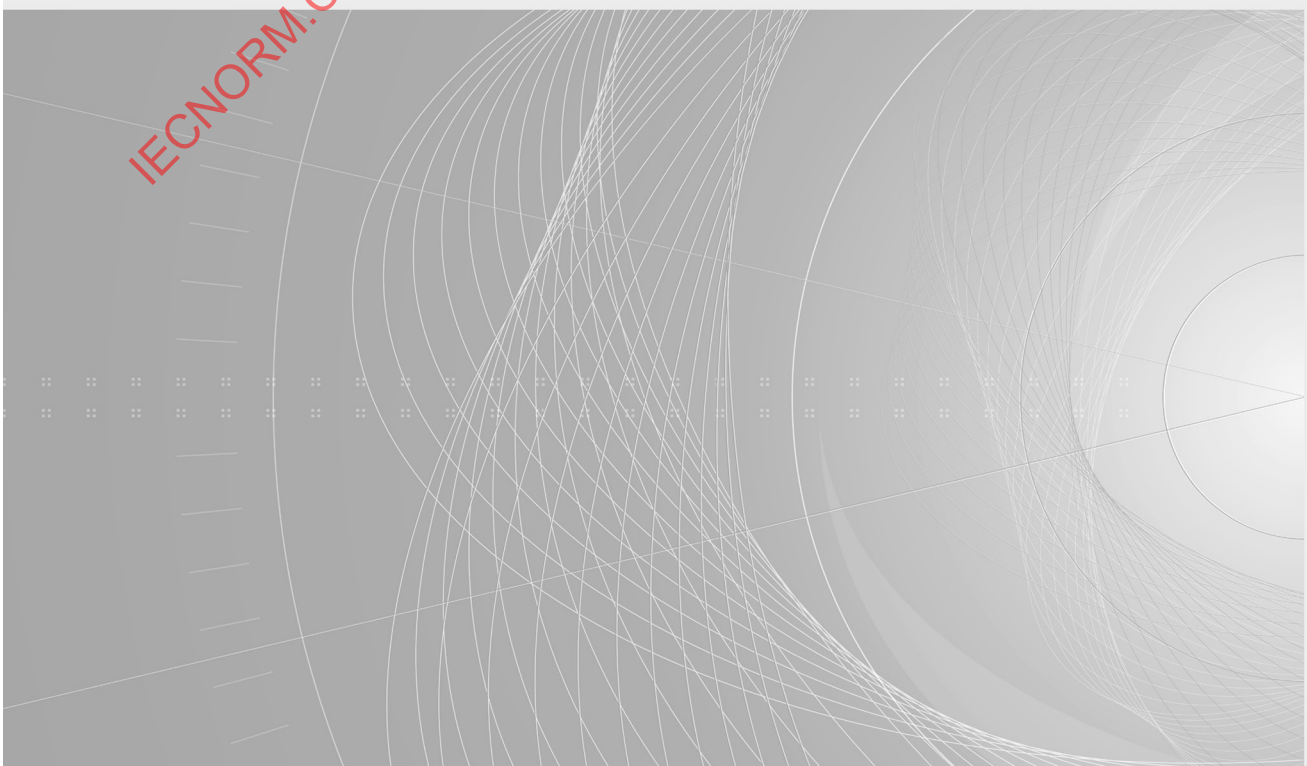
IEC SRD 63273-1

Edition 1.0 2023-08

SYSTEMS REFERENCE DELIVERABLE

Smart city use case collection and analysis – City information modelling – Part 1: High-level analysis



IEC SRD 63273-1:2023-08(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC SRD 63273-1

Edition 1.0 2023-08

SYSTEMS REFERENCE DELIVERABLE

colour inside

Smart city use case collection and analysis – City information modelling – Part 1: High-level analysis

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.020.20; 03.100.70

ISBN 978-2-8322-7442-2

CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 10
2 Normative references 10
3 Terms, definitions and abbreviated terms 10
3.1 Terms and definitions 10
3.2 Abbreviated terms 12
4 Contributing to Sustainable Development Goals 12
4.1 General 12
4.2 Mapping application areas of city information modelling and SDG 11 13
5 City information modelling 14
5.1 Background 14
5.2 The roles of city information modelling 15
5.2.1 General 15
5.2.2 Data integration 15
5.2.3 Geo-visualization 15
5.2.4 Synchronization 16
5.2.5 Simulation 16
5.2.6 Data exchange 16
5.2.7 Data security 16
5.3 City information modelling and its closely related components 16
6 City information modelling application area description 17
6.1 General 17
6.2 New town planning 18
6.2.1 Needs statement 18
6.2.2 Objectives 19
6.2.3 Current practices 19
6.2.4 Gaps in the application 19
6.2.5 Stakeholders 19
6.2.6 Relationships between the stakeholders 20
6.2.7 Scenarios 21
6.2.8 General requirements 21
6.3 Three-dimensional visualization of property and land administration 21
6.3.1 Needs statement 21
6.3.2 Objectives 21
6.3.3 Current practices 21
6.3.4 Gaps in the application 22
6.3.5 Stakeholders 23
6.3.6 Relationships between the stakeholders 23
6.3.7 Scenarios 24
6.3.8 General requirements 25
6.4 Construction approval management 25
6.4.1 Needs statement 25
6.4.2 Objectives 25
6.4.3 Current practices 25
6.4.4 Gaps in the application 26

6.4.5 Stakeholders 26
6.4.6 Relationships between the stakeholders 27
6.4.7 Scenarios 28
6.4.8 General requirements 29
6.5 Project management during construction 29
6.5.1 Needs statement 29
6.5.2 Objectives 30
6.5.3 Current practices 30
6.5.4 Gaps in the application 31
6.5.5 Stakeholders 31
6.5.6 Relationships between the stakeholders 32
6.5.7 Scenarios 32
6.5.8 General requirements 33
6.6 Real estate registration management 33
6.6.1 Needs statement 33
6.6.2 Objectives 33
6.6.3 Current practices 33
6.6.4 Gaps in the application 34
6.6.5 Stakeholders 34
6.6.6 Relationships between the stakeholders 35
6.6.7 Scenarios 36
6.6.8 General requirements 37
6.7 City management using city brain 37
6.7.1 Needs statement 37
6.7.2 Objectives 37
6.7.3 Current practices 37
6.7.4 Gaps in the application 37
6.7.5 Stakeholders 38
6.7.6 Relationships between the stakeholders 39
6.7.7 Scenarios 40
6.7.8 General requirements 41
6.8 Heritage preservation and revitalization 41
6.8.1 Needs statement 41
6.8.2 Objectives 41
6.8.3 Current practices 42
6.8.4 Gaps in the application 42
6.8.5 Stakeholders 42
6.8.6 Relationships between the stakeholders 44
6.8.7 Scenarios 45
6.8.8 General requirements 46
6.9 Transportation infrastructure planning 46
6.9.1 Needs statement 46
6.9.2 Objectives 46
6.9.3 Current practices 46
6.9.4 Gaps in the application 47
6.9.5 Stakeholders 47
6.9.6 Relationships between the stakeholders 48
6.9.7 Scenarios 49
6.9.8 General requirements 49

6.10 Traffic management 49
6.10.1 Needs statement 49
6.10.2 Objectives 49
6.10.3 Current practices 49
6.10.4 Gaps in the application 50
6.10.5 Stakeholders 50
6.10.6 Relationships between the stakeholders 51
6.10.7 Scenarios 52
6.10.8 General requirements 53
6.11 Water management 53
6.11.1 Needs statement 53
6.11.2 Objectives 53
6.11.3 Current practices 53
6.11.4 Gaps in the application 54
6.11.5 Stakeholders 54
6.11.6 Relationships between the stakeholders 55
6.11.7 Scenarios 56
6.11.8 General requirements 57
6.12 Smart census project 57
6.12.1 Needs statement 57
6.12.2 Objectives 57
6.12.3 Current practices 58
6.12.4 Gaps in the application 58
6.12.5 Stakeholders 59
6.12.6 Relationships between the stakeholders 59
6.12.7 Scenarios 59
6.12.8 General requirements 60
6.13 Underground pipeline management based on data lake 60
6.13.1 Needs statement 60
6.13.2 Objectives 60
6.13.3 Current practices 61
6.13.4 Gaps in the application 61
6.13.5 Stakeholders 61
6.13.6 Relationships between the stakeholders 62
6.13.7 Scenarios 63
6.13.8 General requirements 63
6.14 Emergency management and rescue 64
6.14.1 Needs statement 64
6.14.2 Objectives 64
6.14.3 Current practices 64
6.14.4 Gaps in the application 64
6.14.5 Stakeholders 65
6.14.6 Relationships between the stakeholders 66
6.14.7 Scenarios 66
6.14.8 General requirements 67
7 High level system analysis of city information modelling application areas 67
7.1 City information modelling and the stakeholders in its applications 67
7.2 High level system analysis of city information modelling application areas 68

Annex A (informative) List of stakeholders and descriptions for city information modelling use case collection and analysis 69
Bibliography 79

Figure 1 – City information modelling and its closely related components 17
Figure 2 – Positioning city information modelling in new town planning 20
Figure 3 – Positioning city information modelling in the 3D visualization of development applications for public display and planning approvals 24
Figure 4 – Positioning city information modelling in construction project approval management 28
Figure 5 – Positioning city information modelling in real estate registration management 36
Figure 6 – Positioning city information modelling in the city management via city brain 39
Figure 7 – City brain for the city management 40
Figure 8 – The architecture of city brain based on data lake 40
Figure 9 – Positioning city information modelling in the city management via city brain 41
Figure 10 – Positioning city information modelling in heritage preservation and revitalization 45
Figure 11 – Positioning city information modelling structure in traffic management 52
Figure 12 – Positioning city information modelling structure in water management 56
Figure 13 – Relationships between stakeholders when applying CIM in underground pipeline management 62
Figure 14 – Positioning city information modelling in urban underground pipeline management 63
Figure 15 – Relationships between stakeholders when applying CIM in emergency management and rescue 66

Table 1 – Mapping application areas of city information modelling and SDG 11 13

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

SMART CITY USE CASE COLLECTION AND ANALYSIS – CITY INFORMATION MODELLING –

Part 1: High-level analysis

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) following conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for how they are used or for any misinterpretation by any end user.
4) To promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. The use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC SRD 63273-1 has been prepared by IEC systems committee Smart Cities: Electrotechnical aspects of Smart Cities. It is a Systems Reference Deliverable.

The text of this Systems Reference Deliverable is based on the following documents:

Draft	Report on voting
SyCSmartCities/290/DTS	SyCSmartCities/299/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Systems Reference Deliverable is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC SRD 63273 series, published under the general title *Smart city use case collection and analysis – City information modelling*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC SRD 63273 series aims to scope out the requirements of city information modelling standards by collecting and analysing its use cases. Specifically, the IEC SRD 63273 series achieves the objectives of:

a) identifying the key application areas and stakeholders;

b) developing user stories and clarifying the relationship among these stakeholders;

c) collecting and analysing use cases of city information modelling; and

d) scoping out the requirements for city information modelling standards and providing recommendations to IEC regarding urban planning and management.

In this document, application areas refer to the deployment-oriented categories that focus on deploying city information modelling to fulfil a particular purpose.

The IEC SRD 63273 series provides useful information on understanding of city information modelling for standardization committees in IEC and other standards development organizations (SDOs) by:

1) promoting the collaboration and systems thinking regarding city information modelling standards;

2) contributing multiple domain-specific use cases for smart cities; and

3) supporting IEC in fostering the development of standards in the field of electrotechnology to help with the integration, interoperability, resiliency and effectiveness of city systems.

The IEC SRD 63273 series adopts a multi-step approach to generate and collect the use case of city information modelling.

Step I – High-level analysis: The first step aims to generate the list of application areas of city information modelling for a high-level analysis. Needs statements, objectives, current practices, gaps, and scenarios (rationale for applying city information modelling in a specific application area) are investigated for the description of each application area. In addition, the ecosystem, which includes the list of stakeholders and the relationship among the stakeholders, is examined in each application area before developing user stories and use cases.

Step II – User story: The second step aims to develop a list of significant user stories based on the corresponding application area. In each corresponding area, one user story is generated for one specific stakeholder which has been identified in Step I. Each user story follows the same template, which includes one stakeholder (as a specific type of user), a specific situation (when), a goal (I want to), and a reason (so that).

Step III – Use case: The third step aims to develop use cases for a specific application area according to the list of user stories that have been generated in Step II. One user story in Step II can be expanded to be at least one use case. The organization of use cases follows the IEC short use case template (IEC TR 62559-1:2019, IEC 62559-2:2015 and IEC 62559-3:2017), which includes the name of the use case, scope/objective, narrative and list of actors.

Step IV – Use case database establishment and integrative analysis: This step is to establish the use case database of city information modelling and conduct integrative analysis of these use cases.

Step V – City information modelling standard gaps and requirements: This last step is to identify the standard gaps for city information modelling and requirements of the family of city information modelling standards.

The IEC SRD 63273 series contains two parts:

- IEC SRD 63273-1, Smart city use case collection and analysis – City information modelling – Part 1: High-level analysis
- IEC SRD 63273-2, Smart city use case collection and analysis – City information modelling – Part 2: Use case analysis

The scopes of the two parts are defined below.

Part 1 explains how the work of city information modelling use case collection and analysis address sustainable development goals, provides a brief overview of city information modelling, and identifies the key application areas and stakeholders of city information modelling.

Part 2 develops the list of user stories and the database of use cases, conducts integrative analysis of the use cases, scopes out the requirements of city information modelling standards and provides recommendations for IEC and other standards development organizations (SDOs) regarding urban planning and management.

In addition, according to the up-to-date understanding, urban digital twins are also used for describing such technology and solution for smart cities. Urban digital twins indicate the digital twins at the urban scale to enable transformation in how cities are planned, built and managed to deliver better services to make the urban environment more liveable, inclusive, safe, resilient and sustainable. Therefore, the application areas, stakeholders, user stories and use cases of city information modelling, which are identified and developed in the IEC SRD 63273 series, are also applied to urban digital twins to a great extent.

SMART CITY USE CASE COLLECTION AND ANALYSIS – CITY INFORMATION MODELLING –

Part 1: High-level analysis

1 Scope

This part of IEC SRD 63273 explains how the work of city information modelling use case collection and analysis address sustainable development goals, provides a brief overview of city information modelling, identifies the key application areas of city information modelling, and determines the stakeholders and the relationships among them in these application areas.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
city information modelling
CIM
development of digital representations and simulations of a city made up of large quantities of geospatial data, often including real-time data, which enable better city planning and management

Note 1 to entry: The geospatial data are provided using an integration of building information modelling (BIM) and geographic information systems (GIS).

Note 2 to entry: The real-time data are obtained through extensive use of IoT sensors within the city.

Note 3 to entry: City information modelling involves handling large amounts of big data, which are generally brought together using cloud computing.

Note 4 to entry: Artificial intelligence is often used to generate and evaluate different scenarios using city information modelling data to help manage the city better.

3.1.2
stakeholder
individual, team, organization (IEV 831-01-14), or classes thereof, having an interest in a system (IEV 831-01-21)

Note 1 to entry: Usually a stakeholder can affect or is affected by the organization or the activity.

[SOURCE: IEC 60050-741:2020, 741-01-30, modified – The original Note 1 to entry has been replaced.]

3.1.3
use case
specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system

[SOURCE: ISO/IEC 19505-2:2012, 16.3.6]

3.1.4
geographic information system
GIS
information system dealing with information concerning phenomena associated with location relative to the Earth

[SOURCE: ISO 19101-1:2014, 4.1.20]

3.1.5
building information modelling
BIM
use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions

Note 1 to entry: The acronym BIM also stands for the shared digital representation of the physical and functional characteristics of any construction works.

[SOURCE: ISO 29481-1:2016, 3.2]

3.1.6
Internet of Things
IoT
infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical world and virtual world

[SOURCE: IEC 60050-741:2020, 741-02-01]

3.1.7
big data
extensive datasets – primarily in the data characteristics of volume, variety, velocity, and/or variability – that require a scalable technology for efficient storage, manipulation, management, and analysis

Note 1 to entry: Big data is commonly used in many different ways, for example as the name of the scalable technology used to handle big data extensive datasets.

[SOURCE: ISO/IEC 20546:2019, 3.1.2]

3.1.8
cloud computing
paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand

Note 1 to entry: Examples of resources include servers, operating systems, networks, software, applications, and storage equipment.

[SOURCE: IEC 60050-741:2020, 741-01-07, modified – Note 1 to entry has been added.]

3.1.9
artificial intelligence
AI
<discipline> research and development of mechanisms and applications of AI systems

Note 1 to entry: Research and development can take place across any number of fields such as computer science, data science, humanities, mathematics and natural sciences.

[SOURCE: ISO/IEC 22989:2022, 3.1.3]

3.1.10
city model
appropriate set of data which models those physical and social aspects of the city that are relevant for its objectives

[SOURCE: ISO ISO/IEC 30146:2019, 3.5]

3.1.11
spatiotemporal data
data representing a set of direct positions in space and time

3.1.12
application
set of technologies deployed to fulfil a particular purpose

[IEC 60050-741:2020, 741-01-02, modified – In the definition, "software designed" has been replaced by "set of technologies deployed".]

3.2 Abbreviated terms

2D	two dimensional
3D	three dimensional
AI	artificial intelligence
BIM	building information modelling
ANPR	automatic number-plate recognition
CIM	city information modelling
GIS	geographic information system
IoT	Internet of Things
ITS	intelligent transport system
SDGs	Sustainable Development Goals
SDOs	standards development organizations

4 Contributing to Sustainable Development Goals

4.1 General

The United Nations published 17 Sustainable Development Goals (SDGs) to enhance world peace and prosperity, eradicate hunger and poverty, and protect people and the planet by 2030. It calls for innovation and broad collaboration between public and private society. The IEC SRD 63273 series mainly addresses SDG 11 (Goal 11): sustainable cities and communities.

4.2 Mapping application areas of city information modelling and SDG 11

Goal 11 aims to make cities and human settlements inclusive, safe, resilient and sustainable. Specifically, Goal 11 includes ten targets:

11.1 safe and affordable housing;

11.2 affordable, accessible and sustainable transport systems;

11.3 inclusive and sustainable urbanization;

11.4 protect and safeguard the world's cultural and natural heritage;

11.5 reduce the adverse effects of natural disasters;

11.6 reduce the environmental impact of cities;

11.7 provide universal access to safe and inclusive green and public spaces;

11.a a strong national and regional development planning;

11.b implement policies for inclusion, resource efficiency and disaster risk reduction; and

11.c support least developed countries in sustainable and resilient building.

The CIM application areas studied in this document address the full list of targets in Goal 11 (Table 1). One application domain can address more than one target. For example, the application area of new town planning addresses 11.3 inclusive and sustainable urbanization, 11.7 provide access to safe and inclusive green and public spaces, and 11.a strong national and regional development planning.

Table 1 – Mapping application areas of city information modelling and SDG 11

SDG 11 target	Contents	CIM application areas	Connections between SDG 11 and the application areas
11.1 Safe and affordable housing	By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.	• three dimensional visualization of property and land administration • Construction project approval management • Project management during construction • Real estate registration management • Underground pipeline management • Water management	All these CIM application areas are relevant to the whole life cycle of construction for housing, which also includes the civil services for the housing, such as underground pipeline and water management. By adopting CIM in housing constructions and management, the cities are able to manage the land use and provide more safe and affordable housing.
11.2 Affordable, accessible and sustainable transport systems	By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.	• Transport infrastructure planning • Traffic management	These two CIM application areas provide the description of how CIM can be applied in transportation infrastructure planning and traffic management. Both of them enable the city to develop an affordable and sustainable transport system.

