material</i>	Consumable material for work site installation
	Consumable material for foundation work
	Consumable material for structure work
	Consumable material for equipment work
<i>Main building contract</i>	CHR - CP
	CHR - CS

<i>Installing contract</i>	CHR - CS
<i>Material supply contract</i>	MS1 - CP
	MS2 - CP
	MS3 - CS
<i>Structural design contract</i>	CHR - BT
<i>Architectural design contract</i>	CHR - DC
<i>Field work</i>	Pre-studies
<i>Preliminary design</i>	Pre-design
<i>Economic research</i>	Economic study
<i>Detailed design</i>	Detailed design
<i>Preparing procedure before construction</i>	Procedure before works
<i>Construction</i>	Prepare works
	Soil and foundation works
	Structural works
	Equipment works
	Finalising construction
<i>Document of site survey</i>	Document of site survey
<i>Preliminary design</i>	Preliminary design project NTI
<i>Document of economic efficiency</i>	Document of economic efficiency project NTI
<i>Detailed design</i>	Detailed design of project NTI
<i>Procedure document</i>	Procedure document of project NTI
<i>Building</i>	Site prepared
	Foundation
	Structure
	Equipment
	Finished building

Appendix 14. Specific instances' relations in level 0 project 2BS

Number of entity's relation	Source	Instances of source	Target	Instance of target	Figure of instance's relation
1	Environment	<i>Environment of project 2BS</i>	Contract	<i>owner-contractor,</i> <i>owner-designer,</i> <i>contractor-supplier</i>	
2	Environment	<i>Environment of project 2BS</i>	Actor	<i>owner,</i> <i>contractor,</i> <i>supplier,</i> <i>designer</i>	
3	Environment	<i>Environment of project 2BS</i>	Resource	<i>resource of owner,</i> <i>resource of contractor,</i> <i>resource of supplier,</i> <i>resource of designer</i>	
4	Contract	<i>owner-contractor,</i> <i>owner-designer,</i> <i>contractor-supplier</i>	Actor	<i>owner,</i> <i>contractor,</i> <i>supplier,</i> <i>designer</i>	
5	Actor	<i>owner,</i> <i>contractor,</i> <i>supplier,</i> <i>designer</i>	Contract	<i>owner-contractor,</i> <i>owner-designer,</i> <i>contractor-supplier</i>	
6	Actor	<i>owner,</i> <i>contractor,</i>	Resource	<i>resource of owner,</i> <i>resource of contractor,</i>	

Number of entity's relation	Source	Instances of source <i>supplier,</i>	Target	Instance of target <i>resource of supplier,</i>	Figure of instance's relation
7	Actor	<i>owner,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>contractor,</i>		<i>activities in implementation phase,</i>	
		<i>supplier,</i>		<i>activities in operation phase</i>	
		<i>designer</i>			
8	Actor	<i>owner,</i>	Actor	<i>owner,</i>	
		<i>contractor,</i>		<i>contractor,</i>	
		<i>supplier,</i>		<i>supplier,</i>	
		<i>designer</i>		<i>designer</i>	
9	Resource	<i>resource of owner,</i>	Actor	<i>owner,</i>	
		<i>resource of contractor,</i>		<i>contractor,</i>	
		<i>resource of supplier,</i>		<i>supplier,</i>	
		<i>resource of designer</i>		<i>designer</i>	
10	Resource	<i>resource of owner,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>resource of contractor,</i>		<i>activities in implementation phase,</i>	
		<i>resource of supplier,</i>		<i>activities in operation phase</i>	
		<i>resource of designer</i>			
11	Activity	<i>activities in feasibility phase,</i>	Product	<i>survey document,</i>	

Number of entity's relation	Source	Instances of source <i>activities in implementation phase,</i>	Target	Instance of target <i>building,</i>	Figure of instance's relation
		<i>activities in operation phase</i>		<i>report of maintenance process</i>	
12	Activity	<i>activities in feasibility phase,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>activities in implementation phase,</i>		<i>activities in implementation phase,</i>	
		<i>activities in operation phase</i>		<i>activities in operation phase</i>	
13	Product	<i>survey document,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>building,</i>		<i>activities in implementation phase,</i>	
		<i>report of maintenance process</i>		<i>activities in operation phase</i>	

Appendix 15. Specific instances' relations in level 1 project 2BS

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
1	<i>Environment</i>	<i>Economy</i>	<i>Economy relates to project 2BS</i>	<i>Contract</i>	<i>Building contract</i>	<i>Road building contract</i>	
						<i>Bridge building contract</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						<i>Installing light system contract</i>	
2					<i>Design contract</i>	<i>Road and bridge design contract</i>	
3					<i>Supply contract</i>	<i>Material supply contract of road contractor</i>	
						<i>Material supply contract of bridge contractor</i>	
		<i>Administration</i>	<i>Administration relates to project 2BS</i>				
4		<i>Climate</i>	<i>Climate around project 2BS</i>		<i>Building contract</i>	<i>Road building contract</i>	
						<i>Bridge building contract</i>	
						<i>Installing light system contract</i>	
5					<i>Design contract</i>	<i>Road and bridge design contract</i>	
6					<i>Supply contract</i>	<i>Material supply contract of road contractor</i>	
					<i>Material supply contract of bridge contractor</i>		
7	<i>Environment</i>	<i>Economy</i>	<i>Economy relates to project 2BS</i>	<i>Actor</i>	<i>Owner</i>	<i>Owner of project 2BS</i>	
8		<i>Administration</i>	<i>Administration relates to project 2BS</i>		<i>Owner</i>	<i>Owner of project 2BS</i>	
9		<i>Climate</i>	<i>Climate around project 2BS</i>		<i>Owner</i>	<i>Owner of project 2BS</i>	
10					<i>Contractor</i>	<i>Road contractor of</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
						<i>project 2BS</i>		
						<i>Bridge contractor of project 2BS</i>		
						<i>Light contractor of project 2BS</i>		
11				<i>Designer</i>		<i>Road and bridge designer</i>		
12								
				<i>Supplier</i>		<i>Material supplier</i>		
13	<i>Environment</i>	<i>Economy</i>	<i>Economy relates to project 2BS</i>	<i>Resource</i>	<i>Human</i>	<i>Human of owner</i>		
								<i>Human of designer</i>
								<i>Human of contractor</i>
14						<i>Machine</i>		<i>Machine of owner</i>
								<i>Machine of designer</i>
								<i>Machine of contractor</i>
15						<i>Material</i>		<i>Material for implementation phase of project 2BS</i>
								<i>Material for operation phase of project 2BS</i>
		<i>Administration</i>	<i>Administration relates to project 2BS</i>					

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation		
16		Climate	Climate around project 2BS		Human	Human of owner	Figure of instance's relation		
								Human of designer	
								Human of contractor	
17						Machine		Machine of owner	
								Machine of designer	
								Machine of contractor	
18					Material	Material for implementation phase of project 2BS			
							Material for operation phase of project 2BS		
19	Contract	Building contract	Road building contract	Actor	Contractor	Road contractor of project 2BS			
			Bridge building contract					Bridge contractor of project 2BS	
			Installing light system contract					Light contractor of project 2BS	
20			Design contract		Road and bridge design contract			Designer	Road and bridge designer
21			Supply contract		Material supply contract of road contractor			Supplier	Material supplier
					Material supply contract of bridge contractor				
22	Actor	Owner	Owner of project 2BS	Contract	Building contract	Road building contract			

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
						<i>Bridge building contract</i>		
						<i>Installing light system contract</i>		
23					<i>Design contract</i>	<i>Road and bridge design contract</i>		
24		<i>Contractor</i>	<i>Road contractor of project 2BS</i>		<i>Supply contract</i>	<i>Material supply contract of road contractor</i>		
			<i>Bridge contractor of project 2BS</i>			<i>Material supply contract of bridge contractor</i>		
			<i>Light contractor of project 2BS</i>					
25	<i>Actor</i>	<i>Owner</i>	<i>Owner of project 2BS</i>	<i>Resource</i>	<i>Human</i>	<i>Human of owner</i>		
26					<i>Machine</i>	<i>Machine of owner</i>		
27		<i>Contractor</i>	<i>Road contractor of project 2BS</i>		<i>Human</i>	<i>Human of contractor</i>		
28					<i>Machine</i>	<i>Machine of contractor</i>		
29					<i>Material</i>	<i>Material for implementation phase of project 2BS</i>		
						<i>Material for operation phase of project 2BS</i>		
30			<i>Bridge contractor of project 2BS</i>			<i>Human</i>		<i>Human of contractor</i>
31						<i>Machine</i>		<i>Machine of contractor</i>

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
32					<i>Material</i>	<i>Material for implementation phase of project 2BS</i>	Figure of instance's relation
						<i>Material for operation phase of project 2BS</i>	
33			<i>Light contractor of project 2BS</i>		<i>Human</i>	<i>Human of contractor</i>	
34					<i>Machine</i>	<i>Machine of contractor</i>	
35		<i>Designer</i>	<i>Road and bridge designer</i>		<i>Human</i>	<i>Human of designer</i>	
						<i>Machine of designer</i>	
36		<i>Supplier</i>	<i>Material supplier</i>		<i>Material</i>	<i>Material for implementation phase of project 2BS</i>	
						<i>Material for operation phase of project 2BS</i>	
37	<i>Actor</i>	<i>Owner</i>	<i>Owner of project 2BS</i>	<i>Activity</i>	<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	
						<i>Preliminary design</i>	
						<i>Economic research</i>	
38					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
39						<i>Activity in operation phase</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						Repairing errors	<p>The diagram illustrates the relationships between various roles and activities. Roles (Source Level 1) include: Owner of project 2BS, Road contractor of project 2BS, Bridge contractor of project 2BS, Light contractor of project 2BS, Road and bridge designer, and Material supplier. Activities (Target Level 1) include: Fieldwork, Preliminary design, Economic research, Detailed design, Preparing procedure before construction, Construction, Construction monitoring, and Repairing errors. Arrows indicate the following relationships: Owner of project 2BS to Fieldwork, Preliminary design, and Economic research; Road contractor of project 2BS to Preliminary design, Detailed design, Preparing procedure before construction, and Construction; Bridge contractor of project 2BS to Preliminary design, Detailed design, Preparing procedure before construction, and Construction; Light contractor of project 2BS to Detailed design, Preparing procedure before construction, and Construction; Road and bridge designer to Detailed design, Preparing procedure before construction, and Construction; Material supplier to Repairing errors.</p>
40		Contractor	Road contractor of project 2BS	Activity in implementation phase	Detailed design		
					Preparing procedure before construction		
					Construction		
41				Activity in operation phase	Construction monitoring		
					Repairing errors		
42			Bridge contractor of project 2BS	Activity in implementation phase	Detailed design		
					Preparing procedure before construction		
					Construction		
43				Activity in operation phase	Construction monitoring		
					Repairing errors		
44			Light contractor of project 2BS	Activity in implementation phase	Detailed design		
					Preparing procedure before construction		
					Construction		
45				Activity in operation phase	Construction monitoring		

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						Reparing errors	
46		Designer	Road and bridge designer		Activity in feasibility phase	Fieldwork	
						Preliminary design	
						Economic research	
47					Activity in implementation phase	Detailed design	
						Preparing procedure before construction	
						Construction	
48		Supplier	Material supplier		Activity in implementation phase	Detailed design	
						Preparing procedure before construction	
						Construction	
49					Activity in operation phase	Construction monitoring	
						Reparing errors	
50		Supplier	Material supplier		Contractor	Road contractor of project 2BS	
						Bridge contractor of project 2BS	
	Actor			Actor		Light contractor of project 2BS	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
51 52 53 54 55	Resource	Human	<i>Human of owner</i>	Actor	Owner	<i>Owner of project 2BS</i>	
		<i>Human of contractor</i>	Contractor		<i>Road contractor of project 2BS</i>		
					<i>Bridge contractor of project 2BS</i>		
					<i>Light contractor of project 2BS</i>		
		<i>Human of designer</i>	Designer		<i>Road and bridge designer</i>		
		Machine	Owner		<i>Owner of project 2BS</i>		
			Contractor		<i>Road contractor of project 2BS</i>		
					<i>Bridge contractor of project 2BS</i>		
					<i>Light contractor of project 2BS</i>		
			Designer		<i>Road and bridge designer</i>		

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
56		<i>Material</i>	<i>Material for implementation phase of project 2BS</i>		<i>Contractor</i>	<i>Road contractor of project 2BS</i>		
						<i>Bridge contractor of project 2BS</i>		
						<i>Light contractor of project 2BS</i>		
57					<i>Supplier</i>	<i>Material supplier</i>		
58			<i>Material for operation phase of project 2BS</i>			<i>Contractor</i>		<i>Road contractor of project 2BS</i>
								<i>Bridge contractor of project 2BS</i>
					<i>Light contractor of project 2BS</i>			
59						<i>Supplier</i>		<i>Material supplier</i>
60		<i>Resource</i>	<i>Human</i>		<i>Human of owner</i>	<i>Activity</i>		<i>Activity in feasibility phase</i>
				<i>Preliminary design</i>				
				<i>Economic research</i>				
61				<i>Activity in implementation phase</i>	<i>Detailed design</i>			
					<i>Preparing procedure before construction</i>			
					<i>Construction</i>			
62					<i>Activity in operation phase</i>		<i>Construction monitoring</i>	
							<i>Reparing errors</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
63			<i>Human of designer</i>		<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	<p>Figure of instance's relation</p>
						<i>Preliminary design</i>	
						<i>Economic research</i>	
64					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
65			<i>Human of contractor</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
66					<i>Activity in operation phase</i>	<i>Construction monitoring</i>	
						<i>Repairing errors</i>	
67		<i>Machine</i>	<i>Machine of owner</i>		<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	
						<i>Preliminary design</i>	
						<i>Economic research</i>	
68					<i>Activity in implementation phase</i>	<i>Detailed design</i>	

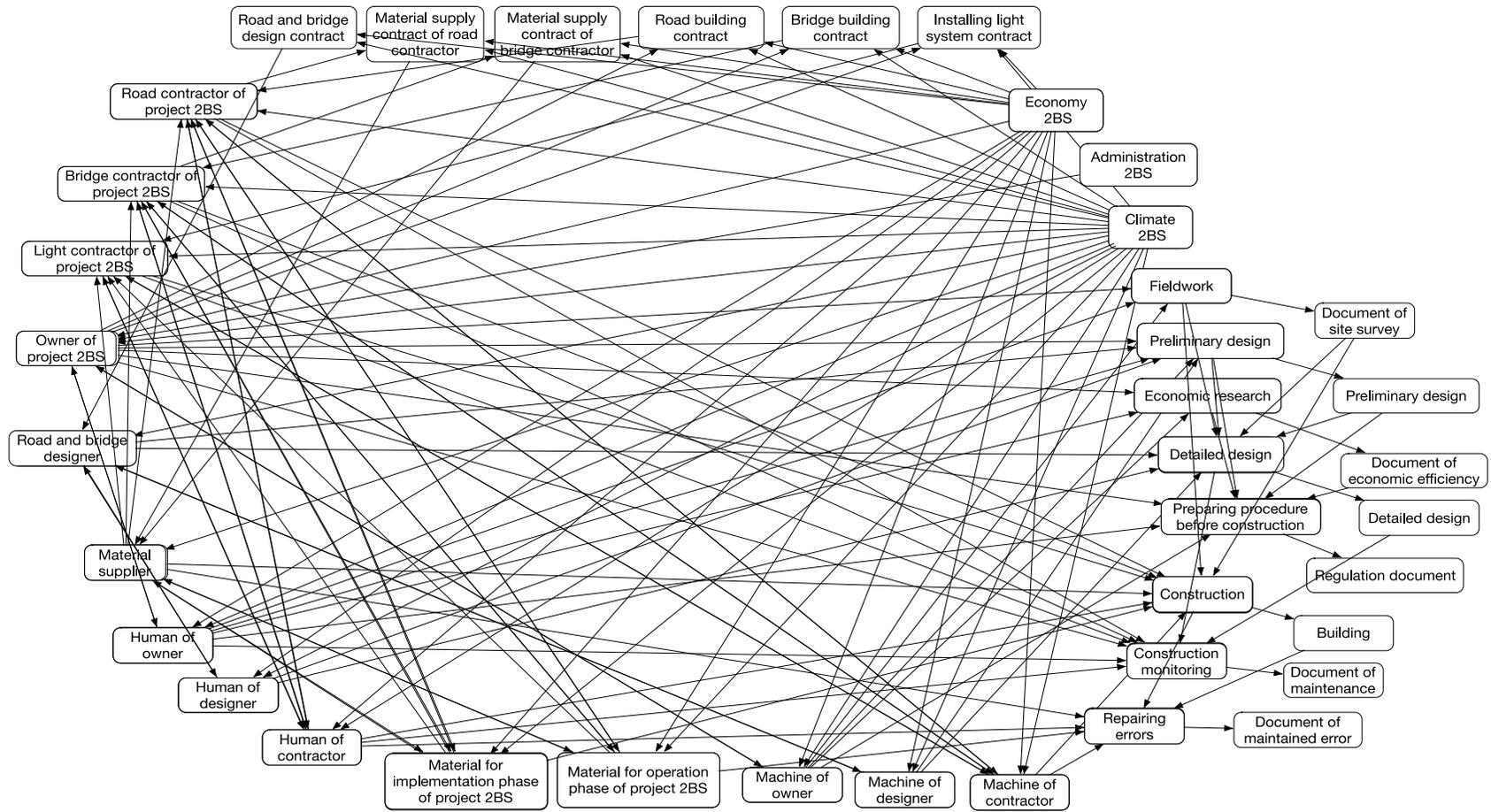
Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						<i>Preparing procedure before construction</i>	Figure of instance's relation
						<i>Construction</i>	
69					<i>Activity in operation phase</i>	<i>Construction monitoring</i>	
						<i>Repairing errors</i>	
70			<i>Machine of designer</i>		<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	
						<i>Preliminary design</i>	
						<i>Economic research</i>	
71					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
72			<i>Machine of contractor</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
73					<i>Activity in operation phase</i>	<i>Construction monitoring</i>	
						<i>Repairing errors</i>	
74		<i>Material</i>	<i>Material for implementation</i>		<i>Activity in implementation</i>	<i>Detailed design</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
			<i>phase of project 2BS</i>		<i>phase</i>			
						<i>Preparing procedure before construction</i>		
						<i>Construction</i>		
75			<i>Material for operation phase of project 2BS</i>		<i>Activity in operation phase</i>	<i>Construction monitoring</i>		
						<i>Repairing errors</i>		
76	Activity	<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	Product	<i>Product of feasibility phase</i>	<i>Document of site survey</i>		
			<i>Preliminary design</i>			<i>Preliminary design</i>		
					<i>Economic research</i>			<i>Document of economic efficiency</i>
77		<i>Activity in implementation phase</i>	<i>Detailed design</i>			<i>Product of implementation phase</i>		<i>Detailed design</i>
			<i>Preparing procedure before construction</i>					<i>Regulation document</i>
					<i>Construction</i>			<i>Building</i>
78		<i>Activity in operation phase</i>	<i>Construction monitoring</i>			<i>Product of operation phase</i>		<i>Document of maintenance</i>
			<i>Repairing errors</i>		<i>Document of maintained error</i>			
79	Activity	<i>Activity in feasibility</i>	<i>Fieldwork</i>	Activity	<i>Activity in implementation</i>	<i>Detailed design</i>		

