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Smart community infrastructures — Common framework for development and operation

Infrastructures urbaines intelligentes — Cadre commun pour le développement et les opérations

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Foreword

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The committee responsible for this document is Technical Committee ISO/TC 268, *Sustainable development in communities*, Subcommittee SC 1, *Smart community infrastructures*.

Introduction

In the foreseeable future, urban density is likely to increase, resulting in further urbanization complexity. From this perspective, a “smart community” approach is an important concept to address such urban challenges by integrating different forms of infrastructures in a rational and efficient manner.

An important aspect of a smart community is integrating infrastructures as “a system of systems”. Until now it has not been possible to ensure consistency across infrastructure types to meet the requirements for smart community infrastructures as owners have focused on just assembling solutions to each subsystem of infrastructures.

In order to ensure consistency of smart community infrastructures as a whole, first, functions of each subsystem need to be clarified and arranged based on the needs for a smart community, and secondly, the perspectives of various stakeholders and lifecycle of infrastructures need to be considered.

Thus, a new framework is needed to develop a procedure followed by all stakeholders in order to establish an orchestration function of each smart community infrastructure component and to achieve information sharing as well as consensus amongst the stakeholders.

For this purpose, ISO/TC 268/SC 1/AHG 1 “Common framework for development and operation of smart community infrastructures” was established to conduct preliminary studies to develop international standards to formulate a framework which realizes well-functioning smart community infrastructures as a whole, considering their characteristics, i.e. “a system of systems”, having various stakeholders, and long lifecycle. These standards will formulate technical procedures for stakeholders to achieve their accountability in developing, operating and maintaining smart community infrastructures as a system of systems. This document presents the results of the study conducted in the AHG. The framework aims to ensure consistency between smart community infrastructures without overlapping with existing work (see Figure 1). It incorporates the metrics as a KPI of the development, operation and maintenance methodology.

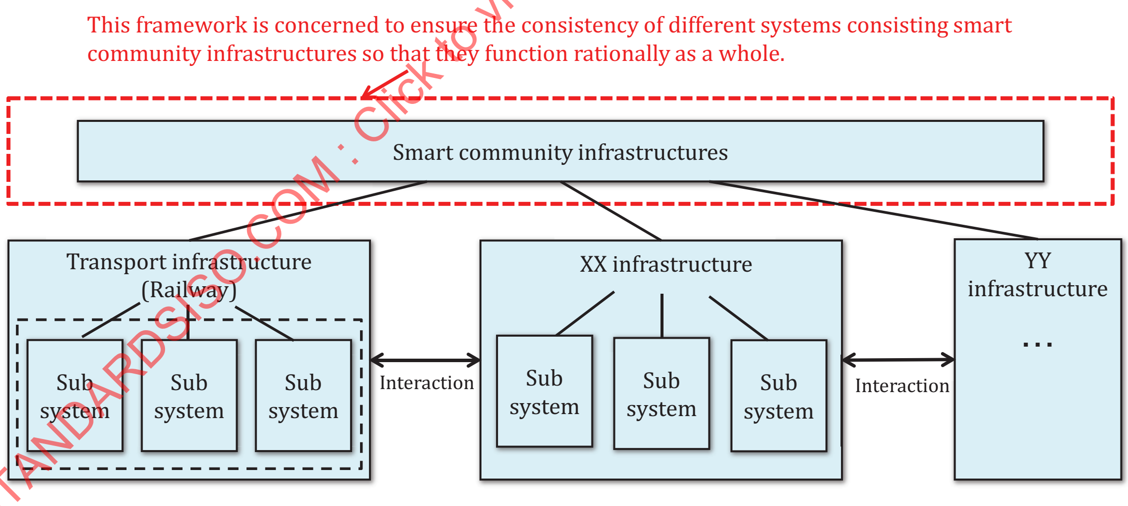

Figure 1 — Scope of the framework

Smart community infrastructures — Common framework for development and operation

1 Scope

This document outlines the basic concept of a common framework for the development and operation of smart community infrastructures. The framework describes the planning, development, operation and maintenance methodology to facilitate the harmonization of each infrastructure as a part of a smart community and ensures that the interactions between multiple infrastructures are well orchestrated.

The framework is applicable to all processes of smart community infrastructures' life cycle (from conceptual design through planning, development, operation, maintenance, redevelopment and feedback). The infrastructures to be covered are energy, water, transportation, waste management, ICT and others.

The framework can be adopted by all relevant stakeholders who are engaged in planning, development and operation of smart community infrastructures, including planners, developers, business operators and suppliers. The framework is intended to cover the processes in which these stakeholders are engaged, such as management, organizational structure, analyses and design methods, and documentations.

2 Possible issues and solutions in developing and operating smart community infrastructures

2.1 Possible issues and solutions

Features of smart community infrastructure can be described as below:

— Smart community infrastructure is infrastructure that has a high level of financial and resource efficiency and convenience for people.

— To achieve the above state, smart community infrastructure

  — has orchestration function to achieve synergy effect of multiple types of infrastructures to improve financial and resource efficiency and convenience for people, and

  — maintains its efficiency in adaptive manners against any changes of city's circumstances including disasters and demographic changes to improve financial and resource efficiency and convenience for people (resiliency / dependability).

NOTE 1 Efficiency means output performance divided by resource input.

NOTE 2 The orchestration function can be implemented by either a centralized approach or a decentralized autonomous approach.

Since smart community infrastructures have the features shown above, they may have three characteristics different from those of conventional infrastructures (see Figure 2). Issues are identified from the characteristics as below. In addition, solutions corresponding to these issues are extracted as elements of the framework.

— Issues due to "a system of systems" and long life cycle:

  — Difficulties in ensuring consistency among components, without which functionality of the whole system of smart community infrastructures cannot occur.

— Considerable influence by interference of external systems or interactions among components onto the quality and performance of smart community infrastructures as a whole.

— Issue due to the participation of many different stakeholders:

— Various interest and wide range of responsibilities dispersed among stakeholders.

In Table 1, specific issues, extracted from the main three issues described above, are summarized along with solutions that will effectively accommodate these issues.

