



**UNIVERSITI PUTRA MALAYSIA**

***AGENT-BASED FRAMEWORK FOR IMPROVING COORDINATION OF  
URBAN INFRASTRUCTURE PROVISION FOR NEW RESIDENTIAL AREAS  
IN IRAN***

**SAEID YAZDANI**

**FRSB 2015 3**



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URBAN INFRASTRUCTURE PROVISION FOR NEW RESIDENTIAL AREAS  
IN IRAN**

**By**

**SAEID YAZDANI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in  
Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

**October 2015**

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## **DEDICATION**

I would like to dedicate this doctoral dissertation to my father, my mother, my wife and my son who have supported me throughout my life with their love, patience, and prayers.

Also, I would like to dedicate it to late Dr. Kamariah who supported me during this throughout my doctoral research journey.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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By

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**October 2015**

**Chair: Mohd Johari Mohd Yusof, PhD**

**Faculty: Design and Architecture**

Urban infrastructures are the main structure of cities, providing potable water, sanitary sewage, mobility, communication, power, and energy. Provision of urban infrastructure systems is a priority in any kind of urban development since without these critical urban systems proper urban development would not be possible. The involvement of different governmental agencies in the process of the urban infrastructure provision requires coordination between these independent agencies, which is an important aspect of the process. This research was prompted by the problem of a lack of coordination between urban infrastructure agencies (UIAs), which gives rise to numerous coordination challenges in the context of urban infrastructure provision in Iran. The aim of this research is to develop and validate an agent-based framework to coordinate the activities of the different agencies involved in the process of urban infrastructure provision in Iran. In order to achieve this, three objectives were developed: To identify and document the barriers impede coordination and drawbacks of lack of coordination in the context of urban infrastructure provision for new residential areas; to analyze and document the various kinds of interdependency among agencies involved in the process of urban infrastructure or new residential areas; and to develop and validate an agent-based framework for coordinating interdependencies among agencies involved in the process of urban infrastructure provision. Toward this end, a Sequential Mixed-method Multiple Case Study, comprising the process of infrastructure provision for five new residential sites in Iran, was designed and conducted. Research findings can be summarized as follows. Firstly, drawbacks of lack of coordination in the context of infrastructure provision can be categorized into seven major problems, such as increased project time and cost, duplication of activities, and the like. Secondly, seven types of coordination barriers can be addressed in the context of infrastructure provision, including differences in governance and management structures, frequent changes in organizational positions, and political pressure, among others. Thirdly, during the three main stages of infrastructure provision for new residential areas there are various kinds of interdependencies such as timing interdependency, resource interdependency, and requisite interdependency. Finally, this research by hybridization of the coordination science and agent-based paradigm, develops and validates an agent-based coordination

framework (ABC-framework) to manage the identified interdependencies. To sum up, by identifying different kinds of interdependencies in the context of urban infrastructure provision, it may provide an empirical guide for decision-makers to consider the potentials and limitations of urban infrastructure systems during the planning of new residential areas. Moreover, it may also offer a logical way for managing the complex process in the domain of urban development issues by means of a set of simple "if-then" roles.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**AGENT-BASED FRAMEWORK BAGI MEMPERBAIKI KOORDINASI  
INFRASTRUKTUR BANDAR DALAM KAWASAN PERUMAHAN BAHARU  
DI IRAN**