Number of entity's relation Level 1	Source Level 0	Source Level 1 phase	Instances of source in Level 1	Target Level 0	Target Level 1 phase	Instance of target in Level 1	Figure of instance's relation
80			Preliminary design			Preparing procedure before construction	
			Economic research			Construction	
		Activity in implementation phase	Detailed design		Activity in operation phase	Construction monitoring	
			Preparing procedure before construction			Repairing errors	
			Construction				
		Activity in operation phase	Construction monitoring				
			Repairing errors				
81	Product	Product of feasibility phase	Document of site survey	Activity	Activity in implementation phase	Detailed design	
						Preparing procedure before construction	
			Preliminary design			Construction	
82		Product of implementation phase	Detailed design		Activity in operation phase	Construction monitoring	
			Regulation document			Repairing errors	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
			<i>Building</i>				

Appendix 16. Total relation of instance in Level 1



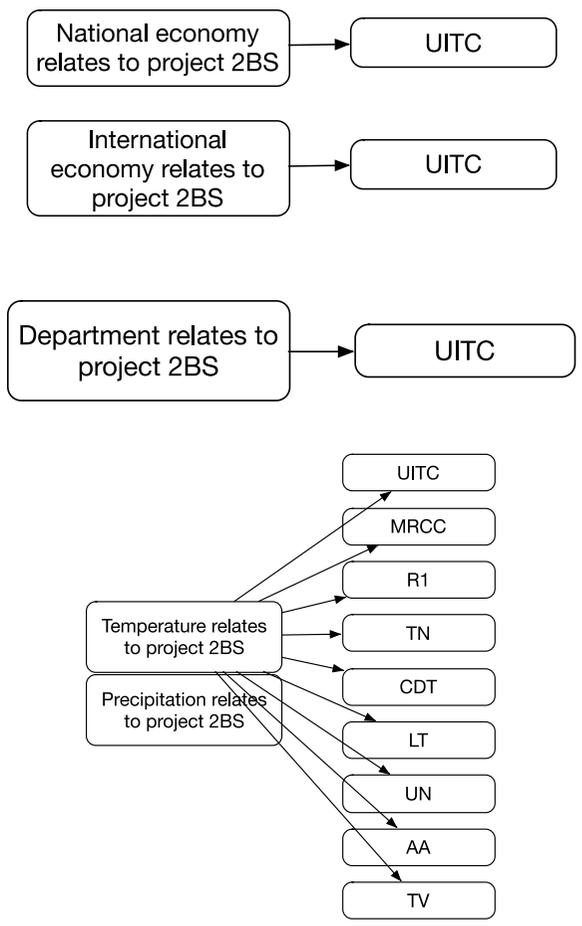
Appendix 17. Specific instances' relations in level 2 project 2BS

Source Level 1	Source Level 2	Instances of source in Level 2	Target Level 1	Target Level 2	Instance of target in Level 2	Figure of instance's relation
<i>Economy</i>	<i>National economy</i>	<i>National economy relates to project 2BS</i>	<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>	
					<i>UITC - RI</i>	
				<i>Installing contract</i>	<i>UITC - TN</i>	
			<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>	
				<i>Architectural design</i>	<i>UITC - CDT</i>	
			<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>	
					<i>MRCC - UN (sand)</i>	
					<i>MRCC - AA (rock)</i>	
					<i>MRCC - TV (steel)</i>	
					<i>R1 - LT (cement)</i>	
					<i>R1 - UN (sand)</i>	
					<i>R1 - AA (rock)</i>	
					<i>R1 - TV (steel)</i>	
					<i>TN - LT (cement)</i>	
					<i>TN - UN (sand)</i>	
					<i>TN - AA (rock)</i>	
					<i>TN - TV (steel)</i>	

	<i>International economy</i>	<i>International economy relates to project 2BS</i>	<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>
					<i>UITC - RI</i>
				<i>Installing contract</i>	<i>UITC - TN</i>
			<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>
				<i>Architectural design</i>	<i>UITC - CDT</i>
			<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>
					<i>MRCC - UN (sand)</i>
					<i>MRCC - AA (rock)</i>
					<i>MRCC - TV (steel)</i>
					<i>RI - LT (cement)</i>
					<i>RI - UN (sand)</i>
					<i>RI - AA (rock)</i>
					<i>RI - TV (steel)</i>
					<i>TN - LT (cement)</i>
					<i>TN - UN (sand)</i>
					<i>TN - AA (rock)</i>
					<i>TN - TV (steel)</i>
<i>Climate</i>	<i>Temperature</i>	<i>Temperature relates to project 2BS</i>	<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>
					<i>UITC - RI</i>
				<i>Installing contract</i>	<i>UITC - TN</i>
			<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>
				<i>Architectural design</i>	<i>UITC - CDT</i>

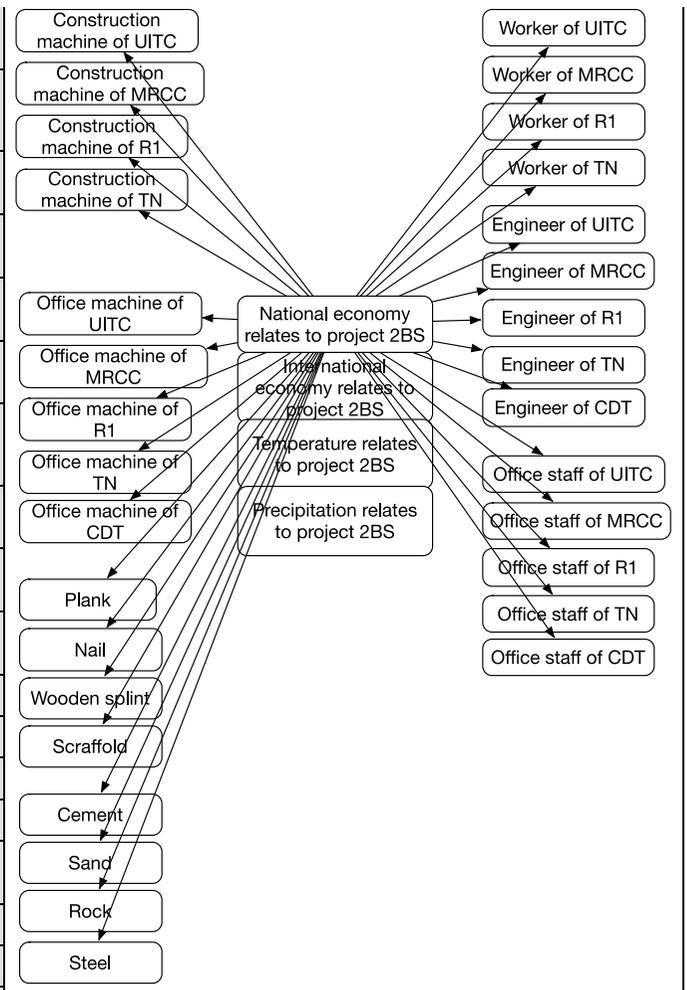
			<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>
					<i>MRCC - UN (sand)</i>
					<i>MRCC - AA (rock)</i>
					<i>MRCC - TV (steel)</i>
					<i>RI - LT (cement)</i>
					<i>RI - UN (sand)</i>
					<i>RI - AA (rock)</i>
					<i>RI - TV (steel)</i>
					<i>TN - LT (cement)</i>
					<i>TN - UN (sand)</i>
					<i>TN - AA (rock)</i>
					<i>TN - TV (steel)</i>
	<i>Precipitation</i>	<i>relates to project 2BS</i>	<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>
					<i>UITC - RI</i>
				<i>Installing contract</i>	<i>UITC - TN</i>
			<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>
				<i>Architectural design</i>	<i>UITC - CDT</i>
			<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>
					<i>MRCC - UN (sand)</i>
					<i>MRCC - AA (rock)</i>
					<i>MRCC - TV (steel)</i>
					<i>RI - LT (cement)</i>
					<i>RI - UN (sand)</i>
					<i>RI - AA (rock)</i>

					<i>RI - TV (steel)</i>
					<i>TN - LT (cement)</i>
					<i>TN - UN (sand)</i>
					<i>TN - AA (rock)</i>
					<i>TN - TV (steel)</i>
<i>Economy</i>	<i>National economy</i>	<i>National economy relates to project 2BS</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
	<i>International economy</i>	<i>International economy relates to project 2BS</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
<i>Administration</i>	<i>Ministry</i>		<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
	<i>Department</i>	<i>Department relates to project 2BS</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
<i>Climate</i>	<i>Temperature</i>	<i>Temperature relates to project 2BS</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
			<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
					<i>RI</i>
				<i>Installing contractor</i>	<i>TN</i>
			<i>Designer</i>	<i>Structural designer</i>	<i>CDT</i>
				<i>Architectural designer</i>	<i>CDT</i>
			<i>Supplier</i>	<i>Material supplier</i>	<i>LT (cement)</i>
					<i>UN (sand)</i>
					<i>AA (rock)</i>
					<i>TV (steel)</i>



	<i>Precipitation</i>	<i>Precipitation relates to project 2BS</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
			<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
					<i>R1</i>
				<i>Installing contractor</i>	<i>TN</i>
			<i>Designer</i>	<i>Structural designer</i>	<i>CDT</i>
				<i>Architectural designer</i>	<i>CDT</i>
			<i>Supplier</i>	<i>Material supplier</i>	<i>LT (cement)</i>
					<i>UN (sand)</i>
					<i>AA (rock)</i>
					<i>TV (steel)</i>
<i>Economy</i>	<i>National economy</i>	<i>National economy relates to project 2BS</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>

			<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
				<i>Office machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
			<i>Material</i>	<i>Reusable material</i>	<i>Plank</i>
					<i>Nail</i>
					<i>Wooden splint</i>
					<i>Scraffold</i>
				<i>Consumable material</i>	<i>Cement</i>
					<i>Sand</i>
					<i>Rock</i>
					<i>Steel</i>
	<i>International economy</i>	<i>International economy relates to project 2BS</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>



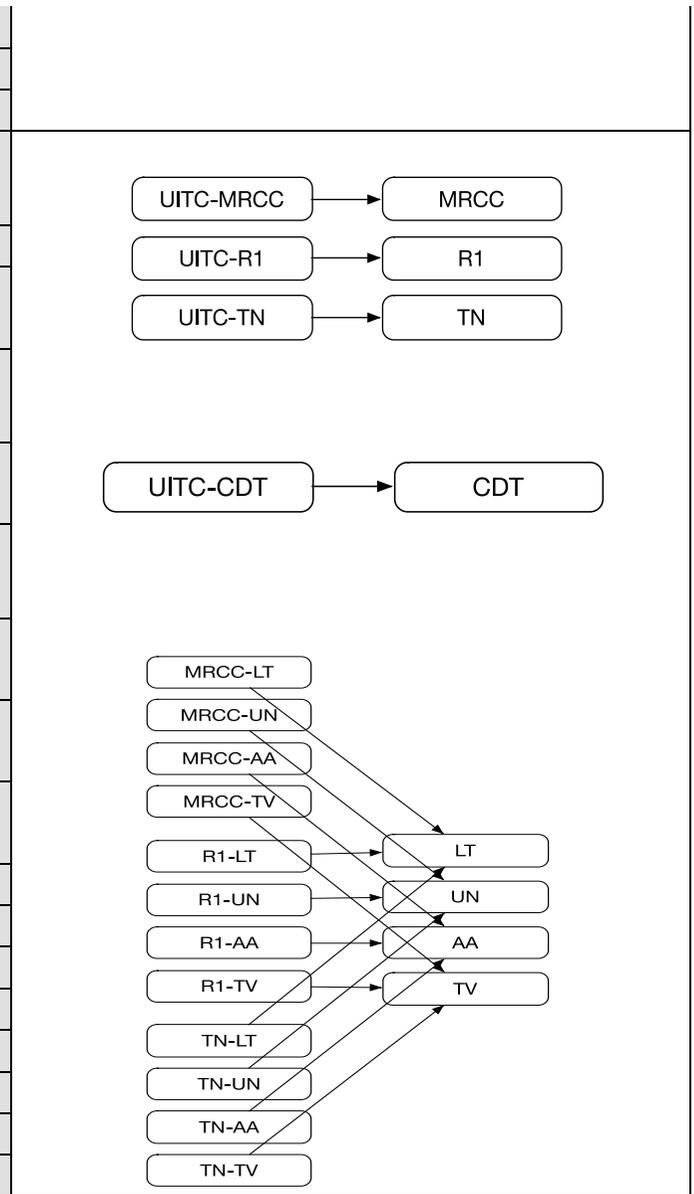
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>
			<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
				<i>Office machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
			<i>Material</i>	<i>Reusable material</i>	<i>Plank</i>

					<i>Nail</i>
					<i>Wooden splint</i>
					<i>Scraffield</i>
				<i>Consumable material</i>	<i>Cement</i>
					<i>Sand</i>
					<i>Rock</i>
					<i>Steel</i>
<i>Climate</i>	<i>Temperature</i>	<i>Temperature relates to project 2BS</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>
			<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>

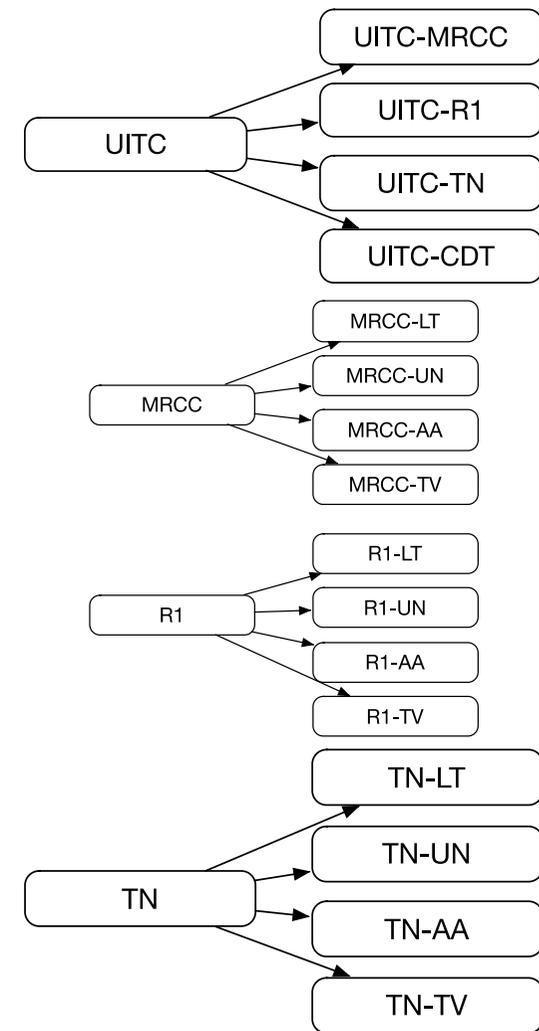
					Construction machine of TN
					Construction machine of CDT
				Office machine	Construction machine of UITC
					Construction machine of MRCC
					Construction machine of R1
					Construction machine of TN
					Construction machine of CDT
			Material	Reusable material	Plank
					Nail
					Wooden splint
					Scraffold
				Consumable material	Cement
					Sand
					Rock
					Steel
	Precipitation	Precipitation relates to project 2BS	Human	Worker	Worker of UITC
					Worker of MRCC
					Worker of R1
					Worker of TN
				Engineer	Engineer of UITC
					Engineer of MRCC
					Engineer of R1

					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>
			<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
				<i>Office machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
			<i>Material</i>	<i>Reusable material</i>	<i>Plank</i>
					<i>Nail</i>
					<i>Wooden splint</i>
					<i>Scraffold</i>
				<i>Consumable material</i>	<i>Cement</i>

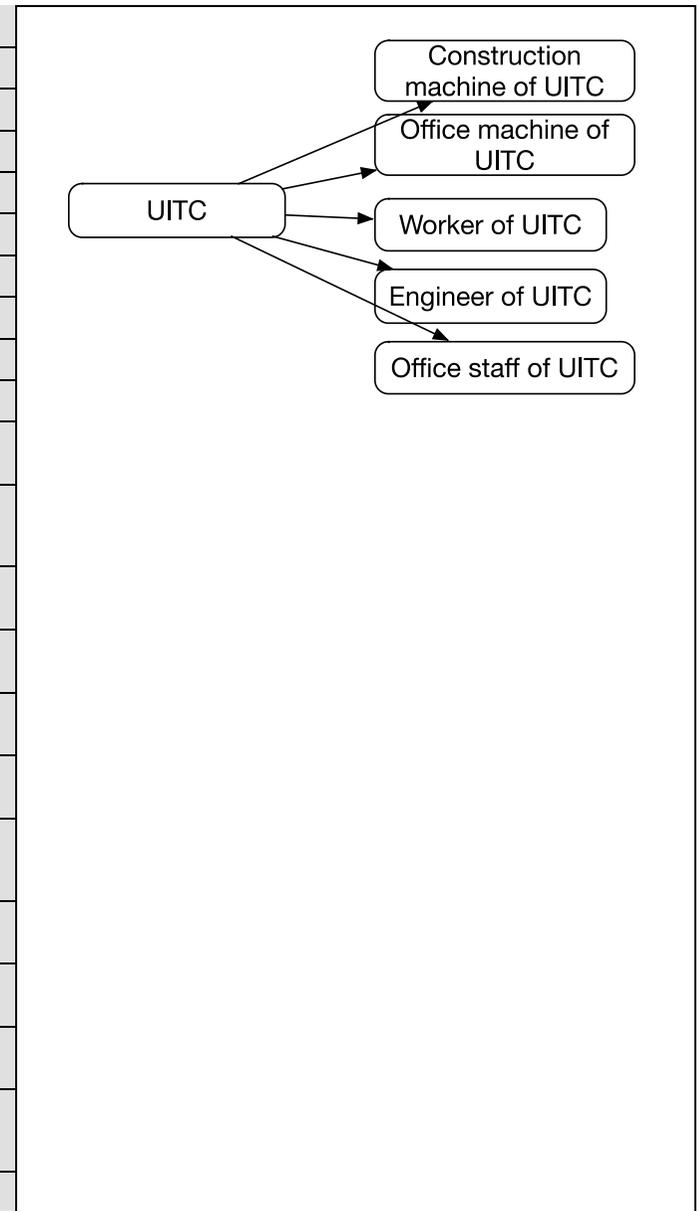
					<i>Sand</i>
					<i>Rock</i>
					<i>Steel</i>
<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>	<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
		<i>UITC - R1</i>			<i>R1</i>
	<i>Installing contract</i>	<i>UITC - TN</i>		<i>Installing contractor</i>	<i>TN</i>
<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>	<i>Designer</i>	<i>Structural designer</i>	<i>CDT</i>
	<i>Architectural design</i>	<i>UITC - CDT</i>		<i>Architectural designer</i>	<i>CDT</i>
<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>	<i>Supplier</i>	<i>Material supplier</i>	<i>LT (cement)</i>
		<i>MRCC - UN (sand)</i>			<i>UN (sand)</i>
		<i>MRCC - AA (rock)</i>			<i>AA (rock)</i>
		<i>MRCC - TV (steel)</i>			<i>TV (steel)</i>
		<i>R1 - LT (cement)</i>			<i>LT (cement)</i>
		<i>R1 - UN (sand)</i>			<i>UN (sand)</i>
		<i>R1 - AA (rock)</i>			<i>AA (rock)</i>
		<i>R1 - TV (steel)</i>			<i>TV (steel)</i>
		<i>TN - LT (cement)</i>			<i>LT (cement)</i>
		<i>TN - UN (sand)</i>			<i>UN (sand)</i>
		<i>TN - AA (rock)</i>			<i>AA (rock)</i>
		<i>TN - TV (steel)</i>			<i>TV (steel)</i>



