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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

ITU-T Y.4550 series – Smart sustainable cities – Integrated management

ITU-T Y-series Recommendations – Supplement 28

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Supplement 28 to ITU-T Y-series Recommendations

ITU-T Y.4550 series
Smart sustainable cities – Integrated management

Summary

Supplement 28 to ITU-T Y-series Recommendations proposes an integrated management solution for smart sustainable cities. With integrated management for smart sustainable cities (IMSSC), sensors, nodes and models can function in an organized way. As a result, when emergency events occur, the data, models and other resources needed, can be rapidly discovered and acquired. To achieve the goal of making a city smarter and more sustainable, the first step is to analyse real-time processes and understand event patterns through event modelling. Additional capabilities, in terms of processing units, application units, as well as models, might be needed. The second step is to fuse processing so that different sources of observation can be combined together to compensate their own deficiencies and attain the goal more efficiently. Finally, services for information resource publishing and sharing as well as result fusing are also necessary to disseminate information across the concerned agencies. By adopting the integrated management system, each city can take a big step towards the implementation of the smart sustainable city vision.

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Introduction

0.1 Background

"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects".

The above definition describes what a smart sustainable city should be. However, significant urban challenges such as security, criminality, pollution, traffic congestion, inadequate infrastructure and response to natural hazards continue to prevent this vision from becoming a reality. Some examples of the challenges faced by cities are listed in Figure 1.

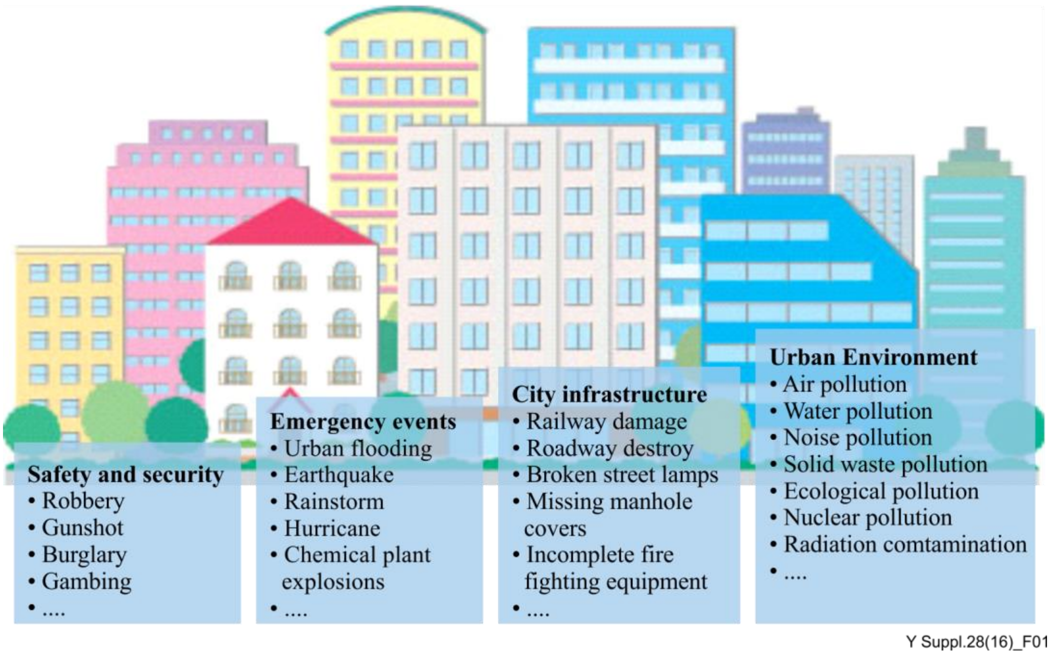

Figure 1 – Examples of challenges faced by cities

In order to successfully address these challenges, cities should take into consideration the deployment of the necessary tools to be able to monitor, map and report what is happening in real time. An effective reporting mechanism will ensure that such problems are tackled rapidly to avoid or reduce possible causalities and economic losses [b-Namb]. As part of a recent widespread urban digitalization process, several cities have deployed a variety of sensors, including cameras, rain gauges and pressure transducers, etc., in order to be able to acquire first-hand information about all of the city's operations in a timely manner. Even if all this information is available in cities, it is unfortunately distributed through different departments or even regions and an effective management mechanism is still lacking.

In response to this challenge, this Supplement proposes integrated management for smart sustainable cities (IMSSC). With IMSSC, the sensors, nodes and models can function in an organized way. As a result, when emergency events occur, the data, models and other resources needed can be rapidly discovered and acquired. To achieve the goal of making a city smarter and more sustainable, the first step is to analyse real-time processes and understand event patterns through event modelling. Additional capabilities, in terms of processing units, application units and models, might be needed. Secondly, there is a need for fusion processing guidance, so that different sources of observations can be combined together to compensate for their own deficiencies and attain the goal more efficiently. Finally, services for information resource publishing and sharing as well as result fusing are also necessary to disseminate information across the concerned agencies. By adopting the integrated management system, each city can take a big step towards the implementation of the smart sustainable city vision.

0.2 Service framework

The users involved in IMSSC are not only municipal departments, but also enterprises and citizens. Municipalities are usually in charge of the daily operation and maintenance of IMSSC which is initiated by them. When emergency events occur, they need to synthesize all the information and make proper decisions to rescue lives and reduce economic losses. Citizens are the users and main beneficiaries of integrated management for smart sustainable cities. They are able to report problems of daily management and emergencies, as well as receive notifications from the municipal authorities. Enterprises can be viewed from two perspectives, some enterprises can take part and assist the municipality to improve the capacities of the integrated management, other enterprises can act simply as ordinary citizens to do the work of reporting or notice feedback. The service framework of IMSSC is represented in Figure 2.

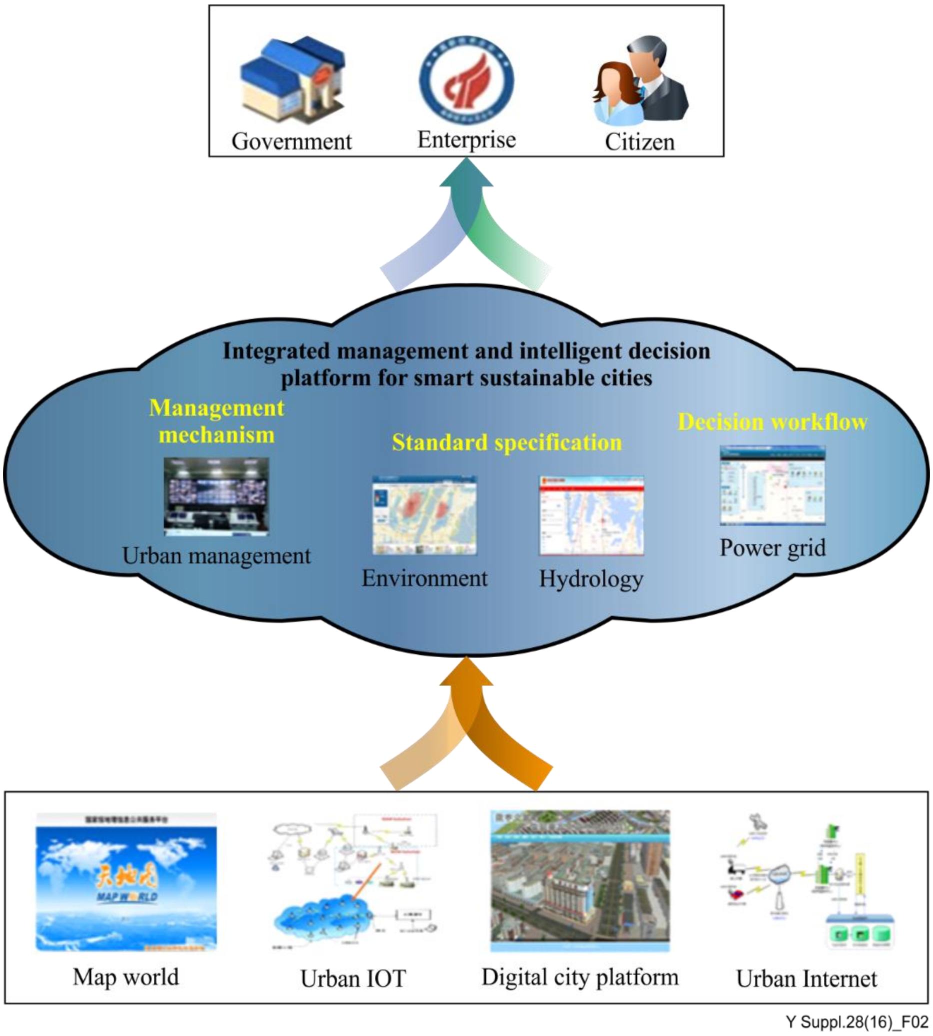

Figure 2 – Service framework of IMSSC

0.3 Intended application

The proposed integrated management for smart sustainable cities aims at tackling four main types of problems, namely inadequate safety and security protection, increasingly worsened urban environment, damaged city infrastructure and natural or man-made emergency events. In this Supplement, these four types of problems are represented as theoretical events through a uniform event information model. They are detected by sensors, recorded by observations, analysed and processed by models and finally settled by a decision made according to nodes. The goal of IMSSC is achieved through the direct management of information resource carriers, events, sensors, observations, models and nodes. The roles of the different information resources in IMSSC are presented in Figure 3.