Oleh

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Infrastruktur bandar adalah faktor utama di dalam pembangunan sesebuah bandar yang merangkumi penyediaan bekalan air, sistem kumbahan kebersihan, mobiliti, komunikasi, kuasa serta tenaga. Penyediaan sistem infrastruktur bandar tertakluk kepada pelbagai aktiviti pembangunan kerana tanpanya, sistem pembangunan kritikal tidak mampu dilakukan secara betul. Penglibatan agensi-agensi kerajaan yang berbeza di dalam proses penyediaan infrastruktur bandar perlu penyelerasan bersepadu dengan agensi-agensi bebas dan ianya merupakan aspek penting di dalam proses infrastruktur tersebut. Kajian ini dirangsang oleh masalah kekurangan penyelerasan di antara agensi-agensi infrastruktur bandar atau Urban Infrastructure Agencies (UIA) di dalam konteks penyediaan infrastruksur bandar di Iran. Kajian ini juga bertujuan untuk membangunkan suatu rangka kerja bagi menyelaraskan aktiviti-aktiviti agensi-agensi berlainan yang terlibat di dalam proses penyediaan infrastruktur tersebut. Bagi mencapai matlamat ini, tiga objektif telah dirangka di mana pertama, untuk mengenalpasti kelemahan kekurangan koordinasi, kedua, untuk mengenalpasti halangan atau rintangan dalam proses penyelerasan dan yang ketiga, untuk mengenalpasti kesalingbergantungan agensi-agensi yang terlibat dalam konteks penyediaan infrastruktur bandar. Sehingga kini, objektif ini telah direalisasikan melalui pelbagai kajian kes kualitatif dalaman yang terdiri daripada penyediaan infrastruktur bagi empat tapak projek kediaman baru di Iran, yang telah pun direka dan dijalankan. Hasil kajian boleh dirumuskan seperti berikut. Pertama, kelemahan kekurangan penyelerasan dalam konteks penyediaan infrastruktur boleh dikategorikan kepada tujuh masalah utama yang melibatkan masa dan peningkatan kos projek, aktiviti yang berulang (duplikasi) dan sebagainya. Kedua, tujuh jenis halangan penyelerasan boleh ditangani dalam konteks penyediaan infrastruktur, termasuk perbezaan di dalam tadbir urus serta pengurusan, perubahan yang kerap dalam kedudukan organisasi, tekanan politik dan sebagainya. Ketiga, di peringkat utama penyediaan infrastruktur bagi kawasan-kawasan perumahan baru terdapat pelbagai jenis kesalingbergantungan yang merangkumi masa dan sumber. Seterusnya, kajian ini melalui penghibridan sains penyelerasan dan ejen berasaskan paradigma (ABC- yakni

rangka kerja) yang telah mampu mengenal pasti isu kesalingbergantungan yang wujud. Secara ringkas, dengan mengenal pasti jenis kesalingbergantungan dalam konteks penyediaan infrastruktur bandar, ianya mampu memberikan suatu kaedah empirikal bagi mencapai keputusan untuk mempertimbangkan potensi serta batasan sistem infrastruktur bandar di dalam perancangan kawasan perumahan baru. Selain daripada itu, ianya juga merupakan suatu kaedah yang logik bagi menguruskan proses rumit atau kompleks di dalam domain isu dalaman pembangunan bandar di mana set mudah “jika-maka” (“if-then”) memainkan peranan penting.





## ACKNOWLEDGEMENT

First and foremost, all praise and thanks to God, the Almighty, for His showers of blessings throughout my research work to complete the task successfully.

I would like to express my sincere and deep gratitude to my supervisor, Dr. Mohd Johari Mohd Yusof, for giving me an opportunity to study for a PhD degree and providing invaluable guidance throughout this research. His motivation, vision, sincerity, and dynamism have deeply inspired me. I would like to thank him for his support and friendship.

I am also extremely grateful to my supervisory committee members, Associate Professor Dr. Kamariah Dola and Prof. Dato' Abang Abdullah Abang Ali for their attention, insightful comments and constructive feedback.

My special thanks to Professor Dr. Mohammad Mahdi Azizi for not only being a salient member of my supervisory committee, but also for his inspirational mentorship during my graduate studies.