<i>Owner</i>	<i>Owner</i>	<i>UITC</i>	<i>Building contract</i>	<i>Main building contract</i>	<i>UITC - MRCC</i>
					<i>UITC - RI</i>
				<i>Installing contract</i>	<i>UITC - TN</i>
			<i>Design contract</i>	<i>Structural design contract</i>	<i>UITC - CDT</i>
				<i>Architectural design</i>	<i>UITC - CDT</i>
<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>	<i>Supply contract</i>	<i>Material supply contract</i>	<i>MRCC - LT (cement)</i>
					<i>MRCC - UN (sand)</i>
					<i>MRCC - AA (rock)</i>
					<i>MRCC - TV (steel)</i>
		<i>RI</i>			<i>RI - LT (cement)</i>
					<i>RI - UN (sand)</i>
					<i>RI - AA (rock)</i>
					<i>RI - TV (steel)</i>
	<i>Installing contractor</i>	<i>TN</i>	<i>Supply contract</i>	<i>Material supply contract</i>	<i>TN - LT (cement)</i>
					<i>TN - UN (sand)</i>
					<i>TN - AA (rock)</i>
					<i>TN - TV (steel)</i>
<i>Owner</i>	<i>Owner</i>	<i>UITC</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of RI</i>
					<i>Worker of TN</i>

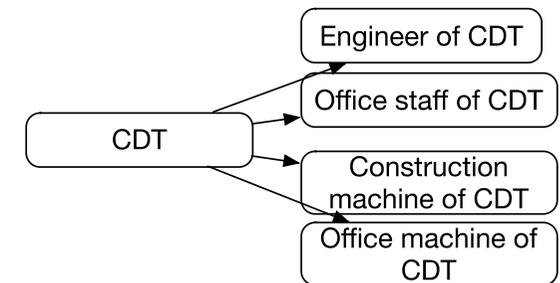
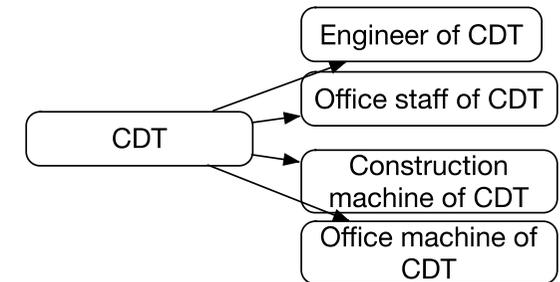


				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>
			<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
				<i>Office machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>

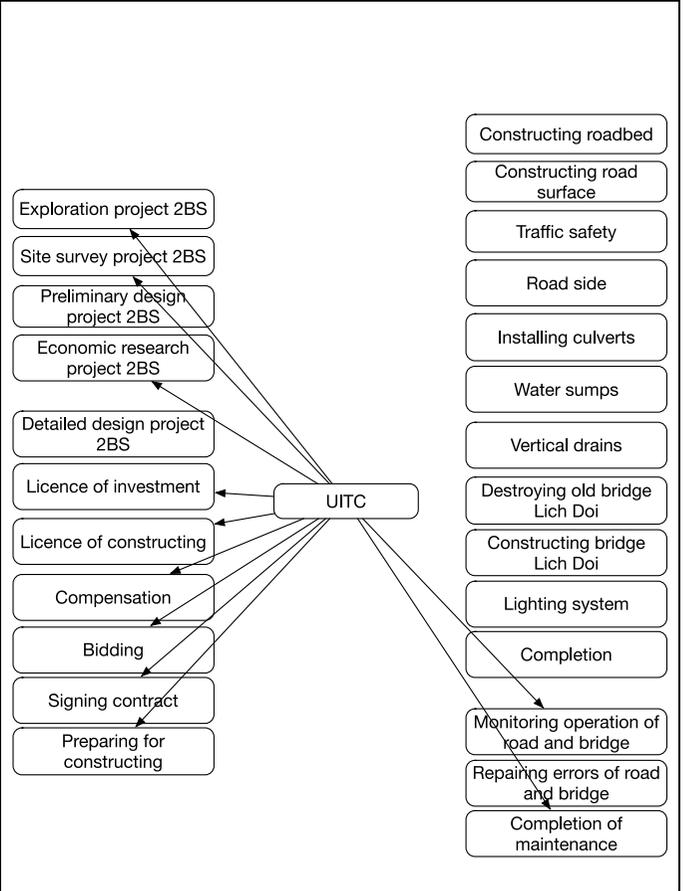


					<i>CDT</i>
				<i>Office machine</i>	<i>Construction machine of UITC</i>
					<i>Construction machine of MRCC</i>
					<i>Construction machine of R1</i>
					<i>Construction machine of TN</i>
					<i>Construction machine of CDT</i>
			<i>Material</i>	<i>Reusable material</i>	<i>Plank</i>
					<i>Nail</i>
					<i>Wooden splint</i>
					<i>Scraffold</i>
				<i>Consumable material</i>	<i>Cement</i>
					<i>Sand</i>
					<i>Rock</i>
					<i>Steel</i>
	<i>Installing contractor</i>	<i>TN</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>

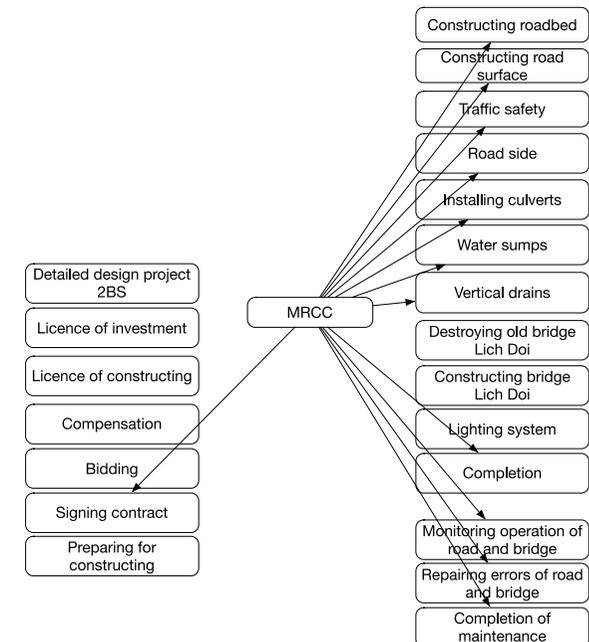
<i>Designer</i>	<i>Structural design</i>	<i>CDT</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>
					<i>Office staff of TN</i>
					<i>Office staff of CDT</i>
	<i>Architectural designer</i>	<i>CDT</i>	<i>Human</i>	<i>Worker</i>	<i>Worker of UITC</i>
					<i>Worker of MRCC</i>
					<i>Worker of R1</i>
					<i>Worker of TN</i>
				<i>Engineer</i>	<i>Engineer of UITC</i>
					<i>Engineer of MRCC</i>
					<i>Engineer of R1</i>
					<i>Engineer of TN</i>
					<i>Engineer of CDT</i>
				<i>Office staff</i>	<i>Office staff of UITC</i>
					<i>Office staff of MRCC</i>
					<i>Office staff of R1</i>



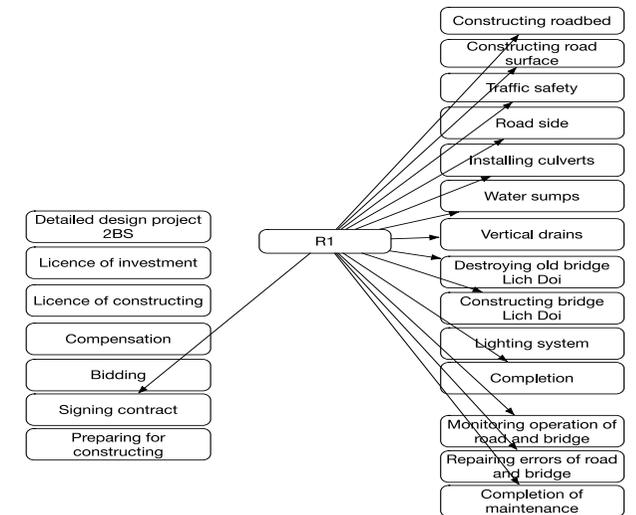
					Office staff of TN
					Office staff of CDT
Supplier	Material supplier	LT (cement)	Material	Consumable material	Cement
		UN (sand)			Sand
		AA (rock)			Rock
		TV (steel)			Steel
Owner	Owner	UITC	Activity in feasibility phase	Field work	Exploration project 2BS
					Survey site of project 2BS
				Preliminary design	Preliminary design project 2BS
				Economic research	Economic research project 2BS
			Activity in implementation phase	Detailed design	Detailed design project 2BS
				Preparing procedure before construction	Licence of investment
					Licence of constructing
					Compensation
					Bidding
					Signing contract
					Preparing for constructing
			Construction		Constructing roadbed
					Constructing road surface
					Traffic safety
					Roadside
					Installing culverts



					Water sumps	
					Vertical drains	
					Destroying old bridge Lich Doi	
					Constructing bridge Lich Doi	
					Lighting system	
					Completion	
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge	
				Performance of maintain work	Reparing errors of road and bridge	
					Completion of maintainance phase	
Contractor	Building contractor	MRCC	Activity in implementation phase	Detailed design	Detailed design project 2BS	
				Preparing procedure before construction	Licence of investment	
					Licence of constructing	
					Compensation	
					Bidding	
					Signing contract	
					Preparing for constructing	
					Construction	Constructing roadbed
						Constructing road surface
						Traffic safety
						Roadside
						Installing culverts

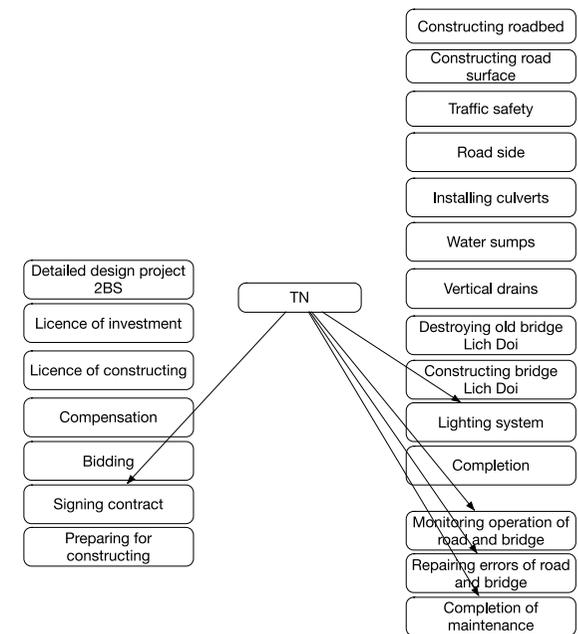


					Water sumps
					Vertical drains
					Destroying old bridge Lich Doi
					Constructing bridge Lich Doi
					Lighting system
					Completion
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge
				Performance of maintain work	Reparing errors of road and bridge
					Completion of maintainance phase
		R1	Activity in implementation phase	Detailed design	Detailed design project 2BS
				Preparing procedure before construction	Licence of investment
					Licence of constructing
					Compensation
					Bidding
					Signing contract
					Preparing for constructing
				Contruction	Constructing roadbed
					Constructing road surface
					Traffic safety
					Roadside
					Installing culverts



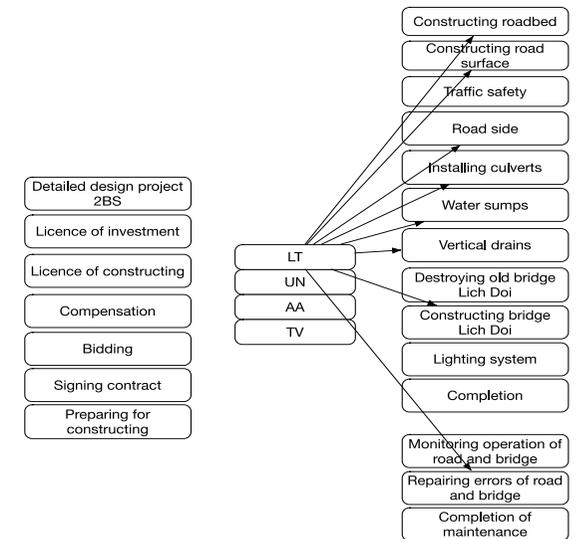
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>
					<i>Completion of maintainance phase</i>
	<i>Installing contractor</i>	<i>TN</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
				<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
					<i>Licence of constructing</i>
					<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>

					Water sumps
					Vertical drains
					Destroying old bridge Lich Doi
					Constructing bridge Lich Doi
					Lighting system
					Completion
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge
				Performance of maintain work	Reparing errors of road and bridge
					Completion of maintainance phase
Designer	Structural design	CDT	Activity in feasibility phase	Field work	Exploration project 2BS
					Survey site of project 2BS
				Preliminary design	Preliminary design project 2BS
				Economic research	Economic research project 2BS
			Activity in implementation phase	Detailed design	Detailed design project 2BS
				Preparing procedure before construction	Licence of investment
					Licence of constructing
					Compensation

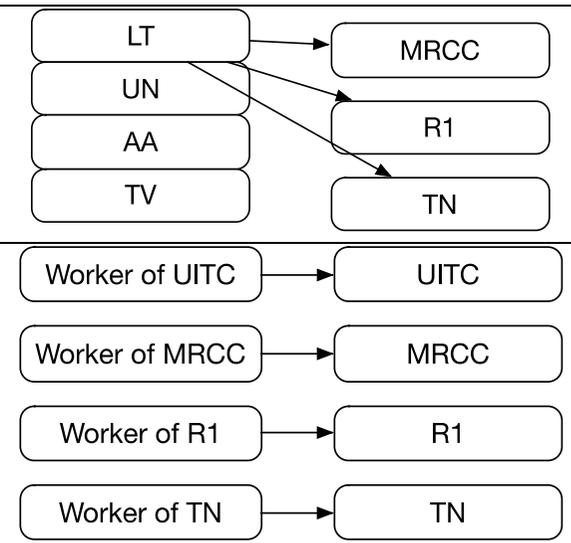


					<i>Bidding</i>	Exploration project 2BS		Constructing roadbed
					<i>Signing contract</i>	Site survey project 2BS		Constructing road surface
					<i>Preparing for constructing</i>	Preliminary design project 2BS		Traffic safety
				<i>Construction</i>	<i>Constructing roadbed</i>	Economic research project 2BS		Road side
					<i>Constructing road surface</i>			Installing culverts
					<i>Traffic safety</i>	Detailed design project 2BS		Water sumps
					<i>Roadside</i>	Licence of investment	CDT	Vertical drains
					<i>Installing culverts</i>	Licence of constructing		Destroying old bridge Lich Doi
					<i>Water sumps</i>	Compensation		Constructing bridge Lich Doi
					<i>Vertical drains</i>	Bidding		Lighting system
					<i>Destroying old bridge Lich Doi</i>	Signing contract		Completion
					<i>Constructing bridge Lich Doi</i>	Preparing for constructing		
					<i>Lighting system</i>			
					<i>Completion</i>			
	<i>Architectural designer</i>	<i>CDT</i>	<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>	Exploration project 2BS		Constructing roadbed
					<i>Survey site of project 2BS</i>	Site survey project 2BS		Constructing road surface
					<i>Preliminary design project 2BS</i>	Preliminary design project 2BS		Traffic safety
				<i>Preliminary design</i>	<i>Economic research project 2BS</i>	Economic research project 2BS		Road side
				<i>Economic research</i>	<i>Economic research project 2BS</i>			Installing culverts
					<i>Detailed design project 2BS</i>	Detailed design project 2BS		Water sumps
				<i>Activity in implementation phase</i>	<i>Detailed design project 2BS</i>	Licence of investment	CDT	Vertical drains
					<i>Detailed design project 2BS</i>	Licence of constructing		Destroying old bridge Lich Doi
				<i>Preparing procedure before construction</i>	<i>Licence of investment</i>	Compensation		Constructing bridge Lich Doi
					<i>Licence of constructing</i>	Bidding		Lighting system
					<i>Compensation</i>	Signing contract		Completion
					<i>Compensation</i>	Preparing for constructing		

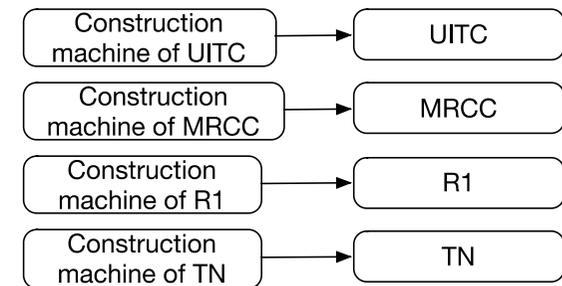
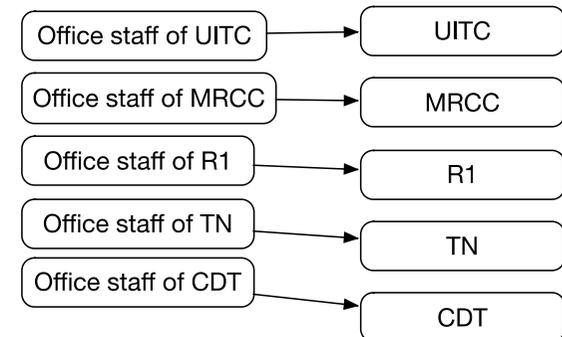
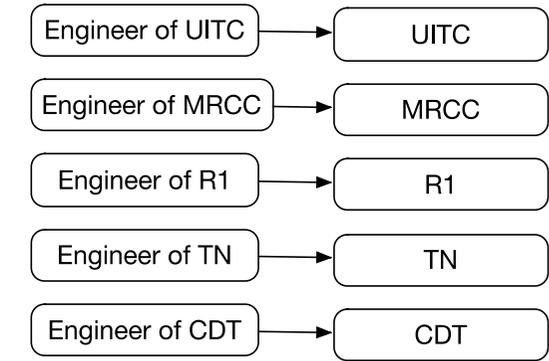
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
<i>Supplier</i>	<i>Material supplier</i>	<i>LT (cement)</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
		<i>UN (sand)</i>		<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
		<i>AA (rock)</i>			<i>Licence of constructing</i>
		<i>TV (steel)</i>			<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>



