Towards Sustainable Information Infrastructure Platform for Smart Mobility
-Project Overview-

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Abstract— **Smart mobility systems, which include Intelligent Transportation System (ITS) and smart energy systems, become more important. There is, however, lack of its platform studies. This paper proposes a sustainable information infrastructure project for smart mobility systems. The project pursues issues that establish an information infrastructure architecture and seamless development method chain for it. The project has mainly two features; 1) applying life-cycle-oriented methods, which are a cycle from system development to operations, to the real world, and 2) dealing with uncertainties when a system begins to be designed. This paper describes an overview of the project.**

Keywords—Smart Mobility, Life-Cycle-Oriented, Uncertainty, Real Word, ITS, Smart Energy.

I. INTRODUCTION

Smart mobility, which includes Intelligent Transportation System (ITS) and smart energy systems, becomes more important. There are lots of researches for smart mobility, most of which, however, have focused on separated techniques such as sensing acquisition, and visualization of automobile probe data, etc. There is a lack of systematic/foundational research on system design, development, and construction of an information infrastructure for smart mobility. For the infrastructure research, it is important that life-cycle-oriented methods must be constructed, since smart mobility systems rapidly change. The life-cycle-oriented methods mean ones that are applied from system development to system operations and feed-backed from the operations to the development after performing operations.

The paper proposes a sustainable information infrastructure project for smart mobility. The project pursues establishing an information infrastructure architecture and seamless-development-methods-chain for it. The project has mainly two features: 1) applying life-cycle-oriented methods, which are a cycle from system development to operations, to the real

world, and 2) dealing with uncertainty when a system begin to be designed. This paper describes the project's overview.

This paper is organized as follows: Section 2 describes a smart mobility information infrastructure where this paper addresses. Section 3 describes our project overview including its features and challenging issues. Section 4 gives definition, categorization of uncertainty, and handling the uncertainties considered in this paper. Section 5 presents our preparation towards this project. Section 6 discusses the project. Section 7 describes some related works. Finally, Section 8 concludes this paper.

II. SMART MOBILITY INFORMATION INFRASTUCTURE PLATFORM

An overview of the smart mobility information infrastructure platform is shown in Fig.1. It consists of three components: information collection into a platform, the platform, and information provision services.

1) The information collection component
The information collection component gathers data from sensing physical world, which include new sensors, shop or tourist resort information, government one, original ITS one, various services by vendors, etc. That is IoT (Internet of Things). The data collected are stored in a database as big data in the platform.

2) The platform component
The platform component consists of the following.
・System documents and assets that include ones from system design to source code programs, etc.
・System contents that operate the smart mobility systems including big data. The platform allows us to provide new services to business companies.

3) The information provision service component
By using the platform, business companies can provide various and innovative services to users. These services

include normal or vulnerable road ones and smart mobility oriented novel ones.
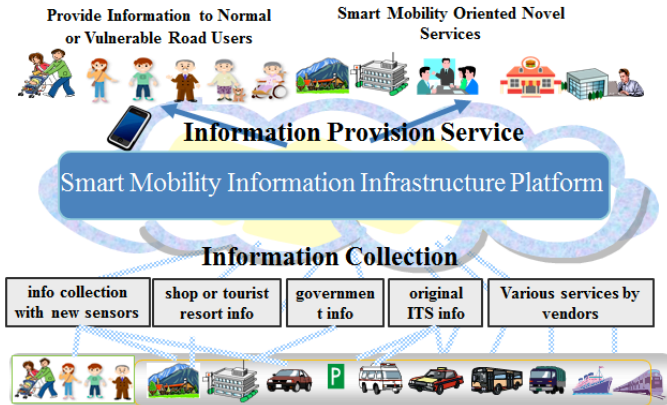

Fig. 1.   Smart Mobility Information Infrastructure Platform.

III.   PROJECT OVERVIEW

(1) Features of the project

Our project has the following features.