**APPROVAL**



This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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## LIST OF ABBREVIATIONS

ABC-Framework	Agent-Based Coordination Framework
ABM	Agent-Based Modeling
ABMS	Agent-Based Modeling Simulation
ABS	Agent-Based System Or Simulation
ACL	Agent Communication Language
BUI	Built Urban Infrastructure
CFP	Calling For Proposal
CO-Agent	Coordinator Agent
C.G.S	City Gate Station
CSS	Complex System Science
EC-Agent	Electric Company Agent
GC-Agent	Gas Company Agent
GUI	Green Urban Infrastructure
HEC	Horizontal External Coordination
HIC	Horizontal Internal Coordination
IBM	Individual-Based Modeling
IGS	Iranian Gas Standard
MAS	Multi-Agent System
ONU	Optical Network Unit
PSI	Parcel Shape Index
SC-Agent	Sewerage Company Agent
TCC-Agent	Tele-Communication Company
TC-Agent	Transportation Company Agent
UIAs	Urban Infrastructure Agencies
UI-Provision	Urban Infrastructure Provision
VIC	Vertical Internal Coordination
VEC	Vertical External Coordination
WC-Agent	Water Company Agent

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Urban infrastructure systems, including water supply, wastewater collection, electric power, piped gas, telecommunication, and transportation, are the pillars and backbone of civilized society. These critical urban systems support virtually all aspects of daily life in modern societies. Therefore, provision of these essential urban structures is a priority in any kind of city development. Coordination is a key enabler in the process of urban infrastructure provision, which will be referred as “UI-provision” in this research. This is because it brings together different agencies involved in the UI-provision to make their endeavors more compatible in terms of effectiveness and efficiency.

In Iran, since various government agencies are involved in the UI-provision, coordination between these independent agencies plays a vital role in the success of the process. In the other words, lack of coordination between different urban infrastructure agencies, which will be referred as “UIAs” in this research, can jeopardize the success of the process. Toward this end, this research aimed to develop a framework to coordinate different governmental agencies involved in the process of UI-provision for a new residential area.

This chapter introduces the motivations and underlying concepts of the research. It begins with section 1.2, which discusses the research background, followed by the determination of the problem statement in section 1.3. The research questions and the research objective are formulated in sections 1.4 and 1.5 respectively. Section 1.6 discusses the research methodology, that is, the research approach and technique, applied in this study. The scope and limitation of the research and research significance are the focus in sections 1.7 and 1.8, respectively. Finally, the organization of the thesis is presented in 1.9.

### 1.2 Research Background

The urban population worldwide is expanding at an unprecedented rate. In 2009, the total urban population of the world ( $3.42 \times 10^9$ ) exceeded the rural population ( $3.41 \times 10^9$ ), for the first time in history (UN, 2010). According to Montgomery (2008), it is projected that a major portion of the world population growth will occur in urban areas, and the world urban population will reach  $5.26 \times 10^9$  by the year 2050. This high rate of urbanization accelerates the need for UI-provision. This is due to the absence of urban infrastructure, and urban expansion resulting in the formation of slums (Otegbulu & Adewunmi, 2009). In conformity with this, Porter (1986) states that urban infrastructure systems are a crucial factor in urban development, because without them development would not occur. However, the significant role of urban infrastructure systems in city development, city function, and city management over short, medium, and long terms has been acknowledged by many authors (see, for example, Zhang, Wu, Skitmore, &

Jiang, 2014; Cidell, 2014; Corvellec, Campos, & Zapata, 2013; Wang, Zhang, Zhang, & Zhao, 2011; Ogun, 2010; Wu, 2010; Seitz, 1995; Cotton & Franceys, 1994; Von Rabenau & Hanson, 1979).

Lack of urban infrastructure is one the main factors in slum formation as well as deterioration of housing conditions in cities (Bremer & Bhuiyan, 2014; Edelman & Mitra, 2006). According to Moreno (2003), absence or presence of these critical urban facilities is a significant difference between formal and informal settlements. In line with this view, Abrams (1964) argues that housing is not just shelter, but is also based on many factors such as social milieu, economic activities, industrialization, and urban infrastructure development. Demand for housing in the real world embodies demand for urban infrastructure systems (Hirsch, 1976). However, the essential step for improving the quality of life of slum dwellers is the provision of urban infrastructure for them (Butala, VanRooyen, & Patel, 2010; McFarlane, 2008).