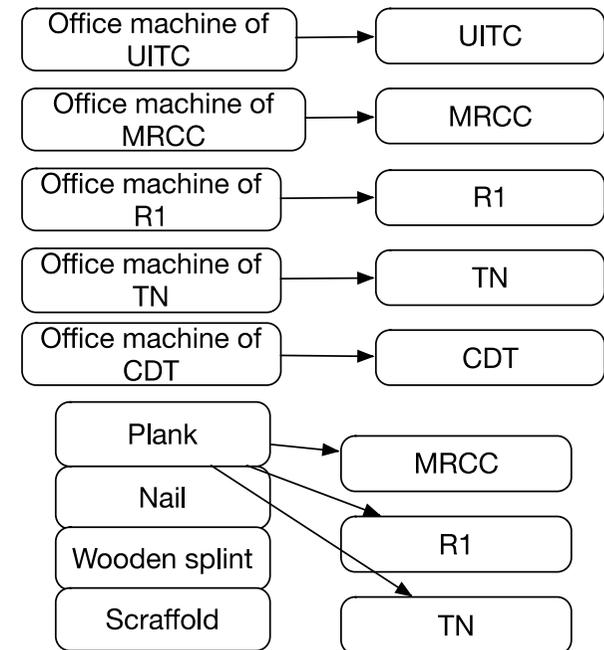
					Roadside
					Installing culverts
					Water sumps
					Vertical drains
					Destroying old bridge Lich Doi
					Constructing bridge Lich Doi
					Lighting system
					Completion
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge
				Performance of maintain work	Reparing errors of road and bridge
					Completion of maintainance phase
Supplier	Material supplier	LT (cement)	Contractor	Building contractor	MRCC
		UN (sand)			R1
		AA (rock)		Installing contractor	TN
		TV (steel)			
Human	Worker	Worker of UITC	Owner	Owner	UITC
		Worker of MRCC	Contractor	Building contractor	MRCC
		Worker of R1			R1
		Worker of TN		Installing contractor	TN



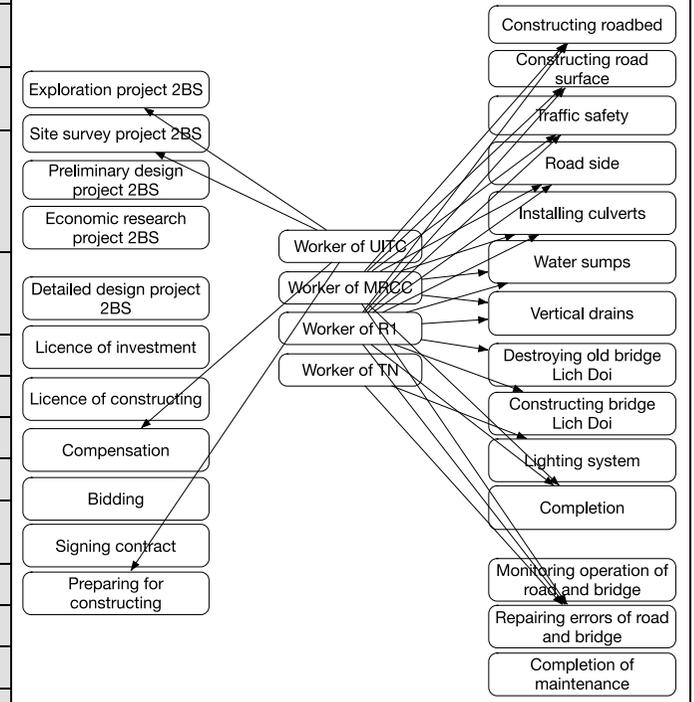
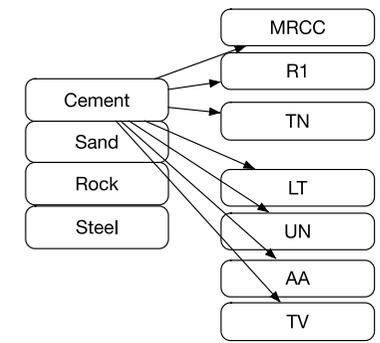
	<i>Engineer</i>	<i>Engineer of UITC</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
		<i>Engineer of MRCC</i>	<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
		<i>Engineer of R1</i>			<i>R1</i>
		<i>Engineer of TN</i>		<i>Installing contractor</i>	<i>TN</i>
		<i>Engineer of CDT</i>	<i>Designer</i>	<i>Structural design</i>	<i>CDT</i>
				<i>Architectural designer</i>	<i>CDT</i>
	<i>Office staff</i>	<i>Office staff of UITC</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
		<i>Office staff of MRCC</i>	<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
		<i>Office staff of R1</i>			<i>R1</i>
		<i>Office staff of TN</i>		<i>Installing contractor</i>	<i>TN</i>
		<i>Office staff of CDT</i>	<i>Designer</i>	<i>Structural design</i>	<i>CDT</i>
				<i>Architectural designer</i>	<i>CDT</i>
<i>Machine</i>	<i>Construction machine</i>	<i>Construction machine of UITC</i>	<i>Owner</i>	<i>Owner</i>	<i>UITC</i>
		<i>Construction machine of MRCC</i>	<i>Contractor</i>	<i>Building contractor</i>	<i>MRCC</i>
		<i>Construction machine of R1</i>			<i>R1</i>



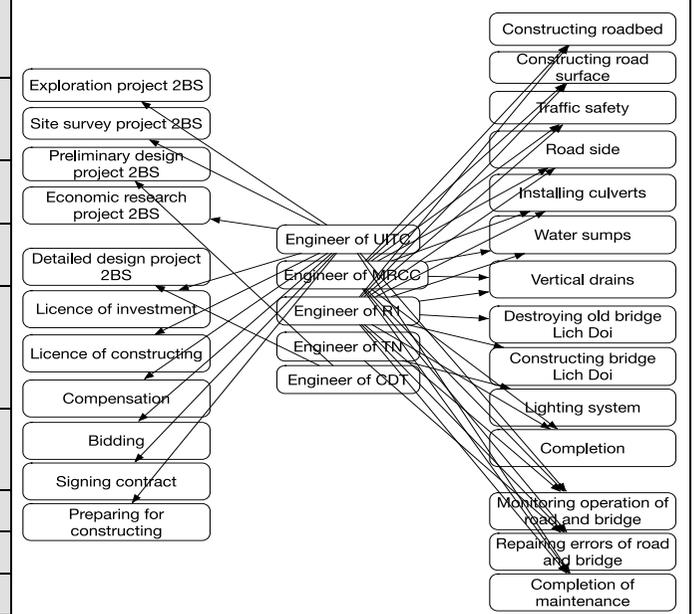
		Construction machine of TN		Installing contractor	TN
		Construction machine of CDT	Designer	Structural design	CDT
				Architectural designer	CDT
	Office machine	Construction machine of UITC	Owner	Owner	UITC
		Construction machine of MRCC	Contractor	Building contractor	MRCC
		Construction machine of R1			R1
		Construction machine of TN		Installing contractor	TN
		Construction machine of CDT	Designer	Structural design	CDT
				Architectural designer	CDT
Material	Reusable material	Plank	Contractor	Building contractor	MRCC
		Nail			R1
		Wooden splint		Installing contractor	TN
		Scraffold			
	Consumable material	Cement	Contractor	Building contractor	MRCC
		Sand			R1
		Rock		Installing contractor	TN



		Steel	Supplier	Material supplier	LT (cement)
					UN (sand)
					AA (rock)
					TV (steel)
Human	Worker	Worker of UITC	Activity in feasibility phase	Field work	Exploration project 2BS
		Worker of MRCC			Survey site of project 2BS
		Worker of R1		Preliminary design	Preliminary design project 2BS
		Worker of TN		Economic research	Economic research project 2BS
			Activity in implementation phase	Detailed design	Detailed design project 2BS
				Preparing procedure before construction	Licence of investment
					Licence of constructing
					Compensation
					Bidding
					Signing contract
					Preparing for constructing
				Construction	Constructing roadbed
					Constructing road surface
					Traffic safety
					Roadside

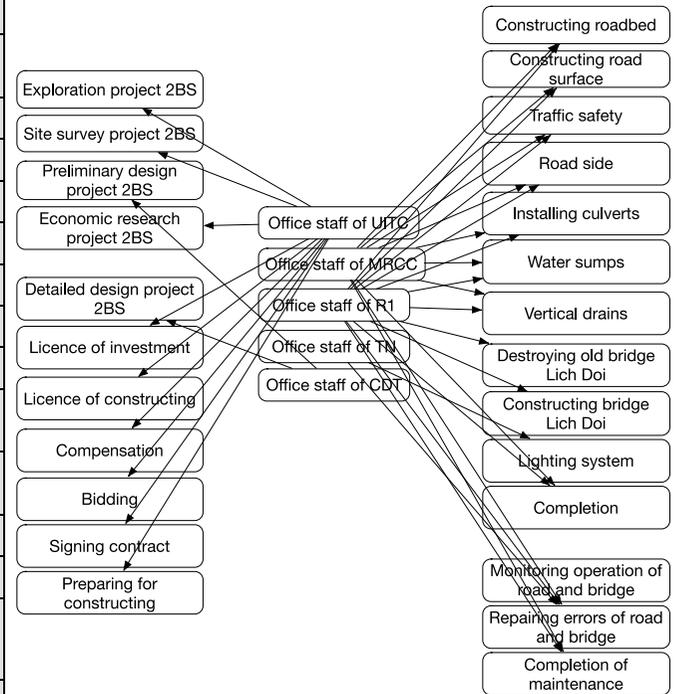


					Installing culverts	
					Water sumps	
					Vertical drains	
					Destroying old bridge Lich Doi	
					Constructing bridge Lich Doi	
					Lighting system	
					Completion	
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge	
				Performance of maintain work	Reparing errors of road and bridge	
					Completion of maintainance phase	
	Engineer	Engineer of UITC	Activity in feasibility phase	Field work	Exploration project 2BS	
		Engineer of MRCC			Survey site of project 2BS	
		Engineer of R1		Preliminary design	Preliminary design project 2BS	
		Engineer of TN		Economic research	Economic research project 2BS	
		Engineer of CDT	Activity in implementation phase	Detailed design	Detailed design project 2BS	
				Preparing procedure before construction	Licence of investment	
					Licence of constructing	
					Compensation	
					Bidding	
					Signing contract	
					Preparing for constructing	

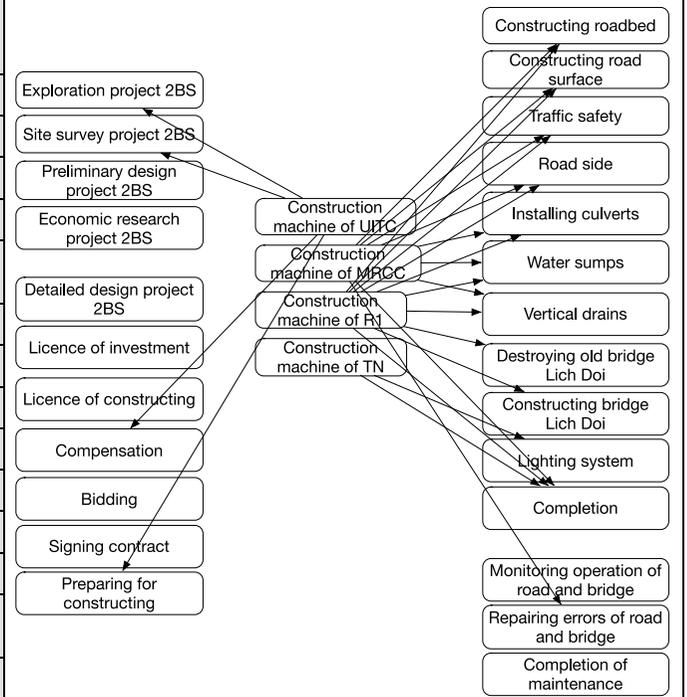


					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>
					<i>Completion of maintainance phase</i>
	<i>Office staff</i>	<i>Office staff of UITC</i>	<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>
		<i>Office staff of MRCC</i>			<i>Survey site of project 2BS</i>
		<i>Office staff of R1</i>		<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>
		<i>Office staff of TN</i>		<i>Economic research</i>	<i>Economic research project 2BS</i>

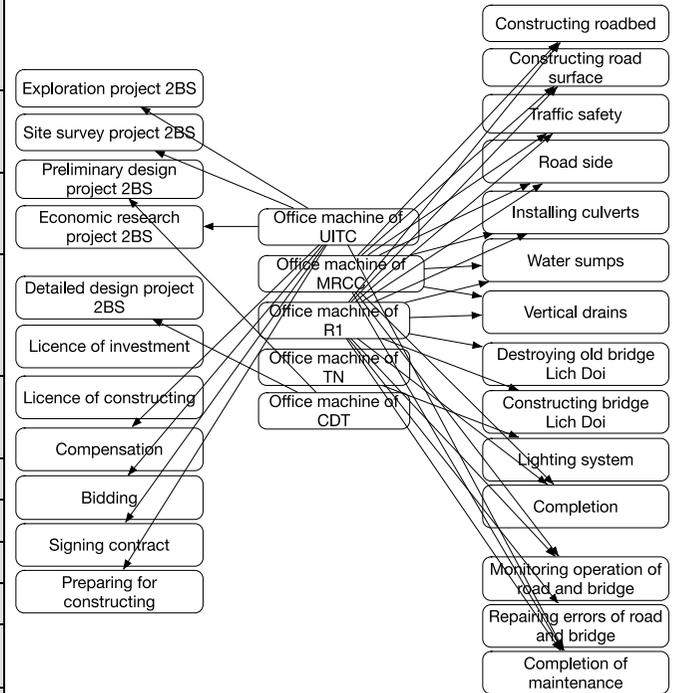
		Office staff of CDT	Activity in implementation phase	Detailed design	Detailed design project 2BS
				Preparing procedure before construction	Licence of investment
					Licence of constructing
					Compensation
					Bidding
					Signing contract
					Preparing for constructing
				Construction	Constructing roadbed
					Constructing road surface
					Traffic safety
					Roadside
					Installing culverts
					Water sumps
					Vertical drains
					Destroying old bridge Lich Doi
					Constructing bridge Lich Doi
					Lighting system
					Completion
			Activity in operation phase	Operation monitoring	Monitoring operation of road and bridge
				Performance of maintain work	Reparing errors of road and bridge
					Completion of maintainance phase



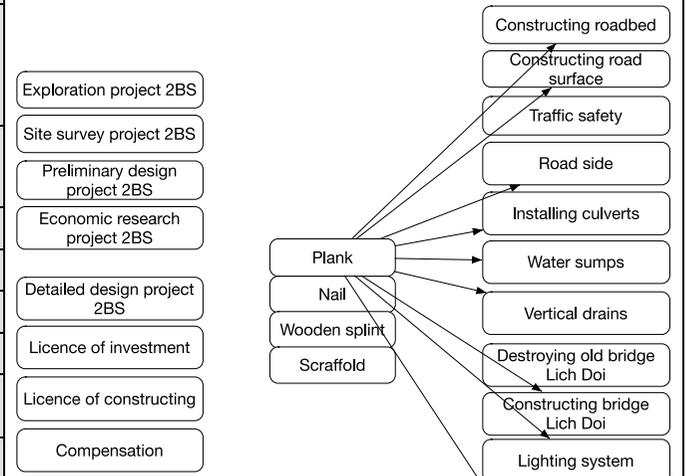
<i>Machine</i>	<i>Constructi on machine</i>	<i>Construction machine of UITC</i>	<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>
		<i>Construction machine of MRCC</i>			<i>Survey site of project 2BS</i>
		<i>Construction machine of RI</i>		<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>
		<i>Construction machine of TN</i>		<i>Economic research</i>	<i>Economic research project 2BS</i>
		<i>Construction machine of CDT</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
				<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
					<i>Licence of constructing</i>
					<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
			<i>Construction</i>		<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
					<i>Monitoring operation of road and bridge</i>
					<i>Repairing errors of road and bridge</i>
					<i>Completion of maintenance</i>
					<i>Constructing bridge Lich</i>



					<i>Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>
					<i>Completion of maintainance phase</i>
	<i>Office machine</i>	<i>Construction machine of UITC</i>	<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>
		<i>Construction machine of MRCC</i>			<i>Survey site of project 2BS</i>
		<i>Construction machine of R1</i>		<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>
		<i>Construction machine of TN</i>		<i>Economic research</i>	<i>Economic research project 2BS</i>
		<i>Construction machine of CDT</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
				<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
					<i>Licence of constructing</i>
					<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>



					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Repairing errors of road and bridge</i>
					<i>Completion of maintainance phase</i>
<i>Material</i>	<i>Reusable material</i>	<i>Plank</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
		<i>Nail</i>		<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
		<i>Wooden splint</i>			<i>Licence of constructing</i>
		<i>Scraffold</i>			<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Contruction</i>	<i>Constructing roadbed</i>

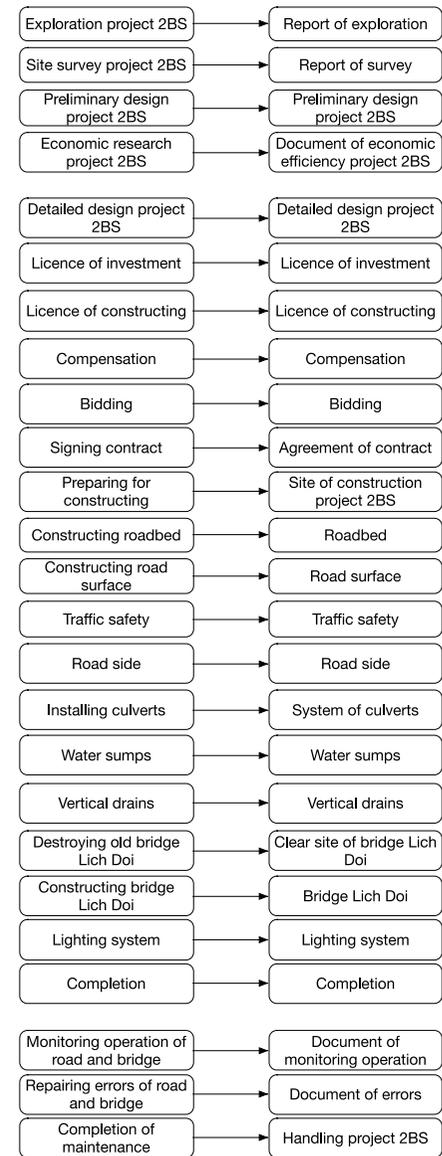


					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Repairing errors of road and bridge</i>
					<i>Completion of maintenance phase</i>
	<i>Consumable material</i>	<i>Cement</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
		<i>Sand</i>		<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
		<i>Rock</i>			<i>Licence of constructing</i>
		<i>Steel</i>			<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>