SDG 11 target	Contents	CIM application areas	Connections between SDG 11 and the application areas
11.3 Inclusive and sustainable urbanization	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.	• New town planning • Smart census project	The CIM application areas of smart census project can help us understand the population in the cities by using an efficient and low-cost approach. The data can be used for the sustainable human settlement planning through a comprehensive understanding of the different population groups in the communities. New town planning is usually triggered by the urbanization (especially rural to urban), which has become an important agenda for sustainable urban development in all countries.
11.4 Protect and safeguard the world's cultural and natural heritage	Strengthen efforts to protect and safeguard the world's cultural and natural heritage.	• Heritage preservation and revitalization	The CIM application area of heritage preservation and revitalization addresses the importance of applying digital technologies to protect and safeguard the heritages in cities.
11.5 Reduce the adverse effects of natural disasters	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to the global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.	• City management using city brain • Emergency management and rescue	The CIM application area of city management using city brain provides the different scenarios of using big data, joint data hub, IoT, cloud computing to manage the city, which include natural disasters. The CIM application area of emergency management and rescue advance the understanding of applying smart technologies especially in fire emergency response and rescue.
11.6 Reduce the environmental impacts of cities	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.	• City management using city brain	The CIM application area of city management using city brain provides the different scenarios of using big data, joint data hub, IoT, cloud computing to manage the city, which include environmental impact of cities.
11.7 Provide universal access to safe and inclusive green and public spaces	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities.	• New town planning • Smart census project	Smart census project can help the city to understand the population groups in the city, which include women, children, older persons and persons with disabilities. The CIM application area of new town planning addresses how to use CIM to have an integrated planning in the new town area to increase the green and public space especially for the special population groups.

5 City information modelling

5.1 Background

The concept of CIM was first proposed in the mid-2000s in the field of urban planning and disaster management. However, the components and technologies were developed in the 2010s. CIM received more and more attention especially from urban planners, architects and city administrators since it can provide a solution for smart city development.

The city was considered as a space carrier from building information modelling (BIM) in the 1970s to 3D geographic information system (GIS) in the 1990s, and then to IBM's Smarter Planet and Smarter Cities initiatives in the early twenty-first century. Today, in order to achieve intelligent urban governance concepts and means, BIM, GIS, IoT, big data, artificial intelligence and cloud computing technology have been used interactively to put forward the concept of CIM to better deal with the availability and complexity of city-related information, to achieve efficient, coordinated and shared urban governance goals, urban economy and infrastructure.

Therefore, the application of CIM is usually operated as a platform, and the CIM platform is used to present the application of CIM as an integrated development of digital representations and simulations of a city.

5.2 The roles of city information modelling

5.2.1 General

The application of CIM provides a highly efficient, multi-functional and integrated management platform for all the stakeholders in cities. It corresponds to a vast spectrum of needs, values and uses in diverse areas such as urban planning, property management, maintenance of heritage and disaster management. The roles of CIM include, but are not limited to,

a) data integration,
b) geo-visualization,
c) synchronization,
d) simulation,
e) data exchange, and
f) data security.

5.2.2 Data integration

The first role of city information modelling is to connect, store and enable access to all information and data regarding a city, from all stakeholders in the city, in one collaborative data hub (integration).

The stakeholders refer to the stakeholders of the specific scenarios. The collaborative hub is a joint data hub that serves different stakeholders. The stakeholders are diverse in different application scenarios, but they mainly include policymakers and workers in different government departments, managers and workers in industries, professionals and the public.

CIM can connect different types of information and data and technologies to build up an intelligent platform to assist us to design and operate a smarter city. Specifically, the connection of data includes the studies of

a) accessibility and availability of data,
b) accuracy and consistency of data,
c) manageability of data, and
d) integration of data.

5.2.3 Geo-visualization

The second role of city information modelling is to visualize multisource data in the nD map (geo-visualization).

CIM supports virtual urban planning and management by transparently representing urban issues to the relative stakeholders. It provides a solution for displaying multisource data in the nD map (e.g. 2D, 2,5D, 3D and 4D), presenting complex urban environments in multiple ways, connecting different stakeholders through a user-friendly platform.

5.2.4 Synchronization

The third role of city information modelling is to update the data automatically in real time (synchronization).

CIM provides a method to automatically update the data via IoT and satellite telemetry data sources, which enable managing the assets of a city also in real time.

5.2.5 Simulation

The fourth scope of city information modelling is to simulate the growth of the city and test specific scenarios to proactively better understand various responses and impacts and acquire knowledge (simulation).

CIM provides real-time or near-real-time simulations of urban growth in order to explore real-world environments, which enable interactions between different users. CIM allows professional users to deploy multiple analytical functions to achieve intelligent urban design and test different design options. Moreover, CIM offers a robust user interface and tool and enables the development of tools for visualizing and evaluating policy scenarios. Therefore, CIM provides solutions for data management, data analysis, problem-solving and design, decision-making and communication activities.

5.2.6 Data exchange

The fifth scope of city information modelling is to exchange data (data exchange).

CIM is operated as a collaborative platform that enables different stakeholders, including citizens, enterprises, professionals and government agencies, to access dynamic city data and information directly. Unifying data formats and a user-friendly design should be considered when CIM is open to the public since not all users have the technical background to use these data. The public is able to ensure accepted principles of data policies, such as obtaining consent before sharing with third parties, checking the usage of data accessed, and managing one's data with necessary controls when they are using CIM for data exchange. The collaborative data hub described in 5.2.2 is one part of the collaborative platform.

5.2.7 Data security

Last but not least, the sixth scope of city information modelling is to protect data (data security).

CIM provides differing levels of access for different stakeholders to enable various data utilizations. It is possible that public access to aggregated data will not be allowed for personal or sensitive information. Different levels of security are implemented in CIM, and access is determined subject to policy and regulatory controls with sharing allowed via data sharing and confidentiality agreements.

5.3 City information modelling and its closely related components

CIM is one of the emerging technologies and solutions for smart cities. The insights gained from CIM inform the continual improvement of the creation and operation of physical assets. Building information modelling (BIM), geographic information system (GIS), Internet of Things (IoT), cloud computing, big data and artificial intelligence (AI) are closely related components of CIM (Figure 1).

CIM also addresses the contribution to electrotechnical aspects of smart cities. First, CIM can facilitate smart electrical energy management techniques and enhance electrical safety. Second, CIM can support electrical system design. Third, CIM is important in helping design telecommunication systems for smart cities. In order for these contributions to be fully realized, CIM used for the electrotechnical aspects of smart cities needs to be abundantly compatible with the way it is used for every other aspect of the city so that, for example, city management can plan and manage all aspects of city infrastructure in an integrated way.

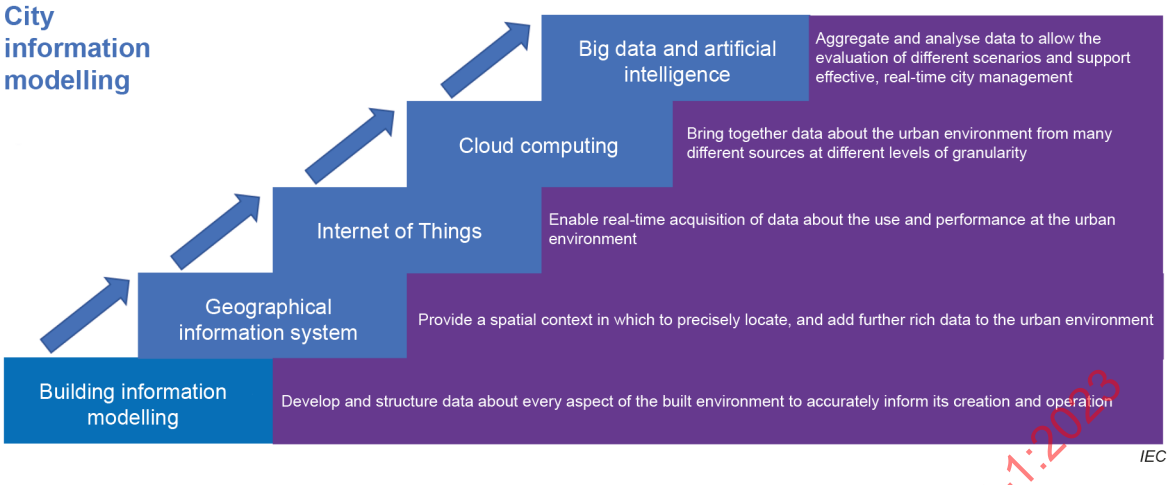


Figure 1 – City information modelling and its closely related components

6 City information modelling application area description

6.1 General

CIM can be applied in a vast scope of areas, include urban planning, whole life cycle of construction project management, disaster management, heritage preservation, transportation planning and management, water and urban utilities management.

Specifically, this document addresses the following application areas:

1) new town planning;
2) three-dimensional visualization of property and land administration;
3) construction approval management;
4) project management during construction;
5) real estate registration management;
6) city management using city brain;
7) heritage preservation and revitalization;
8) transportation infrastructure planning;
9) traffic management;
10) water management;
11) smart census project;
12) urban underground pipeline management based on data lake; and
13) emergency management and rescue.

Each of the above CIM application area descriptions has the following structure.

a) Needs statement: Describes the problems and conditions that CIM can solve or address.

b) Objectives: Describes the aims or goals of applying CIM in the specific area.

c) Current practices: Describes the existing exercises or operations in the specific application area.

d) Gaps in the application: Indicates the differences, especially undesirable ones, between needs statement and the current practices.

e) Stakeholders: Identifies a person or group of people with an interest or concern in the application of CIM in specific application areas.

f) Relationships between the stakeholders: Describes how two or more stakeholders are connected through CIM.

g) Scenarios: Describes the rationale for the new practice in the specific application area, which can include how CIM can help to achieve the objectives and how CIM is able to achieve the needs of different stakeholders in the ecosystem.

h) General requirements: Illustrates the requirements, which can be the function, user, data, laws and regulations, standards, life cycle consideration and others relevant to the application of CIM.

When describing stakeholders for the specific application area of CIM, the following roles are used.

- Primary beneficiary: stakeholders who benefit directly from the solution.
- Secondary beneficiary: stakeholders who benefit indirectly from the solution.
- Tertiary beneficiary: stakeholders who benefit indirectly from the solution at one further step removed.
- Owner: stakeholders who own or manage the solution.
- Designer: stakeholders who can participate in designing the solution.
- Builder: stakeholders who can participate in building the solution.
- Maintainer: stakeholders who can participate in maintaining the solution.
- User: stakeholders who use the solution to help meet their needs.

There can be other roles, for instance, financer, regulator, etc. Some stakeholders will have several stakeholder roles, depending on the application scenario being considered.

6.2 New town planning

6.2.1 Needs statement

a) Different types of new town planning relevant data need to be put into one platform for efficient data query and acquisition (CIM-NS-NTP-01).

b) Different types of models and simulations need to be conducted for different themes for studies in new town planning (CIM-NS-NTP-02).

c) The planning needs to be expressed in an easy-to-understand way (CIM-NS-NTP-03).

d) Different stakeholders need to check and comment on the new town planning in a user-friendly platform (CIM-NS-NTP-04).

e) The authorized groups need to acquire, upload, download, and edit the data in the platform without high skill requirements (CIM-NS-NTP-05).

6.2.2 Objectives

The application of CIM to the planning of new town planning aims to:

a) integrate multiple data on one platform;

b) conduct simulations on a wide range of themes;

c) provide a 3D and timely presentation of the new town planning;

d) facilitate efficient and effective communication between different stakeholders.

6.2.3 Current practices

New town planning addresses shaping a quality living and working environment, facilitating economic development, and promoting the health, safety and general welfare of the community by guiding and controlling the use of land. A lot of new town planning projects around the world, for example in China, India, Indonesia, and Japan, are being conducted.

6.2.4 Gaps in the application

Traditionally, urban planners meet the challenges of generating and organizing of a large quantity of timely data and information and making precise estimations on specific themes (e.g. population growth, housing needs, traffic needs) for the new town planning. Moreover, it is difficult for urban planners to have efficient communication with different stakeholders in the new town planning. The ability to calculate the impact of environmental loss, emissions in the supply chain cycle, etc. is also a gap that will need to be included to accurately conform to net zero obligations by urban planners.

6.2.5 Stakeholders

Stakeholder 1: Urban planner

- Roles: Primary beneficiary of CIM as it will help urban planners do their work better and more effectively. Designers, as urban planners, will be involved to design the CIM platform according to their needs. Users, as they can use CIM as a fundamental tool in their work for the new town planning.
- Responsibilities: Urban planners should develop plans for the new town area that will achieve the aims indicated by the planning of the new town, enable residents to have a better life and employment and increase its sustainability.

Stakeholder 2: Real estate developer

- Role: Secondary beneficiary of CIM as it will help developers to understand the new town planning and identify the business opportunities. Builders, as they will participate to implement the new town planning.
- Responsibilities: Developers are interested in innovation and technology advancement in their property development. They are also interested in the information that the CIM will give them on how the area they are developing fits in with the new town plans, such as how far the homes will be from retail areas and employment areas, and what sort of public transport there might be and so on, to enable them to share their requirements into the overall plans.

Stakeholder 3: Business owner

- Role: Secondary beneficiary of CIM, as it will help business owners to understand the new town planning and identify business opportunities.
- Responsibilities: Companies, especially the large-scale ones, are responsible for communicating with the urban planners and government if they are going to develop business in the new town.

Stakeholder 4: Citizen

Local community member: A person who lives, learns, works, plays, and prays in the communities.

Nonlocal community member: A person who lives, learns or works outside the community but who can live, learn or work in the community.

- Role: Tertiary beneficiary of CIM, as it will help the general public to understand the new town planning and present their community comments. The general public includes indigenous inhabitants if any, the workers who will move their work to the new town, the residents who will move to the new town, etc.
- Responsibilities: General public are encouraged to participate in the new town planning by attending the surveys, public forums, workshops, exhibitions and other events to present their vision and comments.

Stakeholder 5: Urban planning decision maker

- Role: Owner and maintainer of the solution. Usually, the government is the owner and maintainer of the solution and has the final decision on the new town planning.
- Responsibilities: Government or the planning owner makes the final decision on new town planning and offers solutions to overcome the challenges to achieve the needs of different stakeholders.

6.2.6 Relationships between the stakeholders

Urban planners collect data from different organizations and government departments for the simulations in new town planning (Figure 2). They also collect the needs of different stakeholders, develop a plan and submit it to the government. Government has the final decision on the new town planning. Other stakeholders are encouraged to participate in the new town planning by checking the planning proposal and presenting their needs.

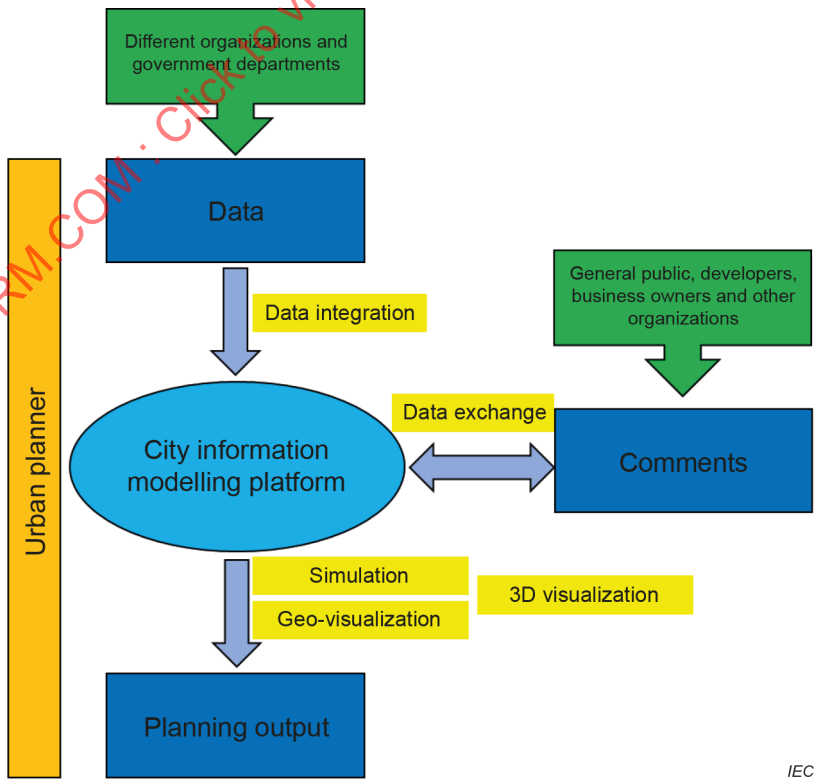


Figure 2 – Positioning city information modelling in new town planning

6.2.7 Scenarios

CIM can become a powerful tool to assist urban planners to achieve smart planning for new town areas. First, CIM provides a hub to collect, store and analyse different types of data. The data include secondhand data of census, traffic, land use, buildings and others, and firsthand data collected from the other stakeholders. Second, CIM enables urban planners to have more effective and efficient communication with the different stakeholders. The stakeholders can view different types of simulation and present their comments according to their needs and experiences. Third, CIM supports urban planners to develop different types of simulation and revise the simulation according to the needs of stakeholders. For example, CIM can simulate the traffic of one bridge according to the population in residential communities, business sections and other organization sectors. Finally, CIM supports the urban planner to visualize the results of planning in a 3D model, which improves efficiency and accuracy.

6.2.8 General requirements

- The CIM platform should integrate different types of data into one hub, such as geographical information, population, traffic, weather, building, underground pipeline system, etc. The standards relevant to CIM should also look at the integration of different types of data which are used by the CIM platform.
- The application of CIM in new town planning considers the stage of planning in a smart city development, and an online platform should be developed for different stakeholders to review the planning and present their opinions and comments.
- The team of urban planning should include CIM professionals.

6.3 Three-dimensional visualization of property and land administration

6.3.1 Needs statement

a) 3D building model objects need to be loaded into a platform that facilitates 3D visualization (CIM-NS-3DV-01).

b) Stakeholders need to be able to view and navigate the new development application in an interactive user-friendly platform (CIM-NS-3DV-02).

c) Data model needs to be able to be accessed for data queries and simulations (CIM-NS-3DV-03).

6.3.2 Objectives

The purposes of applying CIM to 3D visualization of property and land administration include:

a) to review and anticipate the changes in my communities-built environment;

b) to support community engagement in built environment and infrastructure developments;

c) to manage the land use and planning instruments in a data-driven way;

d) to provide spatial and temporal pending and planned infrastructure developments in a digital environment;

e) to create a data supply chain for better assessment and approval metrics and validations;

f) to assess new developments against key community assets.

6.3.3 Current practices

Current process is as follows.

- Project scheme designer – submitter.
  - Prepare paperwork and reports.
  - Lodge.
- Local government assessment officer.
  - Manage paperwork.

- Local government certifier.
  - Review.
- Citizen and advocacy and public interest groups.
  - Public exhibition of plan and documents:
    i) physical list at office or public space, e.g., library;
    ii) textual list or 2D image plan document online;
    iii) newspaper notification (text information).
- Local government assessment officer.
  - Manage paperwork.
- Local government certifier.
  - Review and certify.
- Model is discarded or stored.
  - Construction begins.
  - Model is followed.
  - Model is not followed.