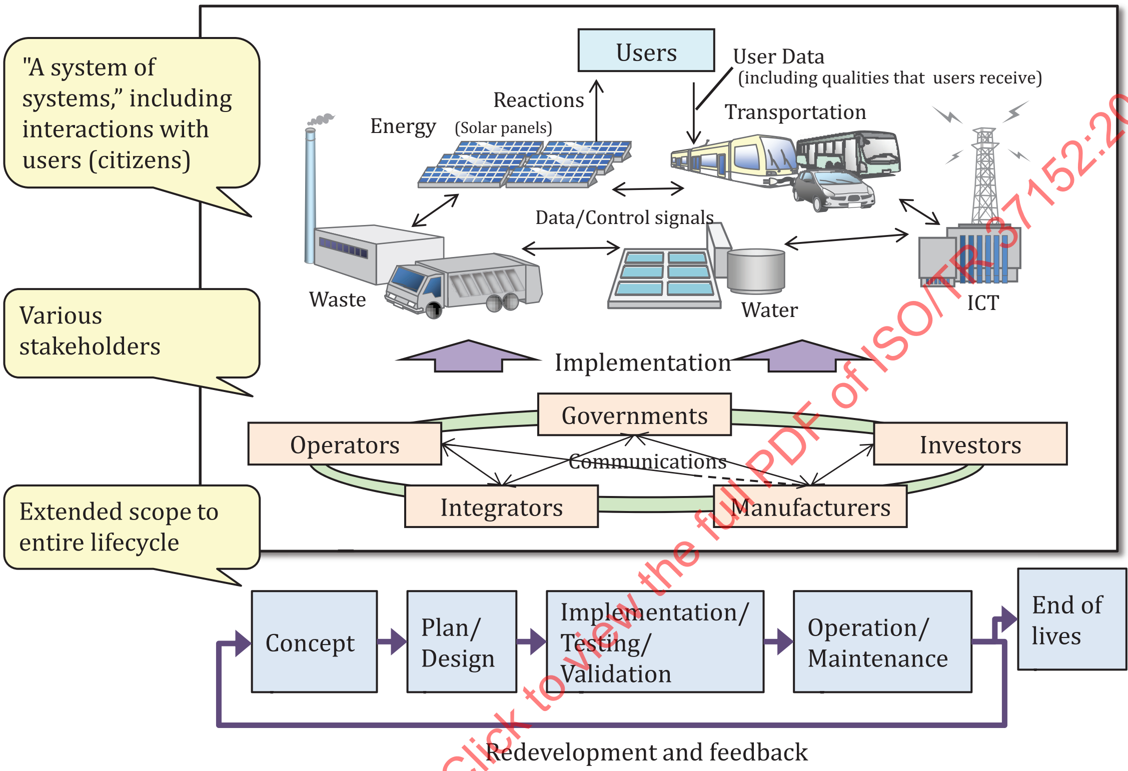

Figure 2 — Characteristics of smart community infrastructures

Table 1 - Possible issues and solutions in developing and operating smart community infrastructures[1] (1 of 2)

Main issues	Specific issues extracted from main issues	Case examples of each specific issue	Solutions (Elements of the framework)
Difficulties in ensuring consistency among components, without which functionality of the whole system of smart community infrastructures cannot occur.	Value added to smart community infrastructures as a whole cannot be shown simply by verifying the performance of each subsystem or component resulting in undervaluation of the appeal integrated infrastructure benefits.	Case example (a) (See 2.2.1.1)	**Element (A)** : Allocation of specifications to each component and validation of the allocating procedures (See 3.2.1).
	Smart community infrastructures may not achieve their target value simply by assembling high performance subsystems / components unless the consistency among the subsystems / components is ensured.	Case example (b) (See 2.2.1.2)	
Considerable influence by interference of external systems or interactions among components onto the quality and performance of smart community infrastructures.	Fluctuation in the parameters of various interactions (in short terms as well as long terms) could curb performance of smart community infrastructures.	Case example (c)～(e) (See 2.2.2.1)	**Element (B) :** Specifications associated with interaction including investigation between outside/inside smart community infrastructures and adopt countermeasures into planning and operation (See 3.2.2).
	Due to limitations in capabilities of external infrastructures, requirements and needs of smart community infrastructures as a whole cannot realised.	Case example (f) (See 2.2.2.2)	

[1] 2.2 and 3.2 of this Technical Report refer to Table 1.

Table 1 - Possible issues and solutions in developing and operating smart community infrastructures[1] (2 of 2)

Main issues	Specific issues extracted from main issues	Case examples of each specific issue	Solutions (Elements of the framework)
Various interest and wide range of responsibilities dispersed among stakeholders.	Stakeholders in different situations make communication complicated.	Case example (g) (See 2.2.3.1)	**Element (C):** Process to facilitate the information sharing and communication among stakeholders (See 3.2.3).
	Many stakeholders of different smart community infrastructures hardly bring efficient information sharing resulting in difficulties in planning and development of smart community infrastructures.	Case example (h) (See 2.2.3.2)	Need comprehensive discussion at the community level, in addition to the elements (A) to (C).

2.2 Case examples of issues

2.2.1 Difficulties in ensuring consistency among subsystems, without which functionality of the whole system of smart community infrastructures cannot occur

2.2.1.1 Value added to smart community infrastructures as a whole cannot be shown simply by verifying the performance of each subsystem resulting in undervaluation of the appeal integrated infrastructure benefits (see Figure 3)

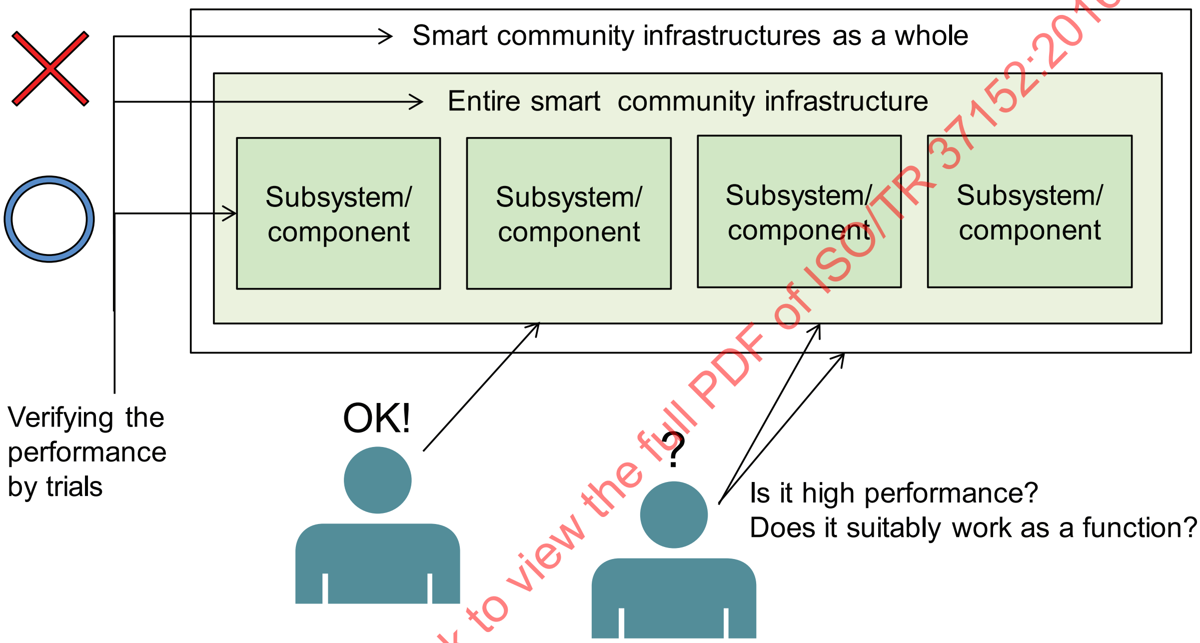

Figure 3 — Difficulty in showing added value to smart community infrastructures as a whole

Case example (a): If the value added of the community brought by the smart community infrastructures is not visible, it would not appeal to users sufficiently to get a return on the investment.