UI-provision is often in the foreground when in discussions on urban development (Ausbel & Herman, 1988). The process of provision of these essential systems has several unique features which are distinct from other construction processes. Firstly, UI-provision is a time-consuming and lengthy process (Young & Hall, 2013; Herder, de Joode, Ligtoet, Schenk, & Taneja, 2011), involving financing, construction, and operation. Secondly, UI-provision is a high cost process and oftentimes deals with cost recovery problems (Wu, 1999). Thirdly, this process is extremely complicated and highly intricate (Sözüer & Spang, 2012). Finally, UI-provision worldwide is invariably the task of the public sector (Ostrom, 1996; World Bank, 1994).

The process of UI-provision in new development areas can be influenced by several factors, including financial aspects, characteristics of the new development areas, and coordination challenges (Linn, 1983). Financing aspects of UI-provision have been frequently scrutinized by many authors (see, for instance, Inderst & Stewart, 2014; Acharya & Sundaresan, 2014; Tsui, 2011; Cummings & Mehr, 1977; Gramlich, 1994, to cite a few). For example, Kessides (1993) points out that UI-provision is more cost-effective when it is subject to user charges. From another perspective, Pethe and Ghokde (2002) maintain that of financing in urban infrastructure development lies in finding new methods such as “municipal-bonds”. Another major aspect of UI-provision, characteristics of new residential areas, has been analyzed by several authors. Kain (1967), for instance, analyzes the impact of urban form, lot size, and density on the cost of UI-provision, and concludes that the shape and size of lots are more important than the density of a new development area. In the same vein, DeMers (2003) discusses the role of the Parcel Shape Index, the ratio of the parcel’s perimeter over the square root of its area, in the total cost of UI-provision. He pointed out that when a Parcel Shape Index (PSI) increases, the cost of UI-provision decreases. Unlike other two major aspects of UI-provision, very few efforts have been devoted to coordination challenges in the context of UI-provision. However, Liu (2004) and Webster and Theeratham (2004) investigate the coordination context of infrastructure provision in China and Thailand, respectively.

In Iran, like in most other countries, urban infrastructure systems are provided mainly by the public sector. Despite emphasizing the importance of cross-sectorial interrelationships in the process of UI-provision (Hickford, Nicholls, Otto, Hall, Blainey, Tran, & Baruah, 2015), in Iran, based on the sectorial planning paradigm (Farhoodi, Gharakhlou-N, Ghadami, & Khah, 2009), the process has been dispersed over different government agencies. Several government agencies, inter alia, Water and Wastewater Company (Water Department and Wastewater Department), Gas Company, Telecommunication Company, Road Department, and Electric Companies are involved in the process of UI-Provision. These government agencies, which are vertically linked to national entities, are set up at the city level to provide their services (Hejazi, 2003).

In Iran, very little effort has been made to investigate the process of UI-provision. These efforts mainly focus on the financing aspects of UI-provision. For example, Azizi (1995) argues about the user-pay system as an effective financing method in UI-provision. As another example, Azizi (2000), from an equity and efficiency perspective, analyzes the implication of the user-pays method in the context of UI-provision in Iran. However, in spite of the vital role of coordination in the context of UI-provision, there is insufficient attention paid to this major aspect of UI-provision. Therefore, this research aimed to fill this gap in the literature by evaluating the process of urban infrastructure provision in Iran.

### **1.3 Problem Statement**

In the context of rapid urban expansion, provision of urban infrastructure systems has been a main concern to citizens, policy makers, scholars, experts, and practitioners. UI-provision is a multi-faceted process. Among the different aspects of UI-provision (Linn, 1983), coordination between different agencies involved in the process of UI-provision plays a vital role in the achievement of the process. That is, coordination brings together these independent agencies to make their activities compatible in order to improve effectiveness and efficiency of the UI-provision process. The importance of coordination in the context of UI-provision is derived from several factors, including complexity in the process of UI-provision; interconnected nature of urban infrastructure systems; and limitation in common resources.