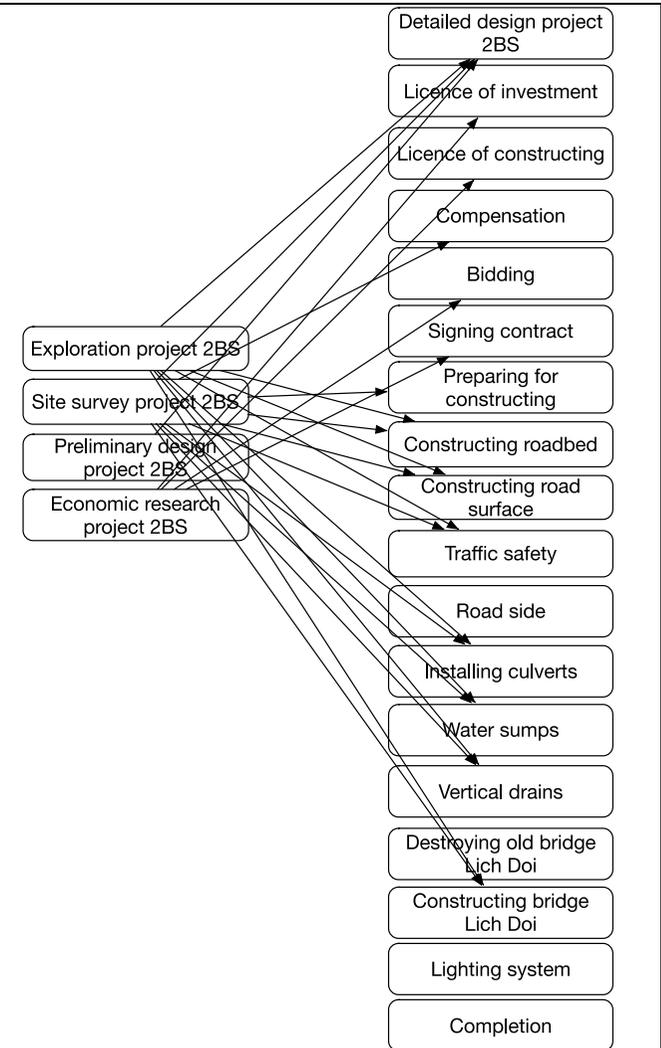
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Roadside</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
			<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
				<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>
					<i>Completion of maintainance phase</i>
<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>	<i>Product of feasibility phase</i>	<i>Document of site survey</i>	<i>Report of exploration</i>
		<i>Survey site of project 2BS</i>			<i>Report of survey</i>
	<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>		<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>
	<i>Economic research</i>	<i>Economic research project 2BS</i>		<i>Document of economic efficiency</i>	<i>Document of economic efficiency project 2BS</i>

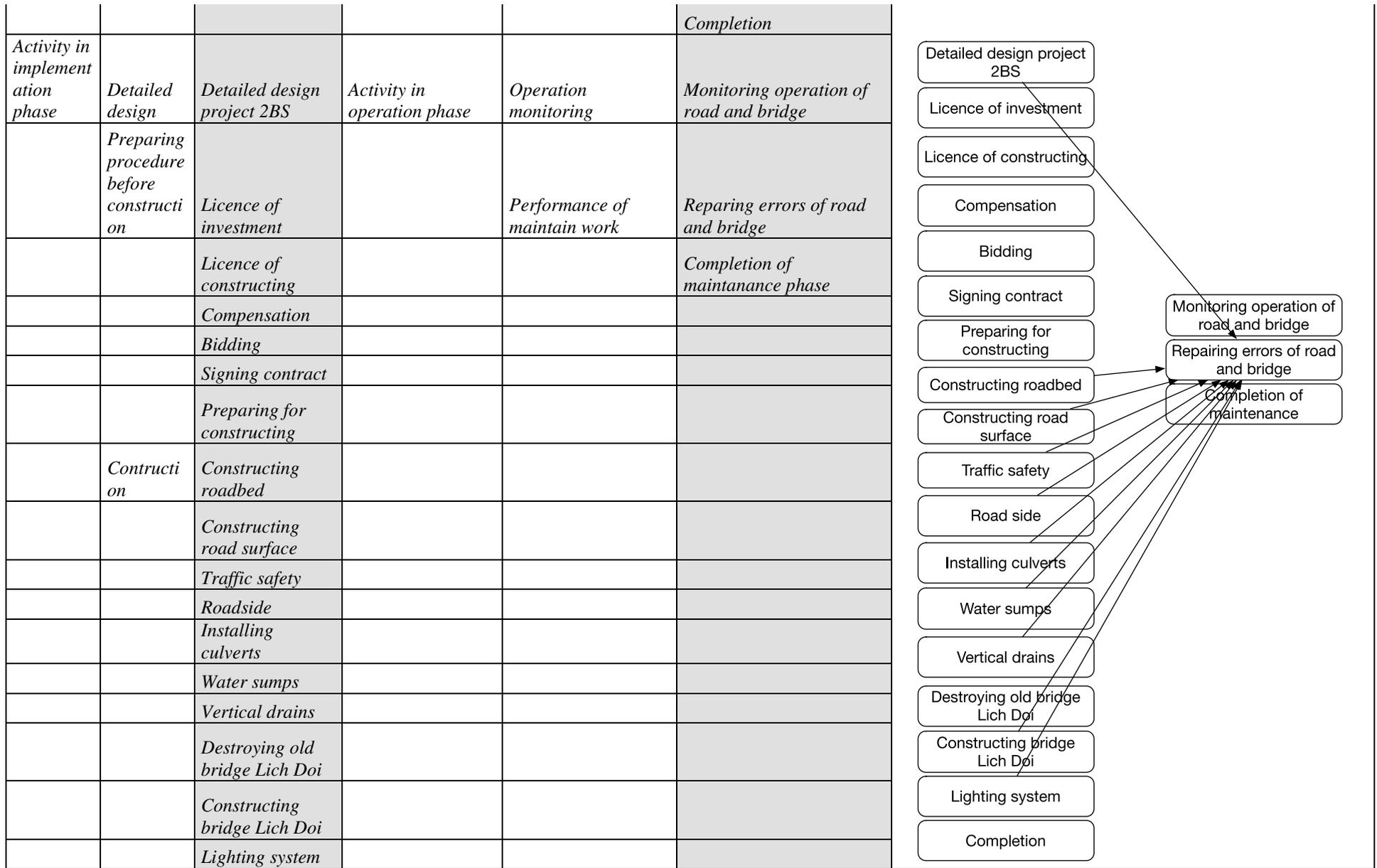
<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>	<i>Product of implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
	<i>Preparing procedure before construction</i>	<i>Licence of investment</i>		<i>Document of procedure project 2BS</i>	<i>Licence of investment</i>
		<i>Licence of constructing</i>			<i>Licence of constructing</i>
		<i>Compensation</i>			<i>Compensation</i>
		<i>Bidding</i>			<i>Bidding</i>
		<i>Signing contract</i>			<i>Agreement of contract</i>
		<i>Preparing for constructing</i>			<i>Site of construction project 2BS</i>
	<i>Construction</i>	<i>Constructing roadbed</i>		<i>Building</i>	<i>Roadbed</i>
		<i>Constructing road surface</i>			<i>Road surface</i>
		<i>Traffic safety</i>			<i>Traffic safety</i>
		<i>Roadside</i>			<i>Roadside</i>
		<i>Installing culverts</i>			<i>System of culverts</i>
		<i>Water sumps</i>			<i>Water sumps</i>
		<i>Vertical drains</i>			<i>Vertical drains</i>
		<i>Destroying old bridge Lich Doi</i>			<i>Clear site of bridge Lich Doi</i>
		<i>Constructing bridge Lich Doi</i>			<i>Bridge Lich Doi</i>
		<i>Lighting system</i>			<i>Lighting system</i>
		<i>Completion</i>			<i>Completion</i>

<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>	<i>Product of operation phase</i>	<i>Document of maintenance</i>	<i>Document of monitoring operation</i>
	<i>Performance of maintain work</i>	<i>Repairing errors of road and bridge</i>		<i>Document of maintained error</i>	<i>Document of errors</i>
		<i>Completion of maintenance phase</i>			<i>Handling project 2BS</i>

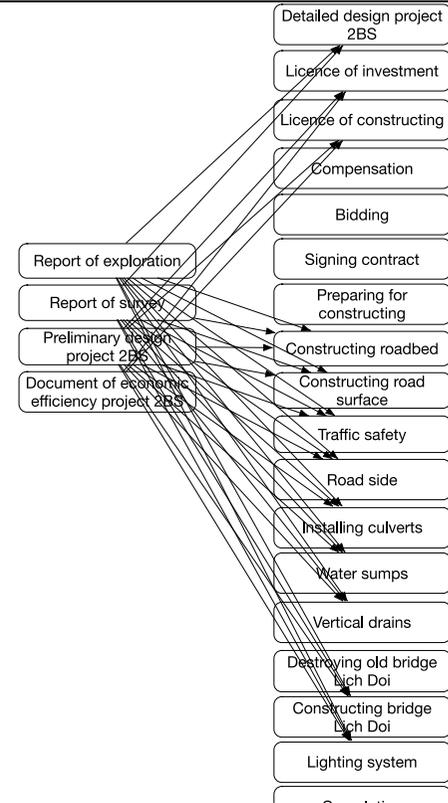


<i>Activity in feasibility phase</i>	<i>Field work</i>	<i>Exploration project 2BS</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
		<i>Survey site of project 2BS</i>		<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
	<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>			<i>Licence of constructing</i>
	<i>Economic research</i>	<i>Economic research project 2BS</i>			<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
				<i>Construction</i>	<i>Preparing for constructing</i>
					<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Road side</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>

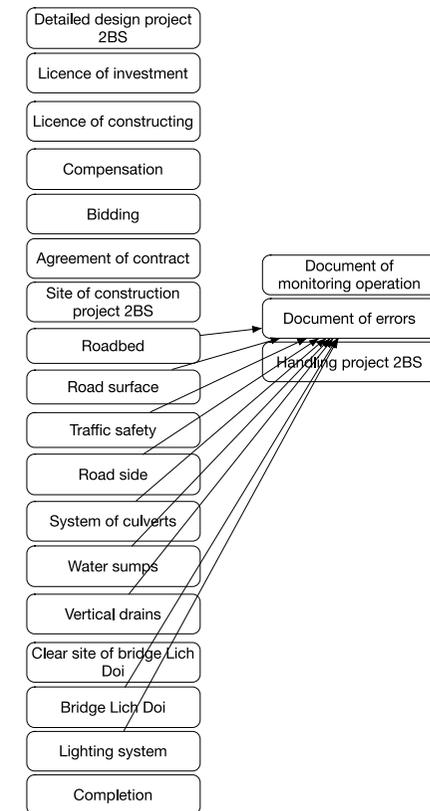




		<i>Completion</i>			
<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>			
	<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>			
		<i>Completion of maintainance phase</i>			
<i>Product of feasibility phase</i>	<i>Document of site survey</i>	<i>Report of exploration</i>	<i>Activity in implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>
		<i>Report of survey</i>		<i>Preparing procedure before construction</i>	<i>Licence of investment</i>
	<i>Preliminary design</i>	<i>Preliminary design project 2BS</i>			<i>Licence of constructing</i>
	<i>Document of economic efficiency</i>	<i>Document of economic efficiency project 2BS</i>			<i>Compensation</i>
					<i>Bidding</i>
					<i>Signing contract</i>
					<i>Preparing for constructing</i>
				<i>Construction</i>	<i>Constructing roadbed</i>
					<i>Constructing road surface</i>
					<i>Traffic safety</i>
					<i>Road side</i>
					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>



					<i>Installing culverts</i>
					<i>Water sumps</i>
					<i>Vertical drains</i>
					<i>Destroying old bridge Lich Doi</i>
					<i>Constructing bridge Lich Doi</i>
					<i>Lighting system</i>
					<i>Completion</i>
<i>Product of implementation phase</i>	<i>Detailed design</i>	<i>Detailed design project 2BS</i>	<i>Activity in operation phase</i>	<i>Operation monitoring</i>	<i>Monitoring operation of road and bridge</i>
	<i>Document of procedure project 2BS</i>	<i>Licence of investment</i>		<i>Performance of maintain work</i>	<i>Reparing errors of road and bridge</i>
		<i>Licence of constructing</i>			<i>Completion of maintanance phase</i>
		<i>Compensation</i>			
		<i>Bidding</i>			
		<i>Aggreement of contract</i>			
		<i>Site of construction project 2BS</i>			
	<i>Building</i>	<i>Roadbed</i>			
		<i>Road surface</i>			
		<i>Traffic safety</i>			
		<i>Roadside</i>			



		System of culverts			
		Water sumps			
		Vertical drains			
		Clear site of bridge Lich Doi			
		Bridge Lich Doi			
		Lighting system			
		Completion			

Appendix 18. Specific instances' relations in level 0 project NTI

Number of entity's relation	Source	Instances of source	Target	Instance of target	Figure of instance's relation
1	Environment	<i>Environment of project 2BS</i>	Contract	<i>owner-contractor,</i> <i>owner-designer,</i> <i>contractor-supplier</i>	<pre> graph TD A[E of project 2BS] --> B[Contract between owner-contractor] A --> C[Contract between owner-designer] A --> D[Contract between contractor-supplier] </pre>
2	Environment	<i>Environment of project 2BS</i>	Actor	<i>owner,</i> <i>contractor,</i> <i>supplier,</i> <i>designer</i>	<pre> graph TD A[E of project 2BS] --> B[Owner] A --> C[Contractor] A --> D[Supplier] A --> E[Designer] </pre>
3	Environment	<i>Environment of project 2BS</i>	Resource	<i>resource of owner,</i> <i>resource of contractor,</i> <i>resource of supplier,</i> <i>resource of designer</i>	<pre> graph TD A[E of project 2BS] --> B[Resource of owner] A --> C[Resource of contractor] A --> D[Resource of supplier] A --> E[Resource of designer] </pre>
4	Contract	<i>owner-contractor,</i> <i>owner-designer,</i>	Actor	<i>owner,</i> <i>contractor,</i>	

Number of entity's relation	Source	Instances of source contractor-supplier	Target	Instance of target supplier, designer	Figure of instance's relation
5	Actor	owner,	Contract	owner-contractor,	
		contractor,		owner-designer,	
		supplier,		contractor-supplier	
		designer			
6	Actor	owner,	Resource	resource of owner,	
		contractor,		resource of contractor,	
		supplier,		resource of supplier,	
		designer		resource of designer	
7	Actor	owner,	Activity	activities in feasibility phase,	
		contractor,		activities in implementation phase,	
		supplier,		activities in operation phase	
		designer			
8	Actor	owner,	Actor	owner,	
		contractor,		contractor,	
		supplier,		supplier,	
		designer		designer	
9	Resource	resource of owner,	Actor	owner,	
		resource of contractor,		contractor,	
		resource of supplier,		supplier,	

Number of entity's relation	Source	Instances of source <i>resource of designer</i>	Target	Instance of target <i>designer</i>	Figure of instance's relation
10	Resource	<i>resource of owner,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>resource of contractor,</i>		<i>activities in implementation phase,</i>	
		<i>resource of supplier,</i>			
		<i>resource of designer</i>			
11	Activity	<i>activities in feasibility phase,</i>	Product	<i>survey document,</i>	
		<i>activities in implementation phase,</i>		<i>building,</i>	
12	Activity	<i>activities in feasibility phase,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>activities in implementation phase,</i>		<i>activities in implementation phase,</i>	
13	Product	<i>survey document,</i>	Activity	<i>activities in feasibility phase,</i>	
		<i>building,</i>		<i>activities in implementation phase,</i>	

Appendix 19. Specific instances' relations in level 1 project NTI

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
1	Environment	Economy	Economy relates to project NTI	Contract	Building contract	Building contract project NTI		
2					Design contract	Building design contract		
3					Supply contract	Material supply contract of contractor		
4		Administration	Administration relates to project NTI			Building contract		Building contract project 2BS
5		Climate	Climate around project NTI			Design contract		Design contract
6						Supply contract		Material supply contract of contractor
7	Environment	Economy	Economy relates to project NTI	Actor	Owner	Owner of project NTI		
8		Administration	Administration relates to project NTI		Owner	Owner of project NTI		
9		Climate	Climate around project NTI		Owner	Owner of project NTI		
10					Contractor	Building contractor of project NTI		
11						Installing contractor of project NTI		
12						Designer		Building designer
13	Environment	Economy	Economy relates to project NTI	Resource	Human	Human of owner		

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
						Human of designer		
14						Human of contractor		
					Machine	Machine of owner		
						Machine of designer		
						Machine of contractor		
15					Material	Material for implementation phase of project NTI		
		Administration	Administration relates to project NTI					
16		Climate	Climate around project NTI		Human	Human of owner		
						Human of designer		
						Human of contractor		
17					Machine	Machine of owner		
						Machine of designer		
						Machine of contractor		
18					Material	Material for implementation phase of project NTI		
19	Contract	Building contract	Building contract project NTI	Actor	Contractor	Building contractor of project NTI		Building contract → Building contractor of project NTI
			Installing contract			Installing contractor of project NTI		Installing contract → Installing contractor of project NTI
20		Design contract	Design contract		Designer	Building designer		Design contract → Building designer
21		Supply contract	Material supply contract of		Supplier	Material supplier		Material supply contract of contractor → Material supplier

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
			<i>contractor</i>					
			<i>Material supply contract of bridge contractor</i>					
22	Actor	Owner	Owner of project NTI	Contract	Building contract	Building contract		
						Installing contract		
23						Design contract		Design contract
24		Contractor	Building contractor of project NTI		Supply contract	Material supply contract of contractor		
			<i>Installing contractor of project NTI</i>					
25	Actor	Owner	Owner of project NTI	Resource	Human	Human of owner		
26					Machine	Machine of owner		
27		Contractor	Building contractor of project NTI		Human	Human of contractor		
28					Machine	Machine of contractor		
29					Material	Material for implementation phase of project NTI		
33			<i>Installing contractor of project NTI</i>		Human	Human of contractor		
34					Machine	Machine of contractor		
35		Designer	Building designer		Human	Human of designer		
						Machine of designer		

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
36		Supplier	Material supplier		Material	Material for implementation phase of project NTI		
37	Actor	Owner	Owner of project NTI	Activity	Activity in feasibility phase	Fieldwork		
								Preliminary design
								Economic research
38						Activity in implementation phase		Detailed design
								Preparing procedure before construction
								Construction
40			Contractor		Building contractor of project NTI	Activity in implementation phase		Detailed design
								Preparing procedure before construction
								Construction
44					Installing contractor of project NTI	Activity in implementation phase		Detailed design
								Preparing procedure before construction
								Construction
46		Designer	Building designer	Activity in feasibility phase	Fieldwork			
					Preliminary design			