1)   Real Life-Cycle-Oriented Project

There are lots of researches and projects that deal with life-cycle system development (Fig.2). Most of these researches, however, have not applied to real world field. Our project is to apply the proposed methods to real world field. Target fields of the project are ITS and smart energy systems. In particular, the ITS company joining this project is the biggest one in Japan. This provides a solid guarantee for our project's success.
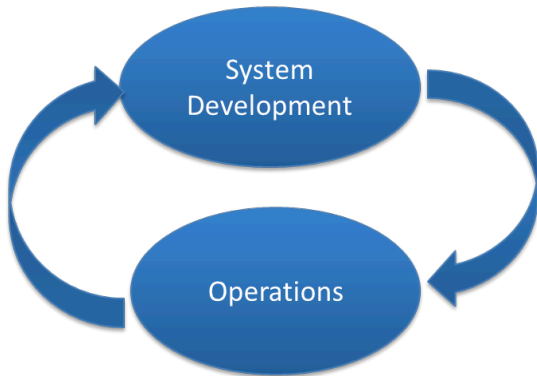

Fig. 2.   Life-Cycle-Oriented Development

2)   Dealing with Uncertainty

The most important feature is that our project deals with uncertainty that is not decided in the system design phase. Recently, many systems become big and complicated. In addition, its requirements of users become ambiguous. In the design phase of a system, some parts of the system itself and operation ways are not decided. This is uncertainty. During operations after building the system, the uncertainty is decided.

In particular, the smart mobility systems, including ITS and smart energy systems, are rapidly changing. Therefore, it is important to rapidly construct a system and to feedback to the system after operating the system.

(2) Challenging Issues of the Project

Our project pursues the following challenging issues (Fig.3). Totally, the object of the project is to establish a sustainable information platform architecture for smart mobility systems.

1) Establishing Life-Cycle-Oriented Architecture

Life-cycle-oriented architecture that includes a cycle from system development to operations seems to be not clear so far. Therefore, this project proposes its architecture.

2) Establishing Life-Cycle-Oriented Technologies

Issues that occur during operations after system construction must be feedback to the system development. Therefore, the project develops traceability technologies from the operations to system development.

3) Establishing System Development to upper phase

In system development process, its upper phase such as system modeling phase is very important. For the modeling phase, many researches have been done. Our project also develops model-driven-based techniques and model checking techniques to apply them to real fields.

4) Establishing Seamless System Development Cycle

There are lots of system development methods. Most of these methods, however, seem to be disjoined from each other, which is not seamless. Seamless cycle that joins each method is needed. Our project develops a seamless process.
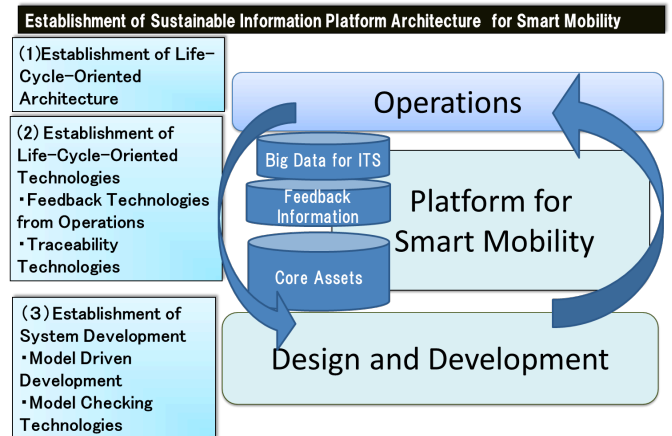

Fig. 3.   Challenging Issues of the Project

IV. UNCERTAINTY

A. Definition of the Uncertainty [1]

In this paper, the authors define uncertainty as necessary but unknown information for system development and operation that are recognized, defined, and named by developers and operators.

First, uncertainty must be recognized its existence by developers and operators. Thus, uncertainty never includes information discovered in later processes although it was necessary for system development and operations.

Second, uncertainty is not ambiguous and hazy information. Uncertainty must be defined as its expected form is described explicitly; in other words, uncertainty must be defined so that anybody can judge if necessary information for system development and operation is obtained or not.

Third, uncertainty should have an abstracted name representing necessary and unknown information for system development and operation.

B. Categorization of the unceertainty [1]

Uncertainty has been categorized in general social systems as described in the related works of this paper. This paper categorizes uncertainty into the following three items.

1) Multiple choice uncertainty:

In decision making, although multiple choices are proposed, one choice out of these multiple choices is not decided. One choice is decided in later process.

2) Parametric uncertainty:

In decision making, although one choice including parameters is decided, values of the parameters are not decided. These values are decided in later process.

3) Composite uncertainty:

The composite uncertainty is an abstract uncertainty composed by one or more multiple choice, parametric, or composite sub uncertainties relating to its corresponding decision making. The composite uncertainty is resolved when all of its sub uncertainties are resolved.