Lack of coordination in the context of UI-provision results in inefficiency, which occurs when spillover across UIAs cannot be managed; when different agencies engage in destructive competition; and when limited resources are fragmented. Lack of coordination in the context of UI-provision could lead to economic problems (Panday & Jamil, 2010; Castalia, 2004), environmental degradation (UTCE/ALMEC, 2004), and social issues (Coutinho-Rodrigues, Simão, & Antunes, 2011; Panday, 2006). Furthermore, lack of coordination may result in drawbacks such as conflict and friction between UIAs, duplication of activities (Panday & Jamil, 2010), and failure in meeting project deadlines (Khan, 1997).

In Iran, like other countries, has adhered to a sectorial paradigm in urban planning, the responsibilities and authorities of UI-provision have been disintegrated over several government agencies. These government agencies, which are vertically linked to provincial and national entities, are established at the city levels to provide urban infrastructure commodities. The multiplicity of decision-makers at central levels, emphasizing central-local relations (Zamani & Arefi, 2012), and lack of horizontal relationship between UIAs (Hejazi, 2003) lead to lack of coordination in the context of UI-provision in Iran.

This research was motivated by the researcher's management experience (over 8 years) as a manager of water and wastewater company and head of a city council in Iran. In which, he observed that the process of UI-provision of in Iran suffers from lack of coordination between government agencies involved in the process. However, despite the significant role of coordination in the context of UI-provision, as discussed in section 1.2, little is known about how government agencies can coordinate their activities in the process of UI-provision for a new residential area. Therefore, the purpose of this study is to understand how UIAs can coordinate their activities in the context of UI-provision for a new residential area in Iran. The following research questions were formulated to help achieve the objectives of this research.

#### **1.4 Research Questions**

As discussed in section 1.3, this research aims to understand how coordination between agencies, which are involved in the process of UI-provision in Iran, can be improved. Due to the nature of this study, it is planned as a non-hypothetical research. To achieve the research objectives, the following questions guide this inquiry.

Main Research Question:

How can agent-based paradigm be utilized to improve coordination between agencies involved in the process of urban infrastructure provision for new residential areas in Iran?

Sub-Research Question 1:

What barriers affect coordination between agencies involved in the process of urban infrastructure provision? and what are their effects?

Sub-Research Question 2:

What kinds of interdependency exist among agencies involved in the process of urban infrastructure provision for new residential areas?

Sub-Research Question 3:

How can interdependencies among agencies involved in the process of urban infrastructure provision be coordinated?



## 1.5 Research Objectives

Research Objective 1:

To identify and document the barriers that impede coordination and the drawbacks of lack of coordination in the context of urban infrastructure provision for new residential areas.

Research Objective 2:

To analyze and document the various kinds of interdependency among agencies involved in the process of urban infrastructure for new residential areas.