City developers generate profit by increasing value of smart communities (including intangible elements such as convenience, comfort, low costs and so on), by introducing smart community infrastructures. To give an example, if heat supply system is introduced to a community, which can reuse exhaust heat from sewage treatment facility, it will be an opportunity to appeal to the users who are willing to live in a community where energy bill and carbon emission are reduced despite comparatively high rent or water bill. However, in case the cooperation between sewage treatment facility and heat supply system is not defined and the expected amount of heat reuse is not clear, it is hard to appreciate much the reduction of energy bill and carbon emission would occur and thus would have limited appeal to end users. As a result, developers will not be able to raise rent or water bill and eventually fail to yield a fair return for additional investment in the heat reuse system.

2.2.1.2 Smart community infrastructures may not achieve their target value simply by assembling high performance components unless the consistency among the subsystems is ensured (see Figure 4)

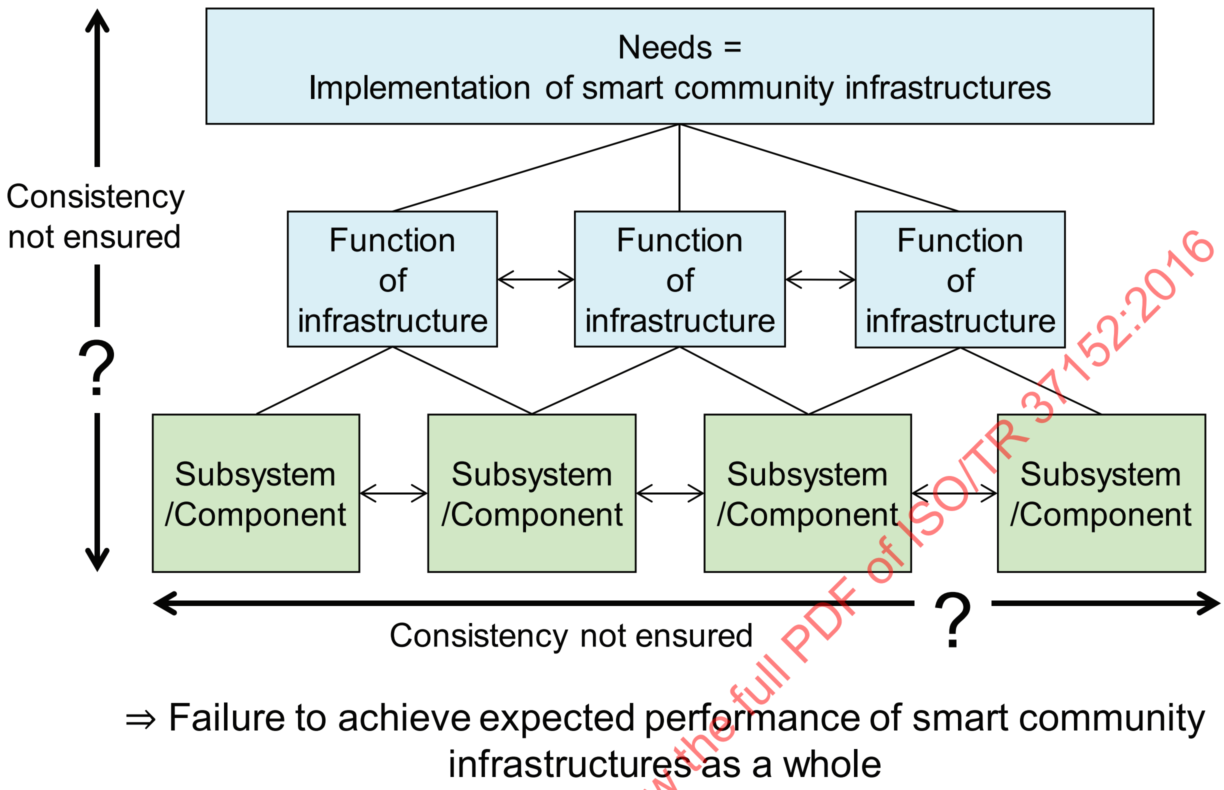

Figure 4 — Difficulty in achieving their target value unless the consistency among the subsystems is not ensured

Case example (b): Inconvenience on passengers due to unconnected and inconsistent services among transportation infrastructures

In a large scale project to integrate individual smart community infrastructures, business risks are often high. In such a situation, projects are divided into small parts or functions to be managed by a particular operator or supplier to make them develop their own infrastructures in their specific technical field. Thus, operators and suppliers focus their arrangements only on the component that they are directly responsible. Such a situation discourages communication on the consistency of broader smart community infrastructures.

For example, Japan Railways have operated a large service network of surface transportation in the country by operating ferries and buses besides railroads, which are of all different forms of infrastructures. Thus, the customers easily travel anywhere by using the network because all transportation services are organically connected, even between a bullet train or Shinkansen and bus servicers. On the other hand, private railroad, ferry and bus companies independently schedule and dispatch their respective trains, ferries or buses to carry their own customers in their small local territories. Thus, when such customers go on a trip across Japan, they are forced to make arrangements for their travel by themselves resulting in inconvenience and reducing satisfaction from travel, making changes between different modes unrealized.

2.2.2 Considerable influence by interference of external systems or interactions among components onto the quality and performance of smart community infrastructures

2.2.2.1 Fluctuation in the parameters of various interactions (in short-terms as well as long terms) could curb performance of smart community infrastructures (see Figure 5)

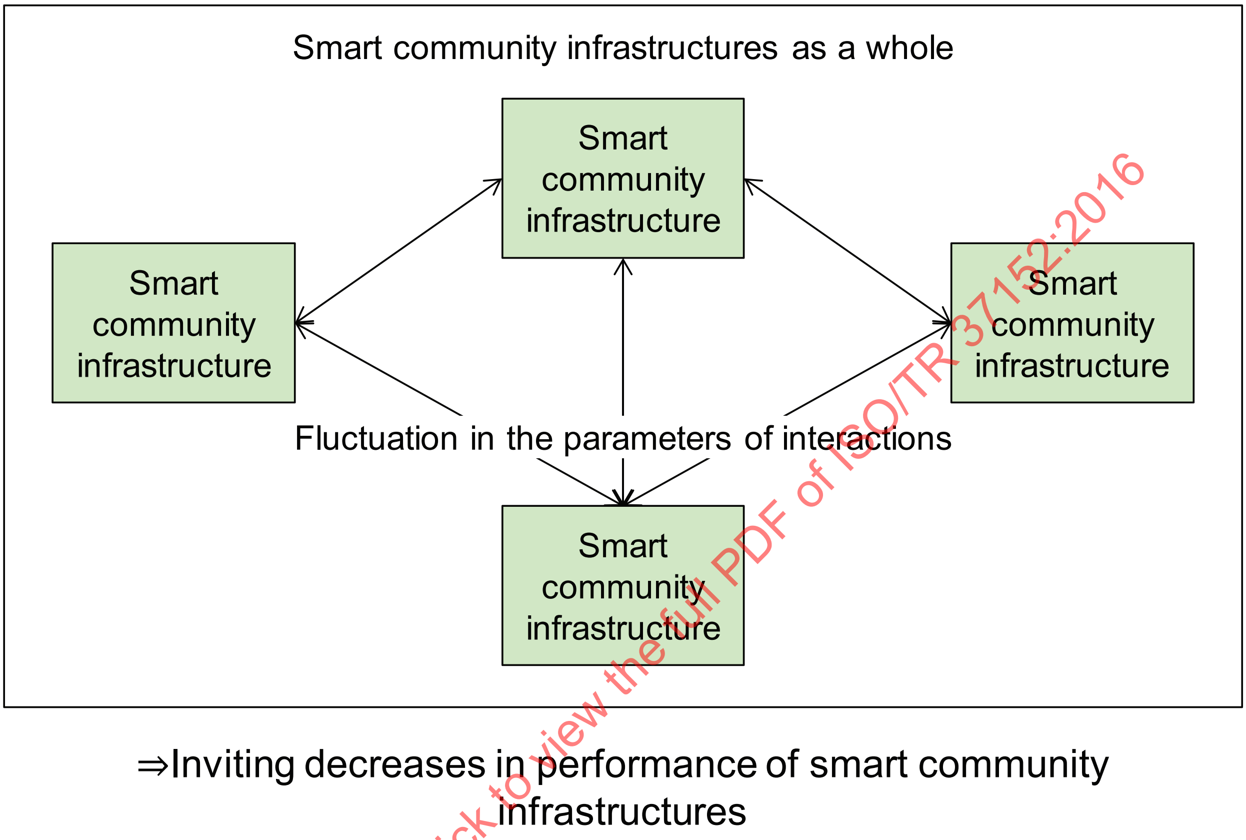

Figure 5 — Fluctuations in the parameters of various interactions

Case example (c): It is necessary to consider the changes in input and output generated from new interactions, different from those of conventional infrastructures, with other infrastructures.

Waste management system, for instance, used to be “the end point” to dispose of waste generated in a community. However, within a smart community it works also as “the starting point” to supply the recycled or upcycled resources back to the community.

As shown in Figure 6, it is necessary to control the changes in input (waste) and output (recycled resources) according to the demands to the resources. It is also needed to determine who should be responsible in case of supply shortages.

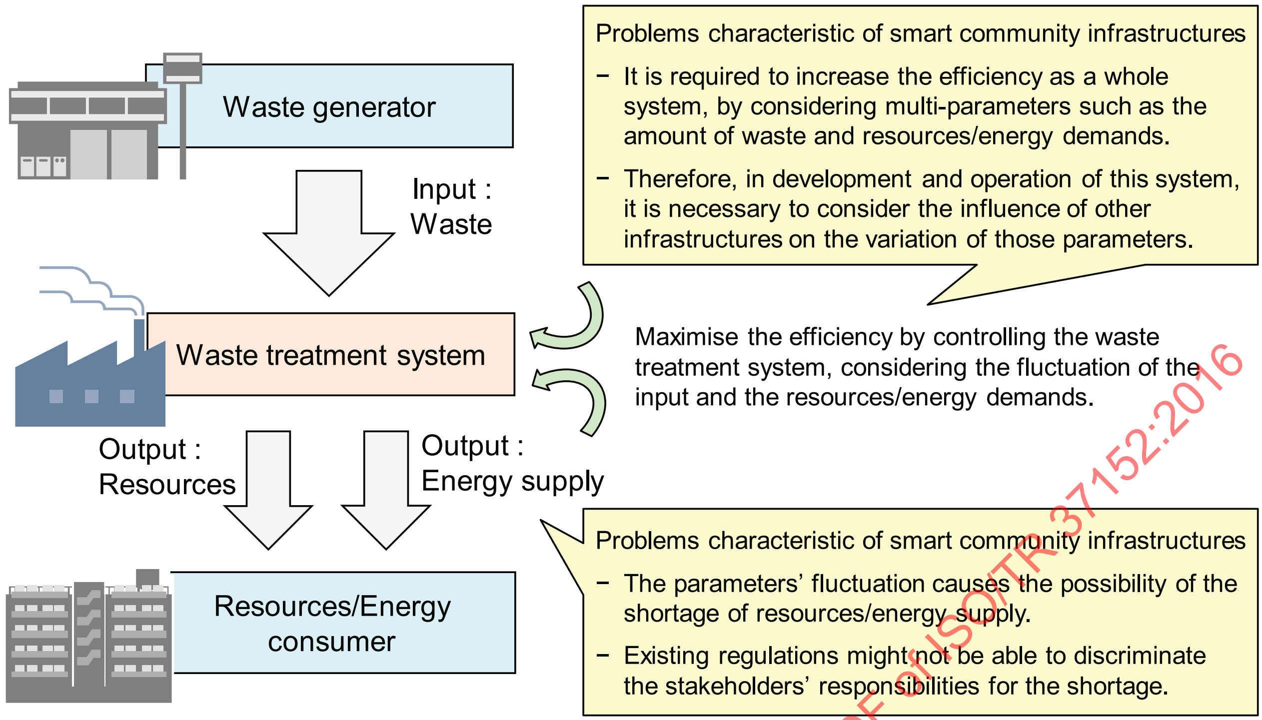

Figure 6 — Case (c): Waste management system

Case example (d): In the integration of smart community equipment with networks internal and external to smart communities, safety and reliability need to be ensured.

Take electric vehicle (EV) for example, it is necessary to consider when it is plugged into the grid, how it may affect other components connected with the grid (see Figure 7). For the safety of EV, it is necessary to take into account the grid and the component connected to it.

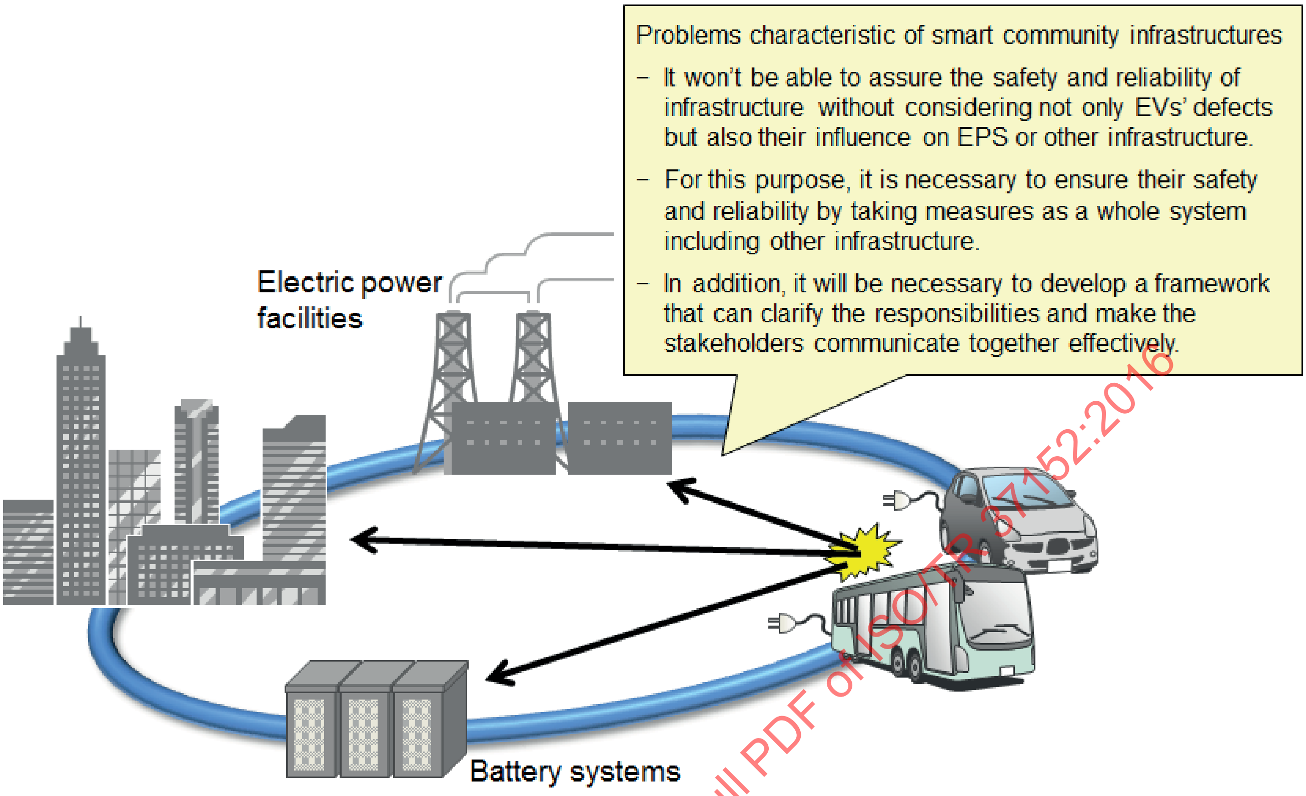

Figure 7 — Case (d): EV plugged to the grid

Case example (e): Changes in neighbouring regions, such as urbanization, should be considered for development of smart community infrastructures.

Some smart community infrastructures, such as transportation or energy, are interconnected with the external systems of neighbouring regions. For this reason, changes in the status of neighbouring regions should be considered to realize full efficiency of infrastructures. When there is a change in population in neighbouring regions, the demand against smart community infrastructures may change accordingly.

2.2.2.2 Due to limitations in capabilities of external infrastructures, requirements and needs of smart community infrastructures as a whole cannot be realized (see Figure 8)

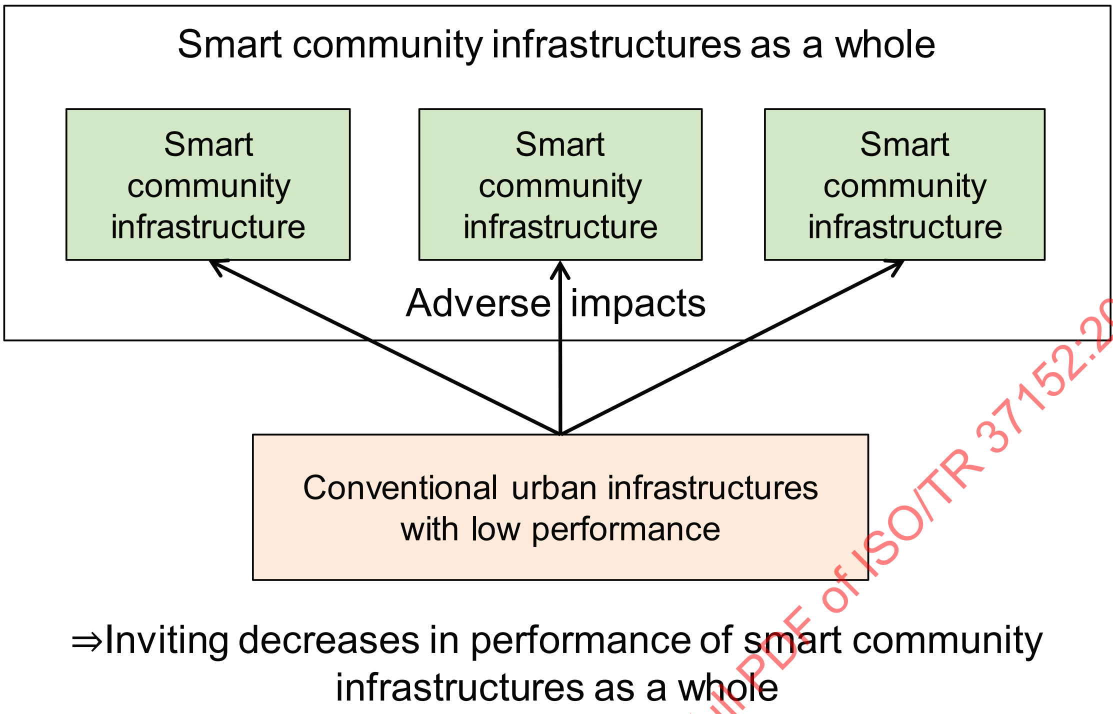

Figure 8 — Limitations in capabilities of external infrastructures

Case example (f): Difference in capacities and qualities of external infrastructures may cause inefficiency and malfunction to bring damages or losses.

Sewage farms built by foreign investment in a developing country would not work as expected without well prepared sewage line network. Reduced efficiency due to poor conditions of interacting infrastructures may cause damages or losses.

2.2.3 Various interest and wide range of responsibilities dispersed among stakeholders

2.2.3.1 Stakeholders in different situations make communication complicated (see Figure 9)

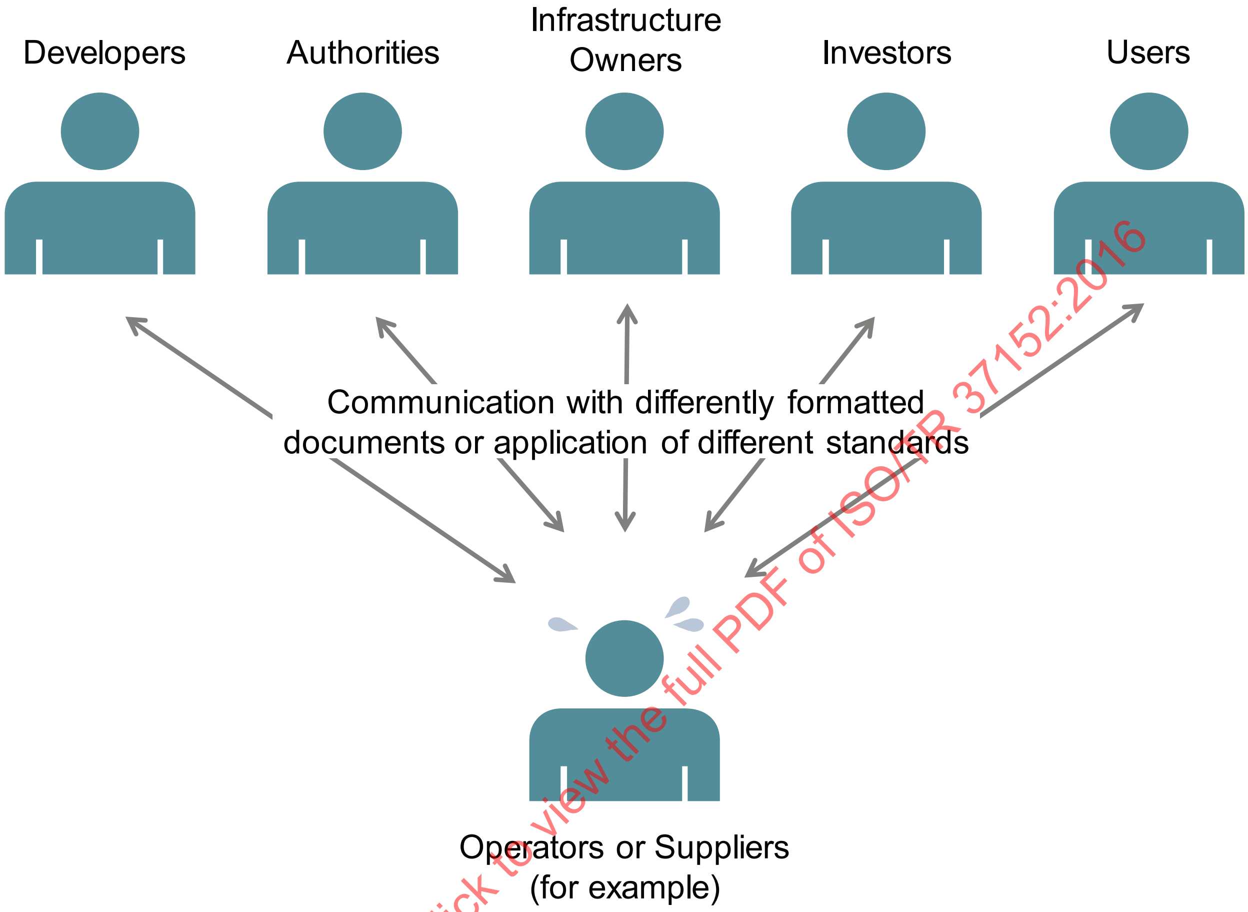

Figure 9 — Stakeholders in different situations

Case example (g): Developers have different departments to manage different infrastructures, or different authorities govern different infrastructures, due to which communication among stakeholders becomes complicated.

In development and operation of smart community infrastructures as a whole, concise and frequent communication is desired among different stakeholders in various fields. In a number of municipalities as a developer, for instance, one department generally manages one specific infrastructure. Therefore, in order to discuss the whole picture of smart community infrastructures as integrated planning, full communication should be arranged inter-departmentally.

In Bangkok, Thailand, three companies run transportation services; State Railways of Thailand for heavy rail and an airport rail link, Mass Rapid Transit Authority of Thailand for metros and Bangkok Mass Transit System Public Company Limited for tramways on viaducts. There is a key junction Downtown Bangkok or Makkasan Station for the airport rail link and Phetchaburi Station for a metro. Both lines were planned around the same time, but the two important stations are not connected despite that they have a large number of passengers. Passengers who change trains at the stations are forced a walk for 10 min on an unsheltered bustling street. This is a typical example given by poor communication among different infrastructure stakeholders, brought by competition or friction among them.

2.2.3.2 Many stakeholders of different smart community infrastructures hardly bring efficient information sharing resulting in difficulties in planning and development of smart community infrastructures (see Figure 10)

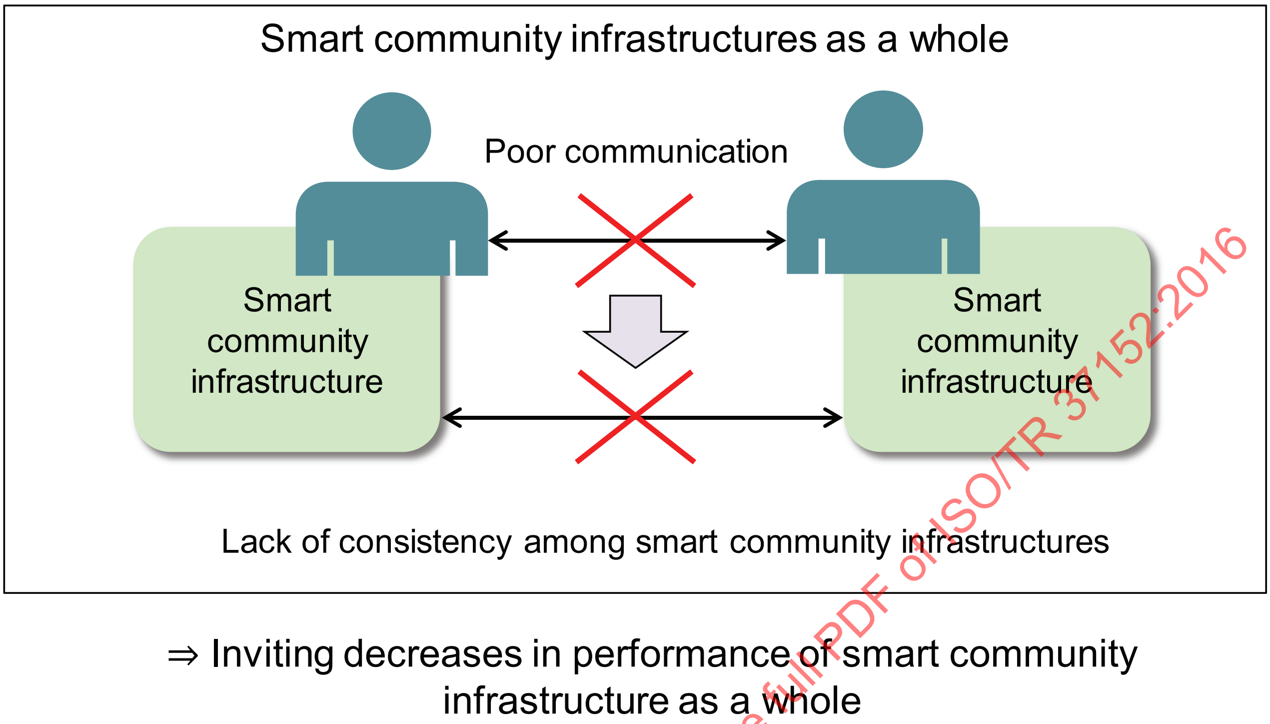

Figure 10 — Many stakeholders of different smart community infrastructures hardly bring efficient information sharing

Case example (h): Difficulty in sharing information related to individual infrastructures makes it complicated to analyse issues for discussing solutions to improve the efficiency of smart community infrastructures as a whole.

For instance, there are some solutions for highly efficient medical care system:

— development of transportation infrastructures for efficient travel by patients;

— development of ICT infrastructures for telemedicine system;

— combination of both solutions.

In order to select the optimal option and to determine the appropriate functions of transportation and ICT infrastructures, it is necessary to analyse the current context relating them.

For this, a process is needed for information sharing among stakeholders of individual infrastructures. Without such process, it would not be possible to obtain necessary information for analysis in timely manner, and thus to discuss how to improve the efficiency of smart community infrastructures as a whole (e.g. allocation of functions or roles to individual infrastructures).

2.3 Related topics to be clarified when developing and operating smart community infrastructure

It is important that the following points are clarified in the course of development and operation of infrastructures (not only smart community infrastructures but also conventional infrastructures). It is expected to discuss whether the framework should involve functions to clarify these points:

— the entities that own the system and their accountability;

— the entities that are responsible for the governance of the system; Entities that fund the governance;

— the entities that are responsible for the management of the system;

— the maintenance model of the system; The process by which the needs for maintenance is determined;

— the beginning and the end of the system. The process and means that are decided;

— ways one accesses/connects to the system and becomes part of it;

— the stakeholders in the system;

— methods to measure system degradation and system failure; and their indicators;

— ways to reconcile different ownership systems in different countries;

— a process to create the initial system; The entities to be invited;

— whether an entity can decline to join the system or not; The response to the refusing entity;

— ways to accommodate changes or to help the system evolve.

3 Outline and benefits of the framework

3.1 General

To resolve each issue arising in Clause 2, three elements of the framework are derived as outlined in Figure 11. It is indicated by these elements that the development and operation of smart community infrastructures should be carried out based on its overall structure beyond individual infrastructures.

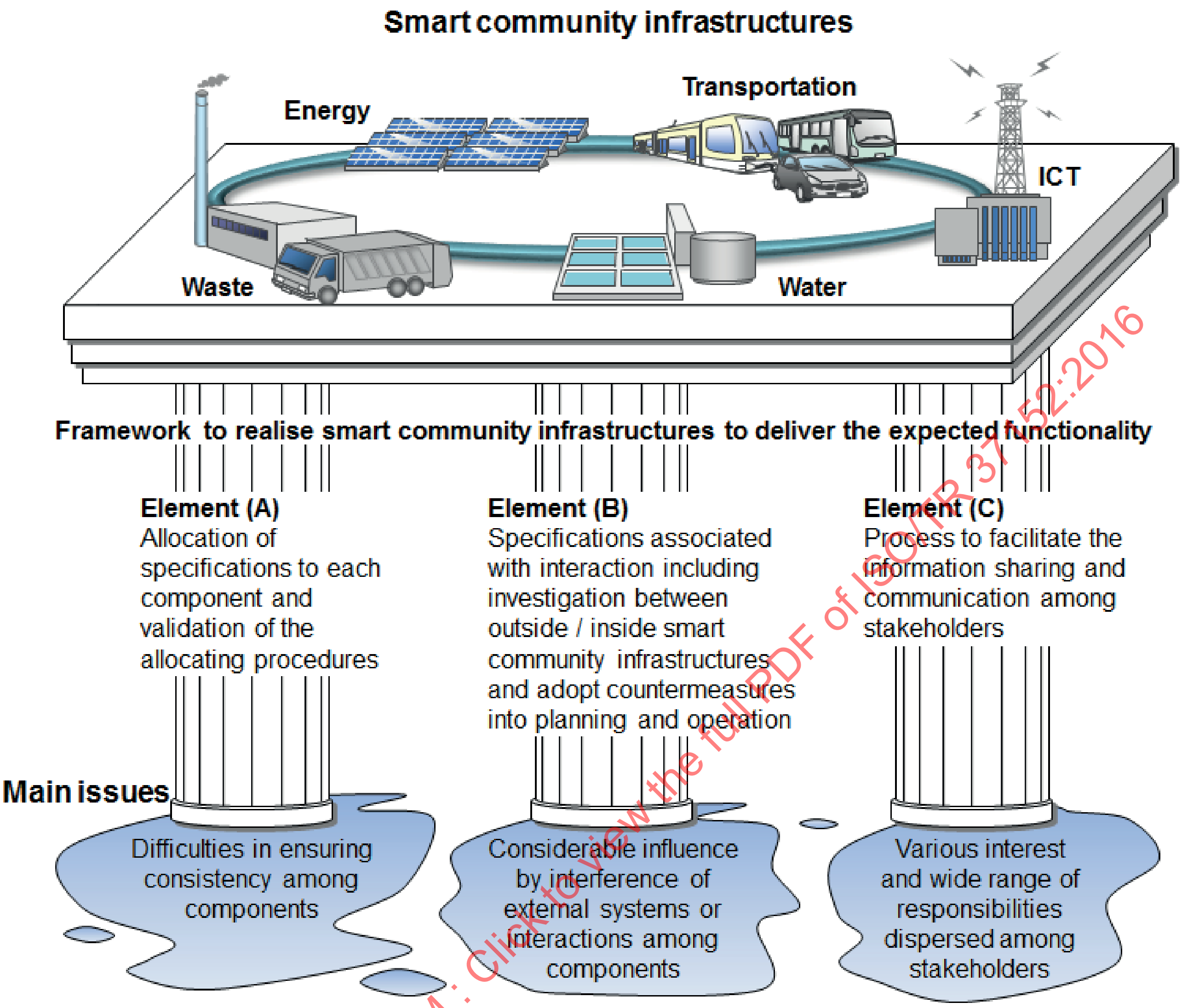

Figure 11 — Three elements of the framework

3.2 Elements of the framework

3.2.1 Element (A): Allocation of specifications to each component and validation of the allocating procedures

The following process is effective in order to ensure the consistency and the functionality of smart community infrastructures as a whole:

— Setting the requirements and needs to the entire smart community infrastructures as the starting point, functions necessary to satisfy them should be allocated from the higher level (individual infrastructures, subsystems, equipment and devices).

  — This step is the most fundamental process to be carried out throughout all development phases, starting from the basic concept, master plan and design.

— In each phase of the development, adequacy of the allocated function and consistency among the allocated functions (if there is any function that interrupts other ones, etc.) should be determined.

— In each phase of the construction, accuracy in the implementation of the design should be verified through tests and analysis.

  — This step should be carried out at any level adequate to test, such as at equipment level or system level as an assembly of equipment, or at the individual infrastructure level.

The above mentioned process is known as “Systems Assurance”, which is a methodology for system design already used in practice for complex systems such as railway system. Especially for the railways, a set of Systems Assurance based processes has been codified in an international standard (IEC 62278 and so on), whose purpose is to ensure satisfaction of the requirements of RAMS (Reliability, Availability, Maintainability, and Safety) of the railway system and to demonstrate the conformity with the requirements.

Take “Safety” in IEC 62278, necessary functions are allocated from the system level down to the device level by setting the safety target for the entire system as the starting point. Then the level of reliability to be achieved (Safety Integrity Level: SIL) is determined for each device. In the construction phase, it is required to prove the satisfaction of SIL by each device by testing or other methods.

While SIL is a concept specifically used for the safety aspect of systems, Systems Assurance process is applied in wide variety of industries such as nuclear power plants and vehicles. Figure 12 shows the life cycle process of smart community infrastructures in terms of Systems Assurance processes.

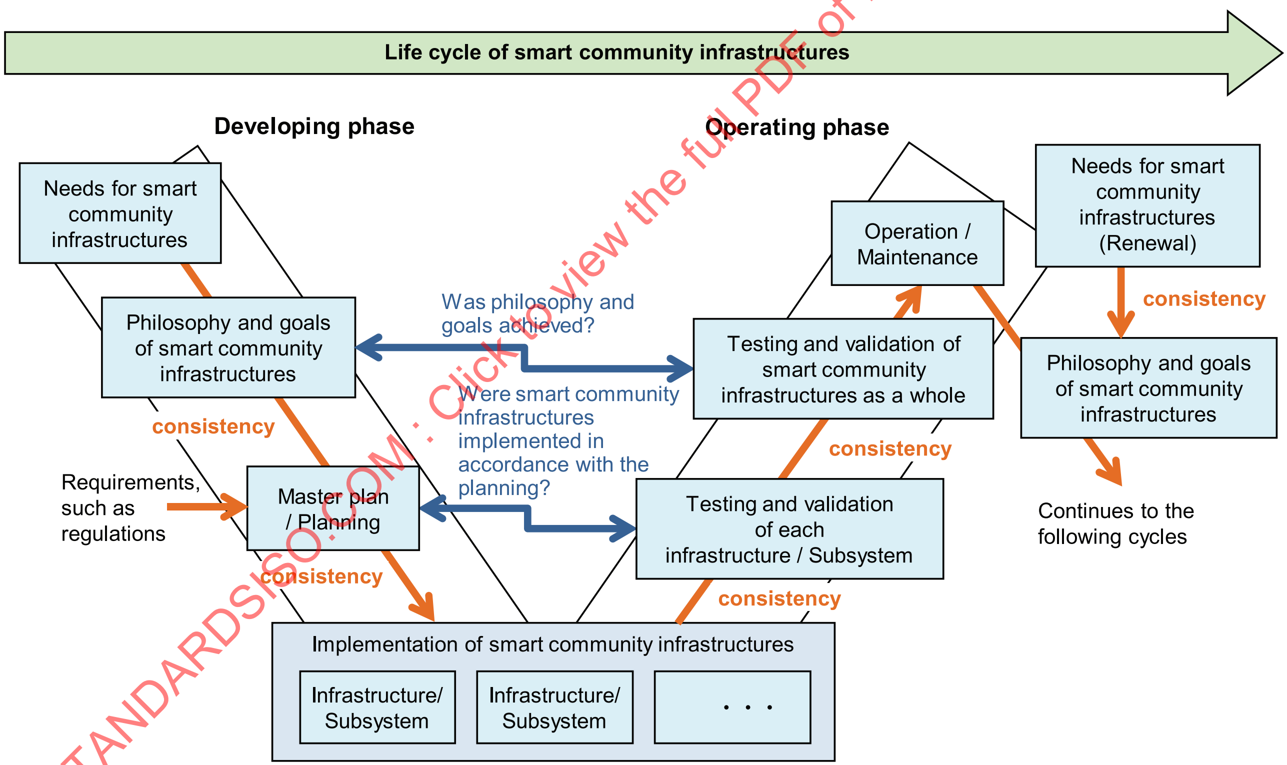

Figure 12 — Example of the process applied to development and operation of smart community infrastructures

3.2.2 Element (B): Specifications associated with interaction including investigation between outside/inside smart community infrastructures and adopt countermeasures into planning and operation

In order to mitigate risks by managing the interactions among individual infrastructures, or the interactions of the internal infrastructures with external systems (including the infrastructures out of the development scope), it is not sufficient only to consider the interactions as “the external conditions”. It is also necessary to consider the changes in these conditions and risks generated from them, which then should be accommodated in the system design (See Figure 13). To consider and accommodate such factors, the following approach can be applied:

— Identify the interactions among individual infrastructures or the interactions of the infrastructures to be developed with external systems;

— Analyse and calculate the changes expected to occur in each interaction, then to extract the risks generated from each interaction;

— Examine the countermeasures to mitigate the risks from the design and operation point of views, then to include them in the system design (including the operation design);

— Demonstrate that the countermeasures devised in the design are physically realized by testing and analysis.

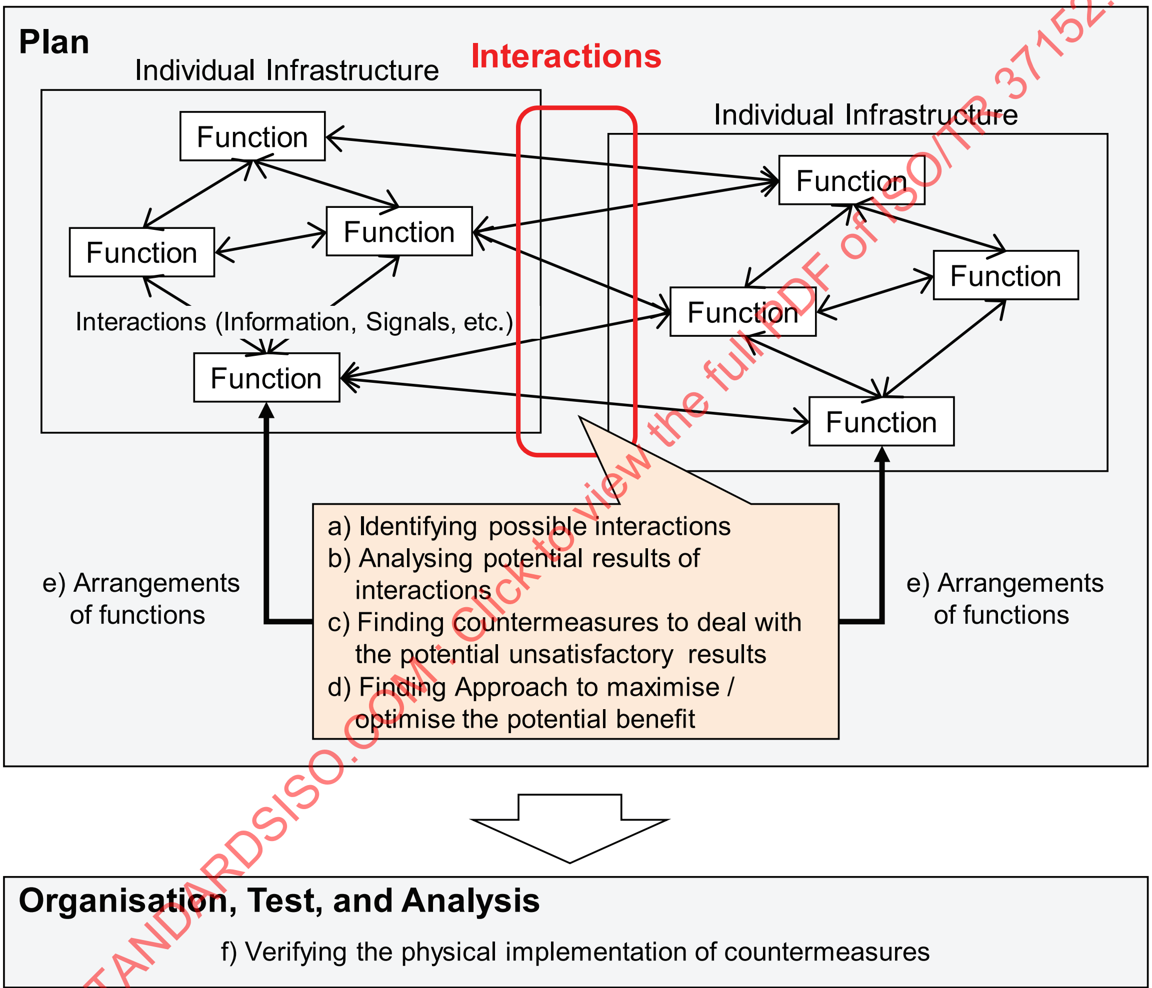

Figure 13 — Process to analyse interactions

3.2.3 Element (C): Process to facilitate the information sharing and communication among stakeholders

As shown in Figure 14, for information sharing on risks and other factors, and for consensus building, two sets of rules should be followed by each stakeholder:

— Rules to determine which information to be shared (specific items and parameters, documentation formats and guidelines, and so on);