C. Handling uncertainty [2].

An outline of handling uncertainty is as follows (Fig.4):
1) Step 1: Making an uncertainty list sheet

From system documents such as requirements and specification, we make an uncertainty list sheet. In the sheet, we make functions such as classifying the uncertainty, its impact factors, etc.
2) Step 2: Making a case list

We extract items of the uncertainty from the sheet made in Step 1. In addition, we make a list that describes variability and its scope for each item.
3) Step 3: Making a feature model

We take a feature-oriented approach from requirements. This approach allows us to make a feature model. We mark items of the uncertainty in the feature model. From this model, we can clarify the uncertainty in the target system.

4) Step 4: Making a partial model including the uncertainty items.

We make a partial model that covers all uncertainty items marked in Step 4.
5) Step 5: Changing the model when the uncertainty items are fixed.

When one of the uncertainty items is chosen in later process, we change the model to reflect it.
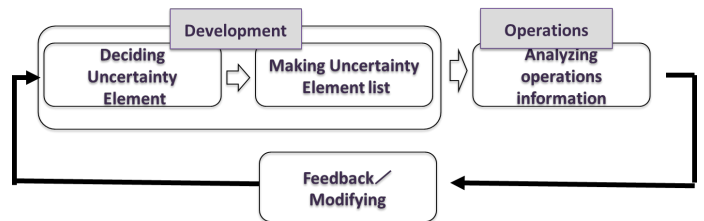

Fig. 4. Handling Process of Uncertainty between System Development and Operations.

V. PREPARATION

The authors have performed many studies towards smart mobility ones as follows.
(1) Uncertainty

Uncertainty has been addressed in management science rather than in software engineering field so far. The authors proposed a framework to manage uncertainty in software system development [1], [2], [3].
(2) Model driven development techniques

The authors developed a model driven tool called clooca [4]. Clooca has been used in education field of Japanese universities.
(3) Model checking techniques

Many model checking techniques have been developed. The authors have also developed the techniques and its tool called Garakabu2 [5]-[8]. Garakabu2 is provided as business tool by a Japanese company.
(4) Applications

The authors developed some applications including ITS field, on-demand-localization services, and smart city, etc. [9]-[12].

VI. DISCUSSIONS

The authors presented our project that performs sustainable information infrastructure platform study. The project has mainly two features: 1) constructing a life-cycle-oriented information infrastructure platform from system development to operations and 2) dealing with uncertainty in decision making phase.

・*Life-cycle-oriented development:*

Recently, collaboration between system development and operations has been addressed. One of them is called DevOps(=Devepment+Operation). DevOps seems to be ambiguous. Our project proposes its research direction.

・*Uncertainty:*

Uncertainty has been addressed in management field. Our project applies uncertainty into software development.

　・ *Seamless development cycle*

Many software development techniques have been developed. These techniques, however, seems to be separated from each other. Our project pursues seamless techniques for these tools.

VII.　RELATED WORK

(1) Uncertainty

In general, uncertainty seems to have been discussed much more in the field of management science rather than in the field of information engineering science. The term "uncertainty" has been used with confusion. Wynne classified meanings of the term "uncertainty" into the following seven category [13].

1) Risk: known damage and probabilities;
2) Uncertainty: known damage possibilities but no knowledge of probabilities;
3) Ignorance: unknown unknowns ;
4) Indeterminacy: issue and conditions, hence knowledge-framing open; maybe salient behavioral processes also non-determinate;
5) Complexity: open behavioral systems, and multiplex, often non-linear processes so that extrapolation from robust data-points always problematic;
6)Disagreement: divergence over framing, observation methods or interpretation. Questions of competence of parties; and
7)Ambiguity: precise meanings (hence salient elements) not agreed, or unclear.

The uncertainty discussed in this paper corresponds to the risk and the uncertainty in the above Wynne's categories.

(2) DevOps (=Development + Operations)

Recently, DevOps, which means that collaboration between system development and its operations must be performed, has been discussed. However, its content is ambiguous. For example, Weiyi Shang proposed that gap between software developers and operators must be resolved by using logs [14]. This paper proposes its direction of DevOps.

VIII.　CONCLUSION

In this paper, the authors proposed an information infrastructure framework for smart mobility systems. In addition, the authors constructed a project for it. By performing the project, the project will give an innovation research direction. There are still, however, many issues that should be investigated to accomplish our project successful. First, system evaluation performed by the project must provide useful information to information society. Second, the seamless tools must be provided to open-source ones for system developers and operators. Finally, our project must give a way to provide our project results to the world.

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