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						<i>Economic research</i>	
47					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
48		<i>Supplier</i>	<i>Material supplier</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
50	<i>Actor</i>	<i>Supplier</i>	<i>Material supplier</i>	<i>Actor</i>	<i>Contractor</i>	<i>Building contractor of project NTI</i>	
51	<i>Resource</i>	<i>Human</i>	<i>Human of owner</i>	<i>Actor</i>	<i>Owner</i>	<i>Owner of project NTI</i>	
52			<i>Human of contractor</i>		<i>Contractor</i>	<i>Building contractor of project NTI</i>	
						<i>Installing contractor of project NTI</i>	
53			<i>Human of designer</i>		<i>Designer</i>	<i>Building designer</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
54		Machine	Machine of owner		Owner	Owner of project NTI		
			Machine of contractor		Contractor	Building contractor of project NTI		
								Installing contractor of project NTI
55					Machine of designer	Designer		Building designer
56		Material			Material for implementation phase of project NTI	Contractor		Building contractor of project NTI
								Installing contractor of project NTI
57								
				Supplier		Material supplier		
60	Resource	Human	Human of owner	Activity	Activity in feasibility phase	Fieldwork		
								Preliminary design
								Economic research
61						Activity in implementation phase		Detailed design
								Preparing procedure before construction
								Construction
63					Human of designer	Activity in feasibility phase		Fieldwork

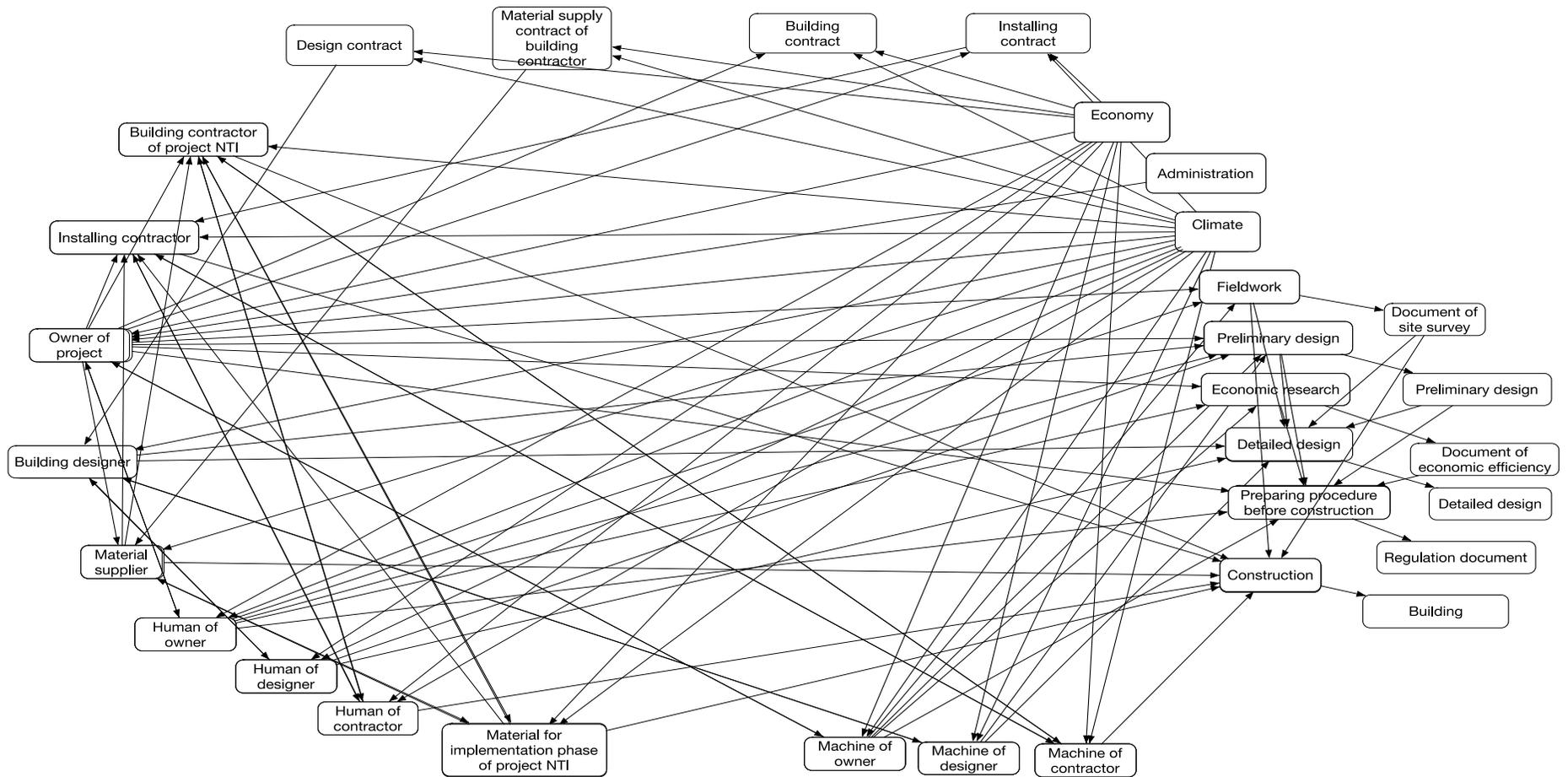
Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
						<i>Preliminary design</i>	Figure of instance's relation
						<i>Economic research</i>	
64					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
65			<i>Human of contractor</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
67		<i>Machine</i>	<i>Machine of owner</i>		<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	
						<i>Preliminary design</i>	
						<i>Economic research</i>	
68					<i>Activity in implementation phase</i>	<i>Detailed design</i>	
						<i>Preparing procedure before construction</i>	
						<i>Construction</i>	
70			<i>Machine of designer</i>		<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	
						<i>Preliminary design</i>	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
						<i>Economic research</i>	Figure of instance's relation	
71					<i>Activity in implementation phase</i>	<i>Detailed design</i>		
						<i>Preparing procedure before construction</i>		
						<i>Construction</i>		
72			<i>Machine of contractor</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>		
						<i>Preparing procedure before construction</i>		
						<i>Construction</i>		
74		<i>Material</i>	<i>Material for implementation phase of project NTI</i>		<i>Activity in implementation phase</i>	<i>Detailed design</i>		
						<i>Preparing procedure before construction</i>		
						<i>Construction</i>		
76	Activity	<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	Product	<i>Product of feasibility phase</i>	<i>Document of site survey</i>		Fieldwork → Document of site survey
			<i>Preliminary design</i>			<i>Preliminary design</i>		<i>Preliminary design</i>
					<i>Economic research</i>		<i>Document of economic efficiency</i>	Economic research → Document of economic efficiency
					<i>Economic research</i>		<i>Document of economic efficiency</i>	Detailed design → Detailed design
77		<i>Activity in implementation phase</i>	<i>Detailed design</i>		<i>Product of implementation phase</i>	<i>Detailed design</i>	Preparing procedure before construction → Regulation document	
						<i>Construction</i>	Construction → Building	

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation	
			<i>Preparing procedure before construction</i>			<i>Regulation document</i>		
			<i>Construction</i>			<i>Building</i>		
79	Activity	<i>Activity in feasibility phase</i>	<i>Fieldwork</i>	Activity	<i>Activity in implementation phase</i>	<i>Detailed design</i>		
			<i>Preliminary design</i>			<i>Preparing procedure before construction</i>		
			<i>Economic research</i>			<i>Construction</i>		
80		<i>Activity in implementation phase</i>	<i>Detailed design</i>					
			<i>Preparing procedure before construction</i>					
			<i>Construction</i>					
81	Product	<i>Product of feasibility phase</i>	<i>Document of site survey</i>	Activity	<i>Activity in implementation phase</i>	<i>Detailed design</i>		
			<i>Preliminary design</i>			<i>Preparing procedure before construction</i>		
			<i>Document of economic efficiency</i>			<i>Construction</i>		
82		<i>Product of implementation phase</i>	<i>Detailed design</i>					
			<i>Regulation document</i>					

Number of entity's relation Level 1	Source Level 0	Source Level 1	Instances of source in Level 1	Target Level 0	Target Level 1	Instance of target in Level 1	Figure of instance's relation
			<i>Building</i>				

Appendix 20. Total relation of instance in Level 1



Appendix 21. Specific instances' relations in level 2 project NTI

Number of entity's relation Level 1	Source Level 1	Source Level 2	Instances of source in Level 2	Target Level 1	Target Level 2	Instance of target in Level 2	Figure of instance's relation
1	Economy	National economy	National economy relates to project	Building contract	Main building contract	DC to CP	
						DC to CS	
						DC to CP	
2				Design contract	Structural design contract	CHR to BT	
					Architectural design	CHR to DC	
3				Supply contract	Material supply contract	MS1 to CP	
						MS2 to CP	
						MS3 to CS	
4	Climate	Temperature	Temperature relates to project	Building contract	Main building contract	DC to CP	
						DC to CS	
						DC to CP	
5				Design contract	Structural design contract	CHR to BT	
					Architectural design	CHR to DC	
6					Architectural design	CHR to DC	

				Supply contract	Material supply contract	MS1 to CP	
						MS2 to CP	
						MS3 to CS	
		Precipitation	Precipitation relates to project	Building contract	Main building contract	DC to CP	
						DC to CS	
					Installing contract	DC to CP	
				Design contract	Structural design contract	CHR to BT	
					Architectural design	CHR to DC	
				Supply contract	Material supply contract	MS1 to CP	
						MS2 to CP	
						MS3 to CS	
7	Economy	National economy	National economy relates to project 2BS	Owner	Owner	CHR	
8	Administration	Department	Department relates to project 2BS	Owner	Owner	CHR	
9	Climate	Temperature	Temperature relates to project 2BS	Owner	Owner	CHR	
10				Contractor	Building contractor	CP	
					Installing contractor	CS	
				Designer	Structural designer	BT	
11					Architectural designer	DC	
12				Supplier	Material supplier	MS1	

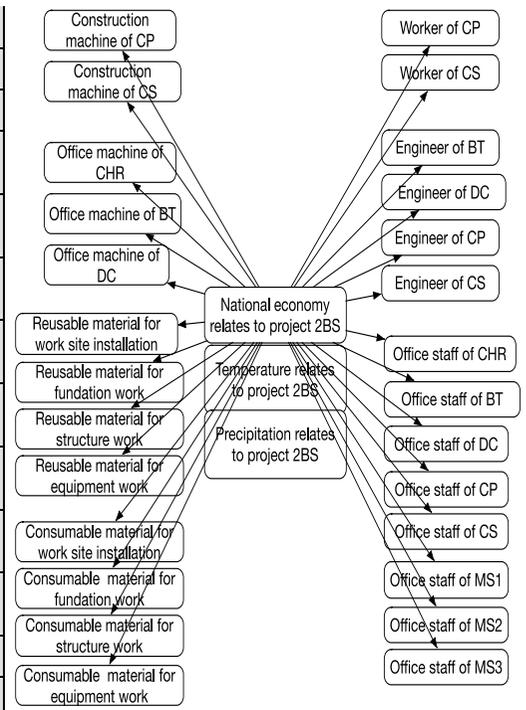
						MS2	
						MS3	
		Precipitation	Precipitation relates to project 2BS	Owner	Owner	CHR	
				Contractor	Building contractor	CP	
					Installing contractor	CS	
				Designer	Structural designer	BT	
					Architectural designer	DC	
				Supplier	Material supplier	MS1	
						MS2	
						MS3	
13	Economy	National economy	National economy relates to project 2BS	Human	Worker	worker team of CP	
						worker team of CS	
					Engineer	Engineer of BT	
						Architect & Engineer of DC	
						Engineer of CP	
						Engineer of CS	
						Office staff of CHR	
				Office staff		Office staff of BT	
						Office staff of DC	
						Office staff of CP	
						Office staff of CS	
						Office staff of MS1	
						Office staff of MS2	
						Office staff of MS3	

						Office staff of MS1
						Office staff of MS2
						Office staff of MS3
14				Machine	Construction machine	Machine of CP
						Machine of CS
					Office machine	Off Mach of CHR
						Off Mach of BT
						Off Mach of DC
				Material	Reusable material	Reusable material for work site installation
						Reusable material for foundation work
						Reusable material for structure work
						Reusable material for equipment work
15					Consumable material	Consumable material for work site installation
						Consumable material for foundation work
						Consumable material for structure work

						Consumable material for equipment work
		International economy	International economy relates to project 2BS	Human	Worker	worker team of CP
						worker team of CS
					Engineer	Engineer of BT
						Architect & Engineer of DC
						Engineer of CP
						Engineer of CS
					Office staff	Office staff of CHR
						Office staff of BT
						Office staff of DC
						Office staff of CP
						Office staff of CS
						Office staff of MS1
						Office staff of MS2
						Office staff of MS3
				Machine	Construction machine	Machine of CP
						Machine of CS
					Office machine	Off Mach of CHR
						Off Mach of BT

						Off Mach of DC	
				Material	Reusable material	Reusable material for work site installation	
						Reusable material for foundation work	
						Reusable material for structure work	
						Reusable material for equipment work	
					Consumable material	Consumable material for work site installation	
						Consumable material for foundation work	
						Consumable material for structure work	
						Consumable material for equipment work	
16	Climate	Temperature	Temperature relates to project 2BS	Human	Worker	worker team of CP	
						worker team of CS	
					Engineer	Engineer of BT	
17						Architect &	

					Engineer of DC
					Engineer of CP
					Engineer of CS
18				Office staff	Office staff of CHR
					Office staff of BT
					Office staff of DC
					Office staff of CP
					Office staff of CS
					Office staff of MS1
					Office staff of MS2
					Office staff of MS3
			Machine	Construction machine	Machine of CP
					Machine of CS
				Office machine	Off Mach of CHR
					Off Mach of BT
					Off Mach of DC
			Material	Reusable material	Reusable material for work site installation
					Reusable material for foundation work
					Reusable material for structure work



						Reusable material for equipment work	
					Consumable material	Consumable material for work site installation	
						Consumable material for foundation work	
						Consumable material for structure work	
						Consumable material for equipment work	
	Precipitation	Precipitation relates to project 2BS	Human	Worker		worker team of CP	
						worker team of CS	
				Engineer		Engineer of BT	
						Architect & Engineer of DC	
						Engineer of CP	
						Engineer of CS	
						Office staff of CHR	
				Office staff		Office staff of BT	
						Office staff of DC	
						Office staff of CP	
						Office staff of CS	
						Office staff of MS1	
						Office staff of MS2	
						Office staff of MS3	

						Office staff of CS
						Office staff of MS1
						Office staff of MS2
						Office staff of MS3
				Machine	Construction machine	Machine of CP
						Machine of CS
					Office machine	Off Mach of CHR
						Off Mach of BT
						Off Mach of DC
				Material	Reusable material	Reusable material for work site installation
						Reusable material for foundation work
						Reusable material for structure work
						Reusable material for equipment work
					Consumable material	Consumable material for work site installation
						Consumable material for foundation work

						Consumable material for structure work	
						Consumable material for equipment work	
19	Building contract	Main building contract	DC to CP	Contractor	Building contractor	CP	DC-CP → Building contractor - CP
		Installing contract	DC to CS		Installing contractor	CS	DC-CS → Installing contractor - CS
20	Design contract	Structural design contract	CHR to BT	Designer	Structural designer	BT	CHR-BT → Structural designer - BT
		Architectural design	CHR to DC		Architectural designer	DC	CHR-DC → Architectural designer - DC
21	Supply contract	Material supply contract	MS1 to CP	Supplier	Material supplier	MS1	MS1-CP → Material supplier - MS1
			MS2 to CP			MS2	MS2-CP → Material supplier - MS1
			MS3 to CS			MS3	MS3-CS → Material supplier - MS1
22	Owner	Owner	CHR	Building contract	Main building contract	DC to CP	<pre> graph LR Owner-CHR --> DC-CP Owner-CHR --> DC-CS Owner-CHR --> CHR-BT Owner-CHR --> CHR-DC </pre>
						DC to CS	
					Installing contract	DC to CP	
				Design contract	Structural design contract	CHR to BT	
					Architectural design	CHR to DC	
24	Contractor	Building contractor	CP	Supply contract	Material supply contract	MS1 to CP	<pre> graph LR BC-CP --> MS1-CP BC-CP --> MS2-CP BC-CP --> MS3-CS </pre>
						MS2 to CP	
						MS3 to CS	

		Installing contractor	CS	Supply contract	Material supply contract	MS1 to CP MS2 to CP MS3 to CS
25	Owner	Owner	CHR	Human	Worker	worker team of CP
26						worker team of CS
					Engineer	Engineer of BT
						Architect & Engineer of DC
						Engineer of CP
						Engineer of CS
					Office staff	Office staff of CHR
						Office staff of BT
						Office staff of DC
						Office staff of CP
						Office staff of CS
						Office staff of MS1
						Office staff of MS2
						Office staff of MS3
				Machine	Construction machine	Machine of CP
						Machine of CS
					Office machine	Off Mach of CHR
						Off Mach of

MS1-CP

MS2-CP

MS3-CS

Installing contractor - CS

Owner-CHR

Office machine of CHR

Office staff of CHR

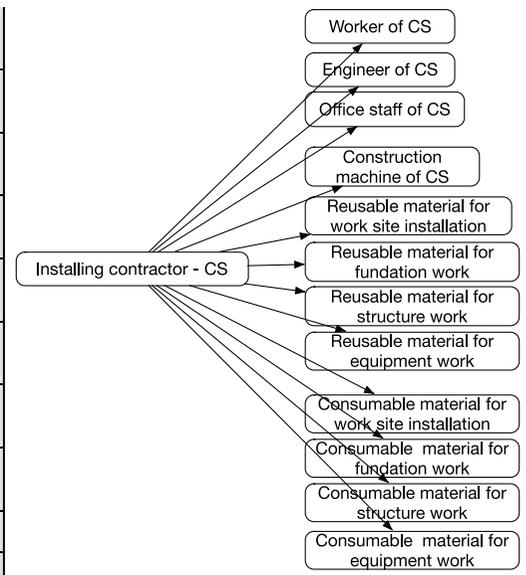
						BT	
						Off Mach of DC	
27	Contractor	Building contractor	CP	Human	Worker	worker team of CP	
28						worker team of CS	
29					Engineer	Engineer of BT	
						Architect & Engineer of DC	
						Engineer of CP	
						Engineer of CS	
					Office staff	Office staff of CHR	
						Office staff of BT	
						Office staff of DC	
						Office staff of CP	
						Office staff of CS	
						Office staff of MS1	
						Office staff of MS2	
						Office staff of MS3	
				Machine	Construction machine	Machine of CP	
						Machine of CS	
					Office machine	Off Mach of CHR	
						Off Mach of BT	
						Off Mach of DC	


```

graph LR
    BC[Building contractor - CP] --> WCP[Worker of CP]
    BC --> ECP[Engineer of CP]
    BC --> OSCP[Office staff of CP]
    BC --> CMCP[Construction machine of CP]
    BC --> RMI[Reusable material for work site installation]
    BC --> RMF[Reusable material for foundation work]
    BC --> RMS[Reusable material for structure work]
    BC --> RME[Reusable material for equipment work]
    BC --> CMI[Consumable material for work site installation]
    BC --> CMF[Consumable material for fundation work]
    BC --> CMS[Consumable material for structure work]
    BC --> CME[Consumable material for equipment work]
  
```

				Material	Reusable material	Reusable material for work site installation	
						Reusable material for foundation work	
						Reusable material for structure work	
						Reusable material for equipment work	
					Consumable material	Consumable material for work site installation	
						Consumable material for foundation work	
						Consumable material for structure work	
						Consumable material for equipment work	
		Installing contractor	CS	Human	Worker	worker team of CP	
						worker team of CS	
					Engineer	Engineer of BT	
						Architect & Engineer of DC	
						Engineer of CP	
						Engineer of CS	