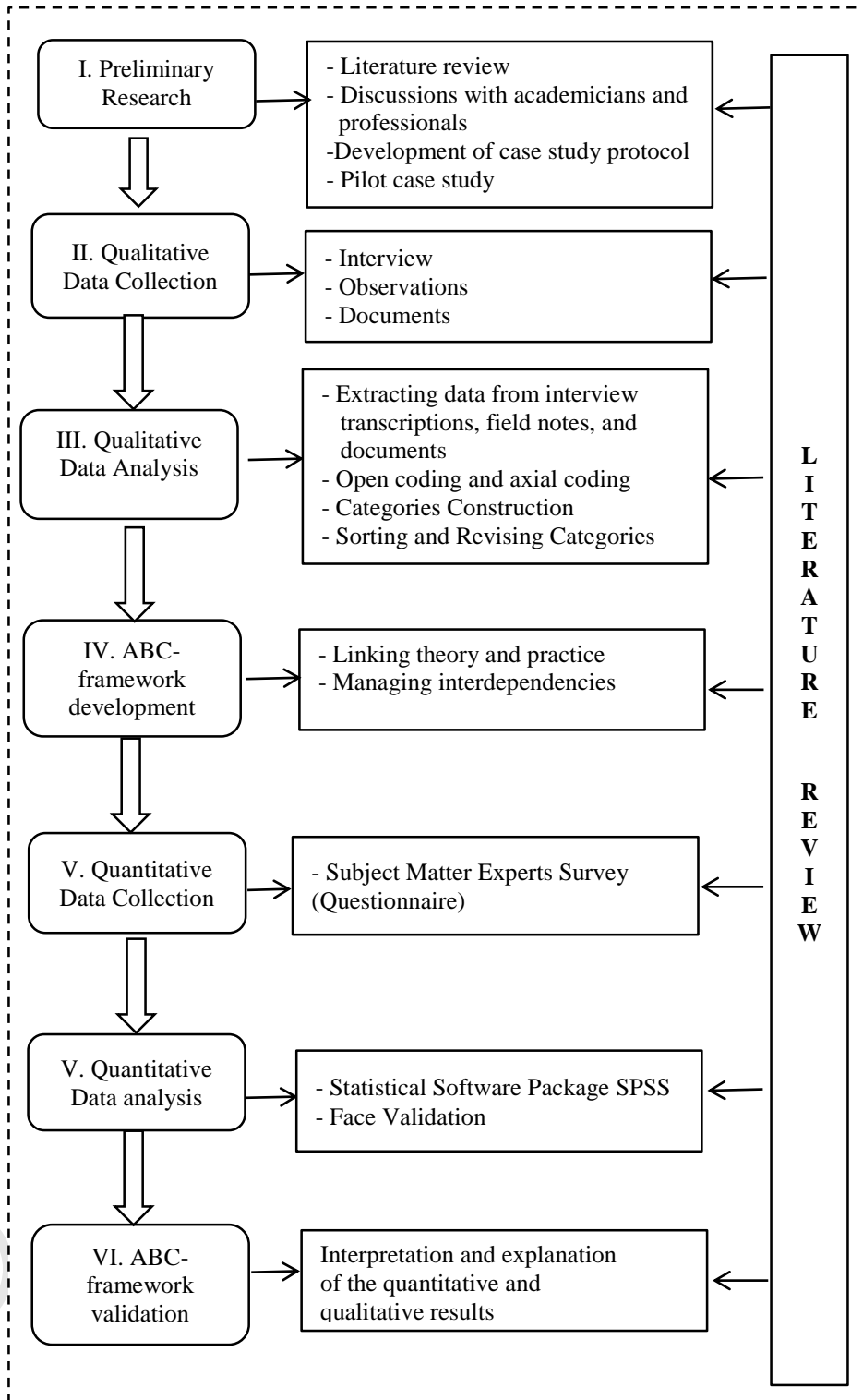
Research Objective 3:

To develop and validate an agent-based framework for coordinating interdependencies among agencies involved in the process of urban infrastructure provision.

## 1.6 Research Methodology

This research study aims to develop and validate a framework (agent-based coordination framework) to improve coordination between agencies involved in the process of UI-provision. With respect to the nature of this research, mixed method is deemed to be a suitable approach for this research. In turn, considering the main question of the research, which is the "how" question, as well as the unique features of the research (researcher has no control on the phenomenon being studied and contemporary set of events in the research) case study was selected as the research technique. Therefore, a sequential mixed-method multiple case study was designed for this research. However, depending on the research questions and objectives, it was decided to give priority to qualitative data collection and analysis.

In the first, qualitative, phase, three main methods of data gathering in qualitative research, namely, interviews, observations, and documents were employed. The general analytic strategy, employed in the analysis stage, is "relying on theoretical proposition" and to construct the categories or findings of the study "explanation building technique" was applied. Also, several strategies were employed in the data collection and data analysis stages to address validity and reliability issues. In second, quantitative, phase, data were collected through a survey of 32 experts from agencies involved in UI-provision, using a questionnaire based on Likert 5-point agree/disagree scale. All quantitative data analyses were performed by means of statistical software package SPSS version 22 (SPSS Inc.). In this research, the investigator examines examples, opinions, and insights into the coordination process in the context of providing urban infrastructure for new residential areas in Iran. To do so, as illustrated in Figure 1.1, this research was undertaken in six main stages: preliminary research stage, qualitative data collection, qualitative data analysis, ABC-framework development, quantitative data collection, quantitative data analysis, and ABC-framework validation. However, in this research, in order to deal with validity and reliability issues, the following strategies are applied: internal validity (strategies: triangulation and member checking); external validity (strategies: maximum variety in selecting of cases and maximum variety in selecting of participants); construct validity (strategies: use of multiple sources of data and reviewing the initial findings by key informants); and reliability (strategies: use of the case study protocol, developing case study database, and triangulation).