Current plans submitted by the developers awaiting approval are put on display through local council websites and in office environments (printed maps or in-house GIS). Online these plans are listed as textual descriptions and details along with associated legal and survey documents available for downloading and viewing.

Some development applications are indicated on an online map as points with a related identifier that links to document downloads. They are not commonly represented as two-dimensional or three-dimensional geometries in a geospatial (GIS) environment.

Digital model or plan images do not continue a pipeline of downstream activities or on a digital thread post the approval and construction process.

6.3.4 Gaps in the application

- Paper based.
- Manual.
- Time intensive.
- Reduced digital validation.
- Reduced automation capabilities.
- Reduced contextual insights.
- Plan literacy required – limiting wider understanding of implications of development in the spatial context.

In reviewing a plan and development application on paper, the public stakeholder needs to open each application and the associated information to gain insight on the vertical extent of the application on display. This is time-consuming and does not allow for quick and spatially based context of all the horizontal and vertical developments underway, as well as the relationship of the proposed objects with the surrounding existing built environment objects.

6.3.5 Stakeholders

Stakeholder 1: Local government certifier

- Role: Primary beneficiary: Maintainer: Stakeholders who benefit directly from the solution.
- Responsibilities: Certifier which benefits directly from the solution as it will speed up validations and certification checks for developments. Certifiers will help maintain the system by determining the rules of the system in regard to new development lodgements and their approval and rejection reporting.

Stakeholder 2: Local government assessment officer

- Role: Secondary beneficiary: User: Stakeholders who benefit indirectly from the solution.
- Responsibilities: Officer who benefits from the solution through monitoring development applications and sending them to other stakeholders within the ecosystem. Officer will utilize the system for administration of new or approved plans. Officers will update the currency of the platform for managing plans and keeping their administration maintained.

Stakeholder 3: Project scheme designer

- Role: Secondary beneficiary: User: Stakeholders who benefit indirectly from the solution.
- Responsibilities: Designer will benefit from the solution as they will be able to easily load and submit plan information for assessment. Designer will participate in suggesting interface improvements and capabilities for them to load plans.

Stakeholder 4: Advocacy and special interest group

- Role: Secondary beneficiary: User: Stakeholders who benefit indirectly from the solution.
- Responsibilities: Advocacy and special interest groups will benefit through being able to access and assess new developments in their community for negative and positive outcomes and put forward comments and analysis. These groups will use the platform to help understand the developments and extract data for analysis.

Stakeholder 5: Platform maintainer

- Role: Maintainer ecosystem: Stakeholders who can participate in maintaining the solution.
- Responsibilities: Maintainer will maintain the quality and currency of data in the system for the other stakeholders.

Stakeholder 6: Citizen

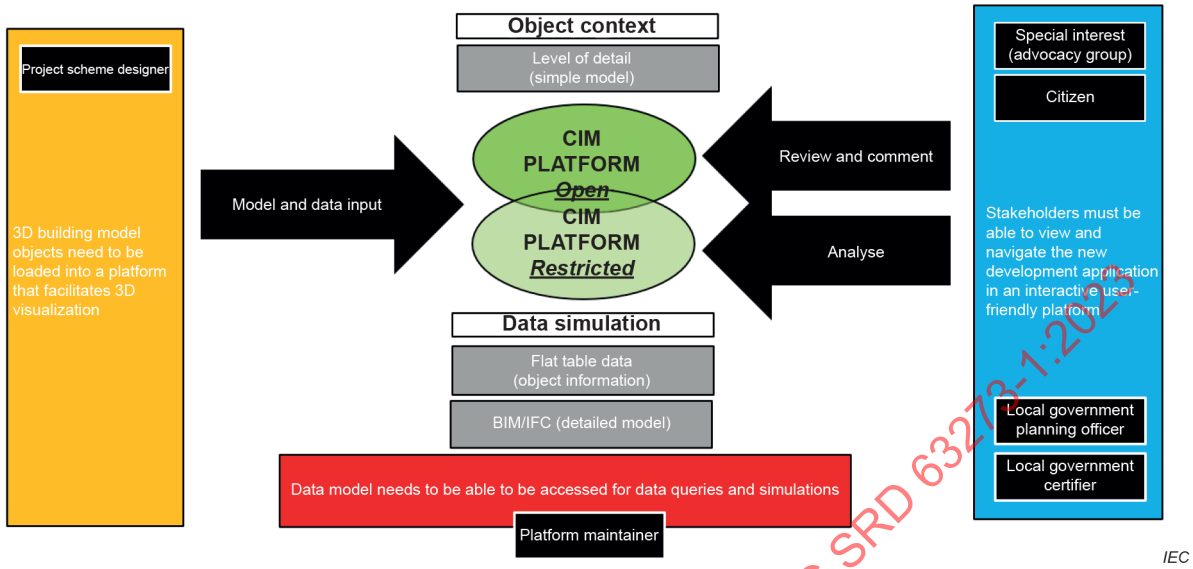
- Role: Tertiary beneficiary: User: Stakeholders who benefit indirectly from the solution.
- Responsibilities: The system will record and maintain comments on new developments from citizens. Citizens will review and comment on developments that are open for public display if they have concerns of the impact on their community.

6.3.6 Relationships between the stakeholders

Project scheme designer submits their plans to the local council, which places the development application on display (Figure 3).

The government certifier and government planning officer can assess the development application in relation to state and local regulations. This is facilitated by a platform maintainer.

A development application is placed on public display through online websites for the public to review and for special interest groups to engage. Special interest groups can have higher level access to the public data accompanying the visualization model to enable further analysis against groups specific location-based data (environmental and social data).



Key

BIM/IFC building information modelling for international foundation class

Figure 3 – Positioning city information modelling in the 3D visualization of development applications for public display and planning approvals

6.3.7 Scenarios

CIM can assist in creating digital 3D spatial objects of the building developments that can be placed and viewed with other geospatial and planning data in a visualization platform to enable insights and context.

This visualization of the built environment allows a user to make an in-context visual assessment of the new proposed development and visually see its spatial relationship to existing built environment objects.

The model is both valuable to visual context and more advanced validation processes such as the relationship between planning instruments and land use. Land administration processes around restrictions and allowances can be performed in a computer-readable format allowing for faster checking and approval processes. Compliant buildings require less time in the approval process and non-compliant construction and development being identified faster for more thorough assessment processes.

This system sets the stage for future regulations around the construction industry that can be applied through computer-readable systems and algorithms updating the parameters for validation within the system. It reduces errors resulting from staff not being up to date with new compliance within the land, planning, and construction industry, and creates a scalable digital thread for future compliance settings.

It is able to meet the needs of the council seeking to provide transparency for their local constituents, whether they be the public, special interest groups or the local business community.

The viewers are empowered through viewing and commenting on the developments that can affect their community or neighbourhood and it assists interested parties who are not literate in development plan paperwork and sketches.

Advocacy and public interest groups can access data and visualizations that help them understand the impact on the community through visual assessment, data analysis and aggregation and simulation analysis.

6.3.8 General requirements

- Regulation: Changes to how plans are drafted and how development applications are submitted to councils and the public for review.
- Standards: The implementation of standards should integrate different types of data into one CIM platform, such as digital plans, BIM and other geographical and infrastructure-related data.
- Platform: Online shared platform for different stakeholders to review the planning and present their opinions and comments.
- Maintenance: The ability to load, maintain, update and retire the spatial objects.

6.4 Construction approval management

6.4.1 Needs statement

a) The platform has the capability of data classification management, and can identify the category of open data, shared data, and closed data (CIM-NS-CAM-01).

b) Documents such as construction project requirements, project scheme, application information, approval results, graphics, and text need to be gathered on the platform (CIM-NS-CAM-02).

c) Different stakeholders need to check, approve and comment on the proposed construction project scheme on a user-friendly platform (CIM-NS-CAM-03).

d) Different stakeholders can have effective communication regarding the project requirements, and results of different approval stages, and acquire project approval results in real time (CIM-NS-CAM-04).

e) In response to the different scenarios of construction project approval management, users can carry out different intelligent operations according to the requirement and authorization, including but not limited to uploading, downloading, editing, and browsing data on the platform, two-dimensional and three-dimensional integrated display, multi-scheme comparison, and intelligent review (CIM-NS-CAM-05).

6.4.2 Objectives

The purposes of applying CIM to construction approval management include:

a) to provide intelligent assistance for approval management and improve the efficiency of government services;

b) to realize the precise management of urban spaces and make the city more suitable for living and working, stimulating the development of urban transportation, environment, history, and culture;

c) to help the public easily understand construction projects and improve public participation in the approval management of construction projects;

d) to promote the linkage between relevant authorities for construction approval, and achieve the whole life cycle of construction project management from land use approval, scheme design, construction, completion and final acceptance of construction projects.

6.4.3 Current practices

The construction approval management covers technical review and administrative approval from land use approval to completion and final acceptance. It is an important work for making urban construction and renewal in order. However, 2D computer-aided design data in construction approval management requires more manual review because that does not link to population, economy, and other relevant data automatically. Usually, the approval involves multiple authorities, and their work mainly focuses on and is limited to their own scopes and functions.

6.4.4 Gaps in the application

a) The 2D graphic design drawings cannot display the complex space design in multiple views and sections. The objects and their characteristics of the proposed project based on the 2D design usually cannot be described well. Moreover, it is not easy for the public to understand the project.

b) The information capacity of 2D drawings is deficient, which causes weak computer-aided review as well as a heavy workload of manual review.

c) The review and approval content lacks the analysis of the 3D spatial relationship between the project and its surrounding urban environment, with the result that it is difficult to make the proposed project aligned with the overall urban design.

d) The approval lacks inter-departmental cooperation, which can lead to the failures of implementation involving multiple authorities.

6.4.5 Stakeholders

Stakeholder 1: Construction project approval managing authority

The construction project approval managing authority usually includes the government department of urban planning, construction and management, and other domains relevant to construction projects.

a) Construction project review manager: According to the rules and specifications, review and check whether the construction project meets the requirements.

b) Construction project public comment manager: Collect and analyse the comments from citizens regarding the construction project.

c) Construction project approval manager: According to different standards, decide whether the construction project should be carried out or not.

- Role: primary beneficiary, owner and builder ecosystem of applying CIM to construction project approval management. CIM can improve government's efficiency on construction project approval. Government has the right to approve construction projects.
- Responsibilities: According to laws, regulations and regulatory documents, government departments review the project schemes submitted by the construction project owner, collect and analyse comments from the public, approve and reject the project.

Stakeholder 2: Real estate developer

- Role: primary beneficiary and builder ecosystem. Real estate developers make money from buying land, and building new houses and apartments, offices, and other real estate product because project approval management helps them better design project schemes. Builder ecosystem, they are responsible for the project scheme.
- Responsibilities: They are responsible for the overall construction of the project, and submit the project scheme to the government departments for reviewing and approval.

Stakeholder 3: Project scheme designer

a) Architectural designer: Professionals who are responsible for architectural design of construction projects.

b) Municipal designer: Professionals who are responsible for municipal facilities design of construction projects, including but not limited to drainage, sewer and water systems.

c) Transportation designer: Professionals who are responsible for roads and transportation facilities design of construction projects.

- Role: secondary beneficiary and designer. The designer professionals apply CIM to facilitate and increase the efficiency of the work of preparing designs and ensure designs take into account associated planning, survey, traffic, electrical and landscaping requirements. They also participate in and take the responsibility for the design and modification of the construction project scheme.

- Responsibilities: Entrusted by the construction project owner to carry out building information modelling and other scheme design, adjust and optimize scheme according to the government's review opinions.

Stakeholder 4: CIM platform and software developer

a) Needs analyst for CIM platform and software: Professionals who collect the platform information, documents and users' needs.

b) CIM platform development engineer: Professionals who are responsible for software design and development.

c) CIM platform operator and maintainer: Persons responsible for the daily operation, maintenance and management of the software.

- Role: secondary beneficiary. CIM platform developers participate in the development of the CIM platform and software especially for project approval management, to improve the quality and service capabilities of their product. Maintainer ecosystem of CIM platform, they guarantee the normal operation and maintenance of the CIM platform and software.
- Responsibilities: According to the approval authority's needs, CIM platform developers design, establish, deliver daily operation and maintenance for the CIM platform, and provide technical support for the approval and management of the construction projects.

Stakeholder 5: Academic researcher

- Role: Second beneficiary and user. Academic researchers are the professionals who do theoretical innovation and consult on city construction project management.
- Responsibilities: Providing consultancy, data analysis and application ideas on city construction project management.

Stakeholder 6: Citizen

a) Citizen who lives near the construction project.

b) Citizen who works near the construction project.

- Role: Tertiary beneficiary and user. The citizens can review and understand the proposed planning and construction project schemes through the CIM platform. They are also one of the users of the CIM platform.
- Responsibilities: When the government displays the proposed construction project, the citizens provide comments according to their needs.

Stakeholder 7: Business owner

- Role: Tertiary beneficiary and user. Business owners realize, evaluate the construction project, and make the investment decisions for benefits.
- Responsibilities: They provide products and services for the citizens and organizations.

6.4.6 Relationships between the stakeholders

- The government, also named the construction project approval authority in this application area, manages the construction project approval, and is authorized to make the relevant decisions.
- The real estate developer submits the proposed construction project, revises the project according to requirement, and implements the project after it is approved.
- The qualified designers are contracted with the construction project developer to carry out project scheme design, including but not limited to architecture scheme, water and electricity system.
- CIM platform developer is responsible for the development, operation and maintenance of CIM platform, and provides technical support for the construction project approval management.

- Academic researchers from the research institutions provide professional services, including but not limited to data collection and analysis, for both government and companies.
- Citizens are one of the main users of the proposed construction, and they should provide comments on the project before its approval.
- Business owners study and evaluate the proposed construction project, make investment decisions, and provide products and services for the public.

In the application area of construction project approval management, the CIM platform acts as a huge data processing centre, intelligent operation centre, and communication platform (Figure 4). The CIM platform can integrate construction project requirements, approval results and other documents into one platform, provide the government with intelligent approval, share multi-departmental and multi-industry data for developers and designers, and provide the public with easy-to-understand construction project schemes. The CIM platform is the bridge for efficient communication among different stakeholders. It can effectively collect public comments on the construction project scheme, thereby optimizing the plan, and assisting city managers with scientific decision-making in planning, construction, and management.

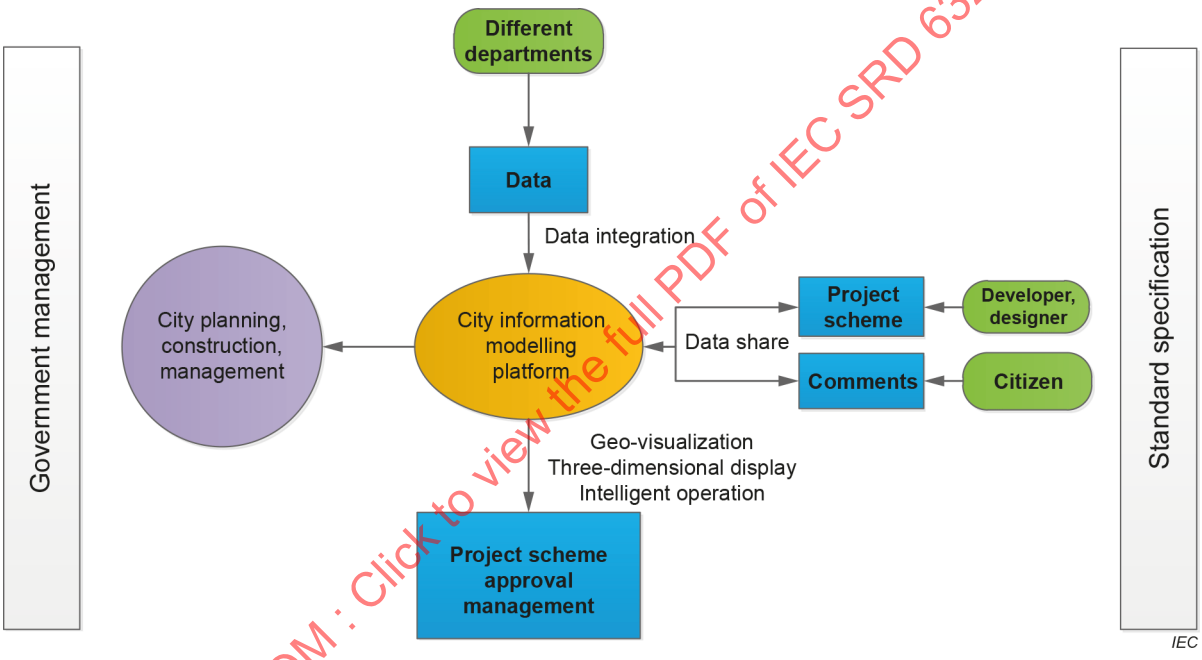


Figure 4 – Positioning city information modelling in construction project approval management

6.4.7 Scenarios

CIM provides a smart tool for effectively supporting construction approval management.

a) CIM gathers all kinds of data, such as existing data of social economy, urban planning and management, which are the basis of a construction approval.

b) CIM enhances the communication between designers and managers. Designers can intuitively and quickly display multiple sets of design schemes for comparison and selection. The CIM platform can assist managers in decision-making and form an optimal design scheme through multiple analyses, such as the three-dimensional analysis capabilities of skyline analysis, and landscape analysis.

c) CIM provides intelligent support for the approval and decision-making in the whole life cycle of constructions, including land use approval, scheme design, construction, completion acceptance. For land use approval, it provides a comparison of the site selection schemes through the three-dimensional display. For scheme design, it provides an automatic comparison of design scheme with more than 100 planning scenarios such as different traffic conditions and urban styles. For construction, it provides a correlation comparison of construction and designs. For completion and final acceptance, it provides automatic compliance verification when the project is completed. For the parts that have problems after automatic comparison and verification, it issues alarms for the approval personnel in an eye-catching and visual way to provide auxiliary support.

d) Through an intuitive interface, the CIM platform allows the citizens to have a better understanding of the planning scheme, and provides a convenient communication channel between managers and citizens. Therefore, the citizens can effectively express and smoothly convey their comments on the planning scheme.

6.4.8 General requirements

Standards should guide an in-depth integration of CIM and construction project approval management. Data standards are formulated for CIM data classification, grading, coding, storage, updating, sharing, and other aspects of construction approval management. Moreover, technical specifications for the construction of the CIM platform are proposed as well.

The CIM platform should integrate multiple types of spatiotemporal data (spatiotemporal data: data representing a set of direct positions in space and time) such as BIM and GIS, which build spatial data connections between 2D and 3D data. Several operations, including collection, integration and fusion of CIM data, are further conducted to support data analysis and application of intelligent approval of construction projects.

The CIM platform should build the review and approval rules for construction projects. The key requirements are index calculation, intelligent approval, etc., which can achieve an automatic reading and judgment and lay the foundation for intelligent approval of construction projects.

The CIM platform should consider the various needs of stakeholders to achieve multiple tasks, e.g. data management, query and display, auxiliary comparison and selection of plans, construction project review, and service management.

6.5 Project management during construction

6.5.1 Needs statement

Significant amount of data is being generated from construction projects. However, most data are never properly utilized. For different stakeholders, CIM presents the perfect opportunity to collect and store data from different sources in a centralized platform so that stakeholders can tap into the data pool and make better data-driven decisions.

The specific needs statements are as follows.

- Design and construction practitioner

  Design and construction practitioners need to ensure project data are created accurately and reflect the actual installation and analyse publicly available data on the platform which feeds back to the design and construction process (CIM-NS-PMC-01).

- Real estate developer

  Real estate developers need to upload data onto one centralized platform and ensure the project complies with authorities' requirements to manage risks (CIM-NS-PMC-02).

- Utility services provider

  Utility services providers need to review new development data and plan for existing services disruption and new services connection and update related data on the platform for future developments (CIM-NS-PMC-03).

- Construction regulator

  Construction regulators need to review the data from the project team for the purpose of enforcement and compliance checking (CIM-NS-PMC-04).

- Citizens

  Citizens need to visualize adjacent developments with the data on the platform and provide feedback (CIM-NS-PMC-05).

- Approval manager

  Approver manager needs to review the data from the project team during the development approval process (CIM-NS-PMC-06).

- Urban planner

  Urban planners need to access data on the platform and plan for urban development using the data (CIM-NS-PMC-07).

- Asset manager

  Asset managers need to use the data for digital twinning and update the data on the platform during the asset life cycle (CIM-NS-PMC-08).

6.5.2 Objectives

The application of CIM to project management during construction aims to:

a) support design and construction practitioners to build the virtual replica for projects of all types and sizes;

b) establish an information exchange protocol; and

c) assist stakeholders to reduce risk and deliver results for projects.

These are the benefits on the project level. In addition, the following objectives can be considered on the city level:

d) assist utility services providers and planners for the planning and approval of the development;

e) assist regulatory bodies to perform auditing and checking on the design and construction of the building including design variations and assumptions.

It is envisaged that d) and e) would improve the transparency, auditability, and accountability of practitioners' work during the life cycle of the asset. The last aim is to

f) make the model ready for digital twinning.

6.5.3 Current practices

Traditionally, projects were delivered in 2D drawing and specification packages. With the recent penetration of digital engineering (DE) and building information modelling (BIM), more and more projects have been delivered in complicated 3D digital format, which normally follows the BIM execution plan agreed with the client at the beginning of the projects. A BIM execution plan is defined as a "plan prepared by the suppliers to explain how the information modelling aspects of a project will be carried out" (PAS 1192-2:2013). During the construction stage, the design models can then be linked further with other dimensions such as time or budget and improved with greater modelling details of each element.

In short, it usually depends on the size of projects, requirements of the clients and technical capability of the delivery team to decide whether a project would be set up in 3D space and eventually built digitally first prior to the construction on site. When it comes to project management, BIM provides unprecedented visibility into a project, demonstrates the project's progress and highlights risks to all stakeholders, which all fall under the responsibility of project managers.

Today in many countries, project delivery with BIM is a standard practice, especially with major projects. However, the information modelled and data generated are normally shared/consumed only within the project team, and there remain values in the data to be unlocked on a city level.

6.5.4 Gaps in the application

To facilitate CIM process of construction projects, there are several gaps to be filled to facilitate city-wide data sharing.

a) Promote ubiquitous application of BIM technology in all markets, for projects of various size and across disciplines. However, the set-up and the promotion of best practice BIM models are not the focus of this document.

b) A city-level data-sharing framework is missing, which prevents data created during design and construction stages from being shared with stakeholders outside of the project team.

c) Realization of values of BIM data. At this stage, data created in BIM space is mainly used for purposes such as clash detection, progress checking and visualization of the project. Data should be better analysed and used to improve design and construction efficiency and accuracy.

d) Critical design inputs, assumptions, and variations during the design and construction stages should be submitted and made available for stakeholders such as regulators and utilities to verify and audit.

6.5.5 Stakeholders

Stakeholder 1: Construction practitioner and project scheme designer

The design and construction team, including but not limited to design practitioners and construction practitioners (including those who provide project management services), real estate developers, etc.

- Role: Owner and builder ecosystem.
- Responsibilities: Ensure the models are developed precisely and updated consistently to reflect changes and variations during the design and construction stages. Model and provide the information required by authorities and utilities. Submit models for audit and verification by regulatory bodies and utilities. Update the model with inspection outcomes and certificates. Upload the data onto a city-wide dashboard and platform.

Stakeholder 2: Utility services provider

- Role: Primary beneficiary and designer and user ecosystem.
- Responsibilities: Once models are received, review against relevant utility standards for compliance, check the impacts of new works on nearby existing services and plan for outages.

Stakeholder 3: Construction regulator

- Role: Primary beneficiary and designer and user ecosystem.
- Responsibilities: Once models are received, ensure compulsory information is correctly recorded within the models (e.g. design assumptions, critical variations such as fire safety design change) and use the models as the basis of site inspections and verification.

Stakeholder 4: Citizen

- Role: Secondary beneficiary and user ecosystem.
- Responsibilities: Be aware of nearby developments, understand their impact and provide inputs when required.

Stakeholder 5: Construction project approval manager

- Role: Secondary beneficiary and user ecosystem.
- Responsibilities: Use the submitted model to effectively engage the public during consultation process as well as coordinate logistics such as transportation of construction materials across concurrent projects in construction stages.

Stakeholder 6: Urban planner

- Role: Secondary beneficiary and user ecosystem.
- Responsibilities: Models created in this process can be used directly in a city-wide digital twin.

Stakeholder 7: Asset manager

- Role: User and maintainer ecosystem.
- Responsibilities: Update the models during asset life cycle and submit to relevant stakeholders where applicable.

6.5.6 Relationships between the stakeholders

Stakeholder 1 is classified as the development team and should submit the models to Stakeholders 2, 3, 5, 6 to seek approval during various stages of the project.

Stakeholders 2 to 7 are essential external stakeholders to the construction process.

Stakeholder 7 takes over the model from Stakeholder 1 and updates the model during asset life cycle. The need to share updates with Stakeholders 2 to 6 depends on the specific project.

6.5.7 Scenarios

BIM has widely been used to help project teams manage project progress and resolve issues during design and construction processes. However, when it comes to the city-level project management, the benefits are yet to be realized.

CIM should use the models created by the BIM process. Within the smart cities context, using CIM in project management and quality assurance falls under smart public services and governance category.

From BIM to CIM, the following objectives should be captured:

1) contribute to the planning and coordination of construction logistics with utilities, traffic control as well as other relevant city departments;
2) help construction regulators to verify and audit project data, such as design assumptions, allowance, and building performance; and
3) help citizens understand the full project development progress, project compliance history and impacts on the local neighbourhood.

The three objectives are envisaged to be delivered via CIM process not with BIM directly. An example is, for objective 3, the project team uploads their BIM models to the CIM platform at different project gateways, and local residents can then view the model and understand the project progress.

Beyond the three main objectives, project data gathered through CIM process can prove to be invaluable during an emergency, for example, major structural or fire incidents. When such incidents occur, relevant stakeholders can investigate all the records of the building and cross-check critical variations since the inception of the building work.

6.5.8 General requirements

The following supporting documents should plan and implement the scenario:

- standards on the city-level data-sharing framework;
- guidelines to introduce a best-practice case study;
- surveys to listed stakeholder groups to gauge interest;
- pilot projects to verify the concept and demonstrate its value.

6.6 Real estate registration management

6.6.1 Needs statement

a) It has the ability to manage real estate registration data, such as application requirements, apply documents, basic documents, graphics, texts, and can categorize them into open data, shared data, and closed data (CIM-NS-RER-01).

b) The platform has the ability to review, approve and evaluate real estate registration cases (CIM-NS-RER-02).

c) The platform can effectively transmit and communicate the requirements, issue application results, and provide users with real-time access to approval results (CIM-NS-RER-03).

d) The platform can carry out different intelligent operations, including uploading, downloading, editing, and browsing data on the platform, 2D and 3D real estate display, electronic license, etc. (CIM-NS- RER-04).

6.6.2 Objectives

The application of CIM to real estate registration management aims to:

a) integrate the real estate, its three-dimensional model data, ownership confirmation and registration in one platform;

b) improve the registration and management of mixed-use real estate, which can include residential or commercial real estate above the ground, underground garages and underground shopping malls;

c) conduct spatial analysis, and generate thematic maps of real estate information;

d) realize multi-dimensional visualization, and improve the public's understanding of the real estate from a multi-dimensional perspective;

e) advance the data exchange and connection among the real estate management authorities, financial institutions, court, civil affairs and other relevant departments to increase the efficiency of registration management;

f) promote the connection among all the departments involved in real estate registration, and realize the effective connection among real estate registration and land use approval, scheme design, construction, completion and final acceptance.

6.6.3 Current practices

Real estate is defined as the property, buildings and air rights above the land, and underground rights below the land. Real estate registration management provides a strong guarantee for legal property rights of citizens and enterprises and secures transactions of real estate, which enables the management of urban land and housing in a better order, promotes a sustainable use of the urban land and space.

At present, the form and spatial distribution of real estate are diversified. Traditional real estate registration management mostly adopts a 2D management model and lacks 3D expression of real estate, which neither provides an intuitive understanding of real estate for the public, nor enables an effective linkage between the approval department and the related business departments. Therefore, it is difficult to meet the demands of real estate registration management in a complex space.

6.6.4 Gaps in the application

a) 2D data cannot display real estate information in multiple views and dimensions, lacking effective 3D communication and interaction for the public. They cannot meet the needs of the approval department for the real estate display and application analysis.

b) The information capacity of 2D data is not enough, which cannot accurately reflect the real estate distribution in 3D space. 2D data cannot accurately express the situation where the right boundaries of above-ground real estate and the underground real estate can overlap.

c) Real estate registration management lacks departmental linkage with approval department of land use approval, scheme design, construction, completion and final acceptance. Moreover, real estate indicators and other information cannot be effectively confirmed in the real estate registration management process.

d) In the process of real estate information sharing and exchange with related business departments – which includes but is not limited to taxation, public security, civil affairs, justice department, banking and finance departments – the depth and breadth of departmental collaborative services are insufficient. It is urged to strengthen data exchange and sharing between different departments.

e) Real estate in the physical world lacks 3D expression, and the association and integration of real estate attributes in the virtual world are deficient.

f) There is a gap between the traditional indigenous land right and sacred place information, which can trigger native title act consultation prior to development.

g) There is also a gap between the inter-departmental land use and existing on the-ground infrastructure to deliver utilities to avoid cutting services.

6.6.5 Stakeholders

Stakeholder 1: Real estate registration authority

a) Real estate registration requirement specifier: The person who formulates regulations of real estate registration.

b) Real estate registration approval officer: The person who checks the registration information and documents submitted by the real estate owner, and decides to approve or reject the registration.

- Role: Primary beneficiary, the application of CIM to real estate registration management can improve the efficiency of administration services. Owner and builder have the right to make decisions on the real estate registration management.
- Responsibilities: According to the regulations and standards, accept the real estate registration items applied by the real estate owner. Manage real estate data information, exchange and share real estate information with the related business authority. Responsible for making policies and regulations.

Stakeholder 2: Real estate owner

- Role: Real estate owners can include the public, organizations, and institutions, who are the primary beneficiary. The CIM platform can provide better service for the real estate owner's application submission. Primary beneficiary and user, the real estate owner apply CIM for their real estate registration application according to the requirements.
- Responsibilities: Submit an application for real estate registration to the real estate registration authority in accordance with the regulations and standards. Submit corresponding application materials under the authority's requirements.

Stakeholder 3: Real estate registration relevant business authority

a) Bank staff relevant to real estate registration: A person who provides and acquires loan information of the real estate.

b) Tax staff relevant to real estate registration: A person who provides and acquires tax information of the real estate.

c) Court staff relevant to real estate registration: A person who provides and acquires legal information of the real estate.

- Role: The real estate related business authority includes but is not limited to taxation, public security, civil affairs, justice, banking and other departments. Secondary beneficiary, CIM can connect them with the real estate registration authority and enable them to acquire the required information and data.
- Responsibilities: Co-construction and sharing of information with the real estate registration authority.

Stakeholder 4: CIM platform and software developer

a) Needs analyst for CIM platform and software: A person who collects the needs of data, function, interface and operation from different users.

b) CIM platform development engineer: A person who is responsible for software design and platform development.

c) CIM platform operator and maintainer: A person who is responsible for the daily operation, maintenance and management of the platform and software.

- Role: Second beneficiary, through participating in the development of the CIM platform and software, the company's product quality and service capabilities can be improved. Maintainer of CIM platform, they guarantee the normal operation and maintenance of the software.
- Responsibilities: According to the needs of real estate registration authority, develop the CIM platform and software to provide technical support and operation and maintenance for real estate registration management.

Stakeholder 5: Academic researcher

- Role: Academic researchers are the professionals who do theoretical innovation and consult on city real estate registration. Second beneficiary. Through participating in the real estate data mining and analysis, the academic researchers can improve their research outputs.
- Responsibilities: Providing consultancy, data analysis and application ideas on city construction project management.

6.6.6 Relationships between the stakeholders

In the application scenario of real estate registration management, the CIM platform acts as a huge centre for data processing, intelligent operation, communication and management (Figure 5). The real estate registration authority and related business departments integrate many different types of data into the CIM platform, such as application requirements, documents, registration basis and other documents. The CIM platform can provide intelligent assistance for data sharing and information exchange among the authority, real estate owners, CIM platform developers and academic researchers. The CIM platform builds a bridge for efficient and effective communication among different stakeholders.

The relationships between the stakeholders include the following.

- Real estate registration authority is the executor of real estate registration management and makes the final decisions.
- Real estate owners are the object of real estate registration service. They submit the real estate registration application to the authority according to regulations.
- Real estate related business authorities and the real estate registration authority exchange and share real estate information and data.
- The CIM platform and software developer is responsible for the development, operation and maintenance of the platform and software, and for providing technical support for real estate registration management.
- The academic researcher provides professional data analysis and service for the real estate registration authority and other companies.

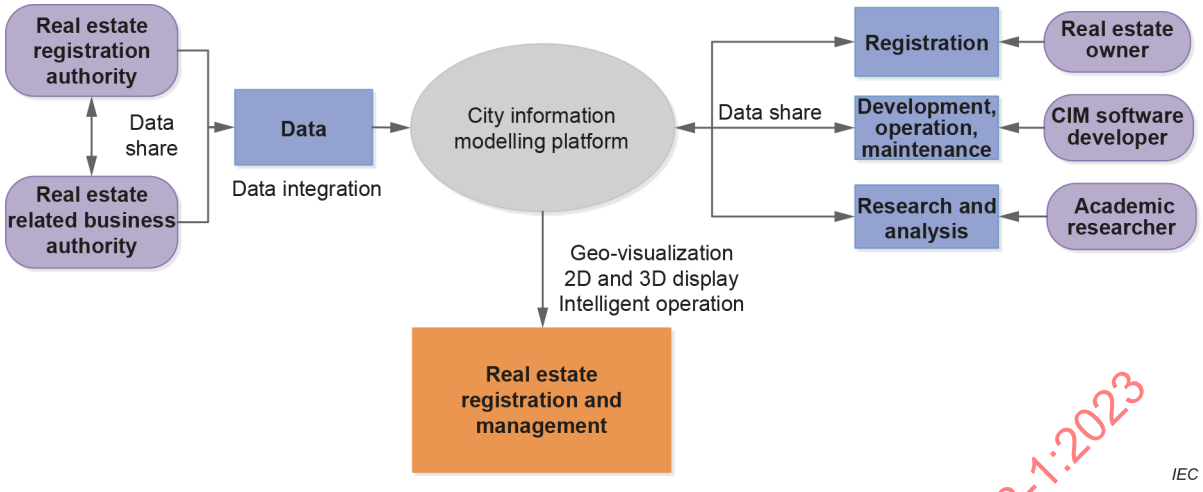


Figure 5 – Positioning city information modelling in real estate registration management

6.6.7 Scenarios

CIM ensures the effective operation, reliable transaction, and owners' rights and interests during the real estate registration process.

Firstly, CIM contains various kinds of data, such as BIM, remote sensing images, DEM (digital elevation model) and real estate ownership data, provides service for data integrity and authenticity in the process of real estate registration approval. Meanwhile, CIM realizes a logical association of spatial information and attribute data on, above and below the land surface, especially having giant advantage of browsing, query, analysis, and management of the underground space. It strengthens legitimate ownership rights and improves the registration process.

Secondly, CIM facilitates effective communication among city administrators, citizens, and other stakeholders. The real estate registration authority uses CIM to associate ownership data with land information and spatialize massive ownership data accurately. It improves registration service efficiency in high quality. Citizens use 2D and 3D integrated digital certificates to quickly browse and query real estate registration information, which enable the process of real estate registration to be more engaged.

Thirdly, CIM is an important tool to realize 2D and 3D ownership data management, analysis and mining, which provides a high-quality data source for city operation and management. It assists urban planning (including but not limited to urban layout analysis, urban structure and size prediction), administration investment and decision-making, and supports urban smart applications (e.g. smart buildings, smart communities).

Fourthly, CIM promotes data sharing and exchange and extends service range among different sectors, such as property, construction, public security, and finance. It creates coordinated management and efficient service across different regions, systems, departments, industries.

Finally, CIM acts as a carrier, extending the life cycle of construction projects. It realizes data and technology integration between real estate registration and the entire construction project approval process. Besides, CIM can use the real estate registration data to verify the completion and value of the construction project. It simplifies the approval process of land and real estate transactions, provides professional services for their market, and boosts the efficiency of administration services.

6.6.8 General requirements

Standards should guide the in-depth integration of CIM and real estate registration management. A series of technical specifications were developed, such as 3D real estate model data modelling standards, data expression standards, data integration guidelines, and sharing and exchange standards.

The CIM platform should integrate multiple spatiotemporal data such as BIM, CAD, historical data, data for multiple time periods and GIS based on underground and above-ground buildings. Spatial data connections were established between 2D and 3D data to realize mixed-use 3D real estate model construction.

The CIM platform should build a real estate registration management system that has the capability of showing the property in 3D for various stakeholders. The CIM platform is needed to provide multi-dimensional data display, spatial analysis, and thematic map output, which can promote the linkage among real estate departments and realize the effective connection with the entire construction project approval process.

The CIM platform should establish a linkage mechanism for exchange and sharing between the real estate registration author and management department, financial institutions, courts, civil affairs and other relevant departments. The CIM platform can improve the efficiency of registration management and serve as a carrier for managing property and energy consumption.

6.7 City management using city brain

6.7.1 Needs statement

a) The urban space needs to be displayed in three-dimensional format (CIM-NS-CBR-01).

b) Different types of urban information need to be stored and accessed in one platform (CIM-NS-CBR-02).

c) City operation needs to be monitored in real time (CIM-NS-CBR-03).

d) City operation needs to be simulated and analysed in real time to issue risk warnings effectively (CIM-NS-CBR-04).

6.7.2 Objectives

The application of CIM to city brain aims to:

a) establish three-dimensional urban space model;

b) integrate different types of urban information;

c) monitor, simulate and display city operation in real time, visually and intuitively.

6.7.3 Current practices

With the development of urbanization, the "urban diseases" such as traffic congestion, parking chaos, imbalance of educational and medical resources, environmental pollution and urban insecurity are increasingly prominent. Risk events, such as earthquake, flood, typhoon, terrorist attack, have not been prevented and controlled actively and accurately. Coordination and dispatching are not timely in emergencies. The transaction processing of local governments for the enterprise and the public is complicated and the processing efficiency is poor. Smart city has become an important part of digital strategy all over the world to solve the above problems. Many countries are developing smart cities, such as United States of America.

6.7.4 Gaps in the application

There are still gaps in smart city construction. The lack of systematic and top design and unified "data baseplate" cause repeated investment and also information barriers of cross-departments, cross-levels, cross-systems, cross-industries, and cross-regions. The efficient collaborative and meticulous urban operation management system driven by data has not yet been realized.

There is also one gap about the big data storage. In the new era of digital economy, urban governance data are growing exponentially. The traditional method of data storage by disc or tape has problems such as high energy consumption, high cost and high risk. The existing data storage scale is small. The data assets are lost rapidly, and the video value is not mined. How to store massive multi-source data has become one of the challenges in smart city construction.

6.7.5 Stakeholders

Stakeholder 1: Local government and administrations

a) Economy manager: a person who is responsible for taking measures for economic development by analysing economic operation state and the influence factors.

b) Market manager: a person who is responsible for market supervision and maintaining good market order, fair market competition.

c) Population manager: a person who is responsible for making statistics of resident population and the floating population and making policies for population development.

d) City safety manager: a person who is responsible for monitoring the sources of urban security risks and finding out the hidden danger to reduce the incidence and harm of safety accidents.

e) Emergency manager: a person who is responsible for dealing with emergency events, such as fire, earthquake and Corona Virus Disease 2019 (COVID-19) to minimize the damage and loss.

f) Public resource manager: a person who is responsible for making plans for public resource construction and providing public service to balance development of public resources.

g) Environment manager: a person who is responsible for monitoring, forecasting and governing environmental pollution.

h) Public appeal manager: a person who is responsible for collecting and solving the issues of concern to the public.

- Role: Primary beneficiary of applying CIM in city brain as they can improve the management efficiency and provide better living and working environment for the citizens based on the city brain. Designer, owner and maintainer of the city brain, as government has the final decision on the top-level design and functions of the city brain. User of the city brain, as government carries out city management based on city brain.
- Responsibilities: Local government should make and release policies on city management (including but not limited to economy, environment, public resources, market, public facilities), invest in the construction of smart city, allow for data acquisition and storage in a data lake, have the final decision on the top-level design, specific architecture and functions of the city brain.

Stakeholder 2: Financial and investment institution

a) Financial supplier and investor: person who invests in one certain industry to get profit.

- Role: Secondary beneficiary as it will help financial and investment institutions to understand industry status and identify the business opportunities. User, as they will use city brain as a fundamental tool in their investment on city industry.
- Responsibilities: They evaluate the potential development and invest in the characteristic industry to get return from their investment.

Stakeholder 3: Academia and research institution

a) Academic researchers: persons who do theoretical innovation, provide consultancy and cultivate talents on city management.

- Role: Secondary beneficiary, as it will help academia and research institutions to understand city operation state and find the existing problems of city management.

- Responsibilities: Academia and research institutions, who can be universities, colleges, research institutes and other institutes, should do theoretical innovation, provide consultancy and cultivate talents on city management.

Stakeholder 4: Citizen

- Role: Tertiary beneficiary, as it will help general public to understand city operation state, enjoy more comfortable living conditions and gain a sense of happiness and security.
- Responsibilities: Citizens are encouraged to participate in the city management by attending the surveys, public forums, and official website to present their comments on the local government's ability with respect to social governance and public service and to let their local government know of any concerns and appeals.

Stakeholder 5: Enterprise

a) CEO: a person who is responsible for the operation, management and making decisions for a company.

- Role: Tertiary beneficiary, as it will help enterprises to understand the current situation of industrial and economic development, enjoy more innovative and dynamic industrial environment and extend profit.
- Responsibilities: Enterprises are encouraged to participate in the city management via attending the surveys, public forums, official website to present their comments on the local government's ability to develop local economy and industry.

6.7.6 Relationships between the stakeholders

The local government and administrations are the leaders of city management. CIM makes the real-time city operation and the future development situation visible and intuitive, and helps the government to accurately and in a timely manner warn of urban problems and quickly make global optimization governance decisions (Figure 6). Through city management, digital economy development, more comfortable and safe living conditions, more innovative and dynamic industrial environment, a fair competitive market environment can be achieved. CIM helps academic researchers in the research relevant to simulations and data analysis for city management. Academic researchers can provide consultancy for local government and administrations when making decisions on policy. CIM also helps financial and investment institutions evaluate the investment. The citizens and enterprises evaluate the service ability of the local government and give feedback on the effect of the city management.

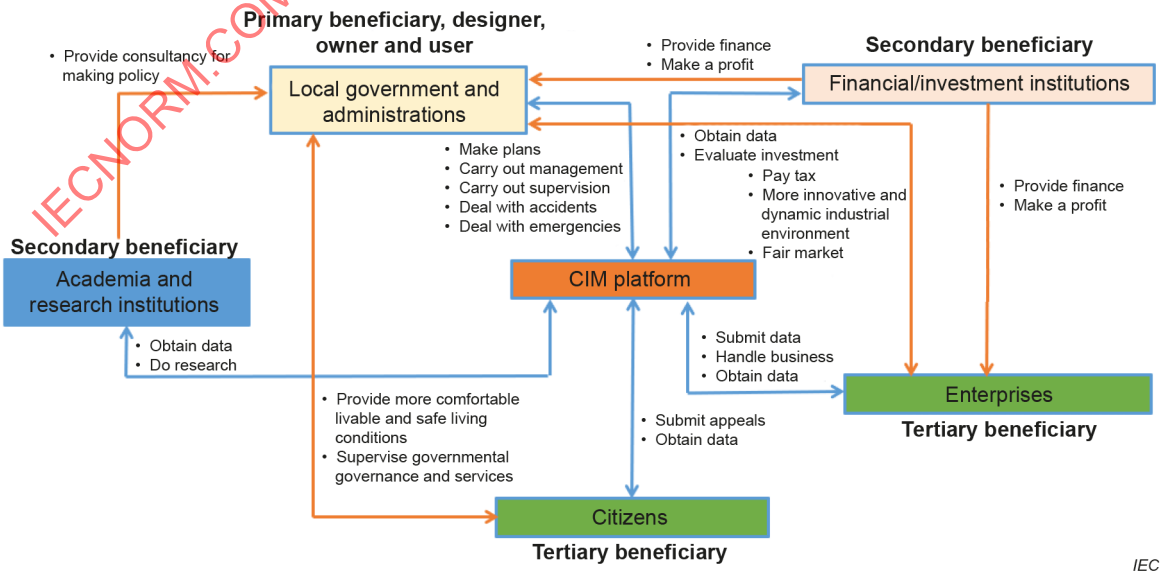


Figure 6 – Positioning city information modelling in the city management via city brain

6.7.7 Scenarios

City brain is a powerful tool to assist the local government to achieve city management. Like the human brain, city brain is one intelligent nerve centre for various systems of the city, which connects the data resources scattered in various departments of the city and gets through the urban neural network, as shown in Figure 7. It makes accurate analysis and scientific decisions on the city operation based on data, AI algorithms and models.

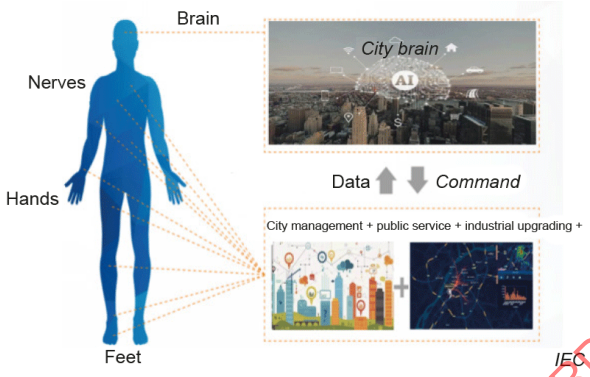


Figure 7 – City brain for the city management

Data lake realizes the acquisition, storage, aggregation, processing and analysis of data from different systems, which is composed of IoT, cloud computing, Blu-ray™ [1], hard disc drive (HDD) and solid state disc (SSD) integration storage, AI and the CIM platform. The architecture of city brain based on data lake is shown in Figure 8.

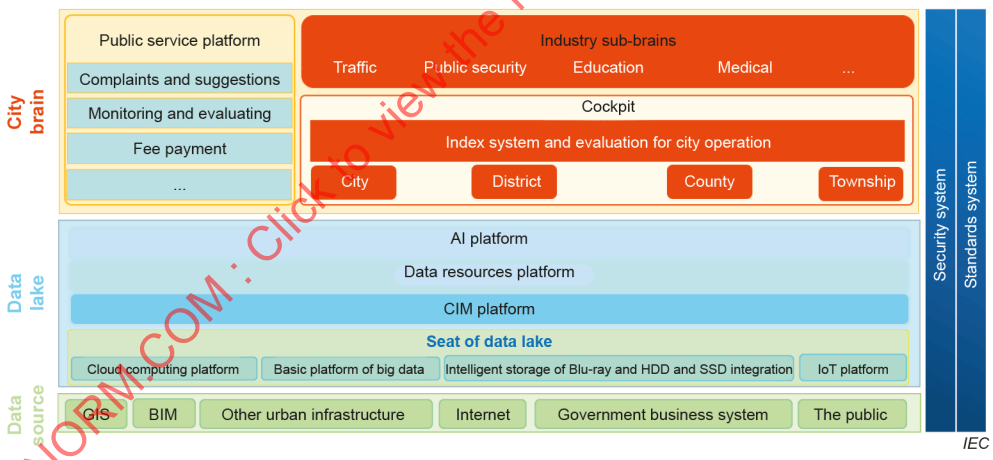


Figure 8 – The architecture of city brain based on data lake

The architecture of city brain based on data lake: Firstly, the CIM can assist in creating three-dimensional city model based on modern surveying and mapping, GIS, BIM, 3D modelling and other technologies. The Internet connects all and enables access via an enterprise network or cloud platform to the data lake. Secondly, CIM integrates dynamic spatiotemporal data and builds a dynamic digital city. Thirdly, CIM displays the real-time city operation state of the whole city or a certain field analysed by the city brain visually and intuitively. Positioning CIM in the city management via city brain is shown in Figure 9.

[1] Blu-ray™ is the trademark of a product supplied by Blu-ray Disc Association. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

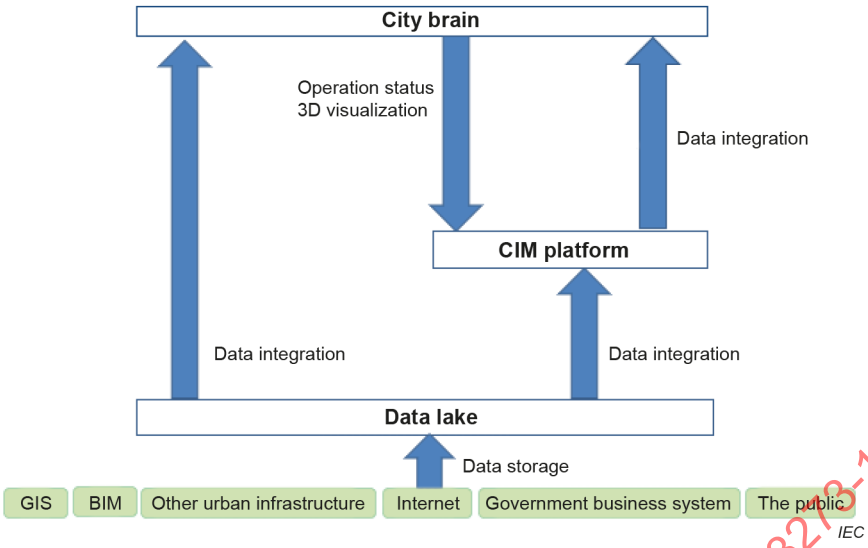


Figure 9 – Positioning city information modelling in the city management via city brain

6.7.8 General requirements

- Standards should specify what kinds of data should be acquired, to integrate different types of data and to evaluate city operation state.
- Data lake should be built for storing, processing and analysing data.
- Mechanism for data supervision and security operation should be established.

6.8 Heritage preservation and revitalization

6.8.1 Needs statement

a) A platform is needed to support data collection, data management and data storage (CIM-NS- HPR-01).

b) Different types of heritage data and information need to be integrated, analysed with high precision and simulated for different themes of revitalization projects (CIM-NS-HPR-02).

c) The revitalization planning needs to be exhibited in an intelligible way, such as 3D modelling (CIM-NS-HPR-03).

d) Heritage operation needs to be displayed in 3D format and be monitored in real time (CIM-NS-HPR-04).

e) Different stakeholders can effectively communicate with each other and comment on the heritage revitalization planning in a user-friendly platform (CIM-NS-HPR-05).

f) Users with authorization can carry out different operations for their requirements without high-level skills, which include uploading, downloading and editing data (CIM-NS- HPR-06).

6.8.2 Objectives

The application of CIM to heritage preservation and revitalization aims to:

a) build heritage building information modelling;

b) strengthen the link between the digital model and the physical realm of heritage assets;

c) provide more effective learning and communication tool for the general public to increase their awareness of heritage preservation;

d) support the preventive conservation and revitalization of heritage places.

6.8.3 Current practices

Heritage preservation and revitalization aim to restore the historical buildings with high heritage value and enforce systematic management of these buildings and communities for a sustainable development.

The main projects are surveying, collecting data, analysing data and making a strategy for protection. Generally, specialists use traditional measurement equipment in the fieldwork, which is manual and time-consuming.

Because of the complexity of historical buildings preservation and pressure of urbanization, digital technology should be used to replace traditional approaches. The applications of digital technology are not only for data storage, but also for the whole life cycle of heritage preservation and revitalization.

With the development of the technology, a number of digital heritage preservation projects have been conducted, such as using 3D modelling technology to build an ancient city model in order to aid the renovation of it.

6.8.4 Gaps in the application

Traditionally, heritage preservation and revitalization meet a large number of challenges.

First, the heritage preservation requires a large workload and many professionals. It involves many problems that include ruined buildings, high density and illegal construction.

Second, the government may lack a clear guide for the specific department which manages the heritage. Some work relevant to heritage preservation is repeated by several different departments and it causes unnecessary cost.

Third, it is difficult to connect the heritage with existing urban database. There is a database of historical buildings, but the accuracy is usually low. More importantly, there is no standard for data format.

Fourth, the application of digital historical buildings protection platform and 3D visualization management is still being developed. Applying 3D and digital technology in heritage preservation is becoming a hot research area, and there is still a lot of space for improvement.

Last but not least, there is a gap between the storage and computing limits to hold historical data, especially as it is processed and analysed to create new insights such as the building materials and their longevity, efficiency or impact on human health, and others.

6.8.5 Stakeholders

Stakeholder 1: Urban planner

- Role: Primary beneficiary as CIM helps their planning and coordination work to be more balanced. Designer ecosystem, as they will help to scope out the requirements of historical building protection. User, they use CIM as a fundamental tool to plan and monitor the management of the historical buildings and their communities.
- Responsibilities: First, urban planners should integrate urban development and historical building preservation in their planning. They are devoted to coordinating a historical building with its surroundings. Second, they should improve the heritage revitalization. They should pay attention to infrastructure of historical districts and make a development plan. Third, they should develop and maintain a digital urban plan information system to make sure public receive the information clearly and in a timely manner.

Stakeholder 2: Real estate developer

- Role: Secondary beneficiary of CIM as it will help them understand the current state of historical districts, identify the development potential and opportunities and design a better project scheme. User ecosystem, as they will use CIM as a fundamental tool in their investment in revitalization projects. Builder ecosystem, they are also involved in the revitalization scheme project.
- Responsibilities: They are responsible for the overall construction of the project and submit the project scheme to the government departments for review and approval. Investing in the project is also a significant part of their responsibilities.

Stakeholder 3: Project scheme designer

- Role: Secondary beneficiary of CIM as it will help them understand the current state of historical districts, identify the development potential and opportunities and design a better project scheme. User ecosystem, as they will use CIM as a fundamental tool in their investment in revitalization project. Builder ecosystem, they are also involved in the revitalization scheme project.
- Responsibilities: They are responsible for the overall construction of the project and submit the project scheme to the government departments for review and approval. Investing in the project is also a significant part of their responsibilities.

Stakeholder 4: Academic researcher

- Role: Secondary beneficiary of CIM as it will help them understand heritage project state, gain a large amount of data on what they want to research and find the existing problems of heritage preservation and revitalization. Designer ecosystem, they are involved in the design and modification of the scheme.
- Responsibilities: Academia and research institutions, who can be universities, colleges, research institutes and other institutes, should do theoretical innovation, provide technical service and cultivate talents on heritage preservation and revitalization.

Stakeholder 5: Construction practitioner

- Role: Secondary beneficiary of CIM as it will help them understand the heritage project state and planning. Maintainer ecosystem, they guarantee the normal operation and maintenance of the CIM platform and heritage district. Operation team includes heritage conservation association, museum, etc.
- Responsibilities: According to relevant policies and heritage revitalization planning, operation team is responsible for guaranteeing the normal operation and maintenance of heritages or historical districts, which includes regular inspection, facilities management, etc.

Stakeholder 6: Business owner

a) Local business owner: business owners who have their store in the historical districts.

b) Nonlocal business owner: Investors who are going to conduct business activities in the historical districts.

- Role: Tertiary beneficiary of CIM as it will help them understand relevant plan and project plan through approval, evaluate the project plan and make the investment decisions; enhance the business foundation surroundings and attract more consumers. They include local business owners and the business CEOs who are making the decision of moving into the historical districts.
- Responsibilities: First, it is an important part of historical districts for local residents, because surrounding shops can satisfy the requirement of the daily life of residents. Second, they motivate the development of historical districts. Visitors can understand the culture of heritage through talking with local businessmen or through local specialities. On the one hand, business activities promote economic development; on the other hand, it plays a propaganda role of heritage.

Stakeholder 7: The public

a) Local community member: Residents who live or work in the local communities or historical districts (e.g. the owner of local construction or houses).

b) Nonlocal community member: Citizens who live or work near the area of historical districts.

- Role: Fourth beneficiary of CIM as it will help the general public understand heritage and improve their awareness of preservation. They include local owners, the citizen who lives near the heritage and tourists.
- Responsibilities: They are encouraged to participate in projects on heritage via presenting comments. They can obtain the cultural background of heritage and the importance of preservation via the CIM platform. Their awareness of heritage preservation can be improved during the course. At the same time, tourists' visiting routes can be collected by navigation applications, which is helpful and useful for administration and management improvement.

Stakeholder 8: Government

a) Construction project approval manager: According to different criteria, decide whether the preservation and revitalization project of historical districts should go ahead or not.

- Role: owner, maintainer and policy maker, because the government has the final decision on heritage preservation and revitalization policies; Designer ecosystem, as they use CIM as a fundamental tool to build a digital historical building protection platform.
- Responsibilities: First, the government should examine and clarify all historical buildings in their region. Furthermore, they should underline the key point of protection. This project should invite experts and urban planners. Second, the government should have the final decision of heritage preservation and revitalization planning and offer solutions to overcome the challenges to achieve the needs of different stakeholders. Third, the government should use CIM to build a digital historical building protection platform. The main content includes data collection, data processing, database integration, 3D modelling and management. They should organize several departments to enforce this work.

6.8.6 Relationships between the stakeholders

CIM serves as a giant data hub, central processing unit and communication platform in heritage preservation and revitalization (Figure 10). It is a massive data processing centre, visual analysis integrator, intelligent operation and maintenance centre, communication platform. First of all, the CIM platform can store and manage different types of data from multiple departments and has huge capacity. Second, CIM integrates modern surveying and mapping, BIM, IoT, digital city and other technologies, and carries out a variety of data analysis in the form of three-dimensional model, which is beneficial for the government to make decisions, and for planners and designers to make more scientific and effective analysis. Third, the combination of CIM platform and IoT is helpful for the real-time monitoring of the overall period of heritage preservation and revitalization project, such as surveying and mapping and environment monitoring. Finally, the CIM platform allows more stakeholders to participate in the heritage revitalization for information flow.

Government is the vital part which has several works: examine the restoration projects, make strategy and policy, enforce the detail protection and building digital platform to manage.

The first two missions are enforced with urban planners, but government has the final decision on heritage protection. Urban planners collect the needs of different stakeholders and make a plan to coordinate urban development with heritage protection.

Real estate developer is participating in the detail protection, including providing funding for the scheme and technology. Academia and research institutions play the role through providing technical support for the team of designers from real estate developer. After construction of project, operation team is responsible for the regular operation and management.

Other stakeholders are encouraged to participate in data collection and reflect on their comments.

It is very important that different stakeholders can communicate on the CIM platform.

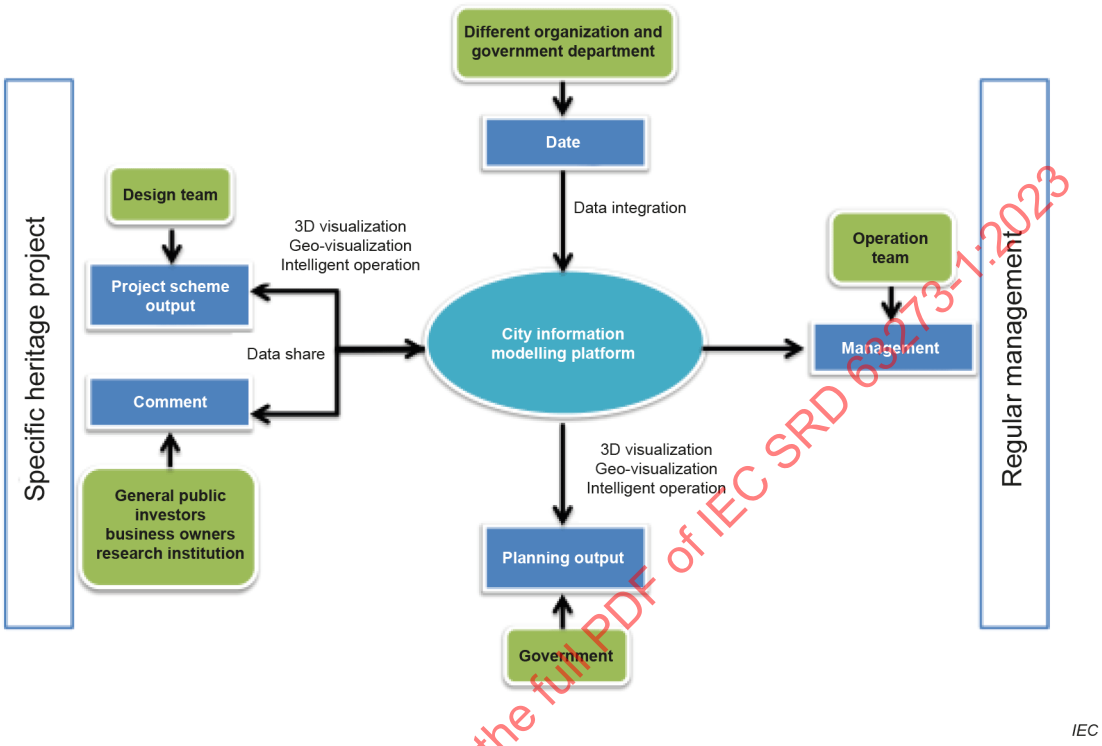


Figure 10 – Positioning city information modelling in heritage preservation and revitalization

6.8.7 Scenarios

First, CIM provides a hub to collect, store and analyse different types of data. The data include the secondhand data of census, traffic and others, and firsthand data collected from the other stakeholders. For example, data collection can use IoT. Initial data collection and cleaning are good practices to confirm the format and accuracy of the data to be compliant prior to data lake ingestion.

Second, CIM creates a communication platform for different stakeholders. It makes different stakeholders become equal partners, not merely independent parts. Preservation department can receive the advice from residents and the public to renew the heritage. Heritage competent department clearly knows what public really require and where shortcoming should be enhanced.

Third, CIM supports heritage simulation in technology. For example, using CIM to simulate the building medium to rebuild a 3D model, and simulate the heritage in the various environments to know what the results will be. Using CIM to simulate the renewal programme so that experts know what the effect is and where the plan should improve. CIM also can be used to simulate the movement of tourists and the impact caused by them.

Lastly, CIM can help the general public to improve public awareness of preservation and revitalization through communicating with different departments and providing the history of heritage.

6.8.8 General requirements

- In the data aspect, when building the specific platform to apply CIM in heritage preservation and revitalization, two important items should be considered. One is the standard of different types of data with different formats. The other one is accessibility. It is easy for different stakeholders to join in communication and discussion by using an open-access platform.
- In the planning stage, experts should consider the repairing materials, environment, preservation method, etc. Because of different environments and conditions, it can lead to inefficient protection. For example, a few ancient buildings have an old structure which is not suitable for modern renovation. If we only repair them in the original way, this can cause problems for residents.
- In management, comprehensive and real-time 3D model monitoring is required. One of the features of an ancient building project is a great range. 3D models can help managers grasp the whole situation more efficiently. And real-time monitoring can help staff address special situations, which can connect with IoT.

6.9 Transportation infrastructure planning

6.9.1 Needs statement

a) Policymakers and modellers need to deliver a plan for transitioning transport infrastructure modelling to a net-zero footing (CIM-NS-TIP-01).

b) Both public and private sector clients need to understand the availability of data, tools and the advancements happening in the industry (CIM-NS-TIP-02).

c) New mobility types, from the small-scales of ridesharing, bike-sharing, and shared scooters to autonomous vehicles and intra-urban electric vertical take-off and landing (eVTOL) vehicles, are planned to enter the mobility market in the next decade. There is a need to accommodate the new travelling possibilities within a set of rules and standards (CIM-NS-TIP-03).

6.9.2 Objectives

The application of CIM to transport infrastructure planning aims to:

a) determine the required capacities and conditions that new infrastructure should satisfy;

b) assess the economic, environmental, and social impacts of the initiatives;

c) allow communities to proactively plan, predict and prepare for developmental impacts;

d) develop optimal scenarios for both the present and future;

e) achieve the larger institutional goals of net-zero and sustainable resource usage;

f) improve the way data and inputs are utilized and how the overall process functions to keep pace with technological growth.

6.9.3 Current practices

A transport model aims to underpin better and more reliable decisions on infrastructure and city services through scientific means of measuring the demand and supply.

Travel demand models constitute an important component of the transport planning and policy-making process. They are regularly used by metropolitan, regional and national planning organizations.

Conventional travel forecasting models date back to the late 1960s and are characterized by static, aggregate, and deterministic supply and demand modules and relationships. The four-step model is the standard, and most simplified, version of a travel forecasting model with the steps of trip generation, trip distribution, mode choice, and route choice (or trip assignment) which provide the mechanism to determine equilibrium flows in a particular network.

Over time, there have been modelling advancements from static to dynamic, from aggregate to disaggregate, to agent-based instead of a part of a more generalized population. There are certain grounds to be standardized going forward.

6.9.4 Gaps in the application

Transportation modelling has become more complex as it has shifted from the traditional four-step model. It is still used in new development traffic impact studies, activity-based models, and most recently, agent-based models like those of multi-agent transport simulation (MATSim).

There tends to be a gap between design occurring, tool utilization, and actual implementation of new technologies and big data effectively into these proven modelling and simulation platforms.

It is also a struggle in practice to make use of modelled outcomes due to the inherently problematized context as a series of what-if and what-about questions that end up challenging the base data and its implicit assumptions.

Issue is also related to how development traffic analyses are completed, and how the models are generated. The models utilized for analysing the impact of new developments on the transportation network are microscopic, analytical, static, aggregate, deterministic, and node-based in form.

On the demand side, there is limited adjustment from the standardized trip generation materials, which are based on a few studies completed decades ago. These materials are rarely questioned and do not give any focus to the user and demographic types or the impact of the existing network and travel patterns.

Net-zero intervention in infrastructure modelling provides a good opportunity for dialogue for fundamental basis for infrastructure justification. The social cost of carbon (SCC) has been called "the most important number you've never heard of" because it underpins climate regulations in countries including the USA and Canada. It is one way to put a price on CO_2 emissions. The UK adopted the use of the shadow price of carbon (SPC) as the basis for incorporating carbon emissions in cost-benefit analysis and impact assessments. However, it takes more account of uncertainty, and is based on a stabilization trajectory. We need a standard on which we can agree and on which to base the calculation when making the modelling.

There is a gap between the intelligent transport system (ITS) professional who is monitoring the traffic condition and mitigating based on current happening and traffic prediction. In contrast, transport modelling is dealing with tactical planning because of the developments. Both would need standards to join together. This is crucial for better socio-economic and environmental perspectives.

6.9.5 Stakeholders

Stakeholder 1: Official of transport infrastructure planning

- Role: Primary beneficiary and owner of CIM, as the infrastructure owner. And maintainer of its own infrastructure.
- Responsibilities: Governments are constantly looking for ways to develop their road networks and other transport links to meet their economic, political, and social needs. In some jurisdictions this will mean building brand-new roads, in others it will mean focusing on refurbishing, widening, and extending existing roads. It also should tackle climate change while balancing trade-offs.

Stakeholder 2: Private infrastructure developer – road and rail companies, etc.

- Role: Secondary beneficiary, builder or maintainer who can also be responsible for the management of roads, and public transportation, etc. New roads are expensive, and governments are often unable or unwilling to commit fiscal spending to roads. This is an area where project financing and public–private partnership projects are becoming more and more common.
- Responsibilities: Provision and management of services, infrastructure construction for improving citizen experience.

Stakeholder 3: Official of environmental authorities

- Role: Secondary beneficiary and designer and user of CIM, as the environmental monitor. And evaluator of its own net-zero or climate change agenda.
- Responsibilities: Officials of environmental authorities are responsible for reducing emissions, building the capability and capacity required to inform decision-making, and maintaining public consent with meeting net-zero goals.

Stakeholder 4: Utility services provider

- Role: Secondary beneficiary and designer and user of CIM. It will help to provide basic necessities to citizens, such as water, electricity, waste management, etc.
- Responsibilities: Utilities in charge of providing sufficient capacities in their obligation for basic necessities as a result of town and city modelling.

Stakeholder 5: Real estate developer

- Role: Primary and secondary beneficiary, builder and user ecosystem of CIM, as it will provide houses and generate necessary related services.
- Responsibilities: Consciously abide by housing laws and regulations; Carry out orderly and legal housing financing activities; Cooperate with authority on the meeting and re-using of housing allocation and modification of supply of different types of housing units, etc.

Stakeholder 6: Citizen

- Role: Tertiary beneficiary and user of CIM, as it will help citizens to understand infrastructure development.
- Responsibilities: Citizens are encouraged to participate in the public forums, official website to present their comments on infrastructure proposals and to let their local government know of any concerns and appeals.

Stakeholder 7: Official in United Nations – United Nations Framework Convention on Climate Change

- Role: Tertiary beneficiary and designer and user of CIM, as it will provide countries with advice on climate change or net-zero objectives, etc.
- Responsibilities: The UN is to assist and facilitate the climate change treaty, the UN Framework Convention on Climate Change (UNFCCC). There are 197 members of this process, and they are known as "parties" to the treaty.

6.9.6 Relationships between the stakeholders

Officials for transport infrastructure planning have the final decision on the new infrastructure planning. Other stakeholders such as the private sector infrastructure, utilities providers and housing developers are encouraged to participate in the new infrastructure planning by investing in the scheme or developing the schemes. Officials of environmental authorities analyse the infrastructure impact on net-zero agenda. Advocacy and special interest group aims to establish a sound environmental and ecological order with the rest of the stakeholders. This advocacy and special interest group is important as it provides support to socially and economically disadvantaged communities.

Citizens will want to see infrastructure housing and real estate developments underpinned by better and more reliable decisions.

United Nations will want to see those developments across nations be accountable to net-zero goals.

6.9.7 Scenarios

CIM especially in transport infrastructure can become a powerful tool to assist the planners to achieve a smart planning of new infrastructure, having made use of expert analysis in engineering, sustainability, and analytical fields.

Many new and emerging technologies such as hydrogen and carbon capture require novel frameworks and incentives to enable low cost, patient capital to bring large-scale investment in transport infrastructure. If that financing is unavailable as a result of the failure in standards for CIM, then there is a very real risk that new net-zero transport infrastructure, as well as measures to increase the resilience of existing assets, will not be developed at the scale and pace required. This is likely the forefront of the battle for the future of economic planning with net-zero consideration.

6.9.8 General requirements

- A standard for value for money analysis vis-à-vis "standard" in gauging what is sufficient usage of the future transportation infrastructure with "green" transportation measures.
- Standards for transport infrastructure models in terms of model capabilities, features, functions, and coverage can be better defined and set anticipation on what it can answer.
- Understanding of the result needs a standard mechanism. This should cater to general audience and authorities.
- The actual happening (some years after the new transport infrastructure is constructed) as a result of the new transport infrastructure would need to be compared with the modelled results. This would help to frame up reliable future infrastructure business cases and modelling. This should be a standard of comparison.

6.10 Traffic management

6.10.1 Needs statement

a) The real-time traffic operation status needs to be understood in an intuitive and easy-to-understand way (CIM-NS-TRM-01).

b) Quantitative and visual analysis models need to be used to analyse the rationality of traffic solutions (CIM-NS-TRM-02).

c) Different types of traffic data need to be standardized and merged into a unified platform to facilitate effective data query and acquisition (CIM-NS-TRM-03).

d) A real-time synchronous update of multi-terminal traffic operating status data based on CIM platform needs to be built (CIM-NS-TRM-04).

6.10.2 Objectives

The application of CIM to traffic management aims at:

a) real-time monitoring of urban traffic operation status;

b) improving the level of urban traffic planning management and decision-making;

c) establishing collaboration and information-sharing channels among various stakeholders.

6.10.3 Current practices

With the rapid pace of urbanization, traffic congestion and frequent traffic incidents have put tremendous pressure on traditional traffic management methods and traffic management resources.

On the one hand, it is difficult for limited traffic management personnel to completely cover the traffic management area of the city. On the other hand, the lag in traffic congestion and traffic incidents information has also increased the difficulty for traffic law enforcement agencies to track the responsible party after the incident, making it difficult for many traffic rule violations to be effectively punished, thereby forming a vicious cycle.

Traffic management is looking into moving traffic efficiently. Speed limit enforcement is a common feature and is dealt with using ANPR in many countries. Other "illegal" acts depend on different countries' traffic laws. "Rather than enforcement, education is a more acceptable approach.

In addition, traditional traffic control only targets motor vehicles, and ignores the management of traffic rule violations of non-motor vehicles and pedestrians. The traffic management system is not yet sound.

The combination of information and communication technology and road traffic management can effectively alleviate traffic problems, improve the level of traffic management, and improve the traffic travel experience of citizens.

6.10.4 Gaps in the application

With the development of the urban road traffic system, traffic law enforcement and management departments should solve emergencies in road traffic in a timely manner and provide a high-quality traffic service. However, the conflict – which is between the lag and complexity of traffic data and personnel restrictions, and the mobility and real-time nature of road traffic operations – makes traffic management more difficult.

In addition, it is difficult for traffic law enforcement and management departments alone to implement an effective road traffic management system. The traffic management should provide a way in which various traffic stakeholders can all be actively involved in the operation and management of urban road traffic.

6.10.5 Stakeholders

Stakeholder 1: Traffic law enforcement department

a) Traffic police: Responsible for patrolling the city's roads, maintaining traffic order, and handling traffic accidents.

b) Traffic command centre manager: Dispatch and command traffic police on duty, supervise the main traffic conditions in the urban area, maintain the traffic management network, and release various pieces of traffic safety information.

c) Technician in traffic law enforcement department: Cooperate with traffic police and traffic command centre. Responsible for traffic data processing and providing technical support.

- Role: Primary beneficiary and owner of CIM, as the traffic law enforcement agency is the responsible department, which should maintain road traffic order, enforce traffic violations and traffic accidents. And maintainer of its own department data and applications.
- Responsibilities: Collect and manage real-time traffic operation data, and carry out the city's road traffic order maintenance, traffic violation punishment, and traffic accident prevention based on the traffic operation data. At the same time, it is responsible for managing the information of motor vehicle certifications, motor vehicles and drivers and keeping this information confidential.

Stakeholder 2: Traffic management department

a) Head of traffic management department: Responsible for overall strategy formulation of traffic management and traffic governance decision-making.

b) Traffic management planner: Participate in the formulation of urban road and traffic facilities planning.

c) Traffic facility maintainer: Responsible for the daily operation management, maintenance, and supervision of traffic technology equipment such as traffic lights, video surveillance, etc.

- Role: Primary beneficiary and owner of CIM, as the traffic management department is responsible for the planning, construction and management of urban roads, ports and shipping, and urban public transportation, as well as supervising traffic facilities maintenance. And maintainer of its own department data and applications.
- Responsibilities: Manage urban road planning, road infrastructure construction and road management data (including taxis, public transportation). Provide urban public transportation planning and operation guidance for public transportation operating companies.

Stakeholder 3: Traffic user (including drivers, cyclists, pedestrians).

a) Local community member: Carry out daily transportation activities around work and life.

b) Nonlocal community member: Carry out daily transportation activities around tourism.

- Role: Secondary beneficiary and user of CIM, as it will provide users with traffic information.
- Responsibilities: Consciously abide by traffic laws and regulations. Carry out orderly and legal traffic behaviour activities. Cooperate with the maintenance of traffic order, the handling of traffic violations, and the law enforcement with respect to traffic accidents.

Stakeholder 4: Public transportation company

a) Bus company chief executive: Responsible for the overall strategic issues and business model of public transport.

b) Bus company planner: Responsible for formulating new bus route planning or optimizing existing travel routes and timings.

c) Bus operations manager: Responsible for managing the buses on a day-to-day basis, including bus driver deployment, bus safety, etc.

- Role: Secondary beneficiary and user of CIM, as it will help managers to optimize public transportation management and identify public transportation travel needs.
- Responsibilities: Provide public transportation travel services in accordance with travel needs. Follow the approved public transportation plan. Cooperate with traffic management and law enforcement agencies to carry out public transportation safety and quality supervision. Responsible for the company's public transportation operation, management and maintenance.

6.10.6 Relationships between the stakeholders

In traffic management, CIM serves as the basic data centre for government and as a communication platform for cross-departmental collaboration (Figure 11). It integrates basic geographic data from various departments and real-time dynamic data from sensor equipment to show the government the real-time status of the three-dimensional traffic operations and to provide the government with traffic operation status monitoring, and traffic operation management technical service support.

At the same time, it can visually display the travel patterns of transportation facilities to relevant stakeholders and collect their opinions, so as to adjust and improve the planning of transportation facilities. In addition, it can also provide information search and visual analysis tools for citizens and public transportation companies.

By installing various sensor devices such as video surveillance, the traffic data are collected and transmitted to the information system platform. After analysing and calculating this data, different traffic information is released for different objects.

The first is for traffic law enforcement and traffic management departments. The data – including dates, traffic violations, traffic accidents and other related location and vehicle information – would be sent to traffic law enforcement inspectors, which assists in issuing notices of traffic violations as a warning to traffic users.

At the same time, with the identification of high-risk and overloaded traffic sections, a traffic solution plan is generated to support the development of traffic planning or adjustment.

The second is to provide road navigation and parking guidance for drivers and other travellers, so that travellers can choose the best transportation route and the best parking place.

The third is to provide public transportation companies with data on urban residents' public transportation travel activities, including travel mode, travel volume, travel destination and others, who would know public transportation needs and then facilitate the adjustment and optimization of public transport business models.

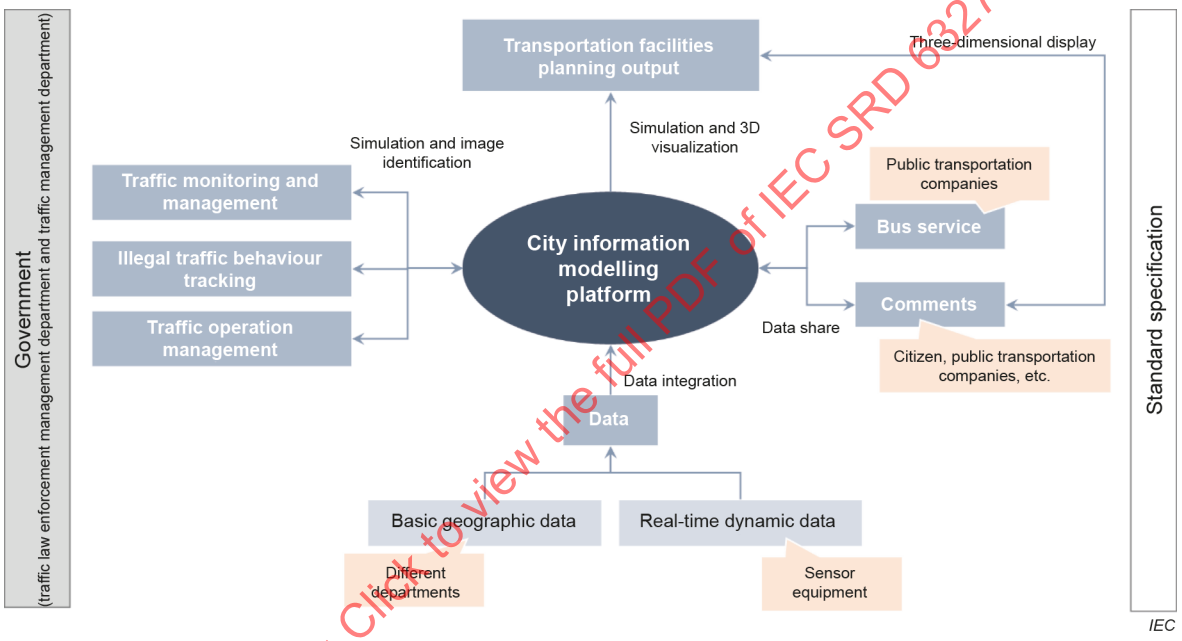


Figure 11 – Positioning city information modelling structure in traffic management

6.10.7 Scenarios

On the one hand, the CIM platform can create a visualized traffic operation map to help traffic management and law enforcement agencies quickly understand the overall urban traffic operation and management, visually view the problematic city roads, and then draw or adjust traffic planning specifically.

On the other hand, the CIM platform can be used as a carrier of information transmission for traffic management and law enforcement agencies, traffic travel objects, and public transportation companies.

Traffic management and law enforcement agencies can use official promotion channels to announce traffic flow control and traffic law enforcement results, which would regulate the behaviours of travel objects.

Users in traffic can obtain information such as road vehicle flow, road monitoring sections, bus arrival information, and transportation infrastructure location in real time through the CIM platform, so as to improve urban traffic experience.

Public transportation companies can get information on public transportation travel objects' behaviour, traffic flow, traffic peaks and other information through the CIM platform, which would assist company managers in optimizing and adjusting bus operating hours, operating routes, and operating modes.

6.10.8 General requirements

- A multi-agent transportation management coordination mechanism should be built.
- Standards for traffic information data collection, database construction, data application scenario and data exchange should be established.
- A safety mechanism for traffic data sharing mechanism among different stakeholders should be built.

6.11 Water management

6.11.1 Needs statement

a) Different types of water management relevant data need to be put into one platform for efficient data query and acquisition (CIM-NS-WAM-01).

b) The existing situation of the water environment management needs to be visually displayed and monitored in real time (CIM-NS-WAM-02).

c) Various easy-to-operate and easy-to-understand visual analysis tools need to be provided for different water management themes (CIM-NS-WAM-03).

d) Different types of assessment models need to be used to infer a feasible solution for water management (CIM-NS-WAM-04).

e) Different stakeholders need to report and acquire water management related information (CIM-NS-WAM-05).

6.11.2 Objectives

The application of CIM to water management aims to:

a) establish a city-wide water environment monitoring network;

b) promote cross-departmental cooperation;

c) provide quantitative and visual water environment analysis models;

d) facilitate the communication between different stakeholders.

6.11.3 Current practices

At present, traditional water management mainly relies on scattered water monitoring and sensing equipment to collect information such as groundwater level, rainfall, river flow, and water quality. Based on that information, departments carry out water affairs, including water supply, water conservancy project construction, water pollution control, and flood control. The fragmentation of the monitoring area and the backward monitoring technology have greatly increased the difficulty of water management.

Secondly, the water affairs of each management department are usually carried out by its department personnel. The work collaboration and information sharing mechanism between different departments has not been established.

In addition, the incomprehensive monitoring information and the singular access to information have also resulted in the incomplete grasp of water resources information by the water management department, which has caused certain obstacles to the development of water conservation, flood control, and pollution control.

6.11.4 Gaps in the application

When carrying out water supply, water saving, flood control, drainage, water environmental protection and ecological construction, water management department needs to collect water resources monitoring and water conservancy project supervision data with wide coverage, high accuracy, and strong current status.

In addition, a large number of water affairs monitoring, and management data would be analysed by low-cost, low-difficulty data mining and analysis tools to support water affairs management decision-making, and improve the justifiability of management and the feasibility of decision-making.

The water management in cities opens up the information channels between the various departments of water management, so as to avoid problems such as inconsistent water management standards and low public service levels due to the mismatch of departmental information.

6.11.5 Stakeholders

Stakeholder 1: Water management department

a) Water resources utilization planner: Responsible for planning the development and utilization of water sources and supervising the water quality of water supply sources.

b) Flood control dispatcher: Responsible for the preparation of flood control and emergency plans for important rivers and lakes.

c) Water conservancy project construction management personnel: Responsible for the approval and review of water conservancy project construction.

d) River and lake managers: Responsible for the development, management and protection of river courses and tidal flats.

- Role: Primary beneficiary and owner of CIM as it provides visualized multi-source water monitoring management data and data analysis tools to support water management administrative affairs. And the water management department can release public water management information. And maintainer of its own department data and applications.
- Responsibilities: Responsible for urban water supply and water resources utilization, water quality monitoring and management; responsible for supervising the construction and operation of water projects, guiding water conservancy facilities management, protection and comprehensive utilization; responsible for the development, governance and protection of rivers and lakes; responsible for organizing the preparation of flood emergency bidding plans and relevant emergency plans and guiding the implementation.

Stakeholder 2: Water law enforcement agency

a) Water law enforcement inspector: Stop and record illegal activities in water resources mining, water conservancy project construction, and sewage discharge during daily inspections.

b) Water law enforcement manager: Manage and dispatch water law enforcement inspectors.

- Role: Secondary beneficiary and user of CIM, as it provides the monitoring data and spatial location of water violation affairs.
- Responsibilities: Inspect rivers, water resources (water supply and drainage), water conservancy project construction, water and soil conservation and other matters in accordance with the law and find and stop corresponding illegal acts.

Stakeholder 3: Water engineering construction company

a) Project progress manager: Responsible for the statistics of the project construction progress, analysing the progress deviation and proposing the progress adjustment plan.

b) Project safety officer: Carry out safety inspections on the construction site environment and construction technical means and guide the construction personnel to carry out safe construction.

c) Engineering quality inspector: Responsible for the quality inspection during the construction process and completion of the project, including the selection of materials, the identification of construction techniques, and the review of safety measures.

- Role: User of CIM, as it provides water engineering construction specifications and the plan locations of water conservancy engineering construction planning.
- Responsibilities: Enquire about the construction requirements of water conservancy projects, carry out the construction of water conservancy project facilities in accordance with the law, and report the progress of water conservancy project construction in a timely manner; accept the supervision and inspection of the safety and quality of the project by the department of water management.

Stakeholder 4: Water works

a) Director of water works: Responsible for the overall operation and management of the water works.

b) Water intake supervisor: Responsible for the water quality inspection and management of the water intake of the water works.

- Role: User of CIM, as it provides planned water intake location, groundwater level, water quality data and water supply standards.
- Responsibilities: Set up water intakes in accordance with the law and provide qualified water resources; report the water use unit and water intake information to the department of water management in accordance with the law; accept the inspection and monitoring of the water source water quality.

Stakeholder 5: Citizen

a) Citizen: Participate in water resources utilization planning and water facility planning of residential areas and give feedback, protect water ecological environment.

- Role: Secondary beneficiary and user of CIM, as the public participate in the decision-making, covering urban water supply and drainage planning, water resources environmental governance planning, water conservancy project planning and others, and participate in water ecological environment supervision.
- Responsibilities: Understand the water management information around the living area; comment and evaluate the water affairs development in their area, and feedback their main comments to the local water management department; actively participate in the supervision of urban water resources management and water ecological environment governance and supervision.

6.11.6 Relationships between the stakeholders

The department of water management is responsible for collecting and managing water affairs monitoring data, publishing water affairs public data, supervising the construction of water conservancy facilities, relevant enterprises such as water conservancy engineering construction companies and water works, and encouraging public participation in water management planning (Figure 12).

The water law enforcement agency is responsible for supervising the implementation of water affairs management.

The water engineering construction company carries out water conservancy project construction in accordance with the requirements of the water management department's specifications and accepts the engineering safety quality inspection, testing and implementation supervision of the water management department and the water law enforcement agency.

In accordance with the regulatory requirements of the water management department, the water works legally sets up water intake points, regularly submits water use units and water consumption data, monitors, and reports water source water quality information, and accepts water intake supervision by water law enforcement agency.

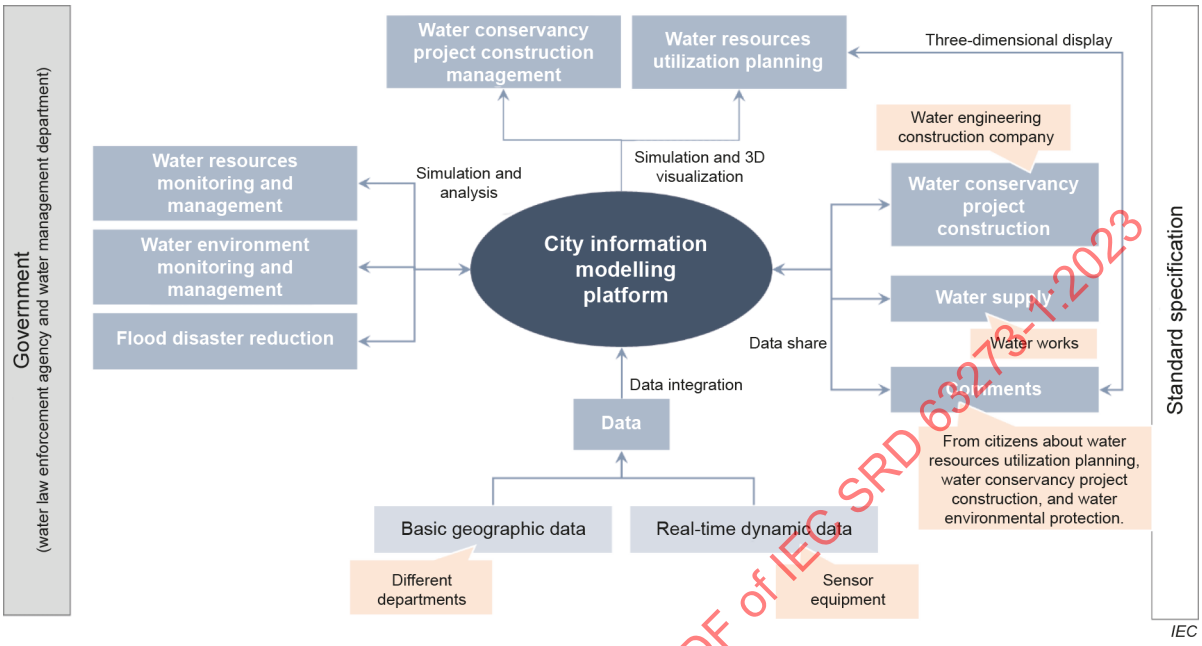


Figure 12 – Positioning city information modelling structure in water management

6.11.7 Scenarios

On the one hand, CIM can realize the integration of water monitoring management data with basic geographic data, three-dimensional models, BIM models and other data, visually locate the spatial location of key areas of urban water monitoring and management and provide accurate supervision data.

On the other hand, it can construct analysis model tools, in-depth mining of water affairs monitoring and management data, development of water ecological environment monitoring and early warning, water resources allocation, flood control simulation and other applications.

In addition, water management department can share information with water law enforcement agencies through CIM and send water monitoring information and spatial positioning on the platform to the mobile terminal to assist law enforcement officers in carrying out on-site water law enforcement.

For water engineering construction companies and water works, CIM can be used as an important information transmission carrier between governments and corporations. Firstly, the government can upload water conservancy project construction plans, water resources development and utilization plans, water source and water quality standards and other information to CIM, so that relevant stakeholders can search for relevant information.

Then water engineering construction companies and water works need to be supervised. Governments could conduct visual browsing and review of data from corporations. For example, water engineering construction companies can upload project models, project safety and quality models, project construction progress and other information to CIM, and water works can upload water use units and water intake information, water source water quality information.

For the public, CIM can provide public water affairs, collect public comments and needs on water management plans, and encourage public participation in these water affairs.

6.11.8 General requirements

- Construct a CIM-based collaboration mechanism for water management department, and guide cross-departmental business data sharing and business collaboration.
- Establish water affairs data standards to regulate the data collection and processing flow of water source, water quality, water level and other monitoring data collection, and application scenario construction.
- Build a guideline of water affair data analysis models to determine the impact factors, to guide the construction and expansion of models, and to support application scenario construction.

6.12 Smart census project

6.12.1 Needs statement

a) Human capital is the most critical capital for contemporary societies' well-being and progress. Providing an accurate and reliable assessment of this capital at small-area, regional and national levels is of paramount value for evidence-based action by governments, civil societies, academics, researchers, and other stakeholders (CIM-NS-SCP-01).

b) Ensuring confidentiality is crucial for the smart census to succeed. A standard addressing confidentiality and data collection needs to make clear that the collection of individual data is to produce statistics, and that there will be no dissemination of individual information or any non-statistical linkage with existing records in other government databases and data collections (CIM-NS-SCP-02).

c) The need to produce more frequent and timely smart census statistics rather than the current five- or ten-year gaps to meet the needs of the population and climate change (CIM-NS-SCP-03).

d) New metadata standards in census need to be defined to facilitate the rise of alternative methods in mathematically deriving the smart census (CIM-NS-SCP-04).

e) Traditional censuses are large operations with massive quantities of data that require coding and editing. To reduce the staff resources required and to improve timeliness, uniformity and accuracy, some countries have already implemented automated coding procedures for addresses, countries, education, occupation, and industry. There needs to be a global standard effort to set the available standards and new ones for smart census (CIM-NS-SCP-05).

f) Assurance and anticorruption. The adoption of new methods and technology can reduce the risk of fraud or corruption through providing more standardized, controlled and auditable records of actions, for example for the records of financial expenditure (CIM-NS-SCP-06).

g) Hard to count population. Authorities have a responsibility to engage fully with the communities they serve. The hard-to-count population can be the ethnic minorities, the homeless, etc. Failing to engage or count these groups can come at a cost – to finances, reputation, resources and, most tragically, to lives. Standard of engagement needs to be defined (CIM-NS-SCP-07).

6.12.2 Objectives

The application of CIM to smart census aims to:

a) establish a modern way of achieving census within reduced budget, at a regular interval, enhanced data analysis and overcome cumbersome census manpower demand with processing constraints. The traditional census is among the most complex and massive exercises a nation undertakes. It requires mapping the entire country, mobilizing and training an army of enumerators, conducting a massive public campaign, canvassing all households, collecting individual information, compiling vast amounts of completed questionnaires and analysing and disseminating the data;

b) understand the wider economic and social impacts of the decisions and policies from the ground;

c) allow communities to proactively plan, predict and prepare for developmental impacts;

d) use smart census to test new business models, public policies, growth plans and economic impacts;

e) underpin better and more reliable decisions on infrastructure and city services through scientific means of measuring the demand and supply;

f) produce more frequent and timely statistics;

g) improve assurance and confidence in smart census;

h) drive down reluctance of the population to participate in the census;

i) increase technical capacities to manipulate data sources.

6.12.3 Current practices

A census aims to count the entire population of a country, and at the location where each person usually lives. The census asks questions of people in homes and group living situations, including how many people live or stay in each home, and the sex, age, and race of each person.

The risk of pandemic and the countries' budgetary condition will jeopardize many censuses of population and housing in many countries through delays, interruptions that compromise quality, or complete cancellation of census projects.

Financing for census can be diverted to address risk of pandemic and economic crisis, leaving census without crucial funds.

Historically hard-to-count populations – low-income households, ethnic minority populations, immigrants, the homeless – who are the likeliest to be missed, especially if the pandemic limits door-to-door canvassing and outreach. This would create a worst-case scenario when it comes to political representation and allocation of resources.

It is possibly well past time to consider the implications of the execution of our traditional census for the new century and what that means for our society. Census deserves accurate counts of our population, but it is maybe time for an upgrade via another way to build a database in order to achieve a much better and evolving census – the smart census.

6.12.4 Gaps in the application

With the explosion of big data types and sources, the real value of using the synthetic smart census models has increased quite substantially. There are several positive applications of this type of modelling that potentially benefit society, governments, healthcare, businesses to improve the economy, employment, housing, living standards, quality of life, mobility, safety, clean environment, and many other aspects.

This is the truly integrated environment going down to the synthetic person level of which nearly every element such as transport, housing, education, water, power, etc. will be relied on.

The recognition is that the majority of the public data available especially in the UK and Europe, including the census data, household surveys, economic data, etc. are already discrete, aggregated in nature and historical by the time they are released for public use. Moreover, there are also data protection regulations surrounding the use of these data.

Any further safeguard would be in ensuring a more realistic and palatable approach towards building a "synthetic" digital human database of characteristics and behaviour of every synthetic person and household. Just as every human progresses through their life, their needs will be mapped in terms of demand and supply aspects, such as the demand for hospitals, education, jobs, amenities, etc. This will in turn measure the supply of these services. This is for a standard of good governance.

This will also replace the enormous monetary and manpower demand on conducting the physical census.

Integration of different models of different societal elements will be much more achievable if this is implemented.

6.12.5 Stakeholders

Stakeholder 1: Official of census statistical department

- Role: Primary beneficiary and owner of CIM, as the census owner. And maintainer of its own data and applications.
- Responsibilities: Manage smart census, and carry out the city's planning, and infrastructure improvements based on modelling results. At the same time, it is responsible for the management of information, and keeps this information safely.

Stakeholder 2: Official of public development agency

- Role: Primary beneficiary, as which should be responsible for the planning and management of hospitals, schools, roads, and public transportation, etc.
- Responsibilities: Provision and management of services, infrastructure construction for improving citizen experience.

Stakeholder 3: Smart cities and net-zero businesses owner

- Role: Secondary beneficiary and user of CIM, as it will utilize information and provide new cities and town innovations.
- Responsibilities: Carry out and cooperate with the public agencies on the management of societal impacts and the enforcement of regulations.

Stakeholder 4: Manager of a public transportation company

- Role: Secondary beneficiary and user of CIM, as it will help managers to optimize public transportation management and identify public transportation travel needs.
- Responsibilities: Provide public transportation travel services in accordance with travel needs and demographic changes. Follow the approved public transportation plan. Cooperate with traffic management and law enforcement agencies to carry out public transportation safety and quality supervision. Responsible for the company's public transportation operation, management and maintenance.

6.12.6 Relationships between the stakeholders

The first relationship would be within enabling the government and its public agencies to use discrete people's behaviour and to understand the wider economic and social impacts of their decisions and policies.

Supporting clean energy growth of businesses by having "digital human" models to test their mitigation strategies on digital human models. This will analyse its direct and indirect impacts to achieve a balance between adaptation and mitigation.

The government would also be wanting to support all future mobility stakeholders to experiment with their services with various business models, infrastructure and policy interventions and to analyse their impact on individual travel.

Enabling housing and real estate market to underpin better and reliable decisions. For balancing between housing needs and affordability.

6.12.7 Scenarios

CIM especially in demand forecasting can become a powerful tool to assist the planners to achieve a smart planning of new infrastructure, having made use of expert analysis in engineering, sustainability, and analytical fields.

Regarding the demand and supply relationship in city mobility and its interaction in land-use, environment with many other elements has a complete scope with the value system of citizen and communities. CIM can advance us to have a better future in service and bring higher productivity with better environmental as well as developmental needs.

6.12.8 General requirements

- To set the standardized questions which as a minimum meet the purpose of analysing and disseminating the data. This would help in the first step towards producing more frequent and timely statistics. Every country is different, but a necessary standard should be the first way forward in order to standardize and also to improve the smart census.
- Classification of data sources that can supplement the census. This is to help in improving assurance and confidence in the future work of smart census.
- Census modelling – methods devising and standard classification of accuracy and usefulness of the methods.
- To shape the common good approach for evolving data protection and to meet the technological challenges of smart census so that new smart census modelling can do more for the planning and the environment. The common good approach proposed here is on data protection, which allows for ease of access for what is considered private data when a modelling motive benefits the larger community. This approach tests whether a modelling motive benefits or erodes a specific element of the common good. With this common good approach, small and medium enterprises or universities can easily use more granular data to develop their technologies under the regulation and the correct governance of data without sacrificing the principle of data privacy.
- Like many regulations and statutes throughout the European Union, these data regulations have not been able to keep pace with the levels of technological advancement. To have such an approach would open up possibilities and better regulate data with a view to improving society.

6.13 Underground pipeline management based on data lake

6.13.1 Needs statement

a) Different types of pipeline information need to be stored and accessed in one platform (CIM-NS-UPM-01).

b) Information needs to be exchanged and shared among different departments (CIM-NS-UPM-02).

c) Pipeline operation needs to be monitored in real time, visually and intuitively (CIM-NS-UPM-03).

d) Pipeline operation needs to be simulated, analysed and predicted (CIM-NS-UPM-04).

6.13.2 Objectives

The application of CIM to urban underground pipeline management aims to:

a) integrate different types of data and information for the whole planning of pipelines, including the basic information, maintenance information, health information and other data;

b) monitor pipeline operation in real time, visually and intuitively;

c) identify the risk for the operation of underground pipeline system;

d) facilitate information exchange and sharing among different departments and build a cross-departmental collaborative mechanism.

6.13.3 Current practices

The scale of underground pipeline is becoming larger and larger especially where there is a rapid urbanization and urban development. In addition to water supply pipeline, there are a variety of other pipelines, such as drainage, gas, heating, sewage, power, communication and industrial. These different kinds of pipelines construct a complex network system and become an important domain for city management. Pipeline leakage, explosion and collapse will seriously affect the safety of people's lives and property.

6.13.4 Gaps in the application

a) The documentation of traditional pipeline information relied on papers, which are scattered and cannot play a guiding role in new project constructions and accident repairments.

b) Daily inspection is manual and there is a lack of risk warning capability.

c) Repairment is based on paper drawings and past experience when there is pipeline leakage, explosion and collapse.

d) Different pipelines are managed by different departments and there is a lack of coordination among departments.

6.13.5 Stakeholders

Stakeholder 1: Municipal commission of urban management

a) Pipeline design supervisor: The person who is responsible for the design of the pipeline system and the rationality and feasibility of design scheme.

b) Pipeline construction supervisor: An official who is responsible for making plans for pipeline construction and reconstruction and supervising the progress and quality of pipeline construction.

c) Pipeline operation supervisor: An official who is responsible for the safe operation of pipelines and supervising operation status of pipelines.

- Role: The role of this stakeholder category includes primary beneficiary, designer, owner and user as the manager of municipal engineering.
- Responsibilities: They should make plans and policies for urban underground pipeline system and supervise urban underground pipeline construction and management.

Stakeholder 2: Pipeline construction and operation company

a) Pipeline construction manager: A person who is responsible for pipeline construction and submitting construction progress and quality to municipal commission of urban management.

b) Pipeline operation manager: A person who is responsible for implementing pipeline patrol and submitting pipeline operating status to municipal commission of urban management.

c) Pipeline safety manager: A person who is responsible for implementing pipeline hidden danger investigation and finding out the potential safety hazards.

d) Pipeline life cycle manager: A person who is responsible for collecting and integrating all the data for pipelines from planning, designing, constructing, to maintaining and scrapping.

e) Pipeline accident manager: A person who is responsible for efficiently and accurately determining accident location, finding the cause and repairing it.

- Role: Secondary beneficiary and user who can be a company for constructing and operating sewage pipeline, rainwater pipeline, water supply pipeline, gas pipeline, heating pipeline, dangerous chemicals pipeline and so on.
- Responsibilities: Pipeline construction and operation company is responsible for construction, maintenance, upgrade, and replacement of the pipelines. It should also perform general survey of pipeline basic information, implement pipeline patrol and hidden danger investigation, and deal with accidents and emergencies.

Stakeholder 3: Engineering construction company

a) Civil engineering construction manager: person who is responsible for constructing subway, road, air raid shelter and so on.

- Role: Secondary beneficiary and user who can be a construction company or its employees for underground space, road traffic, air raid shelter and subway.
- Responsibilities: Engineering construction company should construct urban engineering and avoid damaging the pipelines during project construction.

Stakeholder 4: Citizens

- Role: Tertiary beneficiary and user as underground pipelines are closely related to the daily life of the citizens.
- Responsibilities: Citizens should strengthen the awareness of protecting underground pipelines and prevent actions endangering pipeline integrity.

6.13.6 Relationships between the stakeholders

The municipal commission of urban management is responsible for collecting and managing construction drawings, basic data, maintenance data for pipelines, supervising different pipeline companies for the construction and management of pipelines, communicating with other engineering construction company to coordinate pipeline construction with other engineering constructions, such as underground space, road traffic, air raid shelter and subway, encouraging public participation in pipeline protection (Figure 13).

The pipeline construction and operation company carries out pipeline construction with the permission of municipal commission of urban management, implements pipeline patrol and risk investigation in accordance with the requirements of municipal commission of urban management, submits basic and maintenance data for pipelines, shares construction drawings with other engineering construction company, such as underground space, road traffic, air raid shelter and subway.

The civil engineering construction company shares construction plans and drawings with municipal commission of urban management and pipeline construction and operation company.

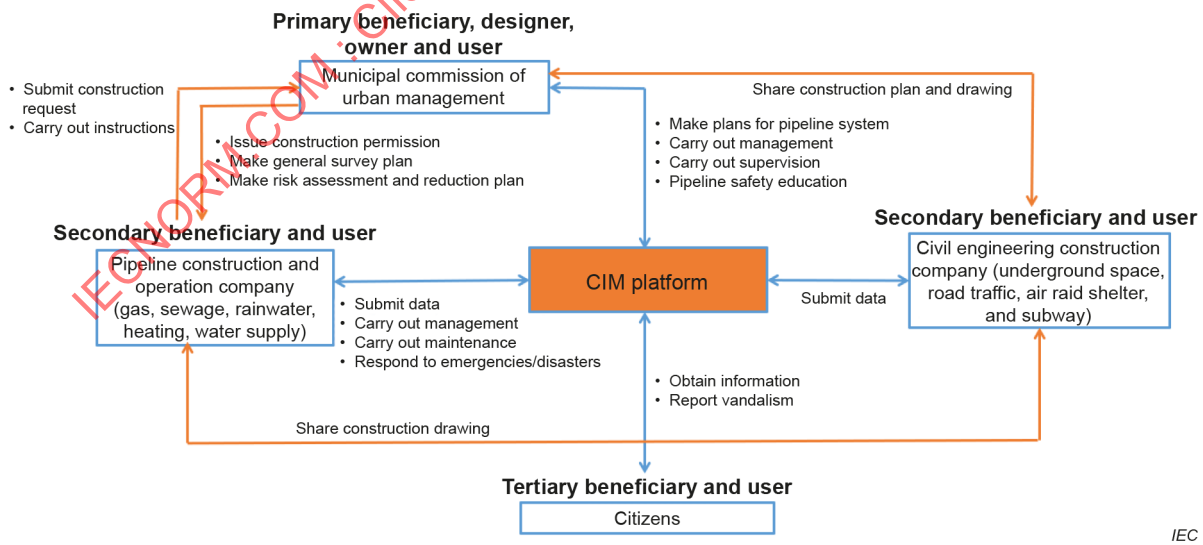


Figure 13 – Relationships between stakeholders when applying CIM in underground pipeline management

6.13.7 Scenarios

CIM collects pipeline basic data (e.g. building time, builder, length, category, diameter and so on) and operation data with geographic data, three-dimensional models, BIM models and other data (Figure 14). CIM visually locates the spatial location of key areas of pipelines, monitors the status of the pipelines, explores the potential safety hazards and makes early warnings. CIM provides one platform for information exchange and sharing among the above stakeholders.

Based on CIM, the municipal commission of urban management conducts supervision of pipeline construction and operation by browsing and reviewing data submitted by pipeline construction and operation company. Also, when the municipal commission of urban management wants to make plans for pipeline system, it communicates and coordinates with engineering construction company to make coordinated construction plan and to avoid those streets being dug repeatedly.

For pipeline construction and operation company, it can carry out pipeline management, monitoring and maintenance. It can find out hidden dangers and quickly determine accident location, for example, when there is pipeline leakage. Also, it communicates and coordinates with other engineering construction company, when necessary, for example, when there is a serious accident.

The engineering construction company browses and reviews pipeline construction drawings to avoid damaging the pipelines when it is constructing subway, road, air raid shelter and so on.

For the public, CIM can provide public with the network diagram of pipelines, collect public report of actions endangering pipeline safety, and encourage public participation in pipeline protection.

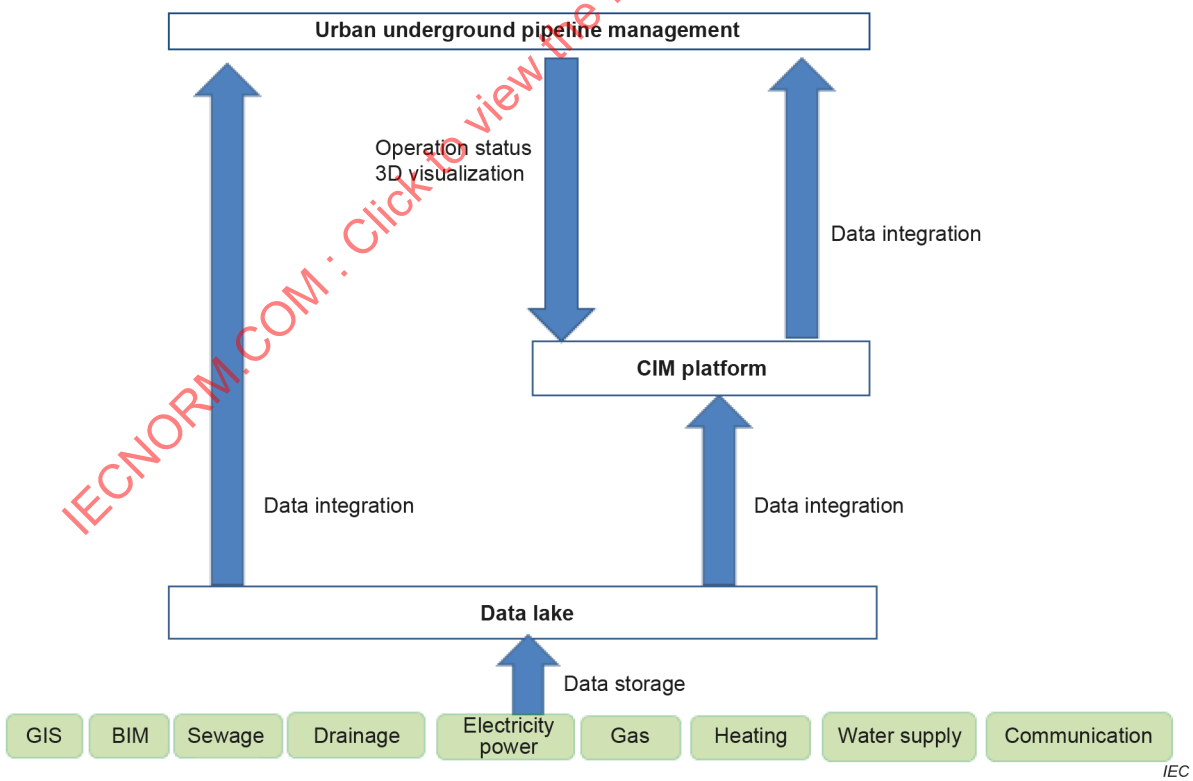


Figure 14 – Positioning city information modelling in urban underground pipeline management

6.13.8 General requirements

- Standards should specify urban underground pipeline information management system.

- Comprehensive management and coordination mechanisms are required for data sharing and project construction collaboration among different departments.
- AI analysis models should examine the risk and decrease the risk.

6.14 Emergency management and rescue

6.14.1 Needs statement

a) The authorized groups need to acquire, upload, download, and edit the data in the platform without high skill requirements (CIM-NS-EMR-01).

b) Stakeholders need to use the CIM platform to understand the on-site inspection and the initial disaster situation on the site, and to issue the corresponding rescue operation plan according to the site situation (CIM-NS-EMR-02).

c) Different types of emergency management and rescue relevant data need to be captured in real time into one platform for efficient data query and acquisition (CIM-NS-EMR-03).

d) Different types of models and simulations need to be conducted for emergency management and rescue (CIM-NS-EMR-04).

e) Stakeholders need to use the CIM platform to report the initial fire situation on site, and receive the emergency rescue plan (CIM-NS-EMR-05).

f) Through the CIM platform, the citizens can know the safety planning of the emergency rescue area in advance (CIM-NS-EMR-06).

6.14.2 Objectives

The application of CIM to emergency management and rescue aims to assist the government's emergency plan management.

According to the disposal mechanism of the city's emergency events, the information system to assist the management of the government's emergency plans is created. The system follows the crisis management theory, combines peacetime and wartime, and prepares, manages and improves the emergency plans at ordinary times. Quickly retrieve and match plans in the event of an emergency. The city three-dimensional model is used to guide the staff to complete the coordination, liaison and supervision of emergency response. After the completion of emergency handling, we should, in a timely manner, deal with the aftermath, evaluate the incident and revise the plan, so as to constantly improve and enhance the city's ability to deal with public events and provide important information guarantee for the government to deal with public emergencies.

6.14.3 Current practices

As a standardized configuration function of smart city, smart fire service is of great significance to the construction of smart city. As a city-level overall solution, intelligent fire protection involves or integrates resources closely related to smart city. Intelligent fire protection construction is in the ascendant and has broad market application prospects.

6.14.4 Gaps in the application

For a long time, the supervision, prevention and control of urban fire safety and the disposal of fire and safety incidents have been faced with two major pain points.

1) In remote monitoring and daily supervision, the construction of firefighting infrastructure lags behind and the informatization monitoring means of firefighting facilities and resources are insufficient. There is insufficient fire supervision in key places of the city, the information sharing degree is poor, and the phenomenon of "data island" is widespread. Urban fire management volume is huge; fire causes, hidden fire hazards are complex and difficult to manage. The informatization and intelligence degree of firefighting are not high; The social firefighting forces are not fully integrated and the public's firefighting awareness is weak.
2) In the disposal of fire and rescue events, the information control of disaster situation and the progress of the scene is insufficient. The information resource allocation means of fire

fighting force is insufficient, and the digital plan system has not been completely established. Lack of practical, visual and intelligent integrated scheduling, decision-making and command platform. The workload of collecting evidence and evaluating after disaster is heavy and the operation is difficult.

6.14.5 Stakeholders

Stakeholder 1: Inspect officer

- Roles: Primary beneficiary of CIM as it will help inspect officers to provide timely feedback on on-site inspections. User as it will help inspect officers to realize data reporting and receiving.
- Responsibilities: Inspect officers should carry out continuous inspection during the activity and the initial fire emergency disposal, reporting in a timely manner the on-site situation of the activity.

Stakeholder 2: Emergency response officer

- Roles: Primary beneficiary of CIM as it will help emergency response officers to provide timely feedback on the disaster scene. User, as it will help emergency response officers to report and receive data during work.
- Responsibilities: Emergency response officers should be in charge of the initial emergency response at the event site, and carry out rescue operations from the commander and the rescue plan generated by CIM.

Stakeholder 3: Commander

- Roles: Secondary beneficiary of CIM as it will help commanders to master the deployment of security personnel and fire equipment on the scene. User, as they can use the CIM platform for scheduling and command.
- Responsibilities: As the first person responsible for fire safety and security activities, the commander should refine various security measures, organize team members to strengthen fire inspection and patrol on the security scene, and implement various preparations for emergency disposal.

Stakeholder 4: Emergency rescue team

- Roles: Secondary beneficiary of CIM as it will help emergency rescue team to understand the emergency rescue deployment situation of the area and site to be rescued. Builder, designer, and user as it will help emergency rescue team to participate in the planning of rescue sites. As users, emergency rescue team uses the CIM platform to deploy, combat and review security sites at work.
- Responsibilities: emergency rescue team should organize emergency rescue, disaster prevention and firefighting. It also should organize and guide the publicity of emergency safety and the mobilization and training of social emergency rescue forces.

Stakeholder 5: Emergency management and rescue specialist

- Roles: Secondary beneficiary of CIM as it will help emergency management and rescue specialists to judge the situation of the disaster site, and help experts to use different emergency rescue plans according to different disaster situations. User, as it will help specialists to judge the disaster situation at the rescue site.
- Responsibilities: Emergency management and rescue specialists need to predict the trend of the disaster and issue the corresponding emergency plan according to the disaster.

Stakeholder 6: Business owner

- Roles: Tertiary beneficiary of CIM as it will help business owners to understand the workflow of emergency management and rescue, and to continue to do related projects. Owner and