				Office staff	Office staff of CHR
					Office staff of BT
					Office staff of DC
					Office staff of CP
					Office staff of CS
					Office staff of MS1
					Office staff of MS2
					Office staff of MS3
			Machine	Construction machine	Machine of CP
					Machine of CS
				Office machine	Off Mach of CHR
					Off Mach of BT
					Off Mach of DC
			Material	Reusable material	Reusable material for work site installation
					Reusable material for foundation work
					Reusable material for structure work
					Reusable material for equipment work



					Consumable material	Consumable material for work site installation
						Consumable material for foundation work
						Consumable material for structure work
						Consumable material for equipment work
35	Designer	Structural designer	BT	Human	Worker	worker team of CP
						worker team of CS
					Engineer	Engineer of BT
						Architect & Engineer of DC
						Engineer of CP
						Engineer of CS
					Office staff	Office staff of CHR
						Office staff of BT
						Office staff of DC
						Office staff of CP
						Office staff of CS
						Office staff of MS1
						Office staff of MS2

```

graph LR
    A[Structural designer - BT] --> B[Engineer of BT]
    A --> C[Office machine of BT]
    A --> D[Office staff of BT]
  
```

						Office staff of MS3	
		Architectural designer	DC	Human	Worker	worker team of CP	
						worker team of CS	
					Engineer	Engineer of BT	
						Architect & Engineer of DC	
						Engineer of CP	
						Engineer of CS	
					Office staff	Office staff of CHR	
						Office staff of BT	
						Office staff of DC	
						Office staff of CP	
						Office staff of CS	
						Office staff of MS1	
						Office staff of MS2	Architectural designer - DC
						Office staff of MS3	Engineer of DC Office machine of DC Office staff of DC
36	Supplier	Material supplier	MS1	Material	Consumable material	Consumable material for work site installation	
			MS2			Consumable material for foundation work	Material supplier - MS1 Material supplier - MS2 Material supplier - MS3
			MS3			Consumable material for structure work	Consumable material for work site installation Consumable material for foundation work Consumable material for structure work Consumable material for equipment work

						Consumable material for equipment work	
37	Owner	Owner	CHR	Activity in feasibility phase	Field work	Pre-studies	
					Preliminary design	Pre-design	
					Economic research	Economic study	
38				Activity in implementation phase	Detailed design	Detailed-design	
					Preparing procedure before construction	Procedure before works	
					Construction	Prepare works	
						Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
40	Contractor	Building contractor	CP	Activity in implementation phase	Detailed design	Detailed-design	
					Preparing procedure before construction	Procedure before works	
					Construction	Prepare works	
41						Soil and foundation works	
						Finalising construction	

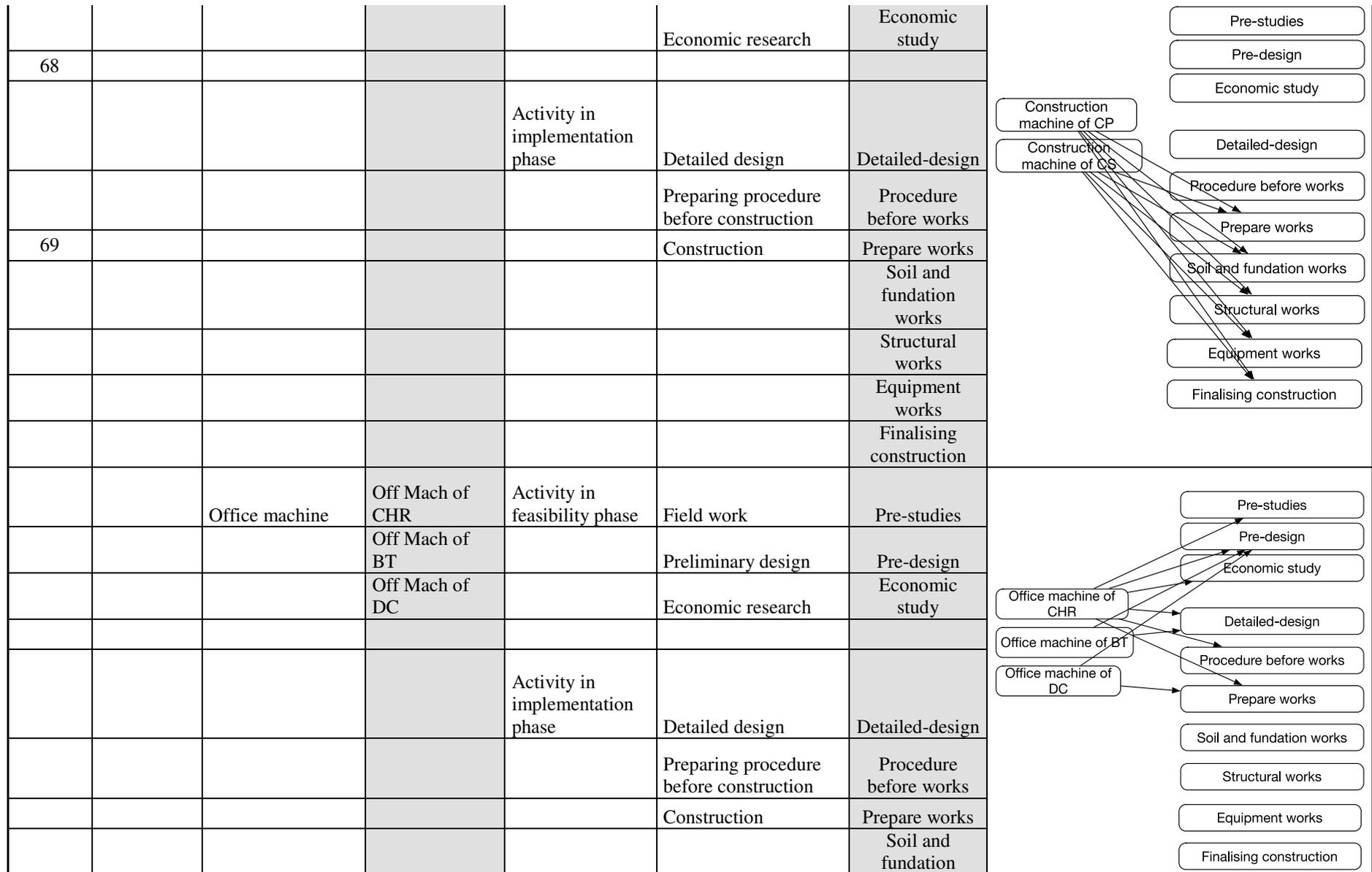
						Structural works	
						Equipment works	
						Finalising construction	
44		Installing contractor	CS	Activity in implementation phase	Detailed design	Detailed-design	
					Preparing procedure before construction	Procedure before works	
					Construction	Prepare works	
45						Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
46	Designer	Structural designer	BT	Activity in feasibility phase	Field work	Pre-studies	
					Preliminary design	Pre-design	
					Economic research	Economic study	
				Activity in implementation phase		Detailed-design	
						Procedure before works	
						Prepare works	
						Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
						Soil and foundation	

						works	
						Structural works	
						Equipment works	
						Finalising construction	
		Architectural designer	DC	Activity in feasibility phase	Field work	Pre-studies	
					Preliminary design	Pre-design	
					Economic research	Economic study	
				Activity in implementation phase			
					Detailed design	Detailed-design	
					Preparing procedure before construction	Procedure before works	
					Construction	Prepare works	
						Soil and fundation works	
						Structural works	
						Equipment works	
						Finalising construction	
48	Supplier	Material supplier	MS1	Activity in implementation phase	Detailed design	Detailed-design	
			MS2		Preparing procedure before construction	Procedure before works	
			MS3		Construction	Prepare works	

			BT				
			Office staff of DC		Installing contractor	CS	
53			Office staff of CP				
			Office staff of CS	Designer	Structural design	BT	
			Office staff of MS1		Architectural designer	DC	
			Office staff of MS2				
			Office staff of MS3				
54	Machine	Construction machine	Machine of CP	Owner	Owner	CHR	
			Machine of CS	Contractor	Building contractor	CP	
					Installing contractor	CS	
55				Designer	Structural design	BT	
					Architectural designer	DC	
		Office machine	Off Mach of CHR	Owner	Owner	CHR	
			Off Mach of BT	Contractor	Building contractor	CP	
			Off Mach of DC		Installing contractor	CS	
				Designer	Structural design	BT	
					Architectural designer	DC	

56	Material	Reusable material	Reusable material for work site installation	Contractor	Building contractor	CP	
			Reusable material for foundation work		Installing contractor	CS	
			Reusable material for structure work				
			Reusable material for equipment work				
		Consumable material	Consumable material for work site installation	Contractor	Building contractor	CP	
			Consumable material for foundation work		Installing contractor	CS	
			Consumable material for structure work				
			Consumable material for equipment work	Supplier	Material supplier	MS1	
						MS2	
58						MS3	
60	Human	Worker	worker team of CP	Activity in feasibility phase	Field work	Pre-studies	
			worker team of CS		Preliminary design	Pre-design	

						works	
						Structural works	
						Equipment works	
						Finalising construction	
		Office staff	Office staff of CHR	Activity in feasibility phase	Field work	Pre-studies	
			Office staff of BT		Preliminary design	Pre-design	
			Office staff of DC		Economic research	Economic study	
			Office staff of CP				
			Office staff of CS	Activity in implementation phase	Detailed design	Detailed-design	
			Office staff of MS1		Preparing procedure before construction	Procedure before works	
			Office staff of MS2		Construction	Prepare works	
			Office staff of MS3			Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
67	Machine	Construction machine	Machine of CP	Activity in feasibility phase	Field work	Pre-studies	
			Machine of CS		Preliminary design	Pre-design	



						works	
						Structural works	
						Equipment works	
						Finalising construction	
74	Material	Reusable material	Reusable material for work site installation	Activity in implementation phase	Detailed design	Detailed-design	
			Reusable material for foundation work		Preparing procedure before construction	Procedure before works	
			Reusable material for structure work		Construction	Prepare works	
75			Reusable material for equipment work			Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
		Consumable material	Consumable material for work site installation	Activity in implementation phase	Detailed design	Detailed-design	
			Consumable material for foundation work		Preparing procedure before construction	Procedure before works	

			Equipment works			Equipment	
			Finalising construction			Finished building	
79	Activity in feasibility phase	Field work	Pre-studies	Activity in implementation phase	Detailed design	Detailed-design	<p>Diagram for row 79: Three boxes on the left (Pre-studies, Pre-design, Economic study) have arrows pointing to three boxes on the right (Detailed-design, Procedure before works, Prepare works). The boxes on the right are stacked vertically.</p>
					Preparing procedure before construction	Procedure before works	
		Preliminary design	Pre-design		Construction	Prepare works	
		Economic research	Economic study			Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
81	Product of feasibility phase	Document of site survey	Document of site survey	Activity in implementation phase	Detailed design	Detailed-design	<p>Diagram for row 81: Three boxes on the left (Document of site survey, Preliminary design, Document of economic) have arrows pointing to three boxes on the right (Detailed-design, Procedure before works, Prepare works). The boxes on the right are stacked vertically.</p>
		Preliminary design	Preliminary design		Preparing procedure before construction	Procedure before works	
		Document of economic	Document of economic		Construction	Prepare works	
						Soil and foundation works	
						Structural works	
						Equipment works	
						Finalising construction	
						Equipment	

						works
						Finalising construction

REFERENCES

- Aaltonen, Kirsi. 2011. "Project Stakeholder Analysis as an Environmental Interpretation Process." *International Journal of Project Management* 29(2): 165–83. <http://dx.doi.org/10.1016/j.ijproman.2010.02.001>.
- Akinci, Burcu, and Martin Fischer. 1998. "Factors Affecting Contractors' Risk of Cost Overburden." 14(February): 67–76.
- Akintoye, Akintola S, and Malcolm J MacLeod. 1997. "Risk Analysis and Management in Construction." *International Journal of Project Management* 15(1): 31–38. <http://www.sciencedirect.com/science/article/pii/S026378639600035X>.
- Andrew R. Atkinson. 1999. "The Role of Human Error in Construction Defects." *Structural Survey* 17(4): 231–36.
- Antoniou, Fani, Georgios N. Aretoulis, Dimitrios Konstantinidis, and Glykeria P. Kalfakakou. 2013. "Complexity in the Evaluation of Contract Types Employed for the Construction of Highway Projects." *Procedia - Social and Behavioral Sciences* 74: 448–58. <http://linkinghub.elsevier.com/retrieve/pii/S1877042813004771>.
- Atkinson, Roger. 1999. "Project Management: Cost Time and Quality Two Best Guesses and a Phenomenon, It's Time to Accept Other Success Criteria." 17(6): 337–42.
- Aven, Terje. 2016. "Risk Assessment and Risk Management: Review of Recent Advances on Their Foundation." *European Journal of Operational Research* 253(1): 1–13. <http://dx.doi.org/10.1016/j.ejor.2015.12.023>.
- Aven, Terje, and Enrico Zio. 2014. "Foundational Issues in Risk Assessment and Risk Management." *Risk Analysis* 34(7): 1164–72.
- Ayachit, Abhishek C, Attarde, and Swapnil Kulkarni. 2014. "ACTIVITY BASED COSTING IN CONSTRUCTION PROJECTS." *International Journal of Advanced Engineering Research and Studies* (2).
- Babaioff, Moshe. 2014. "Contract Complexity."
- Baccarini, D., and R. Archer. 2001. "The Risk Ranking of Project a Methodology." *International Journal of Project Management* 19: 139–45.
- Bakr, Ali F., Khaled El Hagla, and Ayda Nayer Abo Rawash. 2012. "Heuristic Approach for Risk Assessment Modeling: EPCCM Application (Engineer Procure Construct Contract Management)." *Alexandria Engineering Journal* 51(4): 305–23. <http://dx.doi.org/10.1016/j.aej.2012.09.001>.
- Baloi, Daniel, and Andrew D F Price. 2003. "Modelling Global Risk Factors Affecting Construction Cost Performance." *International Journal of Project Management* 21(4): 261–69.
- Barber, Richard B. 2005. "Understanding Internally Generated Risks in Projects." *International Journal of Project Management* 23(8): 584–90.
- Benferhat, Salem, Moonis Ali Eds, and Randy Goebel. 2017. 10351 *Advances in Artificial Intelligence: From Theory to Practice*. <http://link.springer.com/10.1007/978-3-319-60045-1>.
- Berkeley, D., P. C. Humphreys, and R. D. Thomas. 1991. "Project Risk Action Management." *Construction Management and Economics* 9(1): 3–17.
- Bing, Li, A. Akintoye, Peter J. Edwards, and C. Hardcastle. 2005. "The Allocation of Risk in PPP/PFI Construction Projects in the UK." *International Journal of Project Management* 23(1): 25–35.
- Björk, Bo-Christer. 1992. "A Unified Approach for Modelling Construction Information." *Building and Environment* 27(2): 173–94.
- Boateng, Prince, Zhen Chen, and Stephen O. Ogunlana. 2015. "An Analytical Network Process Model for Risks Prioritisation in Megaprojects." *International Journal of*

- Project Management* 33(8): 1795–1811.
- Buntine, Wray. 1996. “A Guide to the Literature on Learning Probabilistic Networks from Data.” *IEEE Transactions on knowledge and data engineering*.
- Burt, Christopher D B, and Simon Kemp. 1994. “Construction of Activity Duration and Time Management Potential.” *Applied Cognitive Psychology* 8(2): 155–68.
- Cano, Andrés, Manuel Gómez, Serafin Moral, and Joaquín Abellán. 2007. “Hill-Climbing and Branch-and-Bound Algorithms for Exact and Approximate Inference in Credal Networks.” *International Journal of Approximate Reasoning* 44(3): 261–80.
- Case, Denise M., and Chrysostomos D. Stylios. 2016. “Fuzzy Cognitive Map to Model Project Management Problems.”
- Chan, Albert P. C., David Scott, and Edmond W. M. Lam. 2002. “Framework of Success Criteria for Design/Build Projects.” *Journal of Management in Engineering* 18(3): 120–28.
- Chandrasekaran, B, and John R Josephson. 1999. “What Are Ontologies, and Why Do We Need Them?”
- Chapman, Chris. 1997. “Project Risk Analysis and management—PRAM the Generic Process.” *International Journal of Project Management* 15(5): 273–81.
- Chapman, R.J. 2001. “The Controlling Influences on Effective Risk Identification and Assessment for Construction Design Management.” *International Journal of Project management* 19: 19, 147–60.
- Chassiakos, Athanasios P., and Serafim P. Sakellariopoulos. 2005. “Time-Cost Optimization of Construction Projects with Generalized Activity Constraints.” *Journal of Construction Engineering and Management* 131(10): 1115–24.
- Chinowsky, P.S. Meredith, J.E. 2001. “Project Performance Control in Reconstruction Projects.” *Strategic Management in Construction* 9364(FEBRUARY 2000): 0–20.
- Cho, KyuMan, TaeHoon Hong, and ChangTaek Hyun. 2009. “Effect of Project Characteristics on Project Performance in Construction Projects Based on Structural Equation Model.” *Expert Systems with Applications* 36(7): 10461–70.
- Cimiano, Philipp. 2006. *Evaluation Ontology Learning and Population from Text*.
- Construction Work*. 2012. Australian government statutory agency <http://www.deir.qld.gov.au/workplace/industry/construction/construction-work/index.htm#.VC0Bghb1bkw>.
- Cooper, Dale, Stephen Grey; Geoffrey, Dale Cooper; Raymond, and Phil Walker. 2015. 1 John Wiley and Sons *Managing Risk in Large Projects and Complex Procurements*.
- Cooper, Gregory~F. 1990. “The Computational Complexity of Probabilistic Inference Using Bayesian Belief Networks.” *Artificial Intelligence* 42(1990): 393–405.
- Darnall, and Preston. 2007. “Project Management in a Complex World.”
- Darwiche, Adnan. 2010. “Bayesian Networks.”
- Dawood, Nashwan. 1998. “Estimating Project and Activity Duration: A Risk Management Approach Using Network Analysis.” *Construction Management and Economics* 16(1): 41–48.
- Dukić, D., G. Dukić, and D. Babić. 2007. “Simulation of Construction Project Activities Duration by Means of Beta PERT Distribution.” *18th International Conference on Information and Intelligent Systems*. http://old.foi.hr/CMS_home/znan_strucni_rad/konferencije/IIS/2007/papers/T06_04.pdf.
- Dziadosz, Agnieszka, Andrzej Tomczyk, and Oleg Kapliński. 2015. “Financial Risk Estimation in Construction Contracts.” *Procedia Engineering* 122(Orsdc): 120–28. <http://www.sciencedirect.com/science/article/pii/S1877705815031045>.
- Eggleston, Karen. 2000. “Simplicity and Complexity in Contracts.” (93).
- El-Diraby, T. A., C. Lima, and B. Feis. 2005. “Domain Taxonomy for Construction Concepts:

- Toward a Formal Ontology for Construction Knowledge.” *Journal of Computing in Civil Engineering* 19(4): 394–406.
- Elkington, P., and C. Smallman. 2001. “Managing Project Risks: A Case Study from the Utilities Sector.” *International Journal of Project Management* 20(1): 49–57.
- Esra Tepeli. 2014. “Processus Formalise et Systemique de Management Des Riques Pour Des Projects de Construction Complexes et Strategiques.”
- Fallis, A.G. 2013. 53 *Journal of Chemical Information and Modeling Knowledge Seeker - Ontology Modelling for Information Search and Management*.
- Fang, Chao, Franck Marle, Enrico Zio, and Jean Claude Bocquet. 2012. “Network Theory-Based Analysis of Risk Interactions in Large Engineering Projects.” *Reliability Engineering and System Safety* 106: 1–10. <http://dx.doi.org/10.1016/j.res.2012.04.005>.
- Faria, E., and Jim Q. Smith. 1997. “Conditionally Externally Bayesian Pooling Operators in Chain Graphs.” *Annals of Statistics* 25(4): 1740–61.
- Feelders, Ad, and Linda C. van der Gaag. 2006. “Learning Bayesian Network Parameters under Order Constraints.” *International Journal of Approximate Reasoning* 42(1–2): 37–53.
- Fidan, Gulsah, and Irem Dikmen. 2011. “Ontology for Relating Risk and Vulnerability to Cost Overrun in International Projects.” *Journal of Computing in Civil Engineering* 25(August): 302–15. [http://ascelibrary.org/doi/abs/10.1061/\(ASCE\)CP.1943-5487.0000090](http://ascelibrary.org/doi/abs/10.1061/(ASCE)CP.1943-5487.0000090).
- Franck Taillandier; Patrick Taillandier; Esra Tepeli; Denys Breysse; Rasool Mehdizadeh; Fadi Khartabil. 2015. “A Multi-Agent Model to Manage Risks in Construction Project.” *Automation in Construction* 58: 1–18. <http://www.sciencedirect.com/science/article/pii/S0926580515001235>.
- Franck Taillandier, Patrick Taillandier, Fethi Hamzaoui, and Denys Breysse. 2016. “A New Agent-Based Model to Manage Construction Project Risks – Application to the Crossroad of Bab El Karmadine at Tlemcen.” *European Journal of Environmental and Civil Engineering* 8189(January): 0–0. <http://www.tandfonline.com/doi/full/10.1080/19648189.2015.1134675>.
- Garbharran, Hari, and Jeevarathnam Govender. 2012. “Critical Success Factors Influencing Project Success in the Construction Industry.” : 90–108.
- Getoor, Lise et al. 2007. “Probabilistic Relational Models.” *Introduction to Statistical Relational Learning*: 129–74.
- Gonzales, Christophe, Lionel Torti, and Pierre-henri Wuillemin. 2017. “Librairie aGrUM : A Graphical Universal Model.” *In Proceedings of the 30th International Conference on Industrial, Engineering, Other Applications of Applied Intelligent Systems, Arras, France. Springer-Verlag.*: 1–10.
- Gruber, Thomas R. 1993. “A Translation Approach to Portable Ontology Specifications.” *Knowledge Acquisition* 5(2): 199–220. <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.101.7493>.
- Guilan Shen, Deying Fang, and Jianbin Chen. 2009. “Application of Ontology Based Reasoning in Risk Identification of Software Projects.” *2009 AsiaPacific Conference on Computational Intelligence and Industrial Applications PACIIA* 2: 165–68. <http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5406622>.
- Hastak, Makarand, and Aury Shaked. 2000. “ICRAM-1: Model for International Construction Risk Assessment.” *Journal of management in engineering ASCE* 16(February): 59–69.
- Heckerman, David. 1999. “A Tutorial on Learning with Bayesian Networks.” : 301–54. <http://dl.acm.org/citation.cfm?id=308574.308676>.
- Hendler, James. 2002. “Agents and the Semantic Web Ontologies on the Semantic Web.” (April 2001): 1–15.

- Hillson, David. 2002. "Extending the Risk Process to Manage Opportunities." *International Journal of Project Management* 20(3): 235–40.
- Hossen, Muhammed Mufazzal, Sunkoo Kang, and Jonghyun Kim. 2015. "Construction Schedule Delay Risk Assessment by Using Combined AHP-RII Methodology for an International NPP Project." *Nuclear Engineering and Technology* 47(3): 362–79. <http://dx.doi.org/10.1016/j.net.2014.12.019>.
- ISO 10006. 2003. "Quality Management Systems — Guidelines for Quality Management in Projects." 2003: 1–40.
- ISO 31000:2009 - *Setting a New Standard for Risk Management: Perspective*. 2010. 30.
- Jensen, Kasper L., Jørn Toftum, and Peter Friis-Hansen. 2009. "A Bayesian Network Approach to the Evaluation of Building Design and Its Consequences for Employee Performance and Operational Costs." *Building and Environment* 44(3): 456–62.
- Jeynes, Jacqueline. 2002. "Risk Management 10 Principles." *Management*: 144.
- Jia Niu, and Raja R.A. Issa. 2015. "Developing Taxonomy for the Domain Ontology of Construction Contractual Semantics: A Case Study on the AIA A201 Document." *ADVANCED ENGINEERING INFORMATICS*. <http://dx.doi.org/10.1016/j.aei.2015.03.009>.
- Jiang, Shaohua, Jian Zhang, and Haiyan Zhang. 2013. "Ontology-Based Semantic Retrieval for Risk Management of Construction Project." *Journal of Networks* 8(5): 1212–20.
- Kallman, James. 2005. 52 Risk Management *Managing Risk in Construction Project*. <http://search.proquest.com.ezp.waldenulibrary.org/docview/227002247/13BFC7EAD42518FD100/6?accountid=14872%5Cnhttp://media.proquest.com.ezp.waldenulibrary.org/media/pq/classic/doc/941151561/fmt/pi/rep/NONE?hl=managing,risks,risk,decisions,decision,making&cit>.
- Khang, Do Ba, and Yin Mon Myint. 1999. "Time, Cost and Quality Trade-off in Project Management: A Case Study." *International Journal of Project Management* 17(4): 249–56. <http://www.sciencedirect.com/science/article/pii/S026378639800043X>.
- Khartabil, F.K., D. Breysse, and F Taillandier. 2013. "On the Risk Management of Construction Project: A Knowledge-Based Approach." *Congrès Français de Mécanique 21*: 1–6.
- Kollarits, Stefan et al. 2009. "Risk Ontology Monotor – an Ontological Basis for Risk Management Together with Document History." : 1–76.
- Krause, Paul J. 1999. "Learning Probabilistic Networks." *The Knowledge Engineering Review* 13(4): 321–51. http://www.journals.cambridge.org/abstract_S0269888998004019.
- Kylindri, Stamatia, G Blanas, Leif Henriksen, and Tanev Stoyan. 2012. "Measuring Project Outcomes: A Review of Success Effectiveness Variables." *Management of International Business and Economic Systems Conference* (May): 212–23.
- Lauritzen, and Spiegelhalter. 1988. "Local Computations with Probabilities on Graphical Structures and Their Application to Expert Systems." *Expert Systems* 50(2): 1–4.
- Leu, Sou-sen, An-ting Chen, and Chung-huei Yang. 2001. "A GA-Based Fuzzy Optimal Model for Construction Time - Cost." *International Journal of Project Management* 19: 47–58.
- Liu, Ze zhao, Zheng wei Zhu, Hui jia Wang, and Jie Huang. 2016. "Handling Social Risks in Government-Driven Mega Project: An Empirical Case Study from West China." *International Journal of Project Management* 34(2): 202–18. <http://dx.doi.org/10.1016/j.ijproman.2015.11.003>.
- Love, P.E.D. et al. 2002. "Using Systems Dynamics to Better Understand Change and Rework in Construction Project Management Systems." 20(August 2015): 425–36.
- Lu, Weisheng, Yi Peng, Chris Webster, and Jian Zuo. 2015. "Stakeholders' Willingness to Pay for Enhanced Construction Waste Management: A Hong Kong Study." *Renewable*

- Maley, Claude H. 2008. *Project Management Concepts, Methods, and Techniques*.
- Mallawaarachchi, H, and S Senaratne. 2015. “Importance of Quality for Construction Project Success.”
- Marzouk, M, and S Azab. 2014. “Environmental and Economic Impact Assessment of Construction and Demolition Waste Disposal Using System Dynamics.” *Resources, Conservation and Recycling* 82: 41.
- Medina Oliva, G., P. Weber, E. Levrat, and B. Iung. 2010. “Use of Probabilistic Relational Model (PRM) for Dependability Analysis of Complex Systems.” *IFAC Proceedings Volumes (IFAC-PapersOnline)* 9(PART 1): 501–6.
- Medina Oliva, G., P. Weber, C. Simon, and B. Iung. 2009. “Bayesian Networks Applications on Dependability, Risk Analysis and Maintenance.” *IFAC Proceedings Volumes (IFAC-PapersOnline)* 2(PART 1): 215–20.
- Mehdizadeh Rasool. 2012. “Dynamic and Multi-Perspective Risk Management of Construction Projects Using Tailor-Made Risk Breakdown Structures.” *PhD Thesis* (Ed 209).
- Meng, Xianhai. 2012. “The Effect of Relationship Management on Project Performance in Construction.” *International Journal of Project Management* 30(2): 188–98.
<http://dx.doi.org/10.1016/j.ijproman.2011.04.002>.
- Middelmann, Miriam H. 2007. *Natural Hazards in Australia: Identifying Risk Analysis Requirements*.
- Mojtahedi, S. Mohammad H, S. Meysam Mousavi, and Ahmad Makui. 2010. “Project Risk Identification and Assessment Simultaneously Using Multi-Attribute Group Decision Making Technique.” *Safety Science* 48(4): 499–507.
- Moselhi, Osama, Daji Gong, and Khaled El-rayes. 1997. “Estimating Weather Impact on the Duration of Construction Activities.” : 359–66.
- Murphy, Kevin, Yair Weiss, and Michael Jordan. 1999. “Loopy Belief Propagation for Approximate Inference: An Empirical Study.” 1.
- Nasir, Daud, Brenda McCabe, and Loesie Hartono. 2003. “Evaluating Risk in Construction–Schedule Model (ERIC–S): Construction Schedule Risk Model.” *Journal of Construction Engineering and Management* 129(5): 518–27.
- Nieto-Morote, A., and F. Ruz-Vila. 2011. “A Fuzzy Approach to Construction Project Risk Assessment.” *International Journal of Project Management* 29(2): 220–31.
- O’Hagan, Anthony et al. 2002. *Uncertain Judgements: Eliciting Experts’ Probabilities*.
- Odeh, A. M., and H. T. Battaineh. 2001. “Causes of Construction Delay: Traditional Contracts.” *International Journal of Project Management* 20(1): 67–73.
- Ofori, George. 1992. “The Environment: The Fourth Construction Project Objective?” *Construction Management and Economics* 10(5): 369–95.
- Patterson, Fiona D., and Kevin Neailey. 2002. “A Risk Register Database System to Aid the Management of Project Risk.” *International Journal of Project Management* 20(5): 365–74.
- Pérez, Ballesteros, Gonzalez-Cruz, and J. P. Pastor-Ferrando. 2010. “Analysis of Construction Projects by Means of Value Curves.” *International Journal of Project Management* 28(7): 719–31.
- Perret, Patrick et al. 2012. “Guide Pratique Pour La Maîtrise et La Gestion Des Risques.”
- Pfeffer, A, and Daphne Koller. 2000. “Semantics and Inference for Recursive Probability Models.” *Proceedings of the National Conference on Artificial Intelligence* (August): 538–44.
<http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Semantics+and+Infer>

- nce+for+Recursive+Probability+Models#0.
- Pierre-Henri Wuillemin, and Lionel Torti. 2012. "Structured Probabilistic Inference." *International Journal of Approximate Reasoning* 53(July): 1–15.
- PMBOK. 2013. *A Guide to the Project Management Body of Knowledge*.
- Potts, Keith. 2008. *Construction Cost Management: Learning from Case Studies*.
- Project Management Institute. 2008. A Guide to the Project Management Body of Knowledge (PMBOK® Guide) - Fourth Edition *A Guide to the Project Management Body of Knowledge (4th Edition)*.
- Raz, Tzvi, Aaron J Shenhar, and Dov Dvir. 2002. "Risk Management, Project Success, and Technological Uncertainty." *R and D Management* 32(2): 101–9.
- Rezakhani, Pejman. 2011. "Fuzzy Risk Analysis Model for Construction Projects." 2(2): 516–31.
- Rita L. Sousa, and Herbert H. Einstein. 2012. "Risk Analysis during Tunnel Construction Using Bayesian Networks: Porto Metro Case Study." *Tunnelling and Underground Space Technology* 27(1): 86–100.
- Rodney, Elodie. 2016. "Développement D'une Méthode de Gestion Des Risques de Projet et D'aide À La Décision En Contexte Incertain- Application Au Domaine Des Énergies Renouvelables."
- safe work australia. 2013. 2013 *Construction Work - Code of Practice*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224864/JCVI_Code_of_Practice_revision_2013_-_final.pdf.
- Sai X. Zeng, Chun M. Tam, and Vivian W. Y. Tam. 2010. "Integrating Safety , Environmental and Quality Risks for Project Management Using a FMEA Method." 21(1): 44–52.
- Sambasivan, Murali, and Yau Wen Soon. 2007. "Causes and Effects of Delays in Malaysian Construction Industry." *International Journal of Project Management* 25(5): 517–26.
- Sanvido, By Victor et al. 1992. "Critical Success Factors for Construction Projects." 118(1): 94–111.
- Schieg, Martin. 2006. VII Journal of Business Economics and Management *Risk Management in Construction Project Management*.
- Schmidt, Mark, and Kevin Murphy. 2009. "Modeling Discrete Interventional Data Using Directed Cyclic Graphical Models." *Proceedings of the Twenty-Fifth Conference on Uncertainty in Artificial Intelligence (UAI '09)*: 487–95. <http://portal.acm.org/citation.cfm?id=1795114.1795171>.
- Serpella, Alfredo Federico, Ximena Ferrada, Rodolfo Howard, and Larissa Rubio. 2014. "Risk Management in Construction Projects: A Knowledge-Based Approach." *Procedia - Social and Behavioral Sciences* 119: 653–62. <http://linkinghub.elsevier.com/retrieve/pii/S1877042814021648>.
- Spackova, Jiri Sejnoha, and Daniel Straub. 2013. "Probabilistic Assessment of Tunnel Construction Performance Based on Data." *Tunnelling and Underground Space Technology* 37: 62–78. <http://www.scopus.com/inward/record.url?eid=2-s2.0-84877060337&partnerID=40&md5=efe8837a1b6bb317f48aac6cafab723a>.
- Studer, Rudi, V Richard Benjamins, and Dieter Fensel. 1998. "Knowledge Engineering : Principles and Methods." 25: 161–97.
- Sun, Ming, and Xianhai Meng. 2009. "Taxonomy for Change Causes and Effects in Construction Projects." *International Journal of Project Management* 27(6): 560–72. <http://dx.doi.org/10.1016/j.ijproman.2008.10.005>.
- Tah, J. H. M., and V. Carr. 2001. "Knowledge-Based Approach To Construction Project Risk Management." (July): 170–77.
- Tang, Jianqiang, Maoping Zhang, Hua Tang, and Yuan Chen. 2015. "Research on Cost

- Management of Construction Project Based on Activity-Based Costing.” (Cmes): 51–54.
- Taroun, Abdulmaten. 2014a. “Towards a Better Modelling and Assessment of Construction Risk: Insights from a Literature Review.” *International Journal of Project Management* 32(1): 101–15. <http://dx.doi.org/10.1016/j.ijproman.2013.03.004>.
- . 2014b. “Towards a Better Modelling and Assessment of Construction Risk: Insights from a Literature Review.” *International Journal of Project Management* 32(1): 101–15. <http://dx.doi.org/10.1016/j.ijproman.2013.03.004>.
- Torti, Lionel, Christophe Gonzales, and Pierre-Henri Wuillemin. 2010. “Reinforcing the Object-Oriented Aspect of Probabilistic Relational Models.” *Proc. of the 5th European Workshop on Probabilistic Graphical Models*: 273–80.
- Torti, Lionel, Pierre-henri Wuillemin, Informatique De Paris, and V I Upmc. 2013. “O3PRM Language Specification.” : 1–11.
- Tserng, H. Ping et al. 2009. “A Study of Ontology-Based Risk Management Framework of Construction Projects through Project Life Cycle.” *Automation in Construction* 18(7): 994–1008.
- Ward, S. 2003. “Transforming Project Risk Management into Project Uncertainty Management.” *International Journal of Project Management* 21: 97–105.
- Weber, P., G. Medina-Oliva, C. Simon, and B. Iung. 2012. “Overview on Bayesian Networks Applications for Dependability, Risk Analysis and Maintenance Areas.” *Engineering Applications of Artificial Intelligence* 25(4): 671–82. <http://dx.doi.org/10.1016/j.engappai.2010.06.002>.
- Wu, Wei-Shing et al. 2015. “Risk Assessment by Integrating Interpretive Structural Modeling and Bayesian Network, Case of Offshore Pipeline Project.” *Reliability Engineering & System Safety* 142: 515–24. <http://www.sciencedirect.com/science/article/pii/S095183201500188X>.
- Yang, Jing et al. 2011. “Stakeholder Management in Construction : An Empirical Study to Address Research Gaps in Previous Studies.” *JPMA* 29(7): 900–910. <http://dx.doi.org/10.1016/j.ijproman.2010.07.013>.
- Yildiz, Acelya Ecem, Irem Dikmen, and M. Talat Birgonul. 2014. “Using Expert Opinion for Risk Assessment: A Case Study of a Construction Project Utilizing a Risk Mapping Tool.” *Procedia - Social and Behavioral Sciences* 119: 519–28. <http://www.sciencedirect.com/science/article/pii/S1877042814021491>.
- Zhang, Hong, and Feng Xing. 2010. “Fuzzy-Multi-Objective Particle Swarm Optimization for Time-Cost-Quality Tradeoff in Construction.” *Automation in Construction* 19(8): 1067–75. <http://dx.doi.org/10.1016/j.autcon.2010.07.014>.
- Zhang, Y. B., Y. Q. Chen, and X. Y. Zhu. 2012. “Risk Management for Construction Projects with Colored Petri Nets: An Agent-Based Modeling Framework.” *2012 IEEE International Conference on Industrial Engineering and Engineering Management*: 2008–12.
- Zhong, Botao, and Yong Li. 2015. “An Ontological and Semantic Approach for the Construction Risk Inferring and Application.” *Journal of Intelligent & Robotic Systems* 79(3–4): 449–63.
- Zou, Patrick X W, Guomin Zhang, and Jia-yuan Wang. 2012. “Identifying Key Risks in Construction Projects : Life Cycle and Stakeholder Perspectives.” *University of New South Wales, Sydney*: 1–14.
- Zou, Patrick X W, Guomin Zhang, and Jiayuan Wang. 2007. “Understanding the Key Risks in Construction Projects in China.” *International Journal of Project Management* 25(6): 601–14.