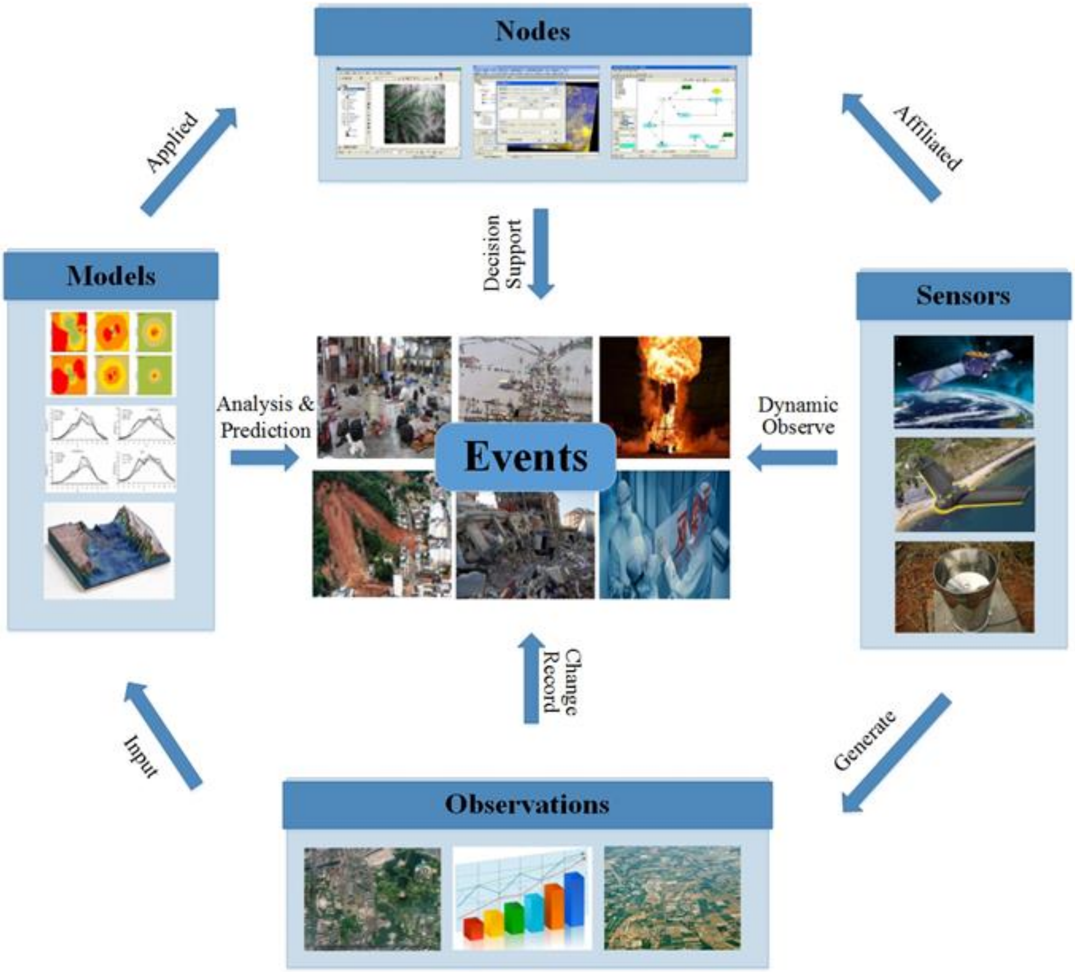

Figure 3 – Roles of the different information resources in IMSSC

These information resources represent the crucial infrastructure for real-time monitoring of city dynamic processes. However, these resources have not yet been efficiently used due to the lack of a unified management of the observation resources and information carriers, the lack of rapid and smooth processing of information and the lack of real-time publishing and sharing services. As a consequence, the interconnection among the different city departments has not yet been established. This is a missed opportunity for every city administration as events such as traffic congestion, urban flooding and pipeline leakage that existed before continue to perpetuate. The operational efficiency of cities is not always as satisfying as it could be, affecting negatively citizens' quality of life. Therefore, it is imperative to implement IMSSC in order to resolve each of the challenges described above.

IMSSC is used to model the information resources of cities uniformly, fuse the data from the information resources to acquire a higher level of information and share the information to serve people in cities [b-Nama]. In this Supplement, information resources are composed of nodes, sensors, data, models and events, among which nodes include sensing nodes, processing nodes and application nodes and sensors are affiliated to sensing nodes. The fusion process aims to fuse the information resources with toponym and maps respectively. Services mainly include data, model and event services. IMSSC is able to ensure the well-organized and efficient operation of people, things and streams in cities, so that disastrous events can be detected in advance and can be avoided in a timely manner before their occurrence. In this way casualties and economic losses can be reduced as much as possible. At the same time, IMSSC is able to provide solutions for widely-existing problems, such as traffic congestion and environmental pollution, etc., improve the living quality of citizens, protect the environment and implement the sustainable development of cities.

1 Scope

The objectives and challenges of IMSSC, as well as the technologies used to address the problems and to achieve the goals of smart sustainable city development are illustrated in clause 6. The specific meta-models, fusion processing workflows and services proposed for IMSSC are presented in clause 7, while clause 8 provides examples pertaining to the application of meta-models, fusion processing workflows and services for IMSSC.

2 References

None.

3 Definitions

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

4A Anytime, Anybody, Anywhere, Anything

4R Right time, Right body, Right place, Right thing

EML Event pattern Markup Language

ESTO Earth Science Technology Office

GIS Geographic Information System

GPS Global Positioning System

ID Identification

ICT Information and Communication Technology

IMSSC Integrated Management for Smart Sustainable Cities

IoT Internet of Things

OGC Open Geospatial Consortium

QoS Quality of Service

RFID Radio Frequency Identification

SSC Smart Sustainable City

SES Sensor Event Service

SOS	Sensor Observation Service
SPS	Sensor Planning Service
UAV	Unmanned Aerial Vehicle
WCS	Web Coverage Service
WMS	Web Map Service
WPS	Web Processing Service

5 Conventions

None.

6 Resources, challenges and technologies of IMSSC

6.1 Resources of IMSSC

IMSSC aims at offering a solution to all of the problems affecting current urban development, including inadequate safety and security protection, increasingly worsened urban environment, damaged city infrastructure and natural or man-made emergency events, in a rapid and efficient way. IMSCC is also expected to improve citizens' quality of life, the efficiency of urban operation and services and competitiveness, while ensuring at the same time that the needs of present and future generations with respect to economic, social and environmental aspects are met.

These problems are the results of the interactions among people, urban infrastructure and the corresponding environment in cities. Citizens are the main players of a city. Their activities determine and influence the existence and evolution of the urban infrastructure and environment. There is a saying that "people who live in cities create the urban landscape." It is human beings that constitute the versatility of a city, create a beautiful life and live it. Consequently, citizens are the direct object of IMSSC.

Urban infrastructure is a general term for all types of urban facilities on which various economic activities and other social activities occur for the survival and development of cities. Urban infrastructure is divided into the engineering infrastructure and social infrastructure. Urban infrastructure is particularly important for production units and is one of the necessary conditions for attaining economic, environmental and social benefits. Engineering infrastructure generally refers to energy systems, water supply and drainage systems, transportation systems, communication systems, environmental systems, disaster prevention systems and other engineering facilities. Social infrastructure refers to the administration, education, health care, business services, finance and insurance, social welfare and other facilities. The urban infrastructure provides citizens with what they need for their daily life. A good urban infrastructure enables improved quality of life and is a significant step toward smart sustainable cities development. Therefore, urban infrastructure is also a direct object of IMSSC.

Urban environment here mainly refers to the natural conditions of the city, including geology, geomorphology, hydrology, climate, flora and fauna, soil and various other factors. Irrational and excessive expansion of the city's development will lead to the deterioration of the environment. Urban environmental quality directly affects the operation of a city and the living conditions of urban inhabitants. To improve inhabitant dwelling, realize IMSSC and achieve harmonious development between human beings and nature, the environment must be the direct object of IMSSC.

The observing, reporting, analysing, forecasting and decision supporting of all these three direct objects are implemented by digital equipment and the associated information systems. In this Supplement, the challenges listed in Figure 1 as well as the direct objects are abstracted for the convenience of information representing. The challenges are abstracted events and represented by event information models. The digital equipment is abstracted as four kinds of information resources, comprising sensors, observations, models and nodes. Among the information resources, sensors are composed of airborne, space borne and ground-based sensor systems, such as satellite sensors, unmanned aerial vehicles (UAVs), vehicle-mounted mobile measurement systems, global positioning systems (GPSs), radio frequency identification (RFID), temperature and humidity monitors, rainfall sensors and other equipment. This equipment is deployed wherever events may occur and is applied in event monitoring. Observations refer to the data generated by sensors, ranging from numerical values to all kinds of images and they carry the information which can reflect the event occurrence. There are several kinds of analysing, processing and forecasting models, such as hydrological analysis models, transportation congestion processing models and pollutant diffusion models, etc. All these models are useful in analysing, processing observations, or making predictions based on historical and present observations in cases when observations are obscure and cannot provide the intuitive situation changes. Nodes can be united sensing centres, integrated processing units or small size application divisions and they are able to offer significant decision support for events. Therefore, information resources, including events, sensors, observations, models, as well as nodes are viewed as the indirect objects of IMSSC in this Supplement. The direct and indirect objects of IMSSC are presented in Figure 4.

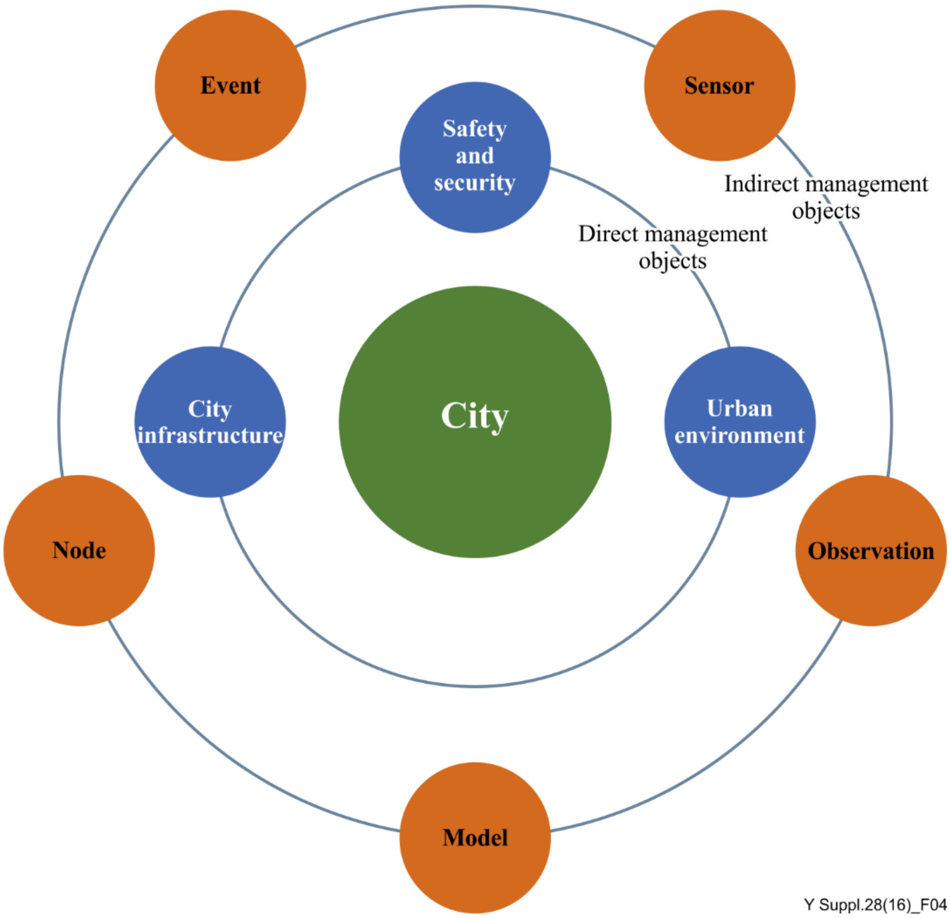

Figure 4 – Direct and indirect objects of IMSSC

6.2 Challenges of IMSSC

In cities nowadays, information resources, like sensors, observations and models, feature different sources, great variety and huge numbers. However, when responding to emergency events, many problems still exist, including:

1) The encoding formats of the information resources are varied and difficult to integrate;

2) The fusion workflow between information resources is not unified, resulting in non-uniform fusion results, inconsistent accuracy and difficulty in fusion processing;

3) The lack of conformity of the information resources and their fusion results service interfaces cause problems in publishing, sharing, discovering and accessing [b-Toppeta].

All of the problems described above pose significant challenges to urban development and to IMSSC. To be specific, the challenges faced by IMSSC can be illustrated from three perspectives:

1) Information resources come from various sources and heterogeneous systems. It is difficult to interconnect such systems for data sharing. Consequently, this leads to difficulties in multi-level collaborative decision-making. Taking sensors as an example, there are space borne platforms (hundreds of orbiting satellites), airborne platforms (thousands of UAVs, airships and balloons, etc.) and ground platforms (millions of ground sensors). However, there is no unified meta-model to represent and manage the huge numbers of heterogeneous sensors. Information resources in large numbers, of different kinds and with multiple representation ways are major obstacles in the development of integrated management for smart sustainable cities. The difficulty of information resource management in smart sustainable cities is demonstrated in Figure 5.

Figure 5 – Difficulty of information resource management in smart sustainable cities

2) Cooperation between the different information resources is lacking and their fusion processing is difficult, leading to incomplete and inaccurate decisions. Just in terms of the observation data, only less than 10% of the present observation data can be processed timely and efficiently and the capability of fusion processing on the space, aerial and ground observation data is insufficient. On one hand, when coping with significant environment and disaster events, the poor timeliness and great time lag of data fusion, processing and collaborative analysis always hinders first-hand data and information from being delivered to the right place on time. On the other hand, the historical surveying and mapping information database cannot be effectively associated and fused with the current observations, forming the obstacles of information overlay and intuitional display. Thus, the status of events and the situation of the schedulable sources cannot be made clear, leading to incomprehensive and inaccurate decisions. The problem of information fusion processing in smart sustainable cities is elaborated in Figure 6.

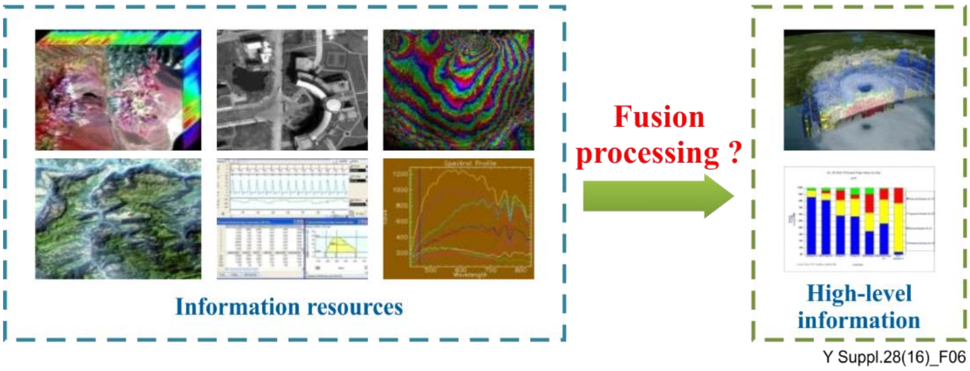

Figure 6 – Problem of information fusion processing in smart sustainable cities

3) The demand granularity of information resources and fusion results are quite different, as are the distributed resources, inconsistent interfaces and passive decision services. The information resource interfaces are different and have different user requirements and distributed service resources. When facing major environmental and disaster events, many problems appear, including which data are needed, which sensors can supply the data, which models are needed and where the models can be found. Currently non-uniform service interfaces are not able to satisfy the complex task requirements and an active service-focused mode is also absent, resulting in problems of passive and untimely decisions. The problem of refined decision-making in smart sustainable cities is shown in Figure 7.

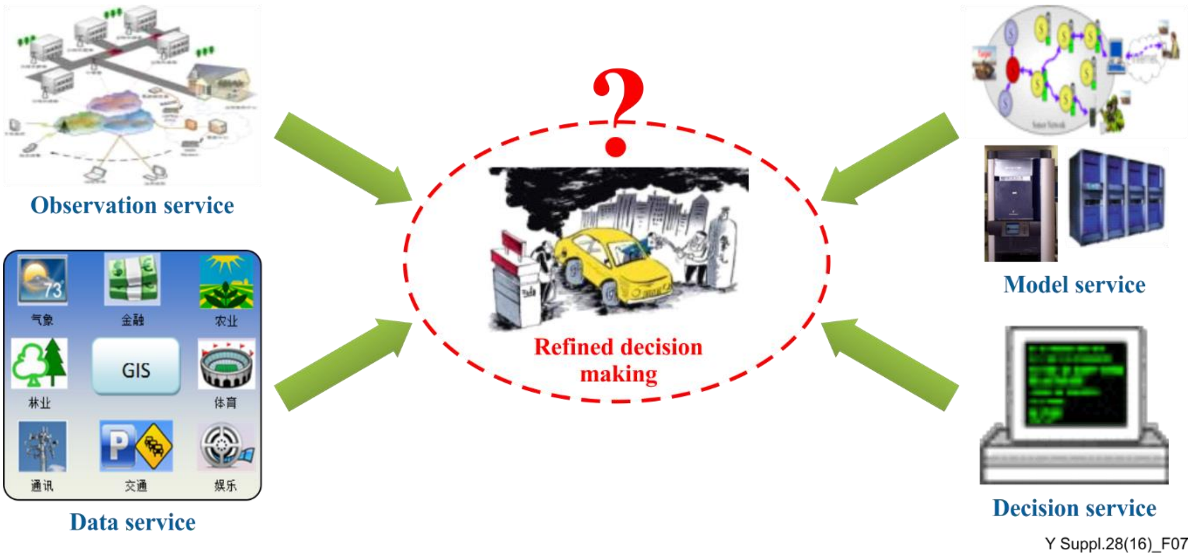

Figure 7 – The problem of refined decision-making in smart sustainable cities

Briefly, the scale of information resources in cities together with the multiple demands of environment and disaster monitoring, is increasing dramatically. There is an urgent need to establish an integrated information management infrastructure to implement resource integration, fusion processing and management services for smart sustainable cities. Through the infrastructure, heterogeneous observation resources can be combined via the Internet, to form dynamic coupling mechanisms for collaborative observations, maximizing the use of observation resources, providing the task-driven service mode based on space and time information and greatly improving the integrated management and service level. During this process, services such as sustainable monitoring of environmental safety, quick response during serious disaster events and the transformation from the anytime, anybody, anywhere, anything (4A) service to the flexible right time, right body, right place, right thing (4R) service can be completed.

6.3 Technologies of IMSSC

Compared with digital city management, from a technical level, the challenge for integrated management for smart sustainable cities is to realize the transformation from online management based on the Internet to the real-time dynamic management based on IoT, from the sensing management of every single sensor to the collaborative management of multiple sensors, from the island of industrial model management to the model web management of application decisions [b-Balazinska].

To be specific, IMSSC consists of observation web, service web and model web technologies.

Observation web technology [b-Simonis] aims at breaking through the barriers of the multiple and heterogeneous observing and sensing modes and at implementing automatic, real-time and comprehensive sensing related to city management and operating status via web, sensing and intellectual technologies. The architecture of the observation web technology used in smart sustainable cities is presented in Figure 8.

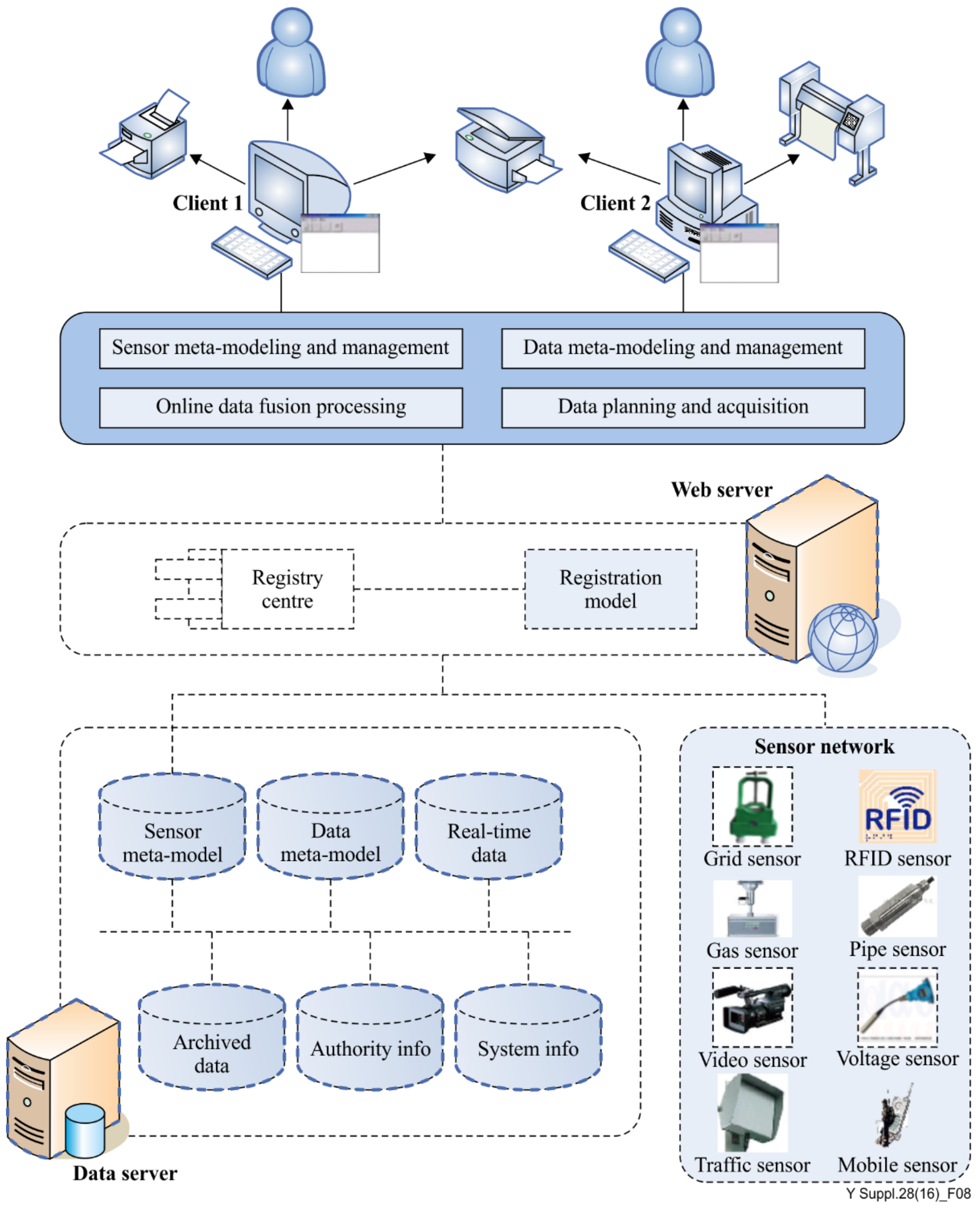

Figure 8 – Architecture of the observation web technology used in smart sustainable cities

Model web technology [b-Nativi] is used to overcome barriers in meta-modelling and catalogue registration technology and to bridge the communication gaps between heterogeneous sensors, models and simulation and decision support systems. Model web technology could be used to solve problems in the expression, understanding, sharing and cooperation of heterogeneous city decision models. Users could realize city integrated emergency decision-making by combining and optimizing these models on decision terminals. The framework of the model web technology used in smart sustainable cities is presented in Figure 9.

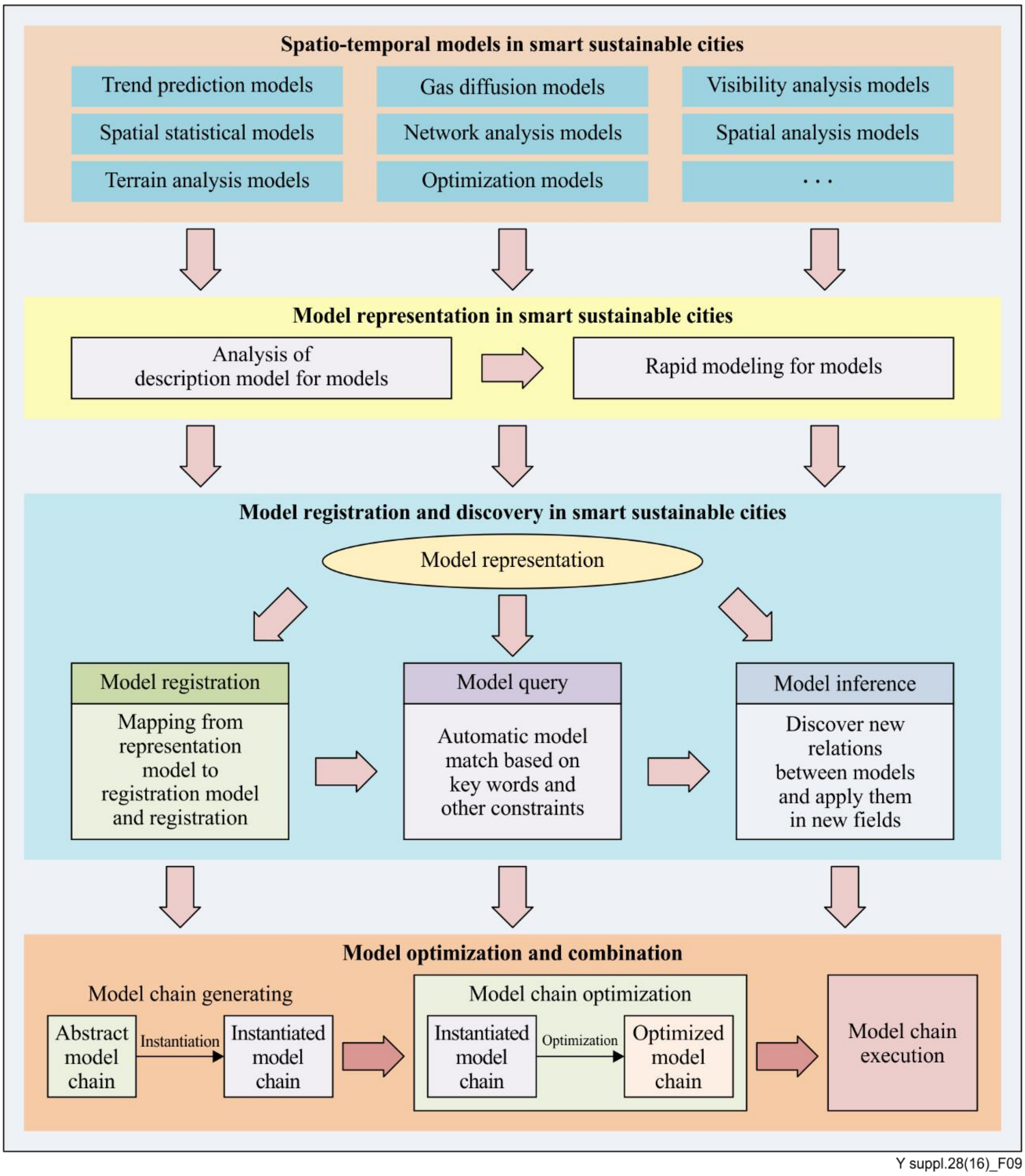

Figure 9 – Framework of the model web technology used in smart sustainable cities

Service web technology [b-ESTO] is used to overcome the obstacles in the workflow and sensor web technologies and to achieve the goal of network intelligent service which is in accordance with specific sensor actions and interface specifications. The framework of the model web technology used in smart sustainable cities is shown in Figure 10.

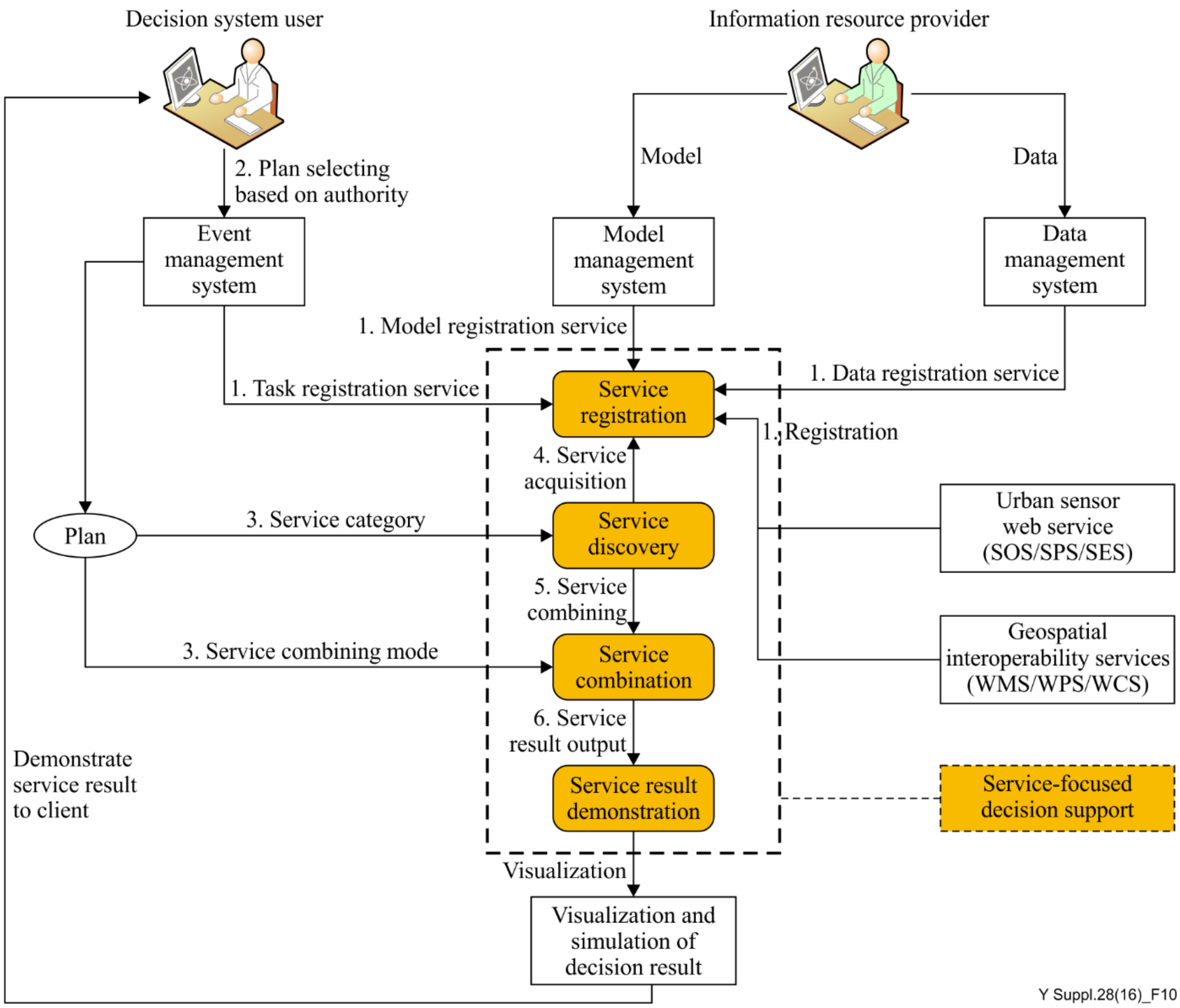

Figure 10 – Framework of the model web technology used in smart sustainable cities

7 Integrated management for smart sustainable cities

7.1 Overview of IMSSC

With the continuous development of smart sustainable cities, the categories and forms of information resources are greatly expanded. A large number of heterogeneous information resources, like nodes, sensors, observations and events, are involved in IMSSC. The relationships between these information resources are complicated, sometimes complementary, reinforced or redundant. However, there is no technical proposal to manage them in an integrated way so that the redundant information can be eliminated, the weakness of one kind of information resource can be supplemented by another or so that several information resources can be combined together to fulfil the tasks more effectively. A technical proposal for IMSSC is proposed in Figure 11. In this proposal, the sensors, observations, models and nodes are encoded and managed in a uniform way in advance and when events occur, the service centre will invoke the sensors, observations, models and nodes to perform the corresponding missions as predefined.

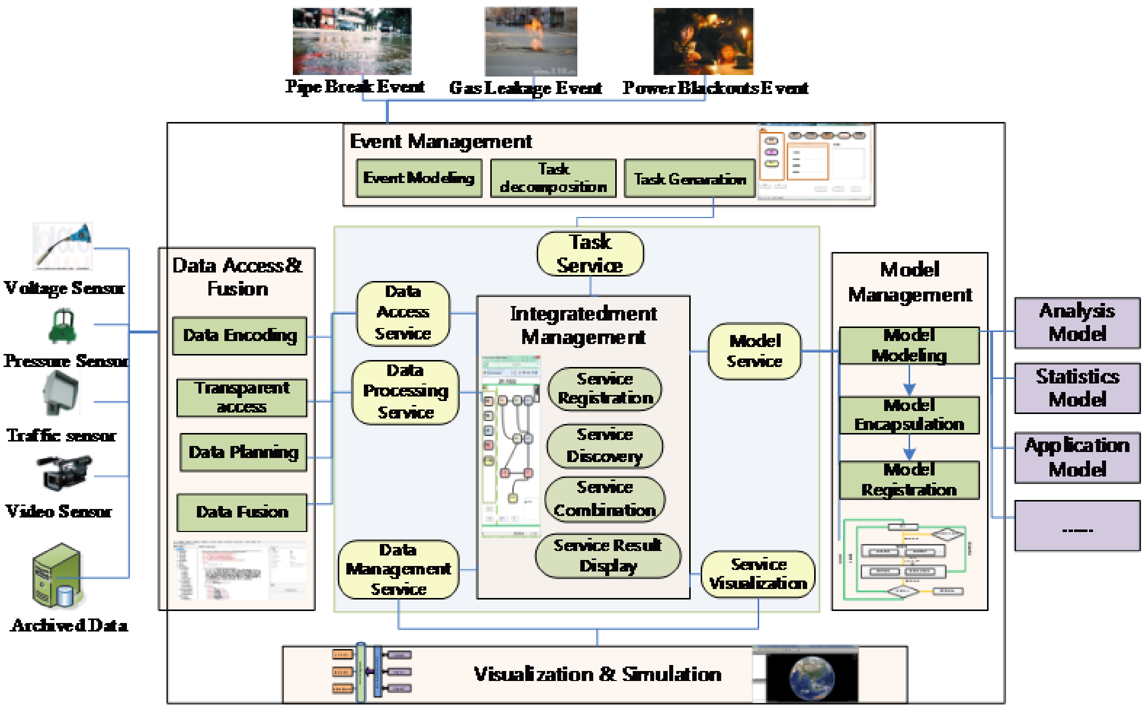

Figure 11 – Technical proposal for the integrated management of smart sustainable cities

To complete the smooth realization of IMSSC, a set of theoretical foundations is needed, including meta-models, fusion processing workflows and sharing services. Meta-models are intended to implement the modelling of these information resources, including nodes, sensors, observations and events, demonstrating their capabilities in different aspects and providing the basis for capability enhancement. Workflows of information resource fusion processing are used to guide the implementation of capability enhancement. Service interfaces are intended for unified and efficient sharing of information, offering decision support for municipal authorities during emergencies. In the infrastructure, the meta-models are the basis and premise for the fusion processing workflows and sharing services, including node metadata [b-Chenh]; observation process metadata [b-Cheng], [b-Chenf], [b-Hu], and [b-OGCc]; observation metadata [b-Di], [b-ISO 19156], [b-OGCd] and [b-OGCg]; event metadata [b-Fan] and [b-OGCe] and model metadata [b-Visconti]. The fusion processing workflows are means to enhance the capabilities of the information resources modelled by the meta-models and shared by the sharing services, consisting of the technical specifications for fusing resources with toponym [b-Smart] and maps separately [b-Chanier]. The sharing service interface specifications [b-Chenb] offer ways to share and manage the modelling results of information resource and fusion processing results, composed of the data [b-Chenc], [b-Chend], [b-Chene], and [b-OGCa], as well as model and event service interface specifications [b-OGCb] and [b-OGCf]. The organization of the theoretical foundation for integrated management under the smart sustainable city environment is described in Figure 12.

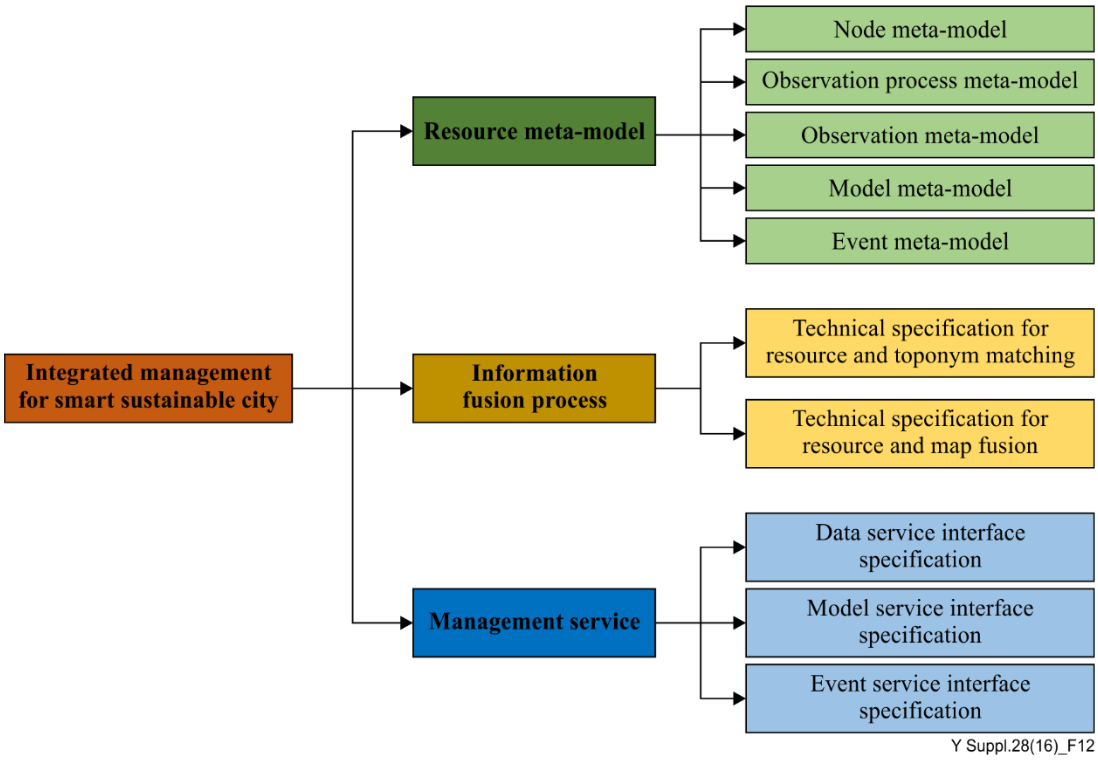

Figure 12 – Organization of the theories for integrated resource management under the smart sustainable city environment

7.2 Meta-models for resource integrating

There are five meta-models for resource integrating, namely the node meta-model, the observation process meta-model, the observation data meta-model, the model meta-model and the event meta-model. In this clause only aspects of the node meta-model are elaborated in detail.

7.2.1 Node meta-model

7.2.1.1 Background of the node meta-model

In current sensor web applications, especially the emergency response and decision support applications for land surface events on the earth, a series of problems exist, such as "more" and "less" sensor web resources, insufficient data processing capability and the lack of a service-focused model [b-Chena]. How to make it possible for people to be able to access observation resources in a transparent, efficient and customized manner and implement the online information fusion, data assimilation, dynamic management and intelligent service for the resources is still a challenge. Thus, there is an urgent need for a unified management model to organize and allocate the sensor web resources [b-Liang]. The node meta-model is aimed at providing an open and unified sensor web node information model in order to realize a unified description for the inherent features of the nodes. Through the node meta-model, it becomes clear which nodes have the capability of completing the data processing and serving needed for a certain task, as well as the working state, timeliness and geolocation of which nodes are able to meet the task requirements. The node meta-model facilitates efficient management and allocations for heterogeneous nodes.

7.2.1.2 Application of the node meta-model

The node meta-model defines the sharing metadata for node resources in a comprehensive smart city management system. The metadata content is confined to the unified description for inherent properties, capabilities and status and space-time information of the nodes. The structure and physical characteristics of the nodes themselves, as well as the node observation data and the associated processing and services are all excluded from the metadata content.

The meta-model can be applied in the integrated discovery and sharing, integrated management, planning and dispatching, as well as in the collaborative observing for all kinds of nodes. The specific application scope of the node meta-model is shown in Figure 13.

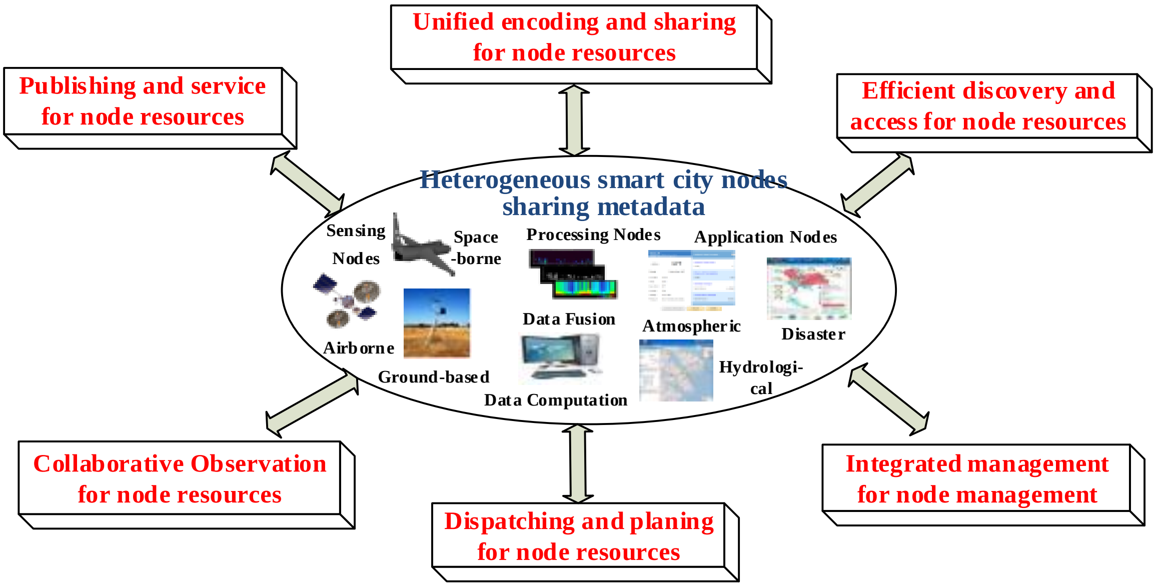

Figure 13 – Application of the node meta-model

7.2.1.3 Content of the node meta-model

Based on the node description components and the different metadata requirements from all kinds of nodes, the node metadata is organized into the general information description framework, with five components, including the sensor tag, performance, state, service and accessibility and a nine-tuple structure [b-ISO 19115-2]. The node meta-model is shown as follows:

Node metadata = {Identification, Characteristics, Capability, Quality, Space-time, Working, Service, Administration, Constraint}.

Among all the meta-model components, identification and characteristics information are tessellations for the sensor tag component, capability and quality information for performance, service information for service and administration and constraint for accessibility. The relationship between the five components and the nine-tuple structure is demonstrated in Figure 14 [b-Chenh].

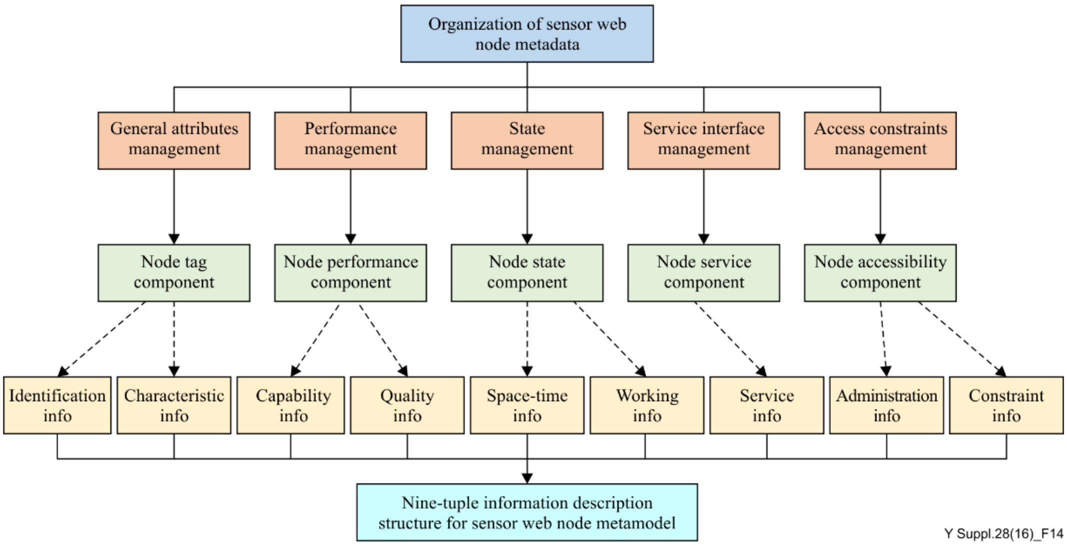

Figure 14 – Description structure for the nine-tuple smart sustainable city node information

1) Identification information: Such information includes keywords and the node name, identity (ID), type, level and dynamic feature, which describe the general information of a node for uniquely identifying a node.

2) Characteristics information: Such information includes node function, suitable fields, core units, platform environment, communication fabric and input and output features that describe the characteristic information of a node. The core units refer to the sensor, processing algorithm, or service to different types of nodes.

3) Capability information: Such information includes function, communication, capability and resource consumption capability features. Heterogeneous nodes have different function capabilities and need to have extended metadata according to a specific node type.

4) Quality information: Such information includes product quality and quality of service (QoS) features. Various nodes have different quality indicators and need to have extended product quality metadata according to a specific node type.

5) Space-time information: Such information includes the time and space referencing framework, location and valid time features that describe the real location and time of a node in dynamic observation systems.

6) Working information: Such information includes the use state, fault state and resource consumption, which can determine whether a node is available at a task moment.

7) Service information: Such information includes the service name, type, address, parameters, provider and mode features that describe the metadata contents of node service interfaces. The relation among the services of a service combination can be represented through the service connection feature.

8) Administration information: Such information includes contact, history and document features that note the important information usable for node administration management.

9) Constraint information: Such information includes access level, legal constraint and security constraint features, which affect the accessibility of a node.

7.3 Technical specifications for the fusion process

There are two technical specifications for the fusion process, namely the resource and toponym matching specification and the resource and map fusion specification. In this clause only aspects of the resource and toponym matching specification are explained in detail.

7.3.1 Resource and toponym matching specification

7.3.1.1 Background of the resource and toponym matching specification

Toponym is important in the GIS databases and it can assist users in the searching, interpreting and analysing of geographic data. Meanwhile, in the Internet of things and construction of smart cities, the scanning, imaging and radar type sensors for aerial and space images as well as ground-based observations and disaster, accident calamity, public hygiene events and welfare events are all carriers of information resources. However, they lack the association with the actual place names, resulting in the difficulty of their being applied in the smart sustainable city. There is research into how to match up and fuse nodes, sensors, observations and events with a toponym database able to label geographic locations that would be beneficial to the unified management, efficient discovery, time and space pattern mining, as well as visualization for all these observation resources. The technical specification for resource and toponym database matching in the integrated management for smart sustainable cities is designed to formulate a unified and efficient workflow to realize the fusion of resources and their toponym. Through the fusion, actual place names can be assigned to corresponding nodes, sensors, observations and events, which will assist in expressing and understanding the observation information.

7.3.1.2 Application of the resource and toponym database matching

The technical specification for resources and the toponym database matching in IMSSC provides a unified workflow for observation resources matching up with the toponym database, including matching the nodes, sensors, observations and event resources up with the toponym database. The technical specification is limited to matching nodes, sensors, observations and event resources up with the toponym database. However, the structure and characteristics information of the resources and toponym database themselves as well as the data processing method and service are not included.

The interface specification of the fusion process can be used to provide technical guidance for matching the observation resources up with the toponym database, to add and correct positions for observation resources and to implement quality supervision as well as efficient management for resources and toponym and so on. The concrete application scope of the resource and toponym matching specification is depicted in Figure 15.

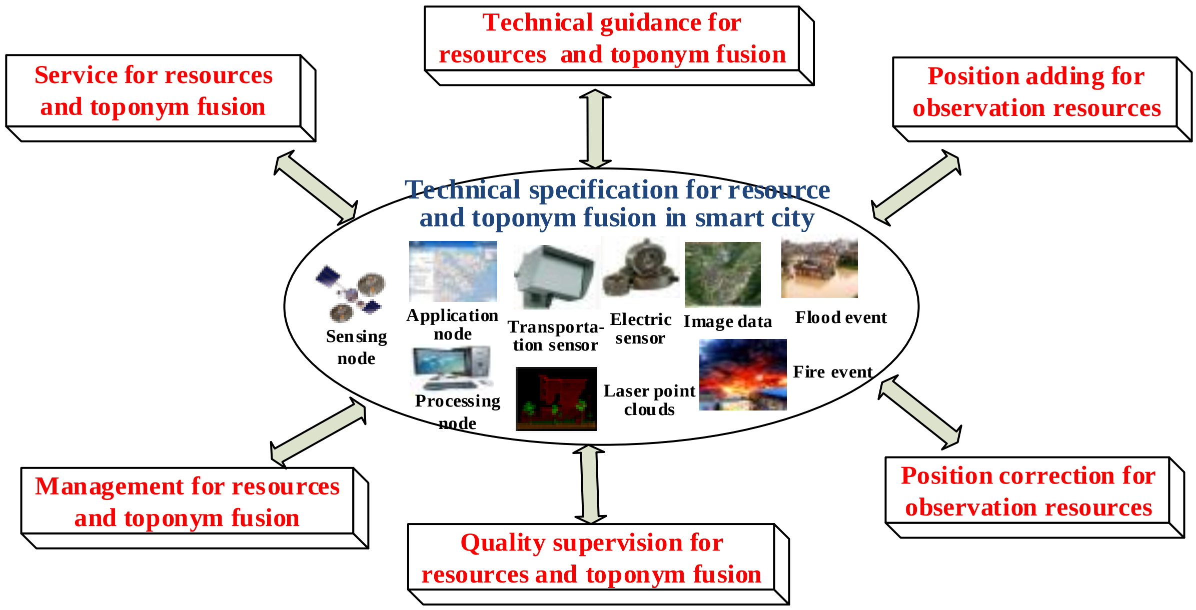

Figure 15 – Application of the resource and toponym database matching

7.3.1.3 Content of the resource and toponym matching specification

The fusion of nodes and the toponym database, assigning the actual place name information to nodes, will make it convenient to overlay nodes on maps or images and will increase the efficiency of sensor accessing and dispatching. Fusing sensors with the toponym database will facilitate the graphical display of sensors on the map and provide data support for sensor planning, arrangements, as well as intensive observations under emergencies. The observations fusing with the toponym database, mainly adding observed properties, will make the demonstration of the data's geographic positions more intuitive and convenient to be invoked at any time. The fusion between events and toponym, adding graphic position labels for events, will contribute to map display, pattern of spatial distribution and causality inferring for events. The technical workflow of matching resources up with the toponym database in IMSSC is shown in Figure 16 [b-Smart].

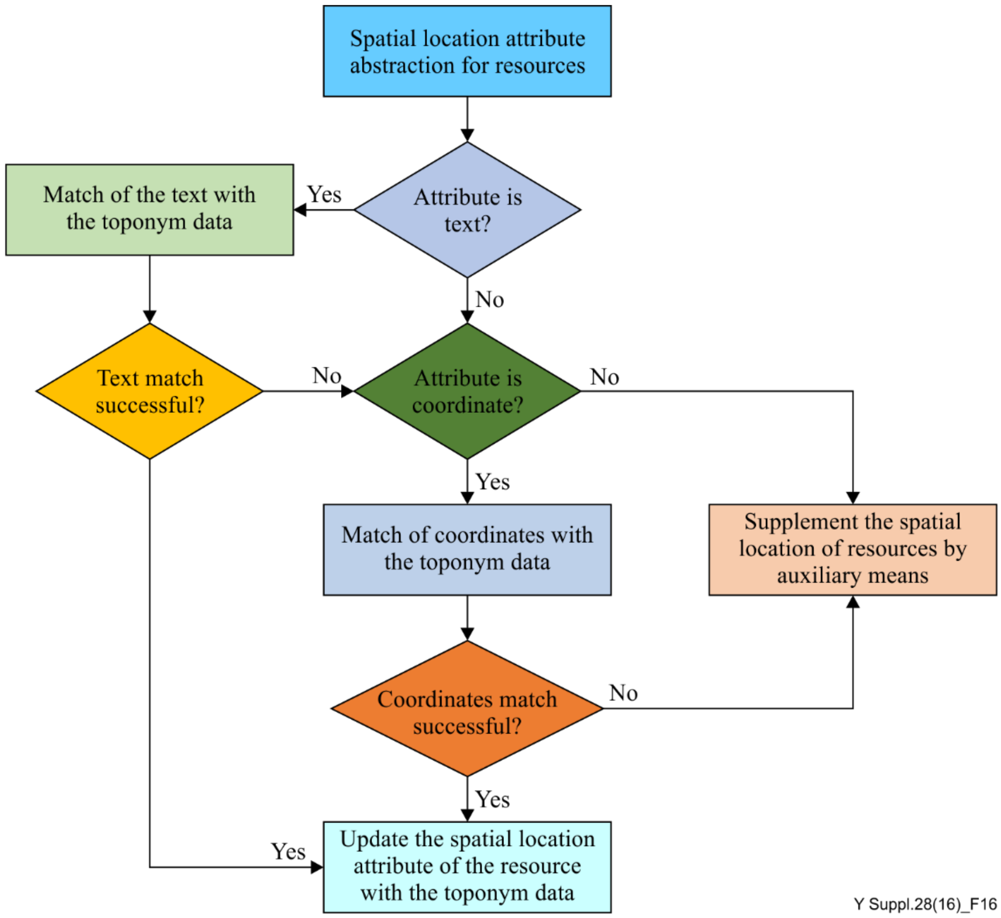

Figure 16 – Technical workflow of matching resources up with the toponym database in the integrated management for smart sustainable cities

7.4 Interface specifications for management service

There are three service technical interface specifications for management service, namely model service interface specification, data service interface specification, and event service interface specification. In this clause only aspects of the model service interface specification are described in detail.

7.4.1 Model service interface specification

7.4.1.1 Background of the model service interface specification

In IMSSC, all departmental applications, such as urban construction, water conservancy, electric power, environmental protection, transportation and fire-fighting, need to be combined with concrete models. However, research is limited to some application fields and systems must be modified or even re-developed when new problems appear. It will take more time and money to restrict the models' application in IMSSC [b-Nativi]. The model service interface specification proposed in this Supplement offers a general and unified service interface and with the storage and invoke for the models separated from the users, the sharing, management as well as interoperability for heterogeneous models or model chains can be implemented.

7.4.1.2 Application of the model service interface

Through the model service interface, model providers can perform the registration, insertion and publishing of the model metadata; model consumers are able to query model metadata information, find the model needed and finally discover, access and invoke the model according to the model ID returned.

The model service interface specification can be exploited for publishing, sharing and reuse of the models. The concrete application scope of the model service interface specification is depicted in Figure 17.

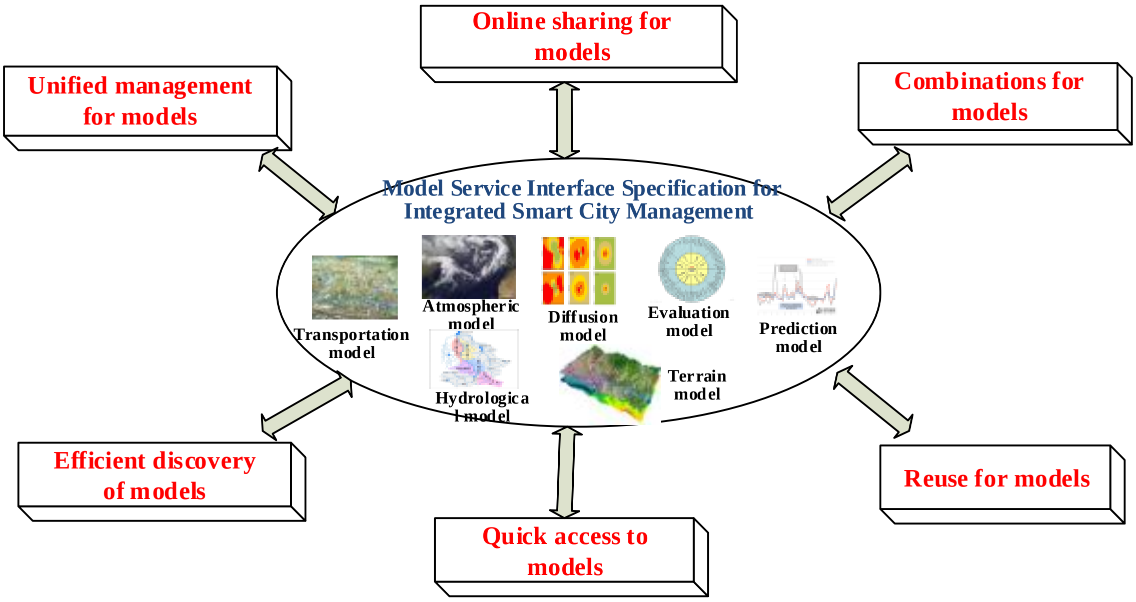

Figure 17 – Application of the model service interface

7.4.1.3 Content of the model service interface specification

The model service under the smart city environment is an open interface and it acts as an intermediate agent between the user and the model storage warehouse. A web service interface is defined in the service interface specification in which queries about the model metadata, input and output, as well as representation for models are allowed. Moreover, the methods of registering new models, deleting existing models and inquiring about new models are all defined in the model service interface specification [b-de Castro]. There are three kinds of operations in the interface specification, namely core, transactional, and enhanced operations. Core operations include the GetCapabilities, DescribeModel and ExecuteModel operations. Transactional operations consist of the InsertModel, DeleteModel and UpdateModel operations. Enhanced operations are composed of the GetFieldOfInterest and GetModelByFunction operations. Among all these operations, only the three core operations are mandatory, while the others are optional. The element structure for the model service interface specification is as explained in Table 1.

Table 1 – Elements of the integrated smart sustainable city management model service interface specification

Interface specification name	Operation type	Operation name	Operation definition	Mandatory or not
Model service interface specification of the integrated management for smart sustainable cities	Core operations	GetCapabilities	Provides access to metadata and detailed information about the models available at a model server.	Yes
		DescribeModel	Enables querying of metadata about the models and model chains available at a model server.	Yes
		ExecuteModel	Provides the execution of models.	Yes
	Transactional operations	InsertModel	Allows registration of new models at the model server.	No
		DeleteModel	Allows the deletion of registered models and all their associated algorithms.	No
		UpdateModel	Allows the update of model parameters and functions.	No
	Enhanced operations	GetFieldOfInterest	Provides access to models from a model service by passing only the field of interest of a user.	No
		GetModelByFunction	Provides access to models from a model service by passing only the expected function of a user.	No

8 Instances of the integrated management for smart sustainable cities

8.1 Daily management

Daily management for smart sustainable cities can be implemented through the following steps. Firstly, access of the monitoring data and processing models of different municipal departments can be achieved by encoding the information resources, such as the nodes, sensors, observation data and models, according to the meta-model proposed in clause 7.2. Secondly, by referring to the fusion processing technical specification in clause 7.3, the integration of different information resources can be realized, together with a higher level of acquired information. Thirdly, the unified management service interface specification can be employed to issue and share nodes, sensors, models and other information resources. When needed, users can access and obtain the corresponding data or models quickly via the uniform service interfaces.

8.2 Emergency response management

The access and integration of all kinds of city monitoring data resources from different departments can be realized by conforming to the theories proposed in this Supplement. Via the technologies of model representation, registration, combination and optimization as well as the combination of the available data resources, model-driven data access can be formed with the model selection. The parameters are optimized and the dual-directional coupling between the data and the models is formed. By encapsulating the data and models into web services, linking them with the decision information requirements from different users and combining concrete city decision task execution workflows, an active and focused service of city decision information can be formed. Finally, typical applications of the intelligent integrated management decision in IMSSC will be established, as shown in Figure 18.

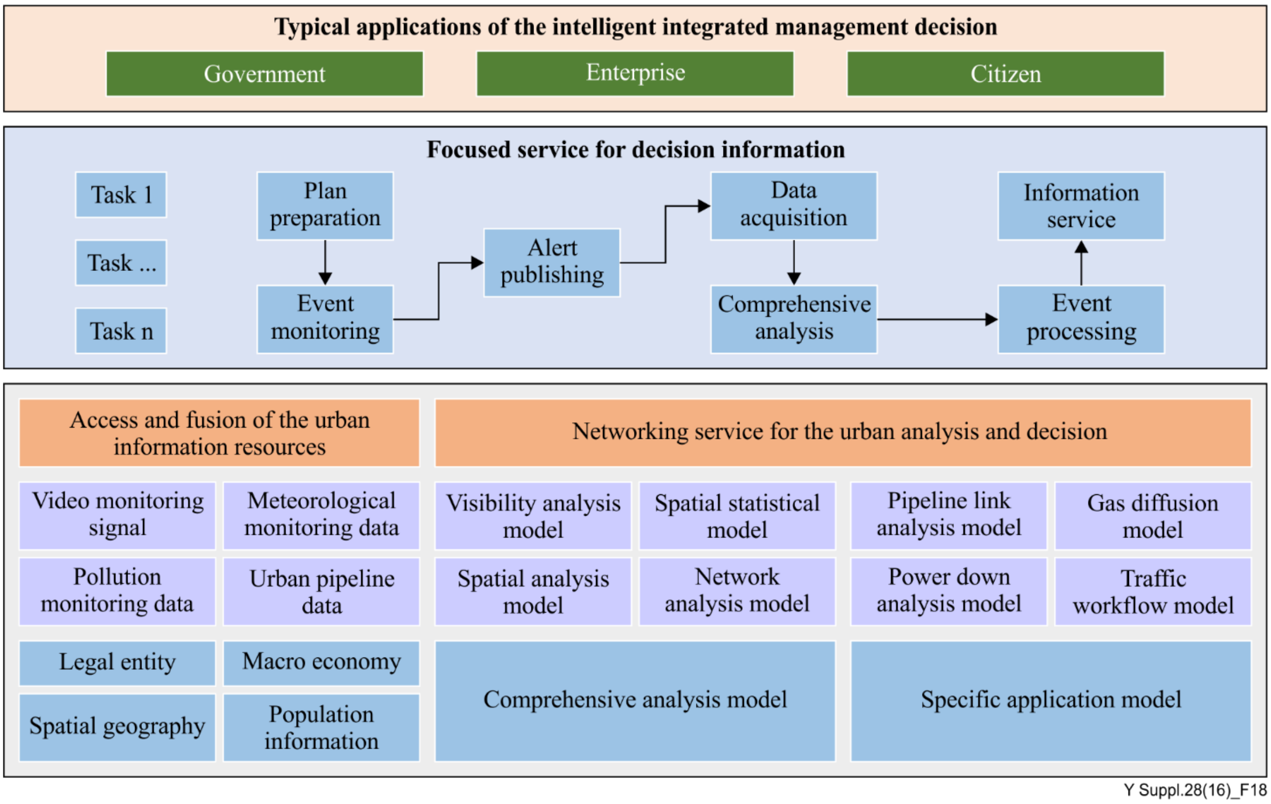

Figure 18 –Typical applications of the intelligent integrated management decision in IMSSC

Aimed at different application topics from multilevel inter-agency intelligent decisions, such as water leakage, power interruption, gas pipeline leakage and so on, the spatial-temporal intelligent analysis and decision model database should be built including general analysis models (visibility analysis model, spatial statistical model, spatial analysis model and network analysis model) and specific application models (pipeline connection analysis model, gas diffusion model, power down analysis model, etc.).

Model information should be expressed in a unified way, so that the models can be conveniently managed and coupled and so that the output of various models can be easily fused. In addition, the model registration centre for cities should be established based on the representation model so that the model registration and discovery can be realized consequently. Moreover, using combination and optimization technology, the abstract and instantiated model chains can be created for decision support in different applications. Through the execution of the model chains, the decision result can be produced, providing support for multilevel intelligent decisions.

When faced with emergency events, the focus is mainly on the task generation, plan preparation and event responding. The theories proposed in this Supplement can be used to provide different data, models and services for different stages respectively.

For example, when a pipeline explosion event occurs in the task generation stage, the network and spatial analysis model, as well as the pipeline network and topography data can be adopted to acquire the location, the severity level and other important information on the event; then the task requirements can be extracted. In the plan preparation stage, by accessing the corresponding data from the departments transparently and performing a comprehensive analysis on the resources, mainly basic geographic data, topography data, data diffusion model, overlay analysis model and network analysis model, the development tendency of the event, the first responders and the emergency facility distribution and other information can be obtained. This provides the basis for making the correct emergency response plan. In the event responding stage, using the road network and real-time traffic information and combining the optimal path, buffer analysis and other models, provides valuable support for a fast response to the emergency. When a multilevel emergency occurs, different service-focused measures should be taken to meet the requirements of the different users, namely municipalities, enterprises and citizens. Municipalities need all the city departments to work collaboratively through the task creation, plan preparation, event monitoring, alert publishing, data acquaintance, comprehensive analysis, event handling and information service, to realize the focused service of the decision information. The relative model and data analysis is performed in the task creation stage together with the task requirements extracted. For example, the gas company is informed during the plan preparation stage to monitor the gas leakage event as well as the situation, locate the event source, feedback the information to the command centre and issue the alert information to the environmental protection, fire-fighting, transportation, communication, surveying and mapping, health care and public security departments. After that, it is necessary to assess the staff, facilities and equipment conditions of the different departments and instruct each concerned department with the appropriate event handling methods to respond promptly. Finally, a communication should be issued to the citizens to inform them about the emergency measures put in place. Through the active focused service described above, decision support for smart pipelines in cities can be provided, proving the efficiency of IMSSC.

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