**Figure 1.1. Research process**

## **1.7 Scope and Limitation**

This study focuses specifically on coordination aspects of provision of urban infrastructure for new residential areas, in Iran. It covers coordination aspects (coordination challenges, coordination barriers, and interdependencies) during the three main stages of UI-provision for new residential areas, namely, site selection, and designing, and implementation stages. It therefore does not deal with coordination aspects during operation and maintenance (O & M) stage of the urban infrastructure systems. Furthermore, this research does not deal with other aspects of UI-provision such as financing issues and physical characteristics of new development areas (Linn, 1983). Alternatively stated, undesirable physical characteristics of new areas and financing matters are beyond the scope of this study.

This research is particularly appropriate for situations where urban planning paradigm adheres to sectorial models, like Iran, in which government agencies, which are vertically linked to national level, are established at the city levels to provide urban infrastructure for the new residential areas. Therefore, the findings of this research can only be generalized in relation to this kind of urban development paradigm.

## **1.8 Research Significance**

This study has been motivated by the lack of research on this topic. Despite the abundance of literature on urban infrastructure provision for new development areas, little has been discussed pertaining to coordination aspects of UI-provision in developing countries like Iran. With respect to the pivotal role of coordination in the context of UI-provision, there is pressing need for applied research on this aspect of the UI-provision process, that is, without which the process would suffer from lack of coordination between agencies involved in the process of UI-provision. Hence, this research contributes to the knowledge by identifying various aspects of coordination, including coordination challenges, coordination barriers, and interdependencies between agencies involved in the process of UI-provision.

Moreover, this research by hybridization of the two different domains of knowledge (coordination theory and agent-based paradigm) and empirical data (research findings), develop an agent-based coordination framework. This framework offers a practical way to coordinate the activities of different government agencies who are involved in the process of UI-provision for new residential areas.

In summary, this study will not only contribute to the body of knowledge by investigating the different facets of coordination aspect of UI-provision, but it will also provide a framework for decision-makers to coordinate their activities in the context of UI-provision for new development areas.

## 1.9 Organization of the Thesis

This PhD thesis is organized in six chapters. Chapter 1 provides an outline of the study, including research background, problem statement, research questions and objectives. It also discusses the importance of the topic and scope of the study.

Chapter 2 provides a critical literature review of the three domains of relevant knowledge, including UI- provision issues and coordination context UI-provision in Iran; a conceptual review on coordination and coordination theory; and agent-based modeling paradigm and its direct root complex system science. This chapter highlights the importance of coordination in the context UI-provision as well as the capability of the agent-based paradigm to deal with coordination challenges in a complex process such as UI-provision.

Chapter 3 explains the research methodology. It discusses the adopted research design, research approach and technique for collecting and analyzing data and reporting findings. It also explains the three main sources of research data and strategies applied in this research for enhancing the validity and reliability of findings.

Chapter 4 presents the main findings of the research, including the drawbacks of lack of coordination in the context of UI-provision; coordination barriers in the process of UI-provision; and interdependencies between UIAs during three main stages of UI-provision. This chapter ends with an analytical discussion on the research findings.

Chapter 5 presents an agent-based coordination framework to coordinate different agencies involved in the process of UI-provision for new residential areas in Iran.

Finally, Chapter 6 summarizes the whole research with highlights on its findings and the proposed framework. The chapter also presents a discussion on the significance of the research findings and recommendations for future